UAB
Universitat Autònoma de Barcelona

Unravelling the transition from hunter-gatherers to farmer in Southwest Asia through the morphological and wear study of dental remains

ALBERT EPITÍE DYOWE ROIG

UAB
Universitat Autònoma
de Barcelona

Unravelling the transition from hunter-gatherers to farmers in Southwest Asia through the morphological and wear study of dental remains

ALBERT EPITÍE DYOWE ROIG

PhD in Prehistoric Archaeology

Directors

Laura M Martínez Martínez

Ferran Estebaranz i Sánchez

Miquel Molist Montaña

2025

A la meva família: Mama, Papa, Marina

Us estimo molt

Natondêndive êboliboli

TABLE OF CONTENT

FIGURES TABLE OF CONTENT

ACKNOWLEDGEMENTS

Es complicat pensar en totes aquelles persones que m'han ajudat al llarg d'aquest camí. Totes aquelles persones que han estat, que m'han acompanyat i que m'han estimat a la seva manera. Gràcies. Fa uns anys, aquesta fita era impensable, i el que està clar és que la feinada no ha estat només meva sinó també de totes aquelles persones que sempre m'han dit un "tu pots" en qualsevol moment de la vida.

Mai estaré lo suficientment agraït al tracte que m'han donat els meus directors de tesi Laura Martínez i Ferran Estebaranz. Com oblidar la quantitat de vegades que he arribat a casa dient a la meva família "M'han alegrat el dia", "M'han il·luminat el camí", "M’agradaria fer com ells". M'han obert les portes en un món que desconeixia més enllà dels articles i els llibres de text i en el que espero poder-m'hi dedicar al llarg de la meva vida, la recerca. La passió amb la que m'han explicat les innumerables coses que desconeixia dins i fora de la universitat. El fet que fessin realitat el meu somni de viatjar a l'Àfrica Subsahariana. Que hagi pogut conèixer món a través de la recerca. M'han fet sentir com l'investigador predoctoral amb més sort del món. Tampoc em podria oblidar de l'Alejandro Pérez-Pérez que de la manera més altruista s'ha preocupat per ajudar-me en tot el que he necessitat en tot moment. Els seus debats amb la Laura, la preocupació per tal de que tots tinguem de tot i estiguem bé, les gestions burocràtiques, la tranquil·litat que transmet i la paciència. Als tres gràcies infinites per fer-me sentir com m'he sentit i per fer-me gaudir de la feina.

Feia 6 anys, al finalitzar el màster em trobava perdut, un cop més, no sabia que fer i vaig recorren al Miquel Molist. Ell va ser la persona que em va proposar fer un doctorat, tot i no veure-ho clar. Em va convèncer de una de les decisions més transcendentals que he pres. I que al cap i a la fi, és d’agrair que creguin en tu per poder fer aquesta fita.

Com he dit anteriorment, al llarg de la tesi he tingut la sort de viatjar, descobrir món, persones, cultures i formes de ser. Un dels millors records que tindré és l'estada d'investigació que vaig fer a Ankara (Turquía) per tots vosaltres:

Doktora eğitimim süresince beni ağırlayan İnsan Davranışsal Ekoloji ve Arkeometri Laboratuvarı'na (İDEA lab – Hacettepe Üniversitesi) içtenlikle teşekkür etmek istiyorum. Bu teşekkür sadece ihtiyacım olan her konuda yardım etmeye istekli oldukları için değil, aynı zamanda akademik yönlerin ötesinde, sohbetlerine ve öğle yemeklerine eşlik etmeme izin verdikleri için ve bana kendi kültürlerini öğrettikleri içindir. Sergiyi kolaylaştırıp, bana harika bir çalışma alanı sağladığı ve orada bulunduğum süre boyunca ve sonrasında bana destek olmaya devam ettiği için hocam Profesör Ali Metin Büyükkarakaya'ya ayrıca müteşekkirim. İlk günden itibaren dil konusunda ne seviyelerde olduğumu anlamama yardımcı olan laboratuvar partnerlerim; Yaren ve Erge'ye de teşekkürlerimi sunarım. Sizinle tekrar çalışmayı gerçekten çok isterim. Hepinize çok teşekkür ederim.Yaşadığım maceralarımı ve ev arkadaşlarım, Nadire ve Zain'i unutamam. Günlük hayatımda hâlâ Türkçe sayıları hatırlamak için şarkı söylüyorum. Birlikte ettiğimiz o derin sohbetler, deneyimlediğimiz iş stresi ve yaptığımız geziler için sizlere çok teşekkür ederim.

Gràcies també a tots els altres investigadors que m'han proporcionat informació i/o m'han deixat un espai en els seus despatxos i laboratoris per poder treballar.

Des dels 6 anys, m'he dedicat a l'handbol i he après que una persona sola no pot guanyar partits si no és amb un bon equip. Puc dir, sense amagar-me que he fet equip amb les millors persones que podria. Gràcies Mama, Papa i Marina per estar al meu costat en tot moment, per fer-me ser la persona que soc i per ajudar-me a guanyar tots els partits complicats que la vida m'ha posat per devant. Gràcies també a la Saray i a la futura nena que ve a la família per dibuixar-nos a tots un somriure encara més gran.

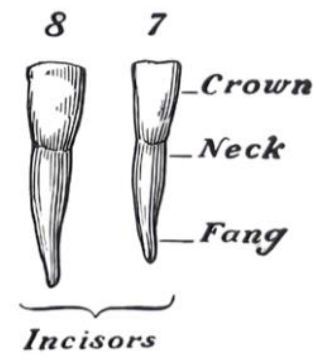
Soc un privilegiat quan penso la gent que em rodeja i en la xarxa de persones que tinc al meu voltant, enumerar a tothom requeriria d'una nova tesi doctoral però no puc deixar d'esmentar la importància que han tingut aquests anys persones com l'Adrià que ha estat al meu costat des dels 3 anys i hem pogut compartir el nostre primer pis com a persones independitzades. El Marc, el Martí i l'Isma que no son conscients lo importants que han estat en aquesta última etapa on la tranquil·litat brillava per la seva absència però ells han estat un oasi de somriures i distracció.

No em puc oblidar de l'Iker i la Júlia ambdós encara que no ho creguin un dels meus pilars, el meu espai de seguretat i de confort. Les nits i tardes de tertúlia, els viatges, els sopars i la companyia valen or.

Gràcies a tota la gent que ha passat pel laboratori al llarg de tots aquests anys i que m'ha fet companyia, en especial al Luís que tot i que siguem el ying i el yang ens hem acompanyat en molts viatges i hem passat per múltiples peripècies. També gràcies a la Berta per donar-me conversa i distreure'm en els moments que tenia la ment en blanc i que s'està convertint en una veterana del laboratori.

En definitiva. Gràcies a totes aquelles persones que m'han aguantat al llarg d'aquests anys, a totes les que m'han acompanyat, totes les que hi són i a totes les que ja no. De tots i totes n'he après una mica.

Gràcies a tu també si has arribat a llegir fins aquí.



CHAPTER 1. INTRODUCTION

CHAPTER 1.

1.1. INTRODUCTION

1.1.1. THIS STUDY

This thesis presents a six-year study of the neolithization process, a significant socio-economic transformation experienced by humans. It offers a novel approach to understanding this phenomenon from a morphological perspective. The analysis of human dental remains from various archaeological sites in Southwest Asia has provided a comprehensive overview of the region, offering a more global perspective than is currently available in the existing bibliography.

This study has been dedicated to examining the historical development of four distinct periods, or more accurately, sub-periods, marking the transition from the era of hunter-gatherers to the advent of agricultural and livestock-raising societies. The study initiates with the Natufian period (13,000-12,800 and 10,300 cal BP), followed by the PPNA period (9,700 - 8,500 cal BP), the PPNB period (8,700 - 6,250 cal BP) and concludes with the Ceramic Neolithic period (starting in the 7th millennia cal BP).

Over the course of my research, I have had the opportunity to work with a wide variety of samples. A significant proportion of the samples have been obtained from the dental collection of the Anthropology Unit of the University of Barcelona, which has been coordinated and directed by Dr. Laura M. Martínez-Martínez and Dr. Alejandro Pérez-Pérez for many years. The collection included samples from several different sites, which will be discussed in detail throughout the course of this thesis. Furthermore, I have had the opportunity to conduct research stays to increase the existing collection and illuminating regions where no samples had previously been obtained. In 2022, I had the opportunity to visit the University of Warsaw, where I was provided with samples from the archaeological sites belonging to the PPNB period of Nemrik 9 and Ali Kosh, located in present-day Iraq and Iran, respectively, by Professor Dr. Arkadiuz Sołtysiak. Additionally, in 2022 I spent three months at the Human Behavioral Ecology and Archaeometry Laboratory (Idea Lab) of Hacettepe Üniversitesi (Türkiye), where I had the privilege of working under the guidance of Professor and Head of the Laboratory, Dr. Ali Metin Büyükkarakaya who kindly granted me access to the Tepecik-Çiftlik site, which dates to the Neolithic Ceramic period, and provided data from the Gre Fila site, which is associated with the PPNA and PPNB periods. Both sites are in present-day Türkiye.

The human species has inhabited the planet Earth for several million years, with almost all of this period spent as hunter-gatherers. The earliest evidence of livestock activities has been dated to 12,000 years ago, coinciding with the end of the Pleistocene Period, or the "Ice Age," as it is more commonly known. The capacity to produce food and other commodities will give rise to novel economic practices and social complexities that diverge from those that currently prevail. The question thus arises as to how agriculture was generated. Was it a widespread and preconceived idea of these societies in which it expanded from a primary area? Alternatively, were new populations moved with this idea to a primary area? Or perhaps the local populations of hunters and gatherers changed their way of life without having any external influence?

DNA studies could provide the answers to these questions. However, there are cases where the original sample may be damaged, in a poor state of preservation, or no longer exist due to anthropogenic causes. The field of human morphometry offers a promising avenue for inquiry. By examining changes in dental morphology across different populations and regions, we can gain insights into the impact of shifts in subsistence economies on human biological adaptations. The use of metric studies to differentiate populations within a single geographical area and the analysis of dental wear to infer population-specific dietary patterns are two promising avenues for investigation. These objectives will be elaborated upon in the subsequent section.

OBJECTIVES

This study aims to examine the morphological changes, particularly tooth size in human teeth across different archaeological periods in the Southwest Asian region. In detail, it investigates whether dietary shifts and changes have influenced dental size over time. This research will contribute to the understanding of the evolutionary processes and adaptations in human teeth associated with different dietary practices and environments.

The study employs a comparative approach, focusing on sub-periods within the Natufian, PPNA, PPNB and Pottery Neolithic. This allows for an in-depth analysis of changes in tooth morphology over time, providing valuable insights into the dietary adaptations of human populations in Southwest Asia.

In the absence of DNA data, variations in dental morphology will be meticulously catalogued and contrasted, as they can offer insights into the ancestral origins, relationships, and migrations of human populations over time. This will be performed using the ASUDAS (Arizona State University Dental Anthropology System), which incorporates comprehensive dental traits with significant value in human evolutionary research, the investigation of ethnic groups, and population genetics. This will facilitate the examination of potential instances of kinship or inbreeding between these different populations.

Following the line of relationship between population. To examine the evolutionary history of populations through the analysis of dental topography. This entails investigating how teeth have evolved in response to environmental and dietary factors over time and comparing the dental topography of different populations to gain insights into genetic inheritance and evolutionary relationships between populations from different chronological periods and/or ecological and geographical environments.

To develop and subsequently apply a novel analytical methodology to assess the rate of tooth wear. This will entail the use of a proxy measure for dentin exposure, thereby enhancing our understanding of dietary practices, health, and other lifestyle-related factors in ancient populations. The approach will facilitate the generation of a more precise tool for investigating tooth wear patterns and their potential correlation with human-environment interactions over time.

1.2. ARCHAEOLOGICAL CONTEXT: GEOGRAPHY, CHRONOLOGY, CLIMA

1.2.1. GEOGRAPHICAL CONTEXT

Southwest Asia (SWA) or the term "Near East" (NE) is used to describe a region that confine several areas located in various parts of West Asia. These areas are situated to the east of the Mediterranean Sea, to the south of the Red Sea and the Sinai Peninsula, to the Southeast of the Persian Gulf, and the North and East of the Taurus and Zagros mountains. The countries that currently occupy this region include Palestine, Syria, Israel, Jordan, Lebanon, Iraq, Iran and a portion of Saudi Arabia and Türkiye.

In this study, the term "Southwest Asia" will be used to refer to this region, as it is a strictly geographical term for all regions of the world. It is important to recognise that the term 'Near East' or 'Middle East' is a geographical designation that originated in Europe and is not universally accepted (Figure 1).

Figure 1 . Geographical region of study. Southwest Asia on the centre and right of the figure and Europe on the left.

The Southwest Asia is a vast region encompassing a diverse range of natural resources and environments, characterised by four distinct bioclimatic zones:

The Mediterranean climate, observed in the Levant of Southwest Asia, which surrounds coastal plains and the slopes of mountains facing the Mediterranean coast. This area is distinguished by a system of depressions, which are the result of the extension of the African Rift Valley, through which the Orontes and Jordan rivers flow. With an average annual rainfall of approximately 500 mm/year, the vegetation is characterised by olive trees, vineyards, holm oaks and pines (Aurenche & Kowzlowsky, 2003).

The central desert zone is circumscribed by a steppe zone, with precipitation levels below 250 mm per year, creating an environment particularly challenging for human occupation, except in the vicinity of oases. Vegetation is virtually absent, except for a few herbaceous plants and palm trees in areas with slightly higher moisture levels, such as the oases mentioned above (Fisher, 2013).

The steppe zone, situated between the central desert and mountainous regions, exhibits significant seasonal temperature fluctuations and receives 250-500 mm of annual precipitation (Palmisano et al., 2021). Oak and pistachio trees dominate the steep slopes, whereas herbaceous plants adapted to arid conditions are dominant in the plains. This region was also the habitat of the primary wild animal species that played a significant role in Southwest Asia's domestication process, as well as wild grains and legumes (Cauvin, 1997). The Anatolian Plateau, northern and central Syria, as well as he north plain of Iraq are included within this bioclimatic zone . The region is delimited to the west by the Jordan and Orontes River valleys, to the north by the Taurus Mountain range, and to the east by the Zagros Mountain range. The Tigris and Euphrates rivers, along with their numerous influents (including the Great Zab, Little Zab, and Diyala of the Tigris and the Khabur and Balikh of the Euphrates), traverse the steppe.

To the west, the mountain range is formed by a double coastal range that runs parallel to the Mediterranean coast. To the west and east, the Zagros and Taurus Mountain ranges from the surrounding mountainous terrain. The region is characterised by high rainfall, reaching approximately 500 mm per year, which favours the growth of a diverse flora, including oaks, holm oaks, pines, and firs, especially in the elevated areas (Hemming et al., 2010; Lelieveld et al., 2012).

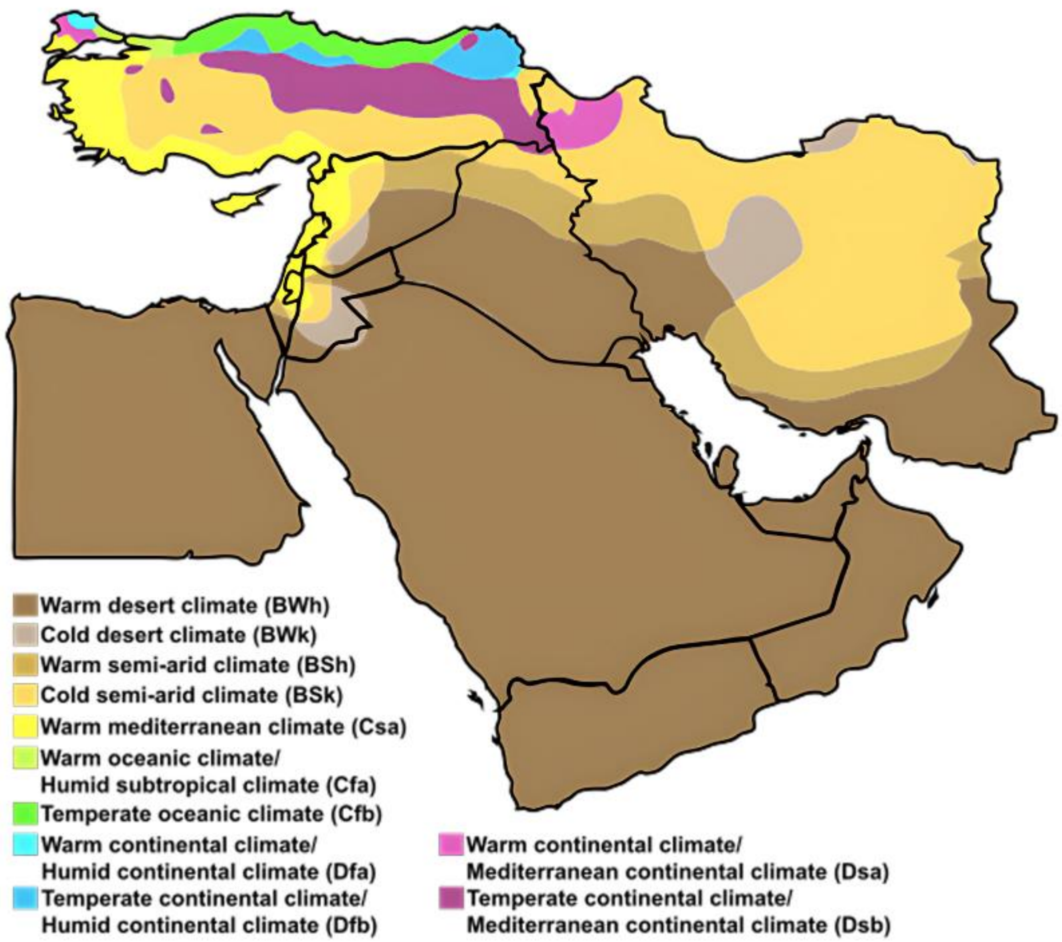


Figure 2 Climatic Map of Southwest Asia with the different bioclimatic areas: Mediterranean, central desert, steppe (semi-arid) and mountain zones.

The diverse topography of the Southwest Asia significantly influences the climate (See Figure 1 and 2). The centre of the Levant exhibits a more continental climate, whereas the coastal sections display a Mediterranean climate, characterised by hot, dry summers and cold, rainy winters. Conversely, the region's typical rainfall regime, with a dry season during the summer months, reflects the influence of the Mediterranean climate. The balance of the year is characterised by erratic rainfall patterns, with some regions, such as the coast of the actual Palestine, receiving 80% of the total annual precipitation between October and February.

The concept of Neolithization has traditionally been associated with the "Fertile Crescent," largely due to the region's distinctive environmental characteristics and the emergence of the initial domesticated wild plant species (Braidwood, 1960; Mellart, 1975; Cauvin, 1994). The Taurus and Zagros Mountain ranges act as natural boundaries for the Fertile Crescent, which extends from the Jordan Valley to the estuary of the Tigris and Euphrates (Simmons et al., 2007).

Given the heterogeneous and diverse nature of the meteorological and geographical regimes covering the Fertile Crescent, alternative models have been developed to classify sites with greater environmental similarity in terms of archaeological data. The 'Golden Triangle' provides an illustrative example of the adoption of plant and animal domestication practices that is useful for understanding this phenomenon (Kozlowski & Aurenche, 2005). However, the most widely used model is that proposed by Aurenche & Kozlowski (2003), which combines the earlier models proposed by Mellart (1975), Redman (1978), and Cauvin (1994).

The Mediterranean Levantine strip is defined by a series of precoastal and coastal reliefs that create depressions extending the enormous African Rift. This area is of primary importance in this context. In turn, this strip has been subdivided in the archaeological literature into the following categories:

- The **Southern Levant region** includes the Jordan Valley and its surrounding areas, which have historically referred as the "Levantine Corridor." This corridor extends from the Mediterranean coast to the Arabian Desert. The extension of Wadi Araba, together with the surrounding hills and plateaus, culminates in the formation of the Negev and Sinai deserts. The border is somewhat blurred in its northern trajectory, extending towards the Damascus Oasis. Consequently, this region has been referred as the Central Levant, a term specifically applied to it.

- The **Northern Levant** lies on the same north-south axis as the Mediterranean coastal plain and the inland plateaus traversed by the Litani, Orontes, and Afrin rivers, which ultimately converge flow into the Mediterranean Sea. The Syrian desert, an extension of the Arabian desert, marks the eastern boundary.
- The **Mountain Arc**, formed by the coastal mountain range extending from the Mediterranean coast to the west and the Taurus and Zagros Mountain ranges to the north and east, may also be considered as a geographically distinct area. The following regions are included in this classification:
- The **High Valleys**, also known as the headwaters of the Tigris and Euphrates, are located in southeastern Anatolia. They are divided by the Euphrates and Tigris rivers and bordered to the east by the eastern Taurus Mountains. They end at the foot of the Taurus Mountains.
- The **Zagros Mountains**, which extend south to the Persian Gulf, are crossed by the Taurus Mountain arc. This region comprises two distinct zones: the more open and tributary-fed western Zagros of the Tigris (Great Zab, Little Zab and Diyala) and the central Zagros.
- Finally, the **Steppe Region** is bisected to the east and north by the Euphrates and Tigris, the two main rivers in the area, and their tributaries.
- **The Jezirah** is a region of flat or gently sloping terrain situated in the foothills between the channels of the Tigris and Euphrates rivers. It extends west of the Euphrates and east of the Tigris across the intervening plateaus. The southern boundary is formed by the Mesopotamian alluvial plain.
- The **Tigris and Euphrates** alluvial plains extend in a southeast direction to the Persian Gulf, while the Mesopotamian plain extends in a southeast direction to the Jezirah.

1.2.2. CHRONOLOGICAL CONTEXT

2.2.1.1. CLIMATIC CHANGE

According to Aurenche et al. (2001) and Kozlowski & Aurenche (2005), the neolithization process is thought to have started at the same time as the Pleistocene to Holocene transition (13,000-11,000 cal BP). Here we briefly review existing reconstructions of the palaeoclimatic record and assess the viability of linking climate change to cultural change in Southwest Asia during the Neolithic and Epipalaeolithic. The GRIP core data (Greenland Ice Core Project) are of great importance for dating climatic events (Fuhrer et al., 1993). Because these cores are dated by a true count of annual layers, characterised by regular changes in electrical conductivity, dust, nitrate, calcium, and ammonium ions – all of which are particularly evident going back to the Younger Dryas – they provide an exceptionally high degree of precision (Johnsen et al., 2001). This series has been corroborated by tie points and well-dated volcanic eruptions.

LAST GLACIAL MAXIMUM (LGM)

Temperature and humidity variations were prevalent throughout the Pleistocene era, with additional climatic variations occurring at the end of this period. Between 25 and 18 thousand years before the present (ka cal BP), the Last Glacial Maximum (LGM) was characterised by cold and dry conditions, which reached their peak approximately 22 thousand years before the present (ka cal BP). The primary source of global data for late Pleistocene climate conditions is ice cores (see, for example, Lowe et al., 2008), which demonstrate that cold and dry conditions persisted until approximately 19–17 ka cal. BP. Isotopic data from cave speleothems in Soreq Cave in the Levant indicate that δ18O values peak about 19 ka cal. BP, indicating extremely cold temperatures (Bar-Matthews et al., 1999). Throughout he LGM, the high levels of lakes were sustained due to the low evaporation rates that were characteristic of this period. However, following a series of temperature and evaporation oscillations, the lakes gradually diminished to approximately 300 m by sea level by 15 ka cal. BP (with a transient spike in levels c. 17 ka cal. BP). The advent of mild and rainy weather, known as the Bølling Interstadial, at approximately 14.67 ka cal. BP, marked the end of glacial conditions in the southern Levant (Maher et al., 2011).

HEINRICH 1 EVENT

The influx of freshwater into the Atlantic Ocean from icebergs originating from northern hemisphere glaciers results in Heinrich episodes, characterised by rapid cooling (Bond et al., 1992; Bond & Lotti, 1995; Heinrich, 1988; Roche et al., 2004). Such changes can be observed in the sedimentary record of Atlantic Ocean cores, manifesting as alterations in foraminifera, a decline in surface sea temperature, and a reduction in oceanic salinity, which can be attributed to the influx of freshwater. On land, these changes are identified by variations in pollen and significant increases in δ18O values, as evidenced by speleothems. These occurrences have been observed to occur approximately every 7,000 years during the last glacial event, with a duration of between 100 and 500 years (Heinrich, 1988). It is noteworthy that rapid transitions to warmer temperatures, such as the Bølling-Allerød, appear to occur immediately following these occurrences (like Heinrich 1 Event). The Heinrich 1 Event occurred between 16.8 and 16.5 thousand years before the present (ka cal. BP) (Maher et al., 2011).

THE BØLLING-ALLERØD

A rapid warming episode occurred at approximately 14.67–14.6 ka cal BP, preceding the Bølling-Allerød. The Bølling-Allerød interstadial was precipitated by the melting of Antarctic ice sheets during an event designated as Meltwater Pulse IA, which occurred after the cold and arid LGM (Weaver et al., 2003). Marine records provide substantial evidence of this warm and humid phase, during which atmospheric CO_2 concentrations (ranging from 200 to 280 ppm) and global temperatures increased by approximately 4–5°C. Five hundred years after the onset of the Bølling-Allerød interstadial, a significant rise in sea levels was observed, reaching a height of twenty metres above the preceding level (Alley et al., 2003; Landmann et al., 1996; Martrat et al., 2004). The Bølling warm phase and the Allerød warm phase are distinguished in certain regional climate records by the Older Dryas (Dryas II), which is characterised by a transient return to glacial conditions (cold and dry). The age of the deposits is estimated to be between 14.5 and 13.7 ka cal. BP). The duration of the period was relatively brief, and it does not appear to have had a significant impact on the eastern Mediterranean region (Severinghaus & Brook, 1999; Bar-Matthews et al., 1997; 1999). In contrast, the Bølling-Allerød periods is regarded as a unified, prolonged phase of climatic enhancement in the southern Levant (Bar-Matthews et al., 1997; Bar-Matthews & Ayalon, 2003). Paleoclimate data from Southwest Asia substantiate the occurrence of the Bølling-Allerød phase. Specifically, the δ18O recordings from Soreq Cave revealed a pronounced decline, reaching a zenith around 14 ka cal BP, indicative of a gradual intensification in precipitation and an increase in temperature (Bar-Matthews et al., 1999).

THE YOUNGER DRYAS (DRYAS III)

In order to gain insight into the underlying changes in settlement patterns, economic systems, and social structures that occurred during the Natufian and PPNA periods in the southern Levant, archaeologists have placed significant emphasis on the Younger Dryas (YD) phase. The onset of this arid period is estimated to have occurred relatively rapidly, around 13 or 12.8 ka cal BP, as indicated by palaeoclimatic data (Alley et al., 2003; Martrat et al., 2004; Severinghaus et al., 1998; Severinghaus & Brook, 1999; Weaver et al., 2003). This phenomenon has been identified as a prevalent and widespread occurrence (Andres et al., 2003). The Younger Dryas was characterised by a significant decrease in temperature. Estimated at approximately 6°C, the advancement of northern glaciers, and the expansion of steppe grasslands across vast regions of Europe. The duration of the climatic cooling period concluded abruptly after approximately 1,300 years, with a marked increase in global precipitation and a temperature rise of approximately 7°C. This transition occurred around 11.64 ka cal. BP, marking the onset of the Holocene (Maher et al., 2011). A significant arid interval in the Levant, the Younger Dryas is distinguished by the prevalence of reduced precipitation and a decline in lake levels. The $\delta^{18}O$ values recorded by speleothems in Soreq Cave indicate a significant increase in precipitation levels, suggesting that the conditions were characterised by extreme aridity and low temperatures (Bar-Matthews et al., 1999; Geyh, 1994). In addition, a significant decline in the volume of Lake Lisan during the Younger Dryas, followed by a partial recovery that ultimately led to the formation of the Dead Sea in the Holocene, has been documented (Bartov et al., 2007; Bookman et al., 2006).

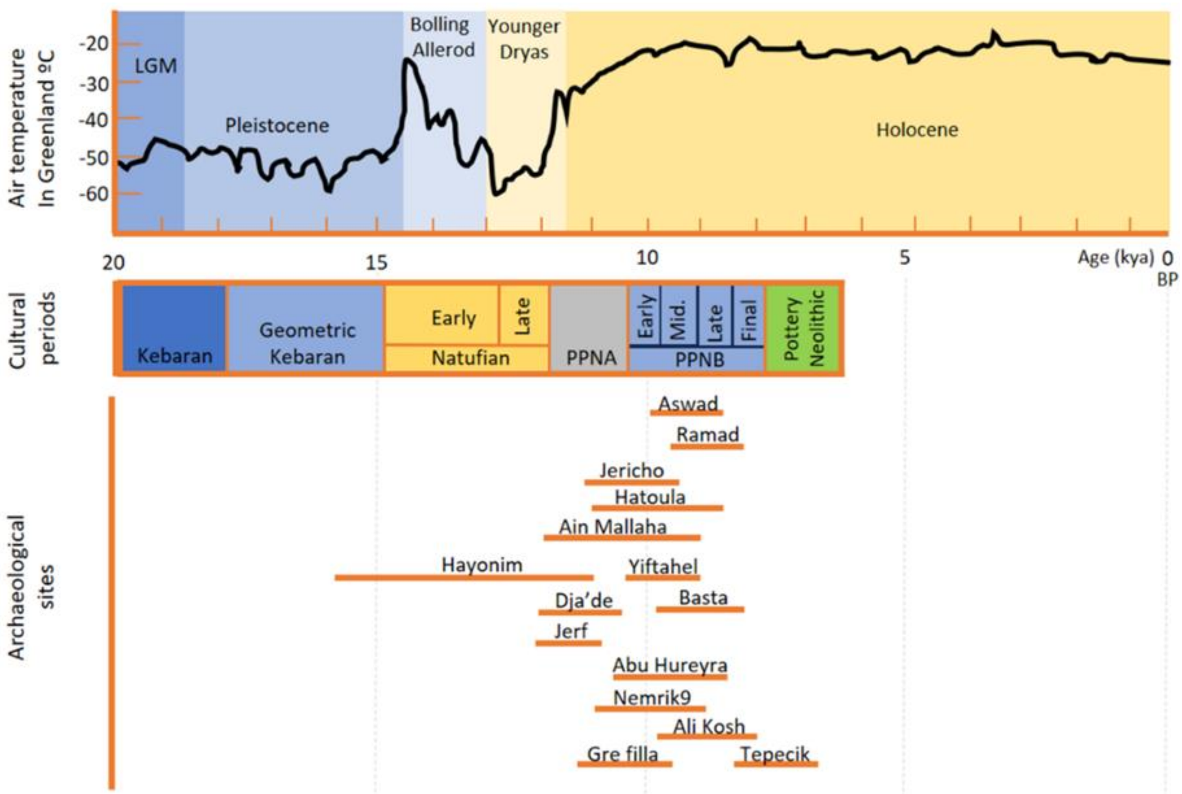


Figure 3 Climatic diagram from 20k years ago to actuality (Zalloua & Matisoo-Smith, 2017). Cultural periods from Natufian to Pottery Neolithic and, archaeological sites in the present study.

THE PREBOREAL PERIOD

Substantial indications that the Younger Dryas period is drawing to a close are provided by a notable escalation in global temperature over the course of a roughly fifty-year period. Based on Greenland ice core dates, the Preboreal (also known as Pollen Zone IV or the oldest sub-phase of the Boreal climatic phase) is a period of rapid warming that commenced approximately 11.4 ka cal. BP (van der Plicht et al., 2004). However, the duration of this period is subject to variation when assessed using different dating methods over the duration of the Boreal period (also known as the Pollen Zone), which are estimated to have lasted around 1,000 years.

The local impact of the Preboreal in the southern Levant on early Neolithic people is still poorly understood but is often linked to the Palaeolithic-Mesolithic shift in Europe. Meltwater caused the Nordic Sea to cool during a two-stage increase in sea surface temperatures, dated to 11.45-11.35 ka and 11.15-11.0 ka cal. BP, respectively. a Preboreal Oscillation (PBO) lasting 200 years between about 11.3 and 11.15 ka cal BP, during which cold, wet weather preceded the abrupt warming of the Boreal (Hald & Hagen, 1998; van der Plicht et al., 2004). Several lines of evidence point to the onset of warmer and wetter conditions in the Southwest Asia during the early Holocene. Speleothem isotopes from the Soreq Cave recorded in central Israel show a decrease in $\delta^{18}O$ values between 10.95 and 9.45 ka cal. BP (Bar-Matthews et al., 1999), indicating a wetter and warmer environment than the preceding Younger Dryas. A significant increase in Pistacia and Quercus (terrestrial sites) and sapropels (marine sites) has been observed in pollen records from a range of Mediterranean marine and terrestrial sites. This change has been termed the Pistacia phase by Rossignol-Strick (1999). The hypothesis that a return to warm, humid weather conditions is supported by the rebound of the Dead Sea is evidenced by the lake levels rising by approximately 9.95 ka cal. BP. The presence of elevated water levels, reinforced terraces and the accumulation of colluvial, alluvial and spring deposits at many sites in the southern Levant indicate increased rainfall and generally wetter weather conditions following the Younger Dryas. (Cordova, 2000; Gvirtzman & Wieder, 2001; Rosen, 2007).

8.2 KA EVENT

Approximately 8,200 years ago, the final dome of the Laurentide Ice Sheet collapsed, precipitating a decline in rainfall in North Africa and Southwest Asia and a precipitous decline in thermohaline circulation int he Nort Atlantic. Recent data from multiple Greenland cores suggest that this arid episode lasted about 160 years, with a pronounced event lasting approximately 70 years, characterised by an anomaly one standard deviation below the mean oxygen isotope values of the preceding millennium (Bar-Matthews et al., 1999). However, changes in Southwest Asia are less well documented. On the other hand, geochemical and geomorphological cave records from the Southwest Asia suggest that the latter part of the ninth millennium cal BP was associated with a temperature decrease of about 1°C and an increase in aridity (Bar-Matthews et al., 1999; Frumkin et al., 2001). Declines in oak, pistachio and other deciduous plants have been recorded in Levantine pollen records, suggesting similar dry and cool conditions (Rossignol-Strick, 1999).

2.2.1.2. CHRONOLOGICAL TERMS

As already mentioned, the first signs of the Neolithic process coincide with climatic variations (see point: 1.2.2 Chronological context). The Neolithic period has been divided into a series of chronoclultural systematizations based on the physical and technical characteristics of the components that make up the material record, as well as the dwellings The term “Natufian” was first employed by Garrod (1928) in the Levantine zone to denote the initial period attributed to the Neolithic process.

This term refers to complex hunter-gatherer societies with a high degree of sedentarisation at the end of the Epipalaeolithic (13,000 - 9,800 cal BP) (Goring-Morris & Belfer-Cohen, 2008). Kenyon (1956, 1960) named and classified the Early Neolithic periods following the Natufian as Pre-Pottery Neolithic A (PPNA) (9,.700 - 8,.500 years ago cal BP), Pre-Pottery Neolithic B (PPNB) (8,700 - 6,250 years ago cal B) and Pottery Neolithic (PN). It should be noted that Early Pottery Neolithic B (EPPNB), Middle Pottery Neolithic B (MPPNB), Late Pottery Neolithic B

(LPPNB) and Late Pottery Neolithic B (LPPNB) are the three periods into which the PPNB is often divided. Despite the prevalence of this classification in numerous studies, it has also been the subject of considerable controversy: some researchers consider the EPPNB to be a transitional phase of the PPNA to PPNB (Bar-Yosef, 1981; Gopher, 1996; Goring-Morris & Belfer-Cohen, 1998), but others, such as Kujit (1998), consider that there is insufficient empirical basis for this. Conversely, a further subdivision, designated Final PPNB or PPNC, has been identified only in the southern Levantine zone.

NATUFIAN

The Natufian culture emerged between 13,000-12,800 and 10,300 years ago cal BP, (Bocquentin, 2003). Its origins are located in the Levant, extending from the Mediterranean coast to Jordan river from west to east, and from the middle Euphrates to the Negev from north to south. In addition to an increasingly uniform cultural base, regional variations are also observed (Valla, 2000; Chambrade, 2012). The Natufian period is divided in three subperiods: the Early Natufian (13.000-12.800-11.300 BP), the middle Natufian (11.300-10.500 BP) and the Late Natufian (11,500-11,200 BP). These categories are based, inter alia, on the study of lithic industries from numerous sites (Bar-Yosef & Valla, 1979, 1991; Bocquentin, 2003).

The residential architecture is characterized by the presence of round or semicircular buildings. Evidence of post holes, often partially buried, in relation to the walls indicates the potential presence of lighter superstructures beneath the stone bases of the walls. As in the preceding period, the construction of buildings was focused on the banks of lakes or rivers and occasionally in naturally occurring cave-like shelters (Aurenche & Kozlowski, 1999; J. Cauvin et al., 1997).

The Natufian period brought a significant advance in the grouping of these huts into hamlets. This development ultimately resulted in the formation of the first fully sedentary communities. Moreover, it was during this period that the superimposition of architectural stages was first observed. This building method was employed throughout the Neolithic period (Valla, 2000). Nevertheless, other groups continued to engage in a state of nomadic movement, particularly in the vicinity of the Dead Sea and the Jordan Valley. The presence of small stations, frequently erected on the surface, is a notable feature of the archaeological record, suggesting their function as temporary refuges for nomadic populations. Moreover, evidence suggests that the emergence of sedentary settlements during the Early Natufian period was not a continuous process throughout subsequent historical periods. Consequently, a return to mobility was observed during the Late Natufian and Final Natufian stages (Cauvin, 1994; Valla, 2000).

The confluence of a variety of ecological zones, including riverbank forest, steppe, and alluvial plain, within the vicinity of the town, suggests a high probability of a broad spectrum of prey. This hypothesis is corroborated by the documented hunting of a substantial number of herbivorous animals and the recorded practices of fishing and hunting of small animals, particularly birds (Mellaart, 1975; Perrot, 1978; Bouchud, 1987; Munro, 2004). The analysis of faunal remains from numerous sites demonstrates the utilisation of resources throughout the year. Furthermore, the diet was significantly influenced by the collection of several plant species from all three settings (Perrot, 1978; Willcox, 2000).

The lithic industry is composed of microliths, exhibiting a similar composition to that observed in the preceding period. The Early Natufian is distinguished by the introduction of a novel cutting method known as the Hélouan retouch, which involves an oblique bifacial retouch on the rear of the segments. Regarding non-geometric components, the microlithisation of armatures underwent a gradual evolution, giving rise to the emergence of novel geometric microliths, including triangles and circular segments. At Middle Euphrates sites, a reduction in the size of microliths was observed, accompanied by the emergence of the first cut stone adzes during the Final Natufian. Although obsidian from Anatolia is beginning to emerge, most of the raw materials employed were local (Cauvin et al., 1997; Cauvin & Chataignier, 1998; Aurenche & Kozlowski, 1999; Chambrade, 2012).

The Natufian culture is particularly known for the significance of its highly standardised bone industry, which includes fishhooks and harpoons, which are more prevalent in the southern Levant, as well as points, punches, eye needles, spatulas, and knife handles (Aurenche & Kozlowski, 1999). The majority of these artefacts are mainly from the southern Levant, together with harpoons and fishhooks (Aurenche & Kozlowski, 1999). Despite the longevity of these items, heavy furniture such as millstones, mortars, and pestles retained their utility at this juncture (Bocquentin, 2003; Akkermans & Schwartz, 2003).

The analysis of multiple graves from this period provides significant insights into the evolution of funeral customs. Generally, burials are located within or near buildings (Bocquentin, 2003; Valla & Bocquentin, 2008). Despite the presence of numerous graves and secondary deposits, the predominant form of interment is individual burial in the earth. This is characterised by the deceased being buried on their side in a flexed posture (Bocquentin, 2003). It is noteworthy that a relatively small number of the deceased were buried with offerings, despite the fact that several graves produced jewellery, which on occasion was composed of shells that originated from locations outside the southern Levant (Belfer-Cohen & Hovers 1992; Bocquentin 1992, 2003; Valla, 2000). In the Early Natufian phase, both individual and multiple burials were observed in equal proportions. These burials were found scattered in inhabited areas, next to houses, under their floors, or in the fill of abandoned buildings. In the Late Natufian phase, a shift in burial practices was observed, with the prevalence of burial clusters in locations external to the habitat, and multiple burials becoming the most common type. The Final Natufian phase, however, is characterised by a reversal of this trend, with a greater number of individual burials, which are scattered (Bocquentin, 2003; Valla & Bocquentin, 2008).

PRE-POTTERY NEOLITHIC A (PPNA)

The Late Natufian in the Levant and the Harifian in the Negev and Sinai are succeeded by the PPNA. In contrast to the Natufian, which spans from 9700±200 to 8700±200 cal BP, the PPNA is represented as a temporal horizon with specific regional variants that overlap with the Natufian. During this period, several cultural groupings emerge. It can be discerned that in the southern Levant, an archaeological group may be distinguished from a lithic industrial group by the distinctive point presence at the El Khiam site (Echegaray, 1963), which produced arrowheads with lateral notches, other sites in the Levant also produce this kind of armature.

KHIAMIAN

The Khiamian period which dates 11,950 and 11,000 cal BP, follows the Natufian period. There is a school of thought amongst archaeologists he authenticity of the period in question, representing a transitional phase between the Natufian and the PPNA cultures (Cauvin, 1994), while others think that it is simply a Sultanian variant (Nadel, 1990) or the product of a combination between the industries of the Sultanian and Natufian strata (Garfinkel, 1996).

The architectural style of the Khiamian period is identical to that of the preceding period. The main difference between the circular structures and the hamlets to which they belonged was that they were no longer systematically buried (Cauvin et al., 1997). Despite a reduction in fishing activity, particularly at sites close to water sources, the subsistence economy continues to rely on a combination of broad-based predation and intensive, diverse gathering practices (Helmer et al., 1998).

One of the main changes that led to the creation of this Khiamian entity was related to the lithic industry. The Khiamian entity is concerned with the lithic industry (Payne, 1976). The presence of El Khiam points, "Hagdud truncation", sickles fitted with bitumen remains and drills, but also a lower frequency of microliths and an absence of heavy tools (axes and adzes) indicate a change in lithic industry practices. The northern Levantine sites have preserved microlithic industries for a slightly longer period, yet they also exhibit a higher frequency of microliths. The sites in the northern Levant retained the microlithic industries for a slightly longer period, but also exhibited the presence of El Khiam points and a micropercussion industry (Bar-Yosef & Belfer-Cohen, 1992; Cauvin et al., 1997). A second notable distinction between the Khiamian and the Natufian is the slightly higher prevalence of female figurines in the former, which are often associated with the Natufian. Additionally, the presence of bull-shaped bucranes within Khiamian settlements should be mentioned (Cauvin, 1977).

The paucity of human remains from the Khiamian period has resulted in a significant gap of knowledge regarding the funeral practices of this era. Four burials from the Khiamian period have been discovered at the Hatoula site in Israel, one of which is located within the confines of a domestic structure. The victims were positioned with their sides or backs bowed (Le Mort, 1994). A small number of scattered bones from disturbed primary burials were discovered in the vicinity of the circular housing structures at the Wadi Tumbaq 1 (Syria) site (Chamel, 2008).

PREPOTTERY NEOLITHIC A – PPNA

The Sultanian culture in the south and the Mureybetian culture in the north represent two of the numerous geographically emergent cultures that comprise the PPNA, which is not regarded as a unified cultural entity. Despite the prevailing view that the Aswadian culture originated in the central Levant, other studies have challenged this hypothesis (Cauvin, 2006). In the case of the Djézireh (Quermézian) and the Zagros (Nemrikian and Mléfatien), alternative civilisations have been proposed (Aurenche & Kozlowski, 1999).

SULTANIAN CULTURE

In accordance with the findings of Cauvin (1994), the PPNA horizon is estimated to have originated between 9,500 and 8,700 cal BC. The Jordan Valley, the Dead Sea region, and the southern Levant are home to Sultanian sites. During this period, several natural areas, including caves, were abandoned. The Euphratic corridor saw the establishment of several locations, including the high valleys and the Zagros (Aurenche & Kozlowski, 1999).

MUREYBETIAN CULTURE

The Mureybetian is characterised by the predominance of circular dwellings, accompanied by rectangular, and occasionally multi-cellular constructions. While these two forms of architecture coexisted in certain locations, there is evidence of a gradual transition fromto the other (e.g. Jerf el-Ahmar, Stordeur & Abbès, 2002). Throughout the Mureybetian sequence, a specific kind of structure, designated as "communal," manifested at numerous locations in the northern Levant. These were substantial, circular, semi-subterranean structures with seating and internal partitions at Tell Mureybet and Jerf el-Ahmar (Stordeur et al., 2001). Similarly, polychrome paintings on the walls of the same kind of constructions were also discovered at the Dja'de el-Mughara site towards the end of the PPNA (Coqueugniot, 2010). The Tell Qaramel site has yielded findings analogous to those of the great circular towers at Jericho (Mazurowski et al., 2009). In a further northern location, the Göbekli Tepe site yielded several substantial circular and oval structures, painted with a plethora of animal motifs and characterised by the presence of imposing T-shaped pillars connected by stone walls (Schmidt, 2003, 2011).

A comparison of the range of fauna at the PPNA locations with data from earlier times reveals no change. However, there has been a notable decrease from fishing. The hunting of ducks was a significant activity in the southern Levant (Chambrade, 2012). From an archaeobotanical perspective, the advent of pre-domestic civilisation is a relatively recent phenomenon (Willcox, 2000).

Despite the PPNA having yielded a greater number of sites than the Khiamian, only a small proportion of these still contain human remains. A significant proportion of these burial sites are in the Southern Levant, but more than 450 individuals having been unearthed at Körtik Tepe in Türkiye. Excavations at this site have also produced fresh information on funeral gestures and customs (Özkaya, 2009). The funerary rituals observed during this period are like those of the Final Epipaleolithic. Additionally, a significant number of primary individual graves, frequently connected to dwellings, have been discovered underground below the floors of homes. The occurrence of burials in the initial community buildings has been documented, most notably at Dja'de el-Mughara and Jerf el-Ahmar. However, the question whether these deposits were the result of voluntary burials remains unclear. For further details, please refer to Akkermans & Schwartz (2003). Furthermore, specific skulls have been observed to have undergone a particular treatment. These skulls were occasionally removed from primary burials and reburied in groups or individually (Kenyon, 1981; Aurenche & Kozlowski, 1999; Stordeur, 2000).

PRE-POTTERY NEOLITHIC B (PPNB)

Unlike the PPNA, the PPNB lacks clearly defined classifications for different archaeological entities. However, the PPNB comprises four distinct periods/categories: Early, Middle, Late and Final (EPPNB, MPPNB, LPPNB, FPPNB). Changes have been observed in the lithic industry at Ain Ghazal. The absence of pottery in chronologies where it is present in other regions, such as the Northern Levant, is particularly noteworthy. Rollefson (1990) proposed the term "PPNC" for the southern Levant region, replacing the previously proposed "FPPNB."

EARLY PRE-POTTERY NEOLITHIC B (EPPNB)

The Early PPNB phase has been identified in the northern Levant, on the Middle Euphrates, Anatolia and Cyprus. The southern Levant has so far. yielded a paucity of sites for this phase, leading some researchers to suggest that the PPNB did not appear until its middle phase. However, the discoveries of Motza site (Khalaily, 2007) near Jerusalem and Qarassa site (Ibañez, 2010) in southern Syria have prompted a re-evaluation of this question, with both sites exhibiting dates and lithic industries comparable to those of the middle phase. These lithic industries bear resemblance to those observed in the early PPNB facies of the northern Levant (Khalaily et al., 2007; Ibañez et al., 2010). The rectangular floor plan was retained, at least in locations in the northern Levant where the structures were rectangular and single storey, in accordance with the residential architectural norms of the period. In a limited number of sites in the Southern Levant, there is a notable shift from the circular layout to a rectangular configuration. As Chambrade (2012) notes, the rectangular plan for Anatolian sites exhibits a fluctuating tendency between curvilinear and rectangular layouts, depending on the specific site.

After a long period of hunter-gathering, the subsistence economy underwent a gradual transition towards a production-oriented approach, which became increasingly evident. The earliest cereals with domestic morphology were identified in Anatolia and the central Levant, even as pre-domesticated crops were being cultivated (Willcox, 2005). At the same time, the first signs of animal domestication emerged, manifestation int the form of livestock (Vigne, 2004; Helmer et al., 2005). The arrival of the goat, most likely already domesticated, on the island of Cyprus suggests a certain degree of animal mastery (Vigne, 2005).

The use of laminar cutting on bipolar nuclei persists as a technique employed in the lithic industry, particularly in the production of sickle elements and large arrowheads. Helouan points, which are related to El Khiam and Aswad points, and the emergence of new armatures with a broad peduncle and lateral fins, called Jericho points, are found in the southern Levant. The advent of the naviform nucleus enabled the slicing of these blades into substantial nuclei. The earliest Byblos points, crafted from colossal unipolar nuclei, emerged in the northern Levant. During this period, the primary objective appears to have been the production of large, uniform blades (M.-C. Cauvin & J. Cauvin 1993; Aurenche & Kozlowski, 1999).

An examination of funeral practices reveals the emergence of specific structures that appear to have been constructed with the deliberate intention of HONORING the deceased. In the subterranean spaces of Dja'de el-Mughara and Çayönü, specific architectural structures have been identified that contain a multitude of graves over extended periods of time, encompassing both primary and secondary burials (Yilmaz, 2010). Similarly, an assemblage of the deceased has been observed at Shillourokambos, where remnants of a burial hole have been discovered (Le Mort, 2011).

MIDDLE PRE-POTTERY NEOLITHIC B (MPPNB)

The PPNB population then expanded across Cyprus and the southern Levant. A considerable number of sites from this period are undergoing expansion. New sites were established in the Middle Levant, and the facies of sites in the Taurus exhibited some differences from those observed in other locations (Rollefson, 1989; Cauvin et al., 1997).

The rectangular architectural style, which can be considered the standard, was prevalent throughout the southern Levant. As outlined by Kuijt and Goring-Morris (2002), the coastal regions saw the construction of rectangular residential structures with considerably more elaborate layouts, while inland sites retained the circular plan. The architectural style of the northern Levantine sites remained unaltered, exhibiting a gradual process of homogenisation and the emergence of a rectangular architectural style (M.-C. Cauvin & J. Cauvin, 1993). Furthermore, plaster and lime were extensively employed for coating and flooring purposes during this period (Kingery et al., 1988).

During this phase, subsistence strategies, encompassing both animal husbandry and agriculture, appear to have undergone a gradual transition towards a production economy (Vigne, 2000, 2005). However, as Kuijt & Goring-Morris (2002) have observed, certain sites appear to have depended on hunting and gathering for their continued existence, as the examples of Kfar Hahoresh, Yiftahel, and Ghwair I demonstrate.

The lithic industry in the northern Levant continued to produce large arrowheads of the Byblos point type. The movement of raw materials, such as obsidian, as well as finished goods over vast distances became increasingly feasible. Furthermore, greenstone polished axes continued to be produced (Cauvin & Cauvin, 1993). In the southern Levant, the employment of naviform nuclei remained widespread, thereby enabling the production of long, straight, and symmetrical blades with predefined shapes. These blades were then used to make tools such as sickles, arrowheads, and drills. Nevertheless, there are considerable geographical variations in the typology of debitage and the way blades are employed. For example, archaeological sites situated in arid environments have been found to have a significantly higher concentration of arrowhead and burin artefacts, whereas those located in the Mediterranean region have a greater prevalence of sickle-related items (Kuijt & Goring-Morris, 2002).

A significant proportion of funerary practices have remained largely unchanged since the preceding period. However, in the southern Levant, at Tell Aswad, Tell Ramad, Beisamoun, Jericho, Ain Ghazal, and Kfar Hahoresh, the technique of overmodelling skulls appears to have become more widespread (Stordeur & Khawam 2007). At this juncture, Koşk Höyük in Anatolia is the only site outside the southern Levant that has yielded overmodelled skulls (Özbek, 2009). In the middle of the PPNB period, the funerary practice of burying the deceased inside their domestic structures while they were still in use became widespread. This contrasts with the previous periods when the deceased were often interred in abandoned buildings. Typically, burials are primary and individual. However, the relationship between the deceased and the living is undergoing a transformation. This is exemplified by the practice of burying the deceased in a circular trench at the front of the home in Tell Halula (Syria), which is then meticulously sealed (Molist, 2001; Ortiz et al., 2013). Similarly, in Aşıklı (Türkiye), the flooring is replastered following interment (Esin & Harmankaya, 1999).

LATE PRE-POTTERY NEOLITHIC B (LPPNB)

As proposed by J. Cauvin et al. (1997), cultures that did not use pottery after 8500 BP are classified as Final PPNB and PPNC. After this phase, the specificities of PPNB begin to diminish, both in terms of the types of sites and the flow of raw materials and completed goods. There seems to be a renewed focus on local economies, with smaller sites in some cases replacing larger ones that have been abandoned.

In the lithic industry, local resources are typically preferred over imported materials (Aurenche & Kozlowski, 1999). In contrast to the notion of a single, universal culture, the archaeological record reveals the emergence of multiple local and regional cultures. A considerable number of sites have already yielded ceramics from this period, while others continue to utilise white dinnerware composed of gypsum or lime plaster (Cauvin et al. 1997). Furthermore, during this period, new populations established El Kowm 2 as a community and inhabited arid regions such as the El Kowm basin. In the vicinity, semi-nomadic sheep herders utilised the Qdeir station as a base camp; analogous sites could be observed in the higher reaches of Umm el-Tlel. Pastoral nomadism flourished in the PPNC (Stordeur, 1993; Cauvin et al., 1997; Alarashi, 2006). This was the prevailing form of social organisation in the El Kowm basin and the southern and central Levant (Rollefson & Köhler-Rollefson, 1993).

Rollefson (1993) originally used the term "PPNC," which is primarily used to refer to the southern Levant, to refer a time period that followed the PPNB and came before the Pottery Neolithic (PN), but only in the central and southern Levant in archaeological sites like Beisamoun and Atlit-Yam 7 in Israel, or Ain Ghazal and Beidha in Jordan. According to Köhler-Rollefson (1993), the further development of PPNB subsistence strategies - combining animal husbandry and cultivation - would have resulted in the abandonment of villages and significant damage to the ecological systems surrounding the agricultural settlements.

Based on socio-economic and socio-cultural adaptations, the PPNC idea would have developed as a result of the reconstruction of the subsistence economy into distinct agro-pastoralist population groups, which was reported around the beginning of the seventh millenia. It should be noted that the changes in the subsistence sphere would not have occurred suddenly; rather, the population would have continued to use agricultural and pastoral methods to adapt to their environment. From this point onwards, however, they would have been organised on the basis of a greater spatial separation of pastoral and agricultural activities (Köhler-Rollefson, 1993).

POTTERY NEOLITHIC (PN)

From the beginning of the 7th millennium, several changes in the archaeological record indicate a partial transformation of the agricultural and pastoral societies. This period is generally referred to as the Late Neolithic by some historiographical schools and as the Pre-

Halaf and Halaf periods by others (Molist, 1998; Gómez Bach, 2011)). The emergence of pottery is one of the most significant developments of this period. It mainly occurred in the northern part of Southwest Asia. In more southern or semi-desert areas, such as the El Kwom region (Syria), the pre-ceramic phase was prolonged with a final PPNB or PPNC. This technological change occurred about 600 years later (Akkermans & Schwartz, 2003; Aurenche & Kozlowski, 2003).

Given the considerable continuity in social and economic characteristics, two distinct phases can be identified between 7,000 and 5,500 cal BP. These periods are delineated by the history of pottery production and, more generally, by the archaeological record. The first phase, from 7,000 to 6,300 cal BP, is characterised by the emergence of several cultural zones or regionalisations, mainly delineated by stylistic standards associated with pottery production. In the same way, Proto-Hassuna groups in the northern plains of Mesopotamia and the Pre-Halaf phase or early pottery production from the Jezirah to the Syrian coast have been distinguished. In recent decades, a small period called Proto-Halaf has been established that would cover the period from 6,300-6,100 cal BC and would mark the characteristics of the more classical Halaf culture, chronologically between 6,100-5,500 cal BP (Akkermans & Schwartz, 2003; Aurenche & Kozlowski, 2003; Cruells & Nieuwenhuyse, 2004).

According to the habitat model, each of these periods witnessed the abandonment of large communities in favour of smaller, more dispersed ones. While there is evidence of continuity in certain northern sites, such as Tell Halula, Akarcay Tepe or Sabi Abyad, this is accompanied by a reorganisation and restructuring of the space, with the agglomerated habitat model being replaced by a dispersed one (Molist et al., 2022). However, small camps or sporadic settlements associated with pastoral activities reappear in semi-desert areas, often around oases or water sources, such as the El Kowm basin or the Palmyra oasis, and in other marginal areas, always of a more steppe type (Cauvin, 1990; Banning, 2002).

Changes in architectural models and construction methods suggest a reduction in labour investment and the abolition of the rigidity of PPNB building types. Buildings are characterised by the resurgence of the circular plan (tholoi), interpreted by some researchers as a dwelling unit and by others as a granaries and/or spaces with complementary functions, and by the continuity of rectangular, often multi-cellular plans (Akkermans & Schwartz, 2003). In addition, the construction of substantial structures is primarily driven by storage needs, (Banning, 2002).

The **appearance of ceramics** marked a significant milestone in the evolution of technology. The addition of crushed calcite to the clay resulted in enhanced resistance to direct firing, making them more suitable for direct use in cooking. Originally, the pottery was characterised by its simple shapes and minimal decoration, yet it exhibited excellent technical quality in its construction. Subsequent regional variations, characterised by distinct morphological and technological advances, as well as ornamental themes, enriched the ceramic assemblage. During the spanning up to the sixth millennium, the so-called Halaf civilisation emerged, during which high-quality productions began to distinguish themselves from simple productions or cooking pots, which, despite their prevalence in archaeological sites, required less labour (Akkermans & Schwartz, 2003; Gómez-Bach, 2011). The former are vessels of high technological quality, likely already moulded using a slow or manual potter's wheel and finished with decorative motifs painted with one or two colours. The high-quality productions are different from the simple productions or cooking pots, which, despite being the most common in the settlements, require less labour (Akkermans & Schwartz, 2003; Gómez-Bach, 2011).

The first type is vessels of high technological quality, probably already moulded on a slow or hand wheel and decorated with decorative motifs painted in one or two colours. Due to these factors, pottery has emerged as the primary component of the archaeological record used to create cultural and often chronological groupings (relative chronology). The absence of ceramic material in the early phases (late PPNB and PPNC) and the continuation of some technological elements of the PPNB, particularly in the stone industry, are particularly evident in the southern Levant or the semi-desert regions of Near East. Other innovations include the establishment of regulated storage systems and the use of seals to identify ownership (Frangipane, 1996; Akkermans, 2014).

In terms of technology, lithic tools have experienced another major shift, with the use of foreign materials, such as obsidian, is decreasing in favour of indigenous resources. There has also been an increase in the production of tools with small blades or flakes, which have lower levels of quality and uniformity. In addition, fewer types of artefacts, such as stone vessels or axes, are being produced. These characteristics have resulted in a simpler industry for daily use, the observance of a double technological cycle, and the maintenance of a high level of investment in selected products made from allochthones raw materials.

Another area where there has been a notable change from previous times is burial practices. Although individuals do still appear in isolated form in abandoned structures, there are now distinct spaces on the outskirts of settlements where people are buried in the form of a cemetery, as is the case at Tell el-Kerk in northwestern Syria or at Tell Sabi Abyad in the Balikh Valley (Akkermans et al., 2014). It was common practice to bury individuals in trenches, usually alone and with their legs bent. According to the pre-Halaf levels of Tell Halula, newborns are occasionally buried in ceramic vessels (Molist, 2013).

Despite the consolidation of the agricultural and livestock farming model into an integrated system within society, there were also notable shifts in economic activities. There was consumption of domestic grain and legume species, which represent a narrower range of variation. In the Jezirah region, pastoralism thrived, while pig rearing was abandoned in favour of cattle. As can be inferred from the patterns of slaughter, the residues on pottery, and the rise in wool-working tools, this must have been the consequence of a stronger focus on animal husbandry techniques that prioritised by-products over meat production (Akkermans & Schwartz, 2003; Evershed et al., 2008).

In parallel with this climatic and ecological change and the subsequent economic transition from hunting, fishing and gathering to a food production economy based on agriculture and husbandry and/or new processing techniques, (Eshed et al., 2006), a reduction and/or morphological alterations in craniofacial and dental structures are evident. (Smith, 1986, Larsen, 1995; von Cramon-Taubadel, 2011; Pinhasi et al., 2006, 2008, 2015; Pokhojaev et al., 2019 ; Menéndez & Buck, 2022), both in Southwest Asia (Smith, 1986, Brace et al., 1987; Kaifu, 1997; Erdal, 1999, Le Luyer & Bayle, 2017; Pinhasi et al., 2008, Alrousan, 2009, Pinhasi 2008, 2015, May et al., 2018; Menéndez & Buck, 2022) and other regions (Smith, 1972, Carlson & van Cerven, 1977; y'Edynak & Fleisch, 1983; Formicola, 1987; Jacobs, 1994, Le Luyer & Bayle, 2017; Nava et al., 2021, Pokhojaev et al., 2019; Godinho et al., 2023; Martin et al., 2023). Understanding the relationship between climatic and dietary changes and tooth morphology could provide valuable insights into the evolution of these traits under natural selection and the adaptations of human populations over time.

1.3. TEETH: MORPHOLOGY, SIZE, WEAR, TOPOGRAPHY

1.3.1. TOOTH MORPHOLOGY

Teeth are of great importance in archaeological and forensic contexts, and apart from being a great source of biological and cultural information, they are the best-preserved human remain in archaeological and palaeontological contexts. The reason why teeth tend to be better preserved than other bones is due to two main factors: 1) The enamel surface is the hardest tissue in the human body due to most of it (95-96%) comes from inorganic sources, namely calcium hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$] (Nanci, 2008);2) Teeth (or teeth germs) are present in every individual, with the exception of a small number of anodontic individuals (Scott et al., 2018).

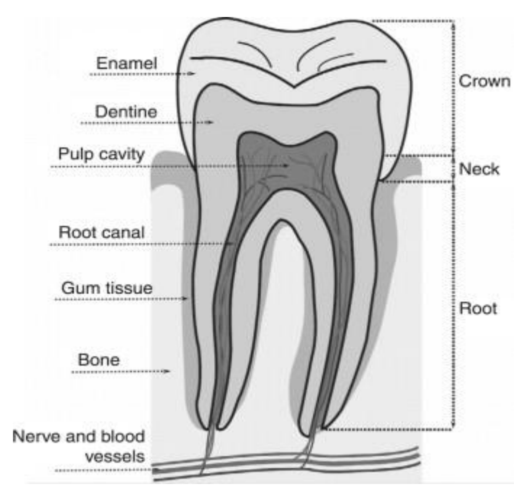


Figure 4 Tooth crown and root morphology.

The human dentition has two sets of teeth, making it diphyodont. These are the permanent dentition, which gradually replaces the primary dentition, and the deciduous dentition, also known as the milk dentition or primary dentition. We can distinguish two parts in each tooth: (1) the crown that is exposed in the oral cavity and (2) the root/s that is positioned in the alveolar cavity of the jawbone (maxilla and mandible) (Figure 4 and 5). The enamel and cementum cover the crown and root of each tooth, respectively. The cement-enamel junction, also known as the cervical line, is where the two structures meet. Below the enamel there is the dentin tissue, which surrounds the pulp cavity - the only soft dental material - lies beneath the layers of cementum and enamel. In addition to these general similarities in dental structure, the morphology of teeth varies according to the type of tooth and the upper or lower maxillary bone in which the tooth is located. This is particularly noticeable in incisors and molars (which have different cusp and foveas patterns).

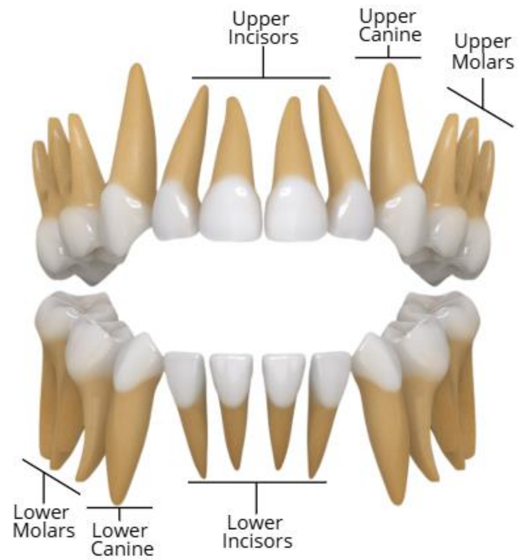


Figure 5 Upper and lower primary human dentition.

Usually, for a better understanding or a better identification, each maxilla and mandible is divided into left and right quadrants. As a result, the dentition is divided into four quadrants: upper right (UR), upper left (UL), lower left (LL) and lower right (LR). The left and right quadrants of the skull are mirror images of each other because they are separated by the median sagittal line. As all mammals, humans are heterodont, each mentioned quadrant contains teeth with different morphologies. There are four different types of teeth in humans: incisors (I), canines (C), premolars (Pm) and molars (M) and the primary dentition is composed by 2 incisors (di1 and di2), one canine (c) and 2 molars (dm1 and dm2) for each quadrant (dental formula 2:1:2/2:1:2) (Figure 5). The permanent dentition is composed by two incisors (I1 and I2), one canine (C), two premolars (Pm3 and Pm4) and three molars (M1, M2 and M3) (Figure 6) (Hillson, 1986).

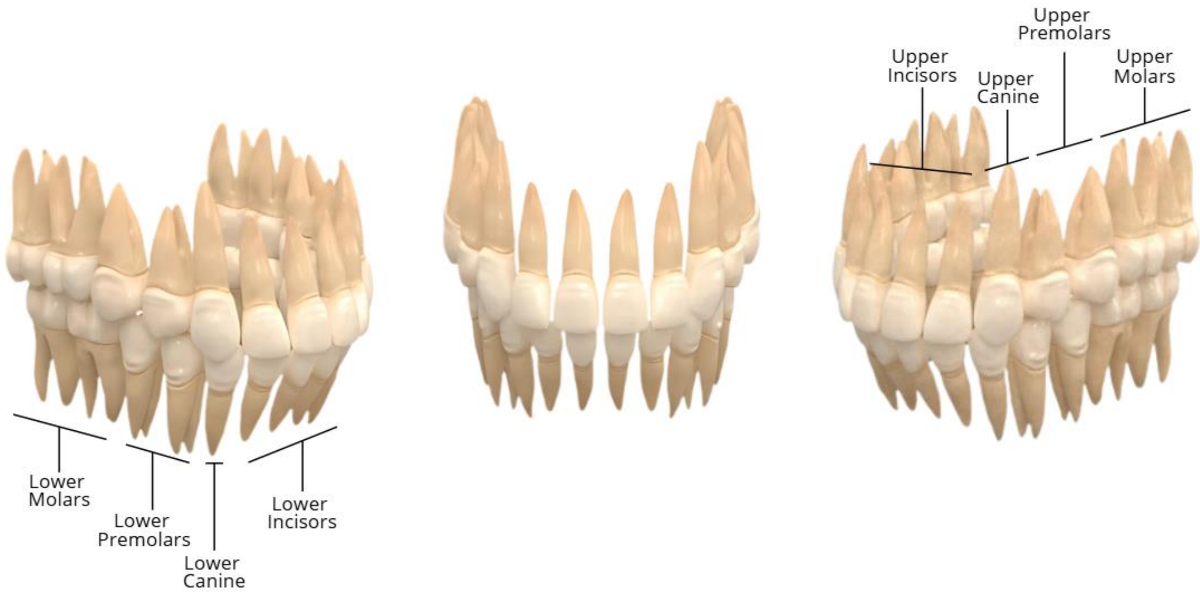


Figure 6 Upper and lower human complete permanent dentition with the lack of M3. (N=,32) the dental formula is 2:1:2:3/2:1:2:3

1.3.1.1. UPPER DENTITION

INCISORS

The incisors are the teeth located closest to the sagittal plane. The central incisors contact each other at the midline, connecting the right and left quadrants, while the second incisors contact the canines on their distal side. Incisors are the unique teeth without apparent cusps; after eruption, the remnants of three cusps, called mamelons, are quickly worn. The incisal surface is characterized by the presence of a cutting blade-like structure with a sharp edge. The incisors are responsible for shearing, chopping and separating food particles in preparation for mastication, the subsequent process.

As postulated by Nelson and Ash (2010), the **maxillary central incisors** are the broadest of all teeth, exhibiting a considerable mesiodistal dimension. Additionally, they are characterized by a rectangular crown form on the labial aspect, which exhibits a slight convexity. When observed from the labial aspect, the mesial aspect of this tooth is often straight or slightly convex, while the distal contour is frequently markedly convex. The incisal surface is typically characterised by a pronounced degree of straightness and crispness. From the lingual aspect, the bottom portion of the tooth is curved, creating a structure known as the cingulum, while the top portion is concave, with mesial and distal borders generating marginal ridges encircling the concavity, known as the lingual fossa.

Although they serve the same purpose and share many traits with their central counterparts, the **maxillary lateral incisors** are substantially smaller in most respects. The lingual surface is frequently less concave, exhibiting discernible marginal ridges and a notable cingulum, whereas the labial surface is somewhat more convex.

CANINES

Canines, which are situated between the incisors and premolars, participate in food processing. Although their morphologies are similar, the upper canines are broader than the lower canines. These teeth are characterised by a single root and a single, well-defined cusp. They are typically the longest and tallest in the tooth set. Most of their surfaces exhibit a pronounced *cingulum*, particularly in the upper canine, and are markedly convex, with marginal ridges discernible on the lingual aspect. The lingual surface of the mandibular canine exhibits a flatter configuration than that of the upper canine, characterised by the presence of marginal ridges and a moderately developed cingulum.

PREMOLARS

Subsequently, the premolars assume the position of the deciduous molars. As primitive mammals possessed four premolars, the first two of which were lost throughout the clade's evolution, there are two premolars in each quadrant, which are referred to as the third and fourth premolars, respectively. The more frequent premolar phenotype is characterised by one or two roots and two cusps. However, there is considerable variation in the number of cusps, with mandibular premolars often displaying a range of one to three. It is frequently observed that the buccolingual dimension of the crown is longer than the mesiodistal dimension. They have a dual function, facilitating the grinding of food with the molars and the shearing of food with the canines. Additionally, they maintain and reinforce the vertical alignment of the face (Woelfel, 1990). It is common practice to refer to molars and premolars as posterior or postcanine teeth.

The crowns of the premolars appear to exhibit a pentagonal configuration when observed from a buccal perspective, with the distal ridge displaying a greater length than the proximal. Two facial grooves are observed on the buccal surface, which exhibits a degree of curvature. The mesial ridge of the main cusp is longer than the distal one in the upper first premolar, a pattern that is not observed in the other premolars. The lingual surface is convex, yet somewhat narrower than the buccal surface. The lingual cusp is sharp but markedly smaller than its buccal counterpart, with the tip bending mesial, except in the case of the upper fourth premolar, where the sizes are equal.

The upper premolars display a more centrally located (bucco-lingual) central groove and mesial and distal fossa. The lower fourth premolar may exhibit an occlusal Y-type cusp pattern, which comprises two lingual cusps in addition to the buccal primary cusp. In contrast to the other premolars, which are single rooted with a tendency for the root to curl distally rather than mesially, the upper third premolar may possess one or two roots, with a furcation occurring at the apical third of the root.

MOLARS

The human dentition comprises three molars in each quadrant of the jaw. In the process of mastication, these teeth are primarily responsible for the grinding of food particles. Additionally, they play a pivotal role in maintaining the vertical alignment of the face (Woelfel, 1990). With a total length of approximately half of the dental arch (51% mandibular and 44% maxillary), the molar teeth are the largest teeth in the jaw and lack precursors in the deciduous dentition (Woelfel, 1990) the first molar erupted just behind the deciduous second molar. The morphology of molars is the most complex, exhibiting significant variation across jaws and between teeth.

Of all the molar teeth (Scott and Turner, 1997; Bailey, 2004; Gómez-Robles et al., 2007), the **first upper molar** has the most stable shape. It frequently comprises two buccal cusps (protocone and paracone) and two lingual cusps (metacone and hypocone). On occasion, an additional Carabelli cusp may be present on the lingual side of the metacone. A transverse groove of the oblique ridge connects the paracone and metacone, whereas a distal oblique groove clearly defines the hypocone (the disto-lingual cusp) in this tooth. The first upper molar typically contains three roots of comparable length, two of which are situated buccally and one lingually. The smallest of the cusps is the hypocone. The tooth's overall squared aspect, as observed from an occlusal perspective, frequently exhibits a greater buccolingual dimension than a mesiodistal one. In most cases, the disto-lingual cusp (hypocone) is the smallest and the mesio-buccal cusp (protocone) is the largest.

In comparison to the first upper molar, the **second upper molar** is typically smaller in size and exhibits a more varied morphology. Nevertheless, the presence of four cusps, it may manifest a reduced hypocone or an absence thus far unobserved. From an occlusal perspective, the proximal side appears to be broader than the distal side. In the absence of the distolingual cusp, the smallest cusp is located distolingually, whereas the largest cusp is often the mesio-lingual cusp. As with the first molar, the proximal and distal foveae are deep and clearly defined, and the oblique ridge is broad. Additionally, three fully developed roots are observed in the tooth.The third maxillary tooth to emerge and the final one in the dental arch is the **third upper molar**. This is the smallest and exhibits the greatest morphological variety of all the molars (Woelfel, 1990).

1.3.1.2. LOWER DENTITION

INCISORS

Despite the notable dissimilarities in the anatomy of the mandibular central and lateral incisors when compared to their upper counterparts, there are nevertheless similarities. The central incisor is typically narrower than the lateral, rendering it the narrowest tooth in the entire set. Indeed, the mandibular central incisor is frequently the smallest tooth in the pair. The buccal surface of these teeth is characterised by a regular, lengthy and almost straight configuration. The lingual surface is less concave than that of the upper central incisor, although the cingulum is still present. In comparison to the maxillary central incisor, the marginal ridges are less discernible. While there may be variations in length and breadth, all incisors possess a single root.

CANINES

The morphology of the lower canines is comparable to that of their higher counterparts. One notable distinction is the shorter width of the lower canines in comparison to the upper canines. They possess a single root and a single, readily discernible cusp. The surfaces are highly convex, similar to those of the upper canines, with a cingulum and lingual surface displaying marginal ridges. The lingual surface of the mandibular canine exhibits marginal ridges and a marginally developed cingulum, resulting in a flatter morphology than that of the upper canine.

PREMOLARS

Most lower premolars exhibit two cusps; however, considerable diversity is observed, with mandibular premolars frequently displaying one or two additional roots. The crowns of these teeth frequently exhibit greater bucco-lingual extension than mesio-distal extension, as observed in the upper premolars. A similar function is performed by combining food processing and shearing. Additionally, they are crucial for maintaining facial verticality (Woelfel, 1990).

As it is said in the upper premolar dentition the crown of the premolar tooth exhibits a pentagonal configuration when observed from the buccal aspect, with the distal ridge being of a greater length than the proximal. Two facial grooves and a slight curvature are present on the buccal surface. The distal ridge of the primary cusp is longer in the other premolars, whereas the mesial ridge is longer in the upper first premolar. Although it is somewhat thinner than the buccal surface, the lingual surface is convex. Except for the upper fourth premolar, in which the cusps are of comparable size, the lingual cusp is sharp but noticeably smaller than its buccal counterpart, with the tip bending mesial. Due to the propensity of the crown to flex lingually, as opposed to the straight structure of the upper premolars, the mandibular premolars exhibit a disparity in cusp size that is more pronounced than that observed in the upper teeth. Despite having a somewhat shorter crown than the third premolar, the mandibular fourth premolar is frequently slightly larger. In contrast to the other premolars, the buccal surface of the mandibular third premolar is convex and exhibits facial grooves that are more pronounced than those observed in the other premolars.

MOLARS

Regarding mesiodistal dimensions, the **lower first molar** is the most prominent in the mandible. It is characterised by two lingual cusps (the entoconid and hypoconid) and three buccal cusps (the protoconid, paraconid and hypoconulid). The distal cusp (hypoconulid) is the smallest, while the mesiobuccal cusp (protoconid) is the largest and tallest. In general, the lingual cusps of the lower molars are sharper than the buccal cusps. Additionally, the buccal side of the crown is often broader than the lingual side. In the occlusal view, three principal fossae (central, mesial, and distal) and multiple grooves (central, media- and distobuccal, and lingual) are observed, along with a multitude of ridges (mesial and distal marginal ridges). There is considerable variation in the arrangement of these distinct qualities. Three primary patterns may be identified based on the quantity of cusps and the connections between the grooves. The most common pattern is Y-5 (five cusps), followed by a four-cusps pattern. Some mandibular first molars may exhibit a tuberculum sextum, a supplementary sixth cusp (Y-6) between the distal and disto-lingual cusps, and a tuberculum intermedium. Additionally, an additional seventh cusp may be present between the lingual cusps.

In the modern human dentition, the **lower second molar** exhibits four cusps and a +4 occlusal pattern. It is typically smaller in size than the first molar. While not to the same extent as the first lower molar, it is somewhat broader in a mesiodistal direction than in a buccolingual direction. In general, the mesial cusps are larger than the distal cusps. In the occlusal view, three primary fossae (central, mesial, and distal) and three principal grooves (central, buccal, and lingual) are frequently observed. Although it has been observed in some human communities, such as Chinese and African groups, Y5 patterns – which consist of five cusps – are uncommon in second lower molars. In comparison to the first lower molar, the two roots are closer to one another and exhibit a bending tendency distally.

Out of all the teeth, the **lower third molar** has the most morphological variance. The most common characteristic is a convex buccal and lingual crown surface, comprising three or occasionally four cusps. The lingual cusps are typically larger than the buccal cusps. The tooth appears wrinkled due to the markedly uneven groove pattern, which comprises multiple pits and grooves. The roots of this tooth tend to fuse together and are relatively short.

1.3.2. NOMENCLATURE

In this thesis, each tooth has been referred to by the first letter of its name (I for incisors, C for canines, Pm for premolars and M for molars), in capital letters in the case of permanent teeth, and in lower case letters, preceded by “d” term, in the case of temporary teeth (deciduous). Each of these letters is followed by a number and two letters. The first letter indicates whether the tooth is lower (L) or upper (U) and the second letter indicates whether the tooth is left (L) or right (R). For example, the lower right first bicuspid is 'M1LR'. The upper left fourth premolar is 'Pm4UL'.

The part of the crown that faces the opposite tooth is called the occlusal surface in premolars and molars (Hillson, 1996). The rest of the crown surfaces are named according to the position of the tooth in the maxilla or mandible. In each arch of the maxilla or mandible, the teeth are arranged in a row so that the surface facing the outside of the mouth or the medial sagittal plane is called mesial, while the opposite surface facing away from the medial sagittal plane is called distal. The surface facing the tongue is called the lingual surface. Finally, the surface towards the outside of the arch, towards the lips and cheeks, is called buccal, labial or vestibular. The word labial is usually used for incisors, while buccal is used for canines, premolars and molars (Hillson, 1996).

1.3.3. LIFE HISTORY PATTERN

A subfield of biology known as "life history pattern" studies the way organisms distribute energy during vital functions, including development, maintenance, reproduction, and the acquisition of independence by their progeny. Moreover, it encompasses the strategies employed by organisms to evade mortality (Bogin, 2003). The timing of birth, the age at which weaning occurs, the length of the various stages preceding reproduction, the number of offspring produced, the number of children per birth, and the lifespan are all crucial elements of the pattern observed in primates, which belong to the class Mammalia (Smith and Tompkins, 1995; Bogin, 1999a). The life strategy pattern thus elucidates the way organisms are shaped by natural selection and other evolutionary processes, with the objective of enhancing their chances of survival and reproduction (biological efficacy) in the context of fluctuating ecological conditions and stresses.

In the field of life strategy, two distinct categories of information can be identified (Skinner and Wood, 2006; Robson and Wood, 2008). The first category encompasses a range of variables, including gestation period, age at weaning, longevity, the interval between births, and the age of first and last reproduction, among others. These variables, which reflect the vital rates of the population and mark the times and patterns of the different strategies, are referred to as Life History Variables (LHV). The second category comprises variables that have been empirically correlated with the Life History Variables in primates. Such variables are designated as life history-related variables (LHRV). Such variables include those pertaining to body mass, brain size and **dental development**. From a palaeontological perspective, the last ones mentioned are of particular significance, as they are variables that can be investigated in hominin fossils to infer the life history variables (LHV).

1.3.4. HUMAN DEVELOPMENT

In comparison to other primate species, modern humans exhibit disparate growth trends (Tanner, 1990; Bogin, 1999a, 2009). These include a lengthy growth phase, extending up to approximately 20 years, a significant interval between weaning and puberty, and the onset of puberty at the commencement of adolescence.

To understand the evolution of our evolutionary lineage's somatic development pattern, it is first necessary to identify the number of stages that characterise the ontogenetic development of Homo sapiens and the traits that differentiate them. The four big stages of the human development model are situated between the postnatal and adult phases of life. (Schultz, 1960; Timiras, 1972; Bogin, 1999a, 1999b, 2001, 2003; Bermúdez de Castro, 2002). These are the stages of infancy, childhood, youth, and adolescence.

After parturition, a postnatal period of slightly over one month ensues, succeeded by the inaugural developmental phase, designated as infancy. The period of infancy lasts until the second deciduous molars (dm2) erupt, which occurs between the ages of two and two and a half years. The development and eruption of deciduous teeth are the defining features of this stage of development. During this time, at least in optimal natural circumstances, the infant is a newborn. The brain grows quite quickly during this time, and the motor and sensory systems are developed enough to allow for environmental exploration.

The subsequent period is designated as childhood, which spans the interval between the eruption of the second deciduous molar (dm2) and the emergence of the first permanent molar (M1). This occurs at approximately 6-7 years of age. At the outset of this period, children are weaned, yet they remain dependent on their parents for sustenance. During this period, children begin to consume a varied diet rich in carbohydrates, lipids and proteins, which is essential for brain growth, as the definitive size of this organ is practically reached at the end of this period. Conversely, physical growth is markedly gradual, and the digestive system has not yet reached full maturity.

Subsequently, it comes the juvenile stage, which is characterised by the maturation of the central nervous system. During this period, the permanent dentition emerges to replace the deciduous dentition. The period between the ages of seven and twelve for males and seven and ten for females' typically spans for five years for males and three years for females. The eruption of the second permanent molar (M2) approximately coincides with the conclusion of this phase in both sexes. This period is characterised by the maturation of both the immune system and the digestive system. The process of achieving autonomy from adult supervision starts when the individual's brain has reached its full cognitive capacity. This phase reaches its conclusion with the onset of puberty, which typically occurs over a relatively brief period, lasting a few days or weeks. This process is characterised by an increase in the release of sexual hormones and the reactivation of the central nervous system that is involved in sexual development. The final stage before the adult period is adolescence. This period, which lasts for the last 5 to 10 years after puberty, should be marked by the appearance of the third permanent molar (M3). Secondary sexual characteristics emerge, as do changes in voice and an acceleration of physical growth.

The typical age at which contemporary humans reach the adult phase, or complete adulthood, is approximately 20 years old (Bogin, 2001, 2003). The conclusion of somatic growth and the attainment of skeletal maturity mark the end of this period. However, the neocortex of the contemporary human brain does not reach full maturity until approximately 30 years of age. The neocortex attains its full volume at approximately six years of extrauterine life (Leigh, 2004). The pruning of neuronal connections in the prefrontal cortex (Petanjek et al., 2011) and the myelination of neuronal axons (Miller et al., 2012) are indicative of this process. Adulthood is comprised of two distinct phases, representing the longest stage of the life cycle. The initial phase is characterised by the establishment of homeostatic processes in physiological, behavioural and cognitive systems, and it persists until the conclusion of the reproductive phase. The second phase is that of senescence and old age, which is characterised by a decline in the functionality of multiple bodily systems and tissues, ultimately resulting in the individual's demise.

Most mammals demonstrate a consistent growth trajectory until reaching puberty, at which point their growth rate begins to decelerate in accordance with a single mathematical function. Moreover, sexual maturity occurs prior to somatic maturity. In highly social mammals, such as primates, a juvenile stage is included between infancy and adulthood, which delays sexual maturity and prolongs somatic development. In these species, the brain is fully formed before the completion of development and the attainment of maturity. For example, chimpanzees and gorillas exhibit a shorter developmental period than humans, and do not experience the conventional stages of childhood and adolescence. However, their developmental trajectory is characterised by a protracted childhood and juvenile phase. The growth of humans can be described by three distinct mathematical functions. The first is the period of growth up to four years of age, which is characterised by a sharp decline in growth. The second is the period between four and ten years of age in girls and between 12 and 14 years of age in boys, during which growth declines more gently. The third is the typical pubertal growth period of adolescence (Bogin, 1999b).

4.3.1.1. ODONTOGENESIS

The term 'odontogenesis' is used in the medical field to describe the formation and eruption of teeth. As with any organ, odontogenesis requires three fundamental processes (Peters and Balling, 1999):

1. *Initiation*, indicating the precise location where the tooth must begin to form.
2. *Morphogenesis*, whereby the cells commence the formation of the rudimentary organ.
3. *Differentiation*, whereby the specific structures of the tooth are formed.

Teeth originate from the embryonic epidermis and dermis (ectoderm and mesoderm, respectively) (Nanci, 2014).

The initial morphological indication of tooth development is the establishment of the dental lamina, which is the result of a notable thickening of the oral epithelium (Jernvall and Jung, 2000; Boughner and Dean, 2008). Subsequently, the dental germ is formed when the dental lamina grows into the underlying connective tissue of the first branchial arch. The formation of an invagination of the epithelium within the mesenchyme is the result of a signalling process between the mesenchyme and the oral epithelium of the dental lamina. The bottom surface of the germ then undergoes another invagination, this time wrapping around the condensed mesenchymal cells at its apex. A cap-shaped structure is formed around the mesenchymal dental papilla as a result of the cervical loops that are created when these new folds grow in the direction of the lower region. The crown of the developing tooth will be sustained by this structure.

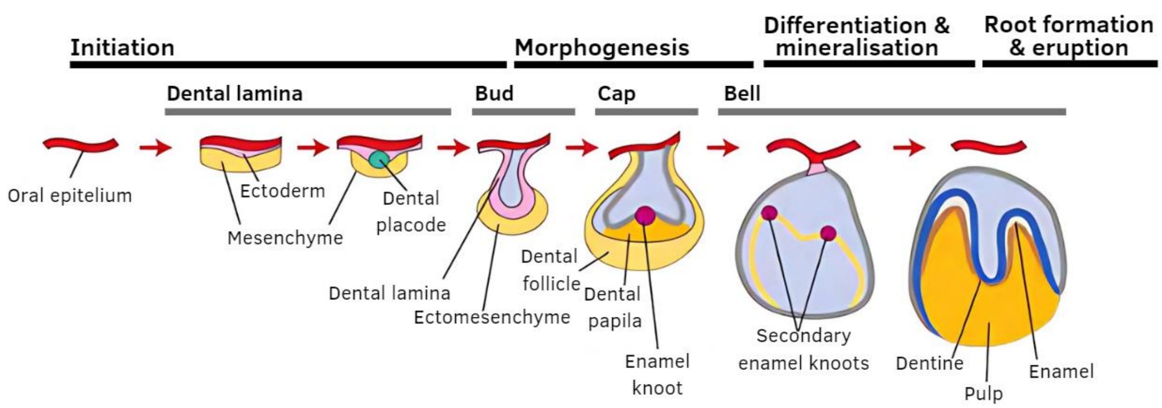


Figure 7 Schematic representation of the events occurring in the histological level during dental development. Adapted combining: Brook, 2009; Nancy, 2014.

The differentiation of the dental lamina from the vestibular lamina of the epithelium marks the onset of the **initiation phase** (Figure 7). At approximately day 28 of embryonic development, the oral epithelium commences a process of thickening at specific locations, thereby forming the dental placodes (Brook, 2009; Nanci, 2008, 2014; Scheuer & Black, 2000, 2004). As the bud forms in the precise locations where the mesenchyme condenses, the formation of these placodes will determine the eventual position of the developing teeth.

The relationship between the ectodermal *Fgf* and *Bmp* genes and the mesenchymal *Pax9* gene plays a pivotal role in determining the location of oral placode formation. The oral ectoderm's *Fgf8* signalling promotes the expression of *Pax9* (the gene encoding the transcription factor that triggers morphogenesis) in the mesenchymal tissue, whereas *Bmp2* and *Bmp4*, which originate from the epithelium, suppress its expression in other regions. The presence of *Bmp4* results in the formation of interdental gaps due to its inhibitory effect on the development of the dental bud. It should be noted, however, that the process of tooth development is not solely dependent on the genes. Indeed, tooth germs in *Pax9* mutant mice exhibit identical growth patterns to those observed in wild mice. This is due to the function of *Dlx* homeobox genes in the early patterning of the dental field, as well as the action of *Pit2* and *Shh* (Brook, 2009). Furthermore, the commencement and advancement of odontogenesis past the initiation stage depends on transcription factors belonging to the *Msx*, *Dlx*, and *Lhx* families. During this phase, feedback loops will control these transcription factors.

The process of dental germ **morphogenesis** (Figure 7), occurring during the proliferating bud stage, entails the involvement of both mesenchymal and epithelial cell division. The cap stage commences when the edges of the bud undergo broadening because of cell division. The pulp of the subsequent tooth will undergo development in part due to the concave mesenchymal component of the cap. Ten enamel organs are generated from each dental lamina in parallel as a consequence of the histogenetic process (Scheuer & Black, 2000). At this juncture, replacement and apoptotic cells converge to form a novel structure designated the main enamel knot (EK). The bell stage ensues after the dissolution of the main EK during the late cap stage, a consequence of the apoptosis that has occurred. In multicusped teeth, the emergence of secondary enamel knots at the cusps is a hallmark of this final phase of morphogenesis.

It has been demonstrated that the repeated activation and inhibition of signalling in the EK is related to the differential growth and folding patterns observed in both the cap and bell stages. These patterns ultimately determine tooth dimensions and cusp patterns, as well as influencing the development of dental tissues. Despite the presence of growth-promoting signals in the enamel knot, the cells within this structure remain non-proliferative. Instead, it is the surrounding cells and the dental papillae that undergo proliferation, thereby facilitating growth and folding of the epithelium (Jernvall & Thesleff, 2000; Brook, 2009).

The principal genes implicated in this process are *Bmp4* and *Fgf*, with the incorporation of the cyclin-dependent kinase inhibitor P21. In the initial stages of mesenchymal morphogenesis, *Pax9* induces *Msx1* expression, which in turn activates *Bmp4*. The process of cellular condensation occurs concurrently with the expression of activin and tenacin. The enamel knot is formed as a consequence of the expression of *Bmp4*, *Fgf3*, *Bmp3*, *Hgf*, and activin in this condensed ectomesenchymal tissue (Thesleff & Nieminen, 1996). The expression of *Bmp* by the enamel knot has been observed to promote the growth of nearby cells. It has been proposed that apoptosis represents the primary mechanism regulating the temporal dynamics of the signalling cascade about the regulation of proliferative signalling (Matalova et al., 2010). *P21* expression is triggered by *Bmp4* (which is highly expressed in mesenchymal tissue) and *Bmp* family members (which are expressed in enamel knots), resulting in apoptosis (Jernvall et al., 1998; Kassai et al., 2005).

The process of **differentiation and mineralization** (Figure 7) initiates when the germ reaches the late bell stage, subsequent to the formation of the cusp pattern during the expansion and folding of the preceding phase. Odontoblasts, which are responsible for the production of dentin, and ameloblasts, which are responsible for the production of enamel, are produced when the cells from the cusp tips undergo differentiation. First, the organic substances that will constitute the dentine matrix—which is predominantly composed of collagen and other proteoglycans, glycoproteins, and proteins rich in carboxyglutamic acid—are secreted by odontoblasts, which extend apically. The ameloblasts that develop from epithelial cells then migrate towards the occlusal surface and synthesise the components of the enamel matrix, namely amelogenin (85%), enamelin, and ameloblastin. In the initial stages of amelogenesis, enamelin is essential for the synthesis of hydroxyapatite, whereas amelogenin is crucial for the formation of crystals.

The **latest stage of development** (Figure 7) for decidual teeth is not reached until the twentieth week of gestation. The first deciduous incisor begins to differentiate in the fifteenth week following fertilisation. The onset of this phase for several permanent teeth was established by Moorreess (1963). For example, the initial mineralised cusps of both the upper and lower first molars may be observed approximately three months after the individual's birth. This process would be expected to occur at approximately three years of age for the second premolars and molars. The third molars are the last teeth to reach this stage of development.

Both odontoblasts and ameloblasts have been observed to express pleiotrophin (*Ptn*), which has been identified as one of the primary essential growth factors for dentinogenesis. As posited by Brook (2009) and White et al. (2007), the *Dspp* gene represents the other principal factor in the secretion of the components that shape both the dentine matrix and the enamel matrix. Throughout the various stages of dentine development, this gene exerts its regulatory influence over odontoblasts by interacting with *Tgf-b, Bmpl, Mmp2,* and *Mmp20*. Moreover, dentine morphogenesis is also contingent upon *Dlx3* (Lezot et al., 2008).

Once the coronal dentin has formed and the enamel matrix has been deposited, the tooth germs begin to create their roots. The mesenchyme that surrounds the enamel organ and is located in the apical part of the tooth germ commences proliferation at the outset of this phase. The mesenchymal cells that populate the dental follicle give rise to both the cells that will form the developing periodontium and the cells that will make up the radicular pulp. More precisely, Hertwig's Epithelial Root Sheets (HERS), which are produced from cells in the enamel organ's cervical loop, undergo apical multiplication and regulate the process by which the pulp and periodontium separate. *Bmp4* is one of the primary regulators of HERS creation and activity, and the biochemical regulation of this process is comparable to that governing dentine formation in the crown (Thomas, 1995).

4.3.1.2. CHEWING CYCLE

The use of teeth for feeding involves a two-stage process of food preparation with the anterior dentition and food reduction with the posterior dentition (Larsen, 1997). This activity, known as the chewing cycle, results in wear of the occlusal surfaces as the upper and lower teeth come into contact with each other or with food (Kay and Hiiemae, 1974; Larsen, 1997).

The chewing cycle (figure 8) is divided into three distinct stages: the opening stage, the force stage, and the closing stage (Hillson, 1996). The cycle starts with the opening stage, during which the food item is introduced into the oral cavity, followed by the closing stage, in which the oral cavity is closed to facilitate contact between the cusps (Hillson, 1996). The force stage is subdivided into two phases: the crushing and grinding of the food (Kay and Hiiemae, 1974).

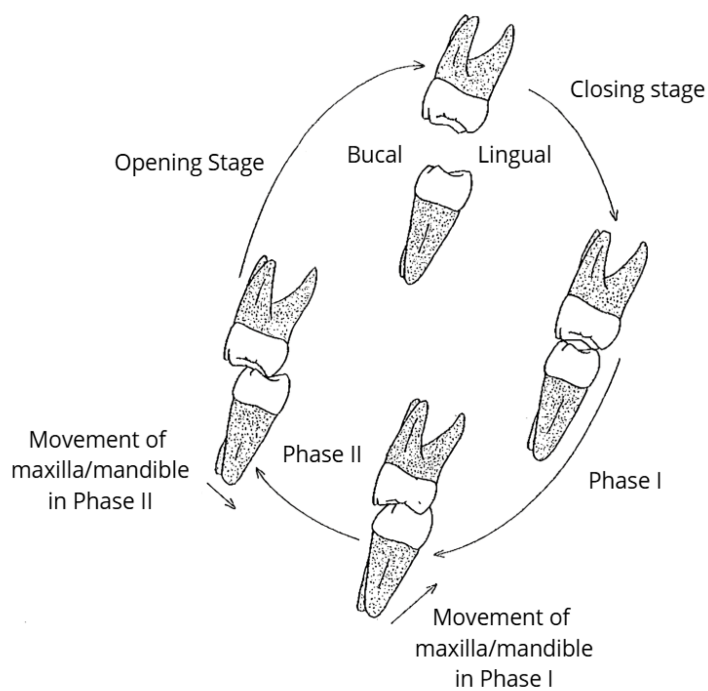


Figure 8 The masticatory cycle is the series of actions and movements that occur during the act of chewing. The image has been modified from that originally presented by Hillson (1996).

Phase I involves the rubbing together of the cusps of the molars in a shearing action, resulting in an occlusion at the central point. Additionally, during this phase, the lingual surfaces of the lingual cusps of the upper molars make contact with the buccal cusps of the lower molars (Hillson, 1996; Kay and Hiiemae, 1974). In **Phase II**, a movement occurs from the central point, whereby the lingual surfaces of the buccal cusps of the lower molars are polished against the buccal surfaces of the lingual cusps of the upper molars (Hillson, 1996). The final part of the chewing cycle is again an opening stage, whereby the jaw opens again.

During the mastication cycle, the Phase I facets engage in a shearing movement, while the Phase II facets perform a grinding movement. Consequently, the wear facets originating from each phase are subject to different mechanisms (Kay and Hiiemae, 1974; Gordon, 1982, 1984; Kay, 1987; Hillson, 1996).

1.4. TOOTH SIZE

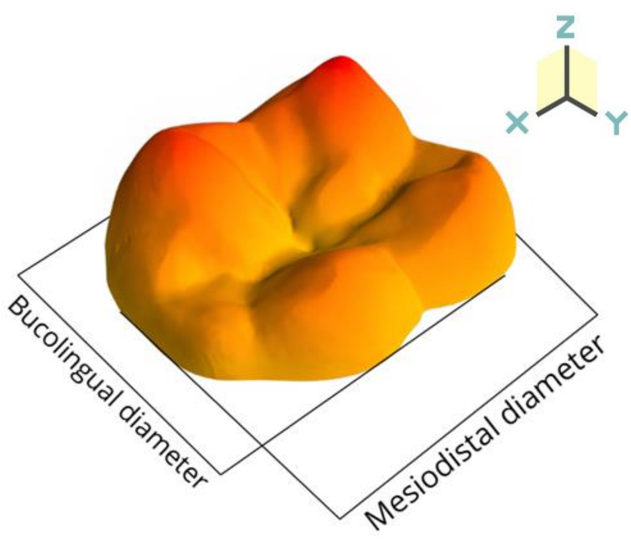


Figure 9 Example of tooth size measurements on a Lower M1.

Given its utility as an indicator of evolutionary change and adaptation processes, a study of tooth size is an indispensable component of physical anthropology studies. Multitude genetic and environmental variables contribute to the observed variation in tooth size within and between human populations (Bailit, 1975) and the course of hominin evolution (Estebaranz et al., 2004 Evans et al., 2016; Irish et al., 2016). It has been demonstrated that human groups engaged in hunting, gathering, and foraging for food have larger dental size than those engaged in farming and other food-processing activities (Larsen, 2015). A notable reduction in tooth dimensions among Homo sapiens has been documented over the past 100,000 years (Fitzgerald and Hillson, 2008). This change is also evident in craniofacial parameters (Smith, 1986; Larsen, 1995; Pinhasi et al., 2008; von Cramon-Taubadel, 2011; Pokhojaev et al., 2019; Menéndez & Buck, 2022), both in Southwest Asia (Smith, 1986; Brace et al., 1987; Kaifu, 1997; Erdal, 1999; Pinhasi et al., 2008, 2015; Alrousan, 2009; Le Luyer & Bayle, 2017; May et al., 2018; Menéndez & Buck, 2022). Furthermore, research has been conducted in other regions (Smith, 1972, Carlson & van Cerven, 1977; y'Edynak & Fleisch, 1983; Formicola, 1987; Jacobs, 1994, Le Luyer & Bayle, 2017; Pokhojaev et al., 2019; Nava et al., 2021; Godinho et al., 2023; Martin et al., 2024).

In recent decades, three morpho-functional adaptation models have been proposed with the aim of characterising, explaining and anticipating such dental variance:

- **The probable mutation effect** (Brace, 1963; Brace & Mahler, 1971; Pinhasi et al., 2008) posits that, in the absence of selection pressure, spontaneous mutations will occur, resulting in a reduction and simplification of dental morphology. The adoption of a Neolithic lifestyle resulted in significant alterations to food practices, which in turn relaxed the selection pressure favouring bigger, more complex teeth. It is anticipated that all dental measurements will decrease overall or exhibit homogeneous variance. Nevertheless, a considerable number of **researchers** have rejected this hypothesis on the grounds that the reduction in tooth size observed in contemporary human populations cannot be attributed solely to the absence of natural selection (Frayer, 1978; Calcagno, 1989).

- **The increasing population density effect** (Macchiarelli & Bondioli, 1986) posits that the increase in population density and the sedentary lifestyle precipitated a precipitous decline in nutritional intake and overall health. Selection for lower nutritional and metabolic needs would have favoured the reduction in body size in the new Holocene environment, and thus a reduction in tooth size. It is anticipated that this model will result in a general decrease in body size and all dental measurements.

- **The selective compromise effect** (Calcagno & Gibson, 1991; Y'Edynak & Fleisch, 1983) suggests that populations with larger teeth are more susceptible to dental crowding and caries, which exerts pressure on smaller teeth. However, to withstand the considerable wear and tear that would have been incurred through the consumption of abrasive foods, which were often the product of Neolithic cooking techniques, it is thought that bigger teeth with stronger enamel were selected for. This concept posits that dental reduction or uniform trends, and general enamel thickening represent the outcomes of a compromise between these two selection forces.

The most commonly used method for investigating dental size variability is the use of simple linear measures, such as distances and angles, along with associated indices. This approach is exemplified by the work of Kieser et al. (1985). The most employed metrics for characterising dental size are mesio-distal (MD) and bucco-lingual (BL) (Figure 9). Although it is frequently impacted by occlusal wear, which limits its application, another measurement type, the cervical-incisal diameter, sometimes referred to as crown height, has also been utilised extensively (Brace, 1967). There are also methods that measure the diagonal distances of the tooth, such as buccoproximal-linguodistal (BP-LD) and buccodistal-linguoproximal (BD-LP), which are not affected by interdental wear.

1.5. NON-METRIC DENTAL TRAITS

All the anatomical variances seen across the teeth are considered when discussing non-metric dental traits (NMDT). These traits are often present or absent, and frequently present at varying degrees of expression (Ullinger et al., 2005; Hanihara, 2008; López-Onaindia & Subirà, 2017; López-Onaindia et al., 2017, 2019, Maaranen et al., 2022). As was previously noted, these traits may be classified into negative features, can be classified into negative features, such as grooves, and positive structures, such as auxiliary cusps, tubercles, or crests (Turner et al., 1991). However, several other characteristics are also considered to be non-metric, like the variations in the number, location, and size of cusps and roots (Scott & Turner, 1997; Higgins et al., 2011; Hughes et al., 2013; Hlusko, 2016).

Consequently, by focusing on the potential manifestations of these characteristics, they can be classified into three primary categories:

1. **Dichotomic traits:** are characteristics that fall into one of two possible categories: present or absent.

2. **Characteristics that are ordered and graduated:** those observed in relation to their developmental stage. Such characteristics may be present or absent, but their degrees of expression may vary.

3. **Characteristics with a changeable but unorganized expression**: The final category confine characteristics such as the mandibular molars' groove pattern or interruption groove, in addition to the incisors' winging. Although there may be more than three forms, they are all distinguished by the fact that they are not distinct developmental stages of a feature.

Both deciduous and permanent dentition share several similar characteristics. However, most dental morphology research has focused on the permanent dentition, since infant burials are less common, and the bones are poorly preserved (Scott & Turner, 1997; Desideri, 2007). Moreover, of the more than one hundred documented NMDT of the human dentition, only about 30 to 40 have been sufficiently characterised, standardised and subjected to extensive anthropological study. In this respect, the scoring system developed by Arizona State University (ASUDAS) is the most comprehensive and employed globally (Turner et al., 1991).

Applying this approach to a complete dentition allows the researcher to obtain 121 variables, that provide an explanation and representation of 35 dental traits. The advantage of this scoring technique is that it is the most widely used, and therefore the literature contains comparative ate from a variety of populations (Pillou & Welsh, 2017; Aksu & Kizildag, 2019; Wang & Zhang 2020; Gutiérrez-Obeid & Vera, 2021). It is also important to note that not all variables will necessarily provide insight into the topic under investigation. For example, some characteristics may not be present in all the examined samples. It is therefore essential to select the most appropriate qualities with great care.

With few exceptions, there is typically minimal discernible sex dimorphism at the phenotypic level with respect to crown and root characteristics, even though genes on the sex chromosomes do play a role in dental development. Moreover, when differences are identified, they are typically minor and variable across samples (Scott & Turner, 1997). The majority of studies have identified differences in the distal accessory ridge of the upper and lower canines (Scott, 1977; Kaul & Prakash, 1981; Kieser & Preston, 1981; Scott et al., 1983), shovel-shaped incisors (Harris, 1980), or Carabelli's tubercle (Goose & Lee, 1971; Kaul & Prakash, 1981; Kieser & Preston, 1981; Townsend & Brown, 1981; Scott et al., 1983).

Consequently, the capacity to integrate data from both sexes to determine population frequencies is an advantage that oral morphological traits share with autosomal genetic traits. Small skeletal collections are of especially interest, since NMDT allows its study as a single sample without having to divide it into discrete sexual categories, as classical metric osteology requires.

Looking the major population groups, including African, Asian, Native American, Aboriginal Australian, and European, certain characteristics are more discriminating than others. Example of this is the seventh cusp in mandibular molars, shovel-shaped incisors, and Carabelli's tubercle (Scott & Turner, 1988). It is widely known that shovel-shaped incisors are more common in Asian and Native American groups. Conversely, Carabelli's cusps are more prevalent in European and African populations, while samples from sub-Saharan Africa tend to exhibit the seventh cusp. In practical terms, Scott and Turner (1988, 1997) provide a general categorisation of the main contemporary human groups based on a description of populations across the world and an analysis of the frequencies of several crown and root features in each of them. The categorisation distinguishes between Western Eurasians, Sub-Saharan Africans, Sino-Americans, Sunda-Pacifics and Sahul-Pacifics. Although not a definitive classification, this system may prove useful in forensic investigations or archaeological materials, as a preliminary hypothesis to exclude the potential origins of the individuals in question. In order to distinguish Western Europeans from the European group, the Eurodont Dental Complex has been described in the context of the previous decade (Scott et al., 2013).

Trait Name	Tooth	Presence score	Description
Curvature	Upper Incisive	3+	The labial surface is markedly convex.
Shoveling	Upper Incisive	3+	Presence of mesial and distal marginal ridges on the lingual surfaces of the upper and lower anterior teeth.
Double Shoveling	Upper Incisive	2+	Mesial and distal ridges on the labial surfaces of the upper anterior teeth
Tuberculum Dentale	Upper Incisive	2+	The upper central incisor exhibits one to several ridges of variable expression
Mesial Canine Ridge	Upper Canine	1+	Lingual surface expresses a hypertrophied mesial ridge and tubercle.
Distal Accessory Ridge	Upper Canine	1+	The lingual surface of the upper and lower canines commonly exhibits a median ridge, as well as mesial and distal marginal ridges.
Distosagittal Ridge	Upper Premolar	1	Existence of a ridge at the sagittal sulcus that extends from the buccal cusp apex to the distal occlusal border.

Mesial/Distal Accessory Cusps	Upper Premolar	2+	Buccal and lingual cusps of the upper premolars are separated by a sagittal sulcus.
Metacone Cusp 3	Upper Molar	4+	Presence and size of the distobuccal cusp.
Hypocone Cusp 4	Upper Molar	4+	Is attached to the distolingual surface of the trigon.
Cusp 5 (Metaconule)	Upper Molar	2+	Presence and size of a fifth cusp between cusps 3 and 4.
Carabelli's Trait	Upper Molar	2+	Development of a cingular remnant on the lingual surface of the protocone.
Parastyle	Upper Molar	2+	Development of a cingular remnant on the buccal surface of the paracone.
Distal Accessory Ridge	Lower Canine	2+	The lingual surface of the upper and lower canines commonly exhibits a median ridge, as well as mesial and distal marginal ridges.
Cusp Number 1	Lower Premolar	2+	The quantity and proportionality of lingual cusps.
Cusp Number 2	Lower Premolar	2+	The quantity and proportionality of buccal cusps.
Anterior Fovea	Lower Molar	2+	The groove separating the protoconid and metaconid may run an uninterrupted course from the central fossa to the mesial marginal ridge complex
Protostylid	Lower Molar	1+	Development of a cingulum derivative on the buccal surface, or a paramolar cusp according to the ASUDAS description.
Deflecting Wrinkle	Lower Molar	2+	Presence and shape of the medial ridge on cusp 2.
Hypoconulid Cusp 5	Lower Molar	1+	Lower molar cusp number, depends on the presence of the hypoconulid
Cusp 6	Lower Molar	1+	Presence and size of the entoconulid, between the hypoconulid and the entoconid.
Mid-Trigonid Crest	Lower Molar	2+	The two major cusps can exhibit ridges that are connected.

Table 1 Human Tooth Crown and Root Morphology. Arizona State University Dental Anthropology System. (Louail, 2018). Non-Metric Dental Traits used in this Research, Root traits are not included in this table and research.

1.6. DENTAL TOPOGRAPHY

1.6.1. HISTORICAL CONTEXT

Numerous studies in the last decades have reinforced the idea that tooth shape in primates adapts to variations in the structural and/or mechanical properties of the foods they consume (Kay, 1975, 1978; Kay & Covert, 1984; Kinzey, 1992; Anthony & Kay, 1993; Bunn & Ungar, 2009; Yamashita et al., 2016). This hypothesis is based on the recognition of the importance of diet as a major selective force for dental morphology of many primate groups, although other hypotheses have emerged to explain the influence of genetic drift on tooth shape (Rathmann & Reyes, 2022; Rathmann et al., 2023; Schroeder & Ackermann, 2023). Given this reality, it has become essential to develop different quantitative approaches to characterise tooth shape. This will provide insight into the relationship between tooth form and function, as well as a better understanding of the dietary factors that generate selection pressure.

The measurement of the shear quotient (SQ) and its derivatives, including the shear ratio (SR), constituted one of the earliest investigations into the analysis of tooth shape (Winchester et al., 2014; Boyer et al., 2015). This method allows the evaluation of the shearing capacity of a tooth by calculating a linear least squares regression between the logarithm of the molar length and the logarithm of the sum of the ridges present on the occlusal surface of the tooth. According to this approach, folivorous and insectivorous primates are distinguished by high SQ values, as they have larger shearing zones necessary to fragment the cellulose of leaves or the chitin of insects (Kay, 1975, 1977; Kay & Covert, 1984; Anthony & Kay, 1993; Ungar, 1998).

This shearing capacity may be explained by selective pressure for chewing efficiency, which is more pronounced in insectivores and folivores than in frugivorous primates (Lucas & Luke, 1983, 1984), since fleshy fruits can be broken down by the tongue or digestive muscles (Lucas, 2004). Kay (1977) focuses exclusively on unworn teeth because the method requires the monitoring of reference points located on the ridges (M'kirera & Ungar, 2003; Bunn et al., 2011); with tooth wear, these reference points tend to become less or not visible.

Furthermore, the assessment of the shear quotient depends on the subjective interpretation of the observer in recognising and counting the ridges, which can lead to results that are subject to interpretation (with intra and interspecific errors associated with the quantification). In the context of tooth form/function characterisation, new approaches have been developed to overcome these limitations. These approaches eliminate the need for reference points and partially minimise subjective judgements, thus allowing objective measurement of tooth shape. These methods mainly include approaches such as tooth topography and geometric morphometrics, both of which focus on the overall geometry of the shapes (Evans & Jernvall, 2009). In some applications of geometric morphometrics, the use of reference points or anatomical markers can be considered to help define the overall shape. They offer the possibility of studying specific aspects of dental structures as well as characterising the overall shape of the teeth.

High-cusped, relatively long-crested teeth, specialised for shearing and cutting, are found in folivores and/or insectivorous primates. These animals have higher SQ values and therefore, according to the results of these studies (Kay, 1975; Ungar, 2010, 2015), superior chewing efficiency. In contrast, frugivorous, omnivores and/or hard object feeders with flatter cusps, more rounded occlusal surfaces and relatively short crested teeth suitable for crushing and grinding have lower SQ values and consequently lower chewing efficiency (Sheine and Kay, 1977, 1982; Kay and Sheine, 1979; Bunn et al., 2011; Ledogar et al., 2013; Winchester et al., 2014; Allen et al., 2015; Boyer et al., 2015). According to these findings, primates that ate tough or brittle items foods (such as cellulose-rich leaves or insect chitin) had a morphology with long shearing crests and sharp cusps that helped them digest food more effectively (Sheine and Kay, 1977, 1982).

However, even with the positive results of these studies, there are problems in quantifying SQ and SR. Firstly, they require a large number of correctly selected landmarks, which could lead to more inter-observer error. Also, the landmarks used to determine the shearing crest length are destroyed as teeth deteriorate. This limits their measurement to comparatively unworn teeth with prominent shearing crests and makes it difficult to calculate both SQ and

SR (Bunn et al, 2011). These limitations have been addressed by a novel dental topography method based on form descriptor metrics, made possible by advances in sophisticated scanning technology.

1.6.2. DENTAL TOPOGRAPHY

During the last 90s and early 00s the use of new digital tools and imaging techniques led to the development of innovative methods of 3D analysis. **Dental topography** is a tool that is used to study the surface of the teeth, employing quantitative measurements that correspond to one or more aspects of the shape. The concept of dental topography is derived from the methodology employed in Geographic Information Systems (GIS), which is used to map territories. Similarly, dental topography enables the quantification of diverse aspects of dental morphology through a comparison with natural landscapes. Consequently, the concepts of dental reliefs, incisions, and angularities are addressed, as well as ridges, depressions, and peaks in a natural context (Zuccotti et al., 1998; Ungar & Williamson, 2000; Ungar & M'Kirera, 2004; Guy et al., 2017a; Avià et al., 2022). At the beginning of this century, studies have started utilising methodologies that are not reliant on GIS (Ungar & Williamson, 2000; Ungar, 2004; Dennis et al., 2004). Dental topography has emerged as a method of quantification and analysis of the overall shape of the tooth. Unlike geometric morphometry, it does not require the use of multiple reference points, but is based on a single measurement (Berthaume, 2016). This approach allows for the comparison of teeth that may exhibit considerable morphological variation, particularly regarding the number of cusps or ridges (Evans et al., 2007; Plyusnin et al., 2008; Santana et al., 2011).

In its early stages, the initial topographic analyses were based on topographic surfaces in two dimensions. In this approach, each point (pixel) was associated with a specific elevation, thereby forming a topography in 2.5D. Over time, this methodology has evolved towards a three-dimensional (3D) representation based on surfaces or meshes. The principal benefit of dental topography in three dimensions is the absence of reference points, which permits the examination of intricate characteristics such as the slope and relief of the tooth. Furthermore, it permits the description of structures that are not visible in occlusal view, such as enamel folds, the enamel-dentin junction, and even enamel thickness (Guy et al., 2013). Furthermore, it enables the acquisition of more detailed phylogenetic information regarding specific topographical characteristics (Winchester, 2016). This methodological approach has resulted in the development of several specific software programs, including Doolkit, MolaR, MorphoTester, Surfer Manipulator, and Teether (Evans et al., 2007; Bunn et al., 2011; Evans & Janis, 2014; Pampush et al., 2016; Winchester, 2016; Berthaume et al., 2020; Thierry et al., 2023).

The development of dental topography has been employed primarily for the characterisation of dental form and the establishment of links between dental form and function in a range of mammals (Ungar & Williamson, 2000; M'Kirera & Ungar, 2003; Ungar & M'Kirera, 2003; Dennis et al., 2004; Boyer, 2008; Ungar & Bunn, 2008; Bunn & Ungar, 2012a, 2012b) have also contributed to this field. The application of this approach has been instrumental in advancing our understanding of dental adaptations linked to food fragmentation (Bock & von Wahlert, 1965; Ungar et al., 2010; Guy et al., 2013; Winchester, 2016; Thiery et al., 2017). This method has been applied to the unworn teeth of the great apes (M'Kirera & Ungar, 2003), as well as to primates in general (Ungar et al., 2018), including notably the cercopithecoids (Bunn & Ungar, 2009; Avià et al., 2022) and the fossil hominins (Ungar, 2004; Berthaume et al., 2018) and also, in modern human populations (Cuesta, 2020).

Furthermore, this approach enabled the derivation of information regarding the ecology and diet of various species, as well as a more comprehensive understanding of the evolution of dental occlusal patterns over time. These analyses may concentrate on either the occlusal surface of the teeth or the junction between enamel and dentine (Skinner et al., 2010; Guy et al., 2015). Furthermore, dental topography enables the description of new species (Boyer et al., 2012) and facilitates the investigation of evolutionary pressures, such as the distribution of ecological niches (Boyer et al., 2012; Godfrey et al., 2012; Berthaume & Schroer, 2017).

Dental topography metrics comprise a number of key parameters, including **curvature** (DNE, Dirichlet Normal Energy; Bunn et al., 2011), **occlusal relief** (OR; Ungar and M'Kirera, 2003), **crown Relief Index** (RFI; Boyer, 2008), **complexity** (OPCR, Orientation Patch Count Rotated; Evans et al., 2007; Evans and Jernvall, 2009, Winchester, 2016) and **ambient occlusion** (PCV; *Portion De Ciel Visible*, Berthaume, 2016a).

2.6.1.1. DIRICHLET NORMAL ENERGY (DNE)

The concept of *Dirichlet normal energy* (DNE) (Figure 10) was first introduced in the field of dental topography by Bunn et al., (2011). It is a metric that is used to quantify the variability in occlusal surface curvature, irrespective of position, size and orientation. DNE is comparable to measuring the sum of squares of the primary curvatures throughout the surface when expressed as a continuous function (Evans, 2013; Winchester, 2016).

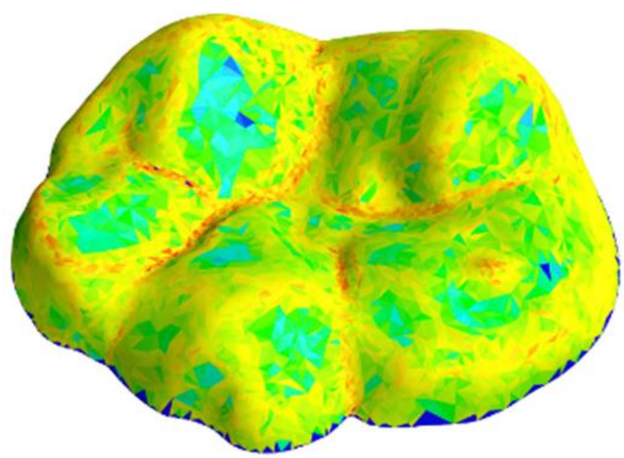


Figure 10 Example of Dirichlet Normal Energy (DNE) obtained with Morphotester.

In the process of quantifying DNE, it is possible to discard a percentage of the data, typically 0.1% of the area × energy. This indicates the existence of anomalies, such as noise or artefacts, such sharp edges or points, which cause energy levels to be out of proportion to the surface (Winchester, 2016). Both convex and concave surfaces result in higher DNE, which is indicative of more dental features such deeper and more severely inclined basins, taller and sharper cusps, and crenulated surfaces. In contrast, short, bulbous cusps result in low DNE values (Bunn et al., 2011; Winchester et al., 2014; Winchester, 2016). Several studies on non-human primates have shown that DNE is a useful technique for tracking the amount of fibrous material in great apes' diets and for distinguishing tooth morphologies according to dietary categories (Berthaume, 2014). A high DNE value is related to an insectivorous, folivorous, or fibrous diet, whereas a low DNE value suggests an omnivorous, frugivorous, or non-fibrous diet (Bunn et al., 2011; Berthaume et al., 2017; Avià et al., 2022). Furthermore, DNE can be employed to assess the dental morphology of teeth exhibiting diverse morphologies across varying wear stages (Pampush et al., 2016a).

2.6.1.2. RELIEF INDEX (RFI)

The relief index (RFI) (Figure 11), is a technique for measuring the total relief of a dental crown, was first presented by Ungar and Williamson (2000). The relief index (RFI) is calculated as the ratio of the crown's three-dimensional outline-projected area to its two-dimensional surface area. Two iterations of the RFI have been created, depending on the surface cropping technique used. The relief index, also known as occlusal relief (OR), is a technique for measuring a dental crown's total relief. It is computed as the ratio of the crown's three-dimensional surface area to its two-dimensional projected area. Only the tooth clipped at the lowest position of the occlusal basin (basin cut-off) is considered by the relief index. This was first suggested by Ungar and M'Kirera (2003). This measurement is focused on the tooth surfaces that are most likely to be employed for mastication. It is calculated as a simple ratio between the three-dimensional surface area of the cropped tooth and its two-dimensional planimetric projected and outline area.

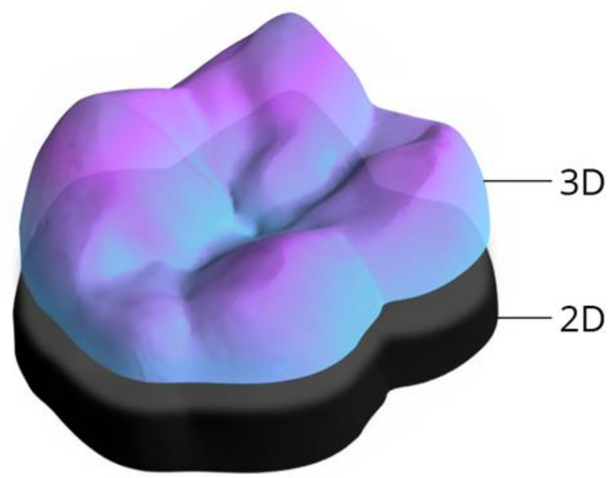


Figure 11 The relief index (RFI) example, comparison of the 3D and 2D.

$$OR = \frac{SA}{OA}$$

This calculation provides a ratio between the tooth's dimensions and the relative height of the cusps (Pampush et al., 2018). In contrast, Boyer's (2008) adaptation of RFI, which involves cropping along the cemento-enamel junction, includes the complete enamel cap in the 3D area summation. The original computation is converted into the natural logarithm of the ratio of the square roots of the enamel crown's three-dimensional surface area and its two-dimensional outline-projected area, oriented in the occlusal view, by Boyer's (Boyer, 2008) formulation for allomeric reasons.

$$RFI = In\left(\sqrt{\frac{SA}{OA}}\right)$$

According to this statistic, teeth with lower crowns or cups have lower RFI values, while teeth with somewhat taller crowns or cusps have higher RFI values. (Ungar and M'Kirera, 2003; Boyer, 2008). The investigation of crown relief has been conducted on a limited basis in fossil hominins (Berthaume et al., 2018) and modern human populations (Górka, 2016). However, as this metric has been extensively researched over the past two decades in primates, proving to be an invaluable tool for categorising teeth according to dietary patterns (Ulhaas et al., 2004; Boyer, 2008; Boyer et al., 2010; Godfrey et al., 2012; Winchester et al., 2014; Allen et al., 2015; Avià et al., 2022). For example, folivores and insectivores, who possess hypsodonty or high crowns/cusps, exhibit higher RFI and OR values than frugivores and hard-object feeders, who have brachydonty or lower crowned/cusped molars (M'Kirera and Ungar, 2003; Ulhaas et al., 2004; Boyer, 2008; Winchester et al., 2014; Allen et al., 2015; Berthaume et al., 2020). Tooth wear can have a significant impact on both RFI and OR ratios, as the height of the cusps decreases with the accumulation of wear (Evans, 2013). It is therefore advisable to consider dental wear when exploring crown relief (Pampush et al., 2016b; Berthaume et al., 2018).

2.6.1.3. ORIENTATION PATCH COUNT ROTATED (OPCR)

In their 2007 study, Evans and colleagues introduced the Orientation Patch Count (OPC) (Figure 12) as a method for quantifying the dental complexity of cheek tooth rows in rodents and carnivores (Evans et al., 2007). The occlusal surface of a tooth is separated into patches by combining adjacent regions with the same orientation as a joint "patch". To enhance the reliability of the method and reduce the susceptibility of the outcome to tooth orientation, Evans and Jernvall (2009) modified the OPC metric into the Orientation Patch Count Rotated (OPCR).

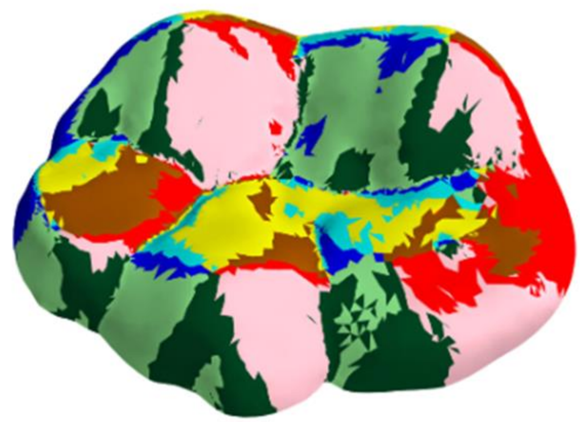


Figure 12 Example of Orientation Patch Count Rotated (OPCR) obtained with Morphotester.

In order to achieve this, the OPCR rotates the tooth eight times in succession across a total arc of 45° (with each rotation being 5.625°), with the OPC calculated at each rotation. The OPCR value is obtained by calculating the mean of the eight individual OPC computations. The OPCR is essentially a measure of the number of occlusal surface elements or "tools" (such as cusps, crests, crenulations, and cutting edges) that are used during the mastication process. Higher OPCR values indicate that an occlusal surface with more of these tools are more effective at digesting meals that contain structural fibre components (Evans et al., 2007; Berthaume et al., 2018).

A substantial body of research has demonstrated that dental complexity is a reliable indicator of dental-dietary adaptation in a range of mammalian taxa, including carnivores, rodents, and bats (Evans et al., 2007; Evans and Jernvall, 2009; Santana et al., 2011; Pineda-Muñoz et al., 2017). As a result of their evolutionary adaptation to consume fibrous, challenging-to-process foods, herbivores and insectivores characteristically exhibit teeth with a sophisticated occlusal surface, as indicated by elevated OPCR values. It thus appears reasonable to conclude that different instruments would be required for the processing and consumption of diverse foodstuffs. However, OPCR appears to be an inadequate indicator of diet within the primate order, with species exhibiting distinct dietary groups exhibiting overlap (Guy et al., 2013; Winchester et al., 2014; Berthaume et al., 2018). This is likely due to the low level of variation in dental complexity observed within primates compared to other mammals (Boyer et al., 2010).

2.6.1.4. PORTION DE CIEL VISIBLE (PCV)

PCV (Portion de Ciel Visible) (Figure 13), a recently developed dental topography metric, is used to measure ambient occlusion (Berthaume, 2016a; Berthaume et al., 2018). It has been employed in numerous research projects. This approach has been employed in research on fossil hominins and primates (Berthaume et al., 2018; Berthaume et al., 2019a, b). The resistance of the morphology to wear has been quantified using PCV (Berthaume et al., 2018). This visualisation technique enables the measurement of the extent to which a surface is exposed to ambient illumination, thereby facilitating the production of more accurate renderings of three-dimensional objects. However, the degree of exposure of the surface to light will vary depending on the direction from which the light originates. However, the direction from which the light originates will affect the extent to which the surface is exposed to it. Furthermore, in the context of dental topography research, only light originating from the positive z-direction (which, in the case of teeth, corresponds to the occlusal direction) is considered. When a tooth is positioned under zenithal light, the parts of the tooth that receive greater illumination from the

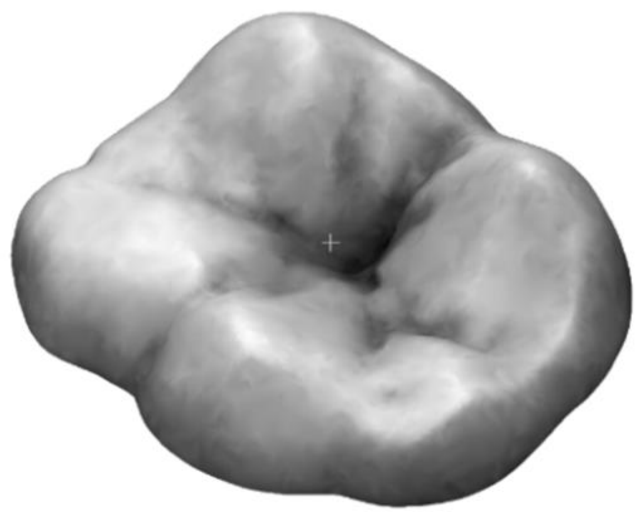


Figure 13 Exemple of PCV - Portion de Ciel Visible obtained with Cloud Compare.

surrounding environment (basins, sides of enamel caps or enamel fissures) (Berthaume et al., 2019a, b) exhibit lower PCV values and greater wear resistance.

A strong association between crown height and PCV was identified in South African hominins, including *Homo naledi, Paranthropus robustus,* and *Australopithecus africanus* (Berthaume et al., 2018). Similarly, primates belonging to the Prosimii and Platyrrhini classes exhibited this correlation (Berthaume et al., 2019b). The latter study indicates that the dietary categories of primates can be accurately predicted based on the average ambient occlusion. Molars with comparatively shorter crowns and cusps, such as those belonging to frugivorous and hard-object feeding species, exhibited higher PCV values than molars with taller crowns and cusps, which are characteristic of folivorous and insectivorous species. This is because the basins are not visible from the exterior. Ultimately, it has been demonstrated that PCV serves as an effective indicator of tooth wear patterns once wear facets emerge (Berthaume et al., 2019b).

1.7. DENTAL MACRO-WEAR

The term 'macro-wear' is used to describe the observable physiological and macroscopic wear of the dentition. This process typically begins with the loss of occlusal enamel and progresses to the underlying dentine that protect the pulp chamber (Larsen, 2002). Due to its cumulative nature, in extreme cases the enamel may disappear completely (Fiorenza et al., 2018; Larsen, 2002).

The process of mastication comprises two distinct phases (see point: 1.2.6 Human Development - Chewing Cicle). In contrast, teeth do not come into direct contact with one another, but rather with the food itself. This results in rapid cutting, which creates a blunt wear pattern on the occlusal surface of the tooth (Kay and Hiiemae, 1974; Holly-Smith, 1984). In the second stage of the process, the teeth contact the food as it is being chewed, resulting in oblique wear (Holly-Smith, 1984). The duration of the first cycle is shorter in the case of more processed food, leading to a greater degree of oblique wear (Holly-Smith, 1984).

Two principal forms of macro-wear have been identified among the agents involved in this process: attrition and abrasion. **Attrition** is the result of contact between teeth, whereas **abrasion** is caused by contact between teeth and food or other exogenous elements during mastication (Larsen, 2002). Consequently, the severity of tooth wear is significantly influenced by the hardness and preparation of the food.

Dental wear has been the subject of extensive study, resulting in the proposal of numerous analytical scales for the assessment of wear patterns in different populations. These include separate studies of adults (Murphy, 1959a, 1959b; Molnar, 1971; Scott, 1979) and subadults (Aiello et al., 1991; Skinner, 1997). The most widely known scale is that of Murphy (1959a, 1959b), who classified the different values of wear from A to H according to the pattern of exposed dentin. Holly-Smith (1984) created a diagram based on the Murphy scale, which is frequently used to estimate age (Hillson, 1996).

Molnar (1971) devised his own scale, once more based on Murphy (1959a, 1959b), in which he utilises values between 1 and 8 for both the anterior and posterior dentition. This is done according to the portion of exposed dentine and, in addition, in accordance with Murphy's difference, the amount of secondary dentin presents on the occlusal surface of the tooth. Conversely, Scott (1979) adapted the approach of Molnar (1971) for application to molars. This entailed a visual subdivision of the molar surface into quadrants, with a value between 1 and 10 assigned to each. The sum of the four values was then used as the final measure of wear. Littleton et al. (2013) further expanded the methodology of Scott (1979) by incorporating the premolars and anterior dentition.

In recent years, high-resolution 3D models have been introduced in the study of dental macrowear, which allows for the inclusion of detailed spatial measurements of the angles of the wear facets in the degree of wear (Benazzi et al., 2012; Fiorenza et al., 2018; Yang et al., 2024; Carrascal et al., 2025). Given the intimate relationship between chewing and diet, these wear patterns have been employed to infer dietary habits of archaeological populations and extinct species (Arnold et al., 2007; Chattah and Smith, 2006; Deter, 2009; Grimoud and Gibbon, 2017). Furthermore, alterations in dental wear can document significant phases in the biological and cultural evolution of past populations, including the availability of food resources, the advent of fire and cooking, and the invention of tools for food processing (Holly-Smith, 1984).

Furthermore, the study of dental wear has been applied in different aspects, including the determination of individual age (Holly-Smith, 1984; Mays et al., 1995; Yang et al., 2024) and the analysis of the use of the mouth as a tool (Lukacs and Pastor, 1988; Bermúdez de Castro et al., 2003; Clement and Hillson, 2012; Molnar, 2008) or to ascertain status and general health (Elzay et al., 1977; Dawson and Brown, 2013) (Figure 14).

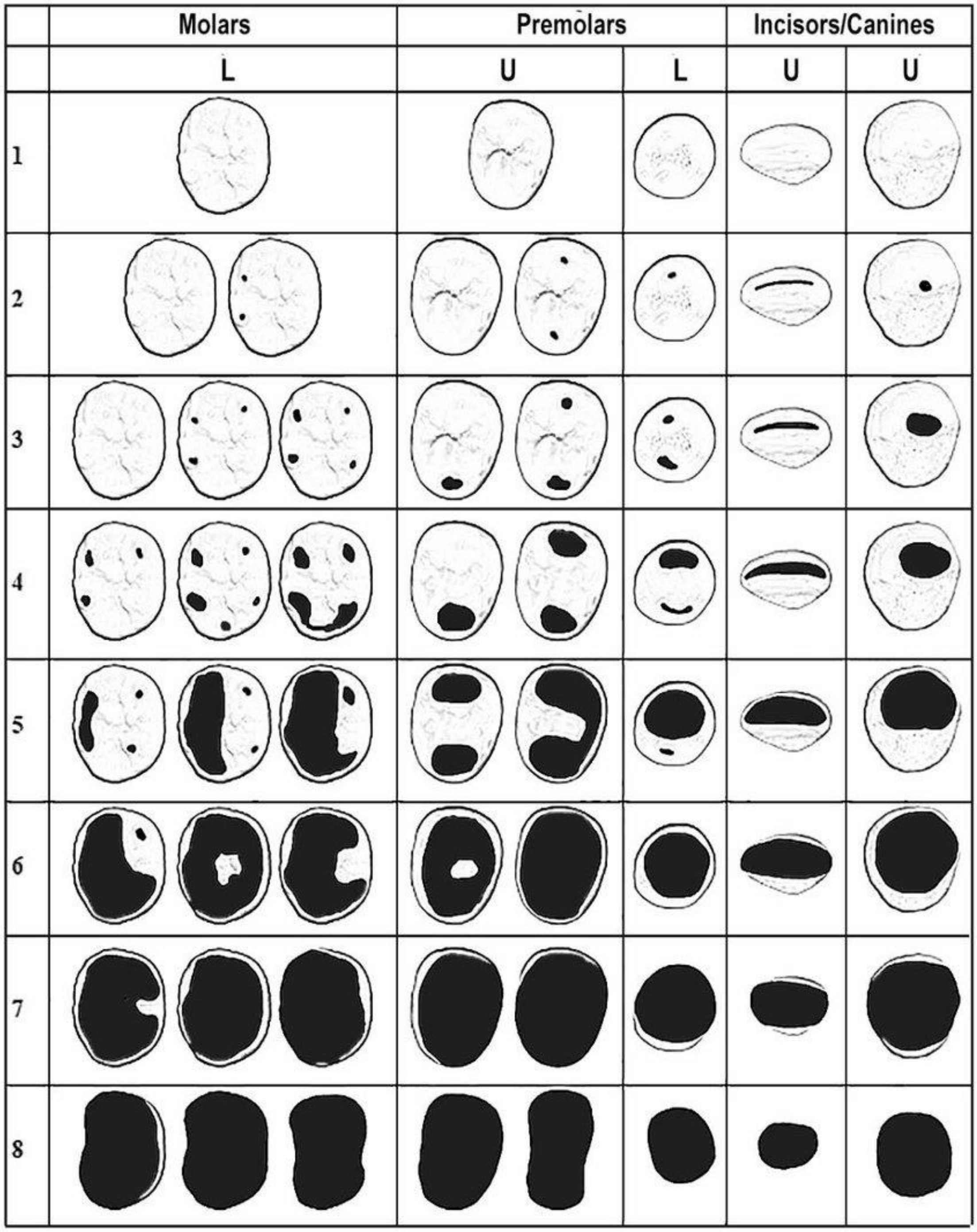


Figure 14 Smith (1971) tooth wear classification in 8 wear stages for each Incisor, premolar and molar groups of teeth.

CHAPTER 2. MATERIALS

CHAPTER 2.

2. MATERIALS

2.1. SAMPLE

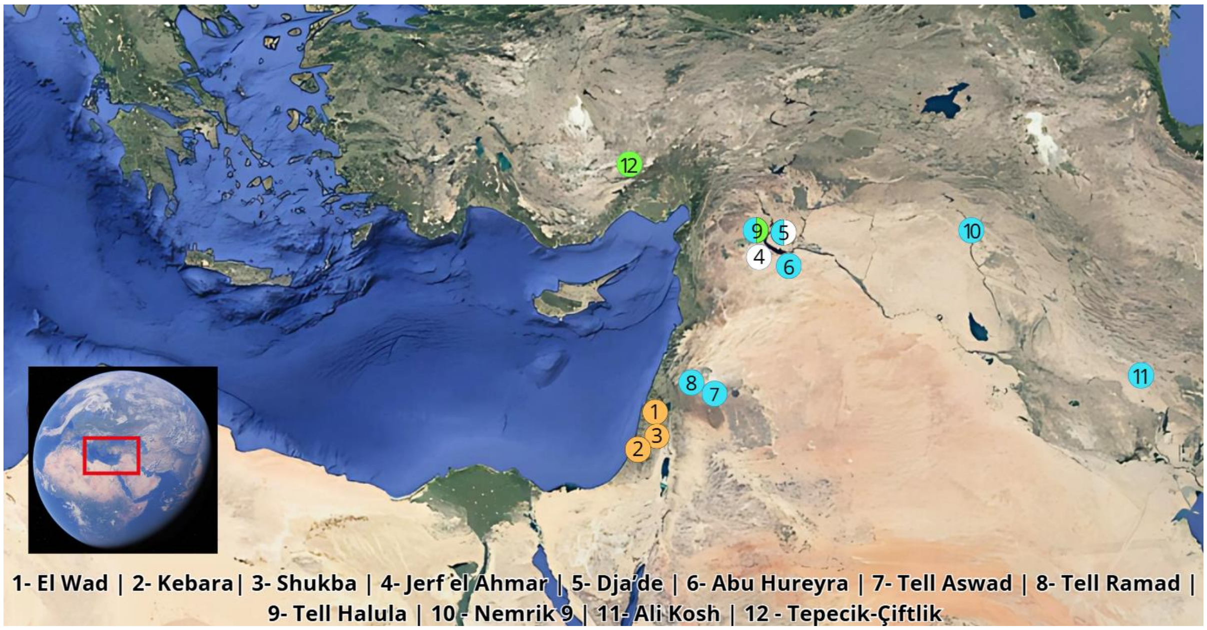


Figure 15 Principal archaeological sites in study from Natufian to Pottery Neolithic periods.

This chapter provides a comprehensive account of the materials employed in this thesis, offering a detailed overview of the archaeological sites that have been the subject of investigation (Figure 15). The description of each site will include its geographical context, with particular attention paid to the precise location and the factors that may affect the interpretation of the findings. Furthermore, details will be provided regarding the researchers who have contributed to the discovery and study of each site, along with an account of the history of the research that has led to the current findings. This context allows for a more nuanced understanding of the relevance of each site and its impact on the archaeological evidence. In sum, this chapter represents a foundational resource for comprehending the methodology and approaches utilized in the analysis of the sites and their contributions to the historical narrative established throughout this thesis.

SITE	N	DATE	PERIOD	REGION	HOST INST.	C14 REF.
El Wad	98	12500	Nat	Levant/Med.	UB[1]	Weinstein-Evron, 1991
Kebara	71	11500	Nat	Levant/Med.	UB	Byrd, 1994
Shukba	28	11500	Nat	Levant/Med.	UB	-
Jerf el Ahmar	15	10650	PPNA	Middle Euphrates	UB	-
Tell Aswad	53	9730	PPNB	Saharo-Arabian desert	UB	Contenson 1973; Stordeur et al. 2010:58
Dja'de	61	9560	EPPNB	Middle Euphrates	UB	Coqueugniot, 2014
Gre Filla	60	9500	PPNA	Anatolia	HU[2]	-
Nemrik 9	35	8900	PPNB	Zagros Mountains	UW[3]	Kozlowski 1994:261f
Ali Kosh	26	8850	PPNB	Zagros Mountains	UW	-
Tell Halula	136	8500	PPNB	Middle Euphrates	UB	Molist et al., 2013
Kharaysin	15	8350	PPNB	Levant/Med.	ASD-CSIC[4]	-
Abu Hureyra	18	8330	PPNB	Middle Euphrates	-	Pinhasi, 2015
Tell Halula	5	8050	PN	Middle Euphrates	UB	Molist et al., 2013
Tepecik-Ciftlik	255	8050	PN PN	South/Centr. Anatolia	IDEAlab[5]/HU	-
Tell Ramad	77	7950	PPNB	Saharo-Arabian desert	UB	Contenson, 2000:21
TOTAL*	**953**					

Table 2 Materioal Used in this study. Site = Location, N = number of studied teeth, DATE = average chronology, PERIOD = cultural period, REGION = geographical location, HOST INST. = Host institution, C14 REF. = C14 cited reference

[1] UB – Universitat de Barcelona
[2] Hacettepe Üniversitesi
[3] University of Warsaw
[4] Archaeology of Social Dinamics – CSIC
[5] IDEAlab - Human Behavioral Ecology and Archaeometry Laboratory, Hacettepe Üniversitesi
*Only Postcanines

2.1.1. NATUFIAN SITES

1.1.2.1. EL WAD

Figure 16 Geographical situation of El Wad archaeological site.

Mugharet el-Wad (Cave of the Valley) is located on the southern escarpment of *Nahal Me'arot* (Valley of the Caves), along with three other caves, Tabun ("Oven"), Skhul ("Children") and Jamal ("Camel"). It faces north-west and lies about 44.5m above sea level and 12.5m above the level of the valley, at a point where the wadi opens out onto the coastal plain. A large cave with a high roof, el-Wad is larger in area than any of the other three caves. According to Garrod's subdivision (Garrod and Bate, 1937), it consists of an outer and an inner chamber and a 71m long corridor. In front of the cave there is a small terrace which slopes slightly downwards to 9.5m from the mouth of the cave. From the terrace, a large talus with a radius of about 45m drops steeply down to the plain (Weinstein-Evron, et al., 2007).

El-Wad has been identified as a notable Natufian site as a result of Garrod's seminal research. The length of the series, the variety and quantity of the findings, and the scale of the occupancy make it an exemplar of a Natufian base camp.

The Natufian strata at el-Wad were originally exposed and their stratigraphy established by Lambert (Weinstein-Evron, 1998, 2008). He discovered two tombs on the terrace, surrounded by stone walls and grinding tools. These were the first ever discovered on Mount Carmel and were eventually identified as Natufian. Inside the cave, the first known example of ancient art in Southwest Asia was discovered: a bone sickle handle shaped like a baby animal.

In the initial characterisation of the archaeological sequence, Garrod identified the Mousterian (Layer G) as the earliest deposit, followed by three Upper Palaeolithic assemblages (Layers E, D, and C). She concluded with the historic (Layer A) and Natufian (Layers B2 and B1) deposits. The Middle Palaeolithic and Upper Palaeolithic materials were found to be intermingled in Layer F (Garrod, 1931). Subsequently, Garrod revised the hypothesis (Garrod, 1951), proposing that layers G and F constituted a singular cultural entity, which she designated a "transitional industry" situated between the Upper Palaeolithic and Middle Palaeolithic technocomplexes.

Garrod was able to distinguish between the early (Layer B2) and late (Layer B1) Natufian stages using typological criteria based on her excavations at el-Wad. While the Late Natufian was presumably limited to the terrace, the Early Natufian covered both the terrace and the cave's exterior chambers I and II (Garrod & Bate, 1937; Weinstein-Evron, 2008). The Early Natufian period is characterised by the presence of terrace features and buildings, which include a retaining wall, pavements, and numerous basins carved out of the bedrock. The early phase was further identified by the tightly flexed skeletons of both individual and group inhumations and the ornamented graves. A significant quantity of Early Natufian artefacts and bone tools were discovered. The Early phase lithics were distinguished by mostly bifacial "Helwan" retouch and comparatively longer lunates than those discovered in the later phase. While sickle blades were common, the microburin method (procedure for cutting up lithic blades) was rather uncommon.

A total of eleven graves, containing the remains of approximately 18–19 individuals, have been unearthed. It is assumed that all the tombs are Late Natufian in date, although one is thought to be of historic origin. Furthermore, some isolated bones and teeth were also recovered, the details of which will be presented in a subsequent report. The skeletons are numbered in accordance with the sequence of their excavation, whereas the burials are numbered in accordance with the sequence of their discovery. Given that at least 96 skeletons were identified from Garrod's excavations at el-Wad. (Garrod and Bate, 1937; Belfer-Cohen et al., 1991).

The remains of ten graves have been identified by investigators, comprising approximately 16 individuals within the upper portion of the Natufian series. However, Garrod (Garrod and Bate, 1937) attributed the majority of the 62 burials she discovered to the Early Natufian period, while only a small number were assigned to Late Natufian affiliation. The graves contain individuals of varying ages and sexes, as well as those in flexed to firmly flexed postures. In comparison to Garrod's Natufian assemblage, it is notable that a greater proportion of our assemblage comprises children. While not observed by Garrod (Garrod and Bate, 1937), the absence of heads in several burials is occasionally interpreted as a distinctive feature of the Late Natufian (Belfer-Cohen, 1988).

1.1.2.2. KEBARA

Figure 17 Geographical situation of Kebara archaeological site.

The cave of Kébara (Mugharet el-Kebarah, Me'arat Kabara) is situated on the western slope of Mount Carmel in the Nahal Taninim valley, 13 km south of the El Wad site. The entrance is of considerable dimensions and oriented in a north-westerly direction, thereby affording access to the Mediterranean. This opening provides access to a distinctive and irregularly shaped room. The cavity measures 26 meters in length and 20 meters in width. Its ceiling is formed by three vaults of unequal height, with an 18-metre-high “chimney” situated in its eastern corner. The bedrock is inclined in the direction of the cave's lowest point (Bar-Yosef et al., 1992). A small terrace is located in front of the cave, that was partly formed during the Upper Paleolithic period by the fall of an enormous block (Bar-Yosef et al., 1992).

The environment of the site during the Natufian period has not been the subject of a study. However, it may be reasonably assumed that it was similar to that of El Wad or Shukba characterised by a Mediterranean clime (Weinstein-Evron 1997, 1998). The sea, which is currently situated 2.5 km away, must have been located 8-10 km away from the cave during Natufian times (Bar-Yosef & Sillen, 1993).

A preliminary investigation was conducted in 1927 at the entrance to the cave by M. Stekelis, who did not pursue further excavation (Garrod, 1954). In 1930, Garrod and McCown, who were not aware of the excavation conducted by M. Stekelis, undertook their own investigation of the site. At the entrance to the cave, a 2.50 m square was opened, where a Natufian level was identified. This was a previously unknown level of microlithic industry. It was later baptised by Garrod as the Kébarien level (Garrod, 1932a; Garrod, 1954). Additionally, a level belonging to the Aurignacian period was also discovered.

In 1931, the excavation was assigned to F. Turville-Petre and C.A. Baynes, who were funded by the British School of Archaeology in Jerusalem and the American School of Prehistoric Research (Bar-Yosef & Callander, 1997). In a period of three months, the team excavated the surface of the cave ensemble to a depth of three meters, which equates to a volume of approximately 900 m^3 (Bar-Yosef et al., 1992: p. 500). No screening was conducted. Additionally, they are credited with conducting a deep probe at the entrance to the cave. The cave is entirely devoid of its natural deposits, yet the terrace is preserved intact (Turville-Petre, 1932).

Excavations were resumed in 1951 under the direction of M. Stekelis. It shows that the prehistoric beds at the entrance to the cave were completely overturned in the Middle Ages and that the terrace is covered with large collapsed rock blocks between which there is no archaeological bed. A survey on the lower part of the terrace is not free plus native material

(Bar-Yosef et al., 1992). Palaeolithic excavations have been carried out in the cave. These lower levels were excavated again in 1968 under the direction of O. Bar-Yosef and E. Tchernov, and then from 1982 to 1990 under the direction of O. Bar-Yosef and B. Vandermeersch.

The excavation yielded no evidence of a Natufian structure (Turville-Petre, 1932). The upper part of the level contains only a few hearths without equipment, the attribution of which to Natufian has been questioned (Bar-Yosef & Sillen, 1993). This absence of architectural features is notable in contrast to the exceptional richness of the archaeological material discovered in the cave (Turville-Petre, 1932). The bone material is of exceptional quality and has been well preserved. In addition to the artefacts, a considerable number of bone points were also discovered. These were found to be complete, of an excellent quality of craftsmanship, and polished to a high standard. Furthermore, numerous harpoons and several hooks were also unearthed (Bar-Yosef & Tchernov, 1970). Additionally, three distinctive artefacts were unearthed.

Two groups of human bones were discovered within the confines of the Kebara cave. One was situated at the entrance to the cavity, while the second, which merits further discussion regarding its attribution to Natufian was located at the bottom of the cave.

In the initial sepulchral assemblage, at the entrance of the cave, multiple individuals were discovered superimposed on top of each other with stones, reaching a depth of 0.60 m and 1 m below the original deposit surface (Turville-Petre, 1932). It is also noteworthy that a set of burnt bones was discovered at a depth of three metres, scattered across the back of the cave, at the boundary between layers B and C. F. Turville-Petre provides the following specification: "From a stratigraphic perspective, given the limited thickness of this layer (only 25 cm), it is not possible to ascertain with certainty whether these cremated remains should be attributed to the C level occupation or to the early Natufians". In the absence of any evidence of cremation among the numerous Natufian burials now known, it seems reasonable to associate these remains with the Level C culture (Turville-Petre, 1932). This argument, which excludes the possibility of attributing these burnt bones to the Natufians, has been reiterated subsequently (e.g. Bar-Yosef et al., 1971). This is on the grounds that such practices have not yet been encountered during this period.

The C14 dating obtained for one of these bones (12,470 ± 180 BP) is unambiguous in its correspondence with the Natufian period (Bar-Yosef & Sillen, 1993). Furthermore, no archaeological argument exists that would allow this chronological attribution to be called into question. It would be unjustifiable to exclude these burnt bones from our study. The radiocarbon dating results provide compelling evidence that the burnt material can be attributed to the Natufian level (Edwards, 1991; Webb & Edwards, 2002).

The anthropological collection of Kebara is curated at the *Peabody Museum* of Harvard University. It appears that the collection was transferred to the Museum at the same time as those from Shukba and El Wad.

In his description of the human material found at the cave entrance, F. Turville-Petre states that it is a collective burial pit that closely resembles the burial pits at Mugharet el-Wad. In both instances, the bodies appear to have been interred without any attempt at orientation and interred with stones (Turville-Petre, 1932). The individuals are relatively complete, and each ensemble is homogeneous. The bones of the extremities are under-represented, which can be attributed to the excavation and sampling techniques employed, which may have resulted in the inadvertent omission of small bones, as observed in the El Wad site.

The evidence indicates that, as in the cave of El Wad, the site contains multiple individual and successive burials. The recognition of individuals on the ground and the precise separation of the bones of each of them lends support to the hypothesis of individual deposits, separated from each other, which suggests that the remains were buried successively (Turville-Petre, 1932; Garrod, 1954). The characteristics of these grouped burials preclude the use of the term "collective grave pit" (Turville-Petre, 1932) as neither pit nor collective structure have been identified. As in El Wad, our analysis suggests that sepulchral pits are predominantly individual in nature. The precise position of the skeletons is unknown; however, the articulated joints in anatomical position indicate that the knees of two children were fully flexed.

1.1.2.3. SHUKBA

Figure 18 Geographical situation of Shukba archaeological site.

Shukba or also called Shuqba Cave is situated in the western Judean Hills, approximately 28 kilometres northwest of Jerusalem, has long been acknowledged as a significant archaeological site. From the cave, one can observe Wadi en-Natuf, a valley extending westward into the Mediterranean coastal plain. It has been of great importance to our understanding of Levantine prehistory, particularly that of the Epipalaeolithic era.

In 1924, Alexis Mallon undertook a rapid examination of the cave, which subsequently attracted the attention of the scientific community for the first time (Mallon, 1925). Mallon recognised the potential of the site and recommended that further excavation be conducted by the British School of Archaeology in Jerusalem. As a consequence of this proposal, Dorothy Garrod undertook a pioneering excavation in 1928 that contributed to the definition of the Natufian culture (Garrod, 1928).

In their one-season excavation, Garrod concentrated their efforts on the centre chamber and a small sounding in a nearby room. A Late Levallois-Mousterian layer and, most importantly, the earliest stratified evidence of what she called the "Natufian" – *a Mesolithic society that* *had not been previously documented in Palestine* – were among the rich stratigraphic sequences she discovered. A distinctive microlithic flint tool industry, worked bone artefacts and faunal remains, predominantly comprising gazelles with substantial evidence of domestic dogs, were all identified within the Natufian stratum. Perhaps the most fascinating aspect of the findings is the insight they offer into the funerary customs of the era, as evidenced by the fragmented remains of 45 human bones. (Garrod and Bate, 1942). In July 2000, nearly three-quarters of a century after Garrod's excavation, a new preliminary season was conducted at Shukba Cave. The objective of this recent work was to build upon Garrod's foundational research by identifying the limits of her original trench, assessing the archaeological potential of the remaining deposits, surveying the cave terrace, and conducting a preliminary survey of the immediate vicinity of the cave in Wadi en-Natuf.

The importance of Shuqba Cave extends well beyond its role in defining the Natufian culture. Other research has emphasised the cave's significance in understanding the transition from mobile hunter-gatherer societies to more sedentary lifeways (Bar-Yosef, 1998), the earliest evidence of dog domestication in the Levant, and the development of complex mortuary practices in the Epipaleolithic (Belfer-Cohen, 1995).

The anthropological collection amassed by Shukba is curated at the *Peabody Museum* at Harvard University. The material seems to have departed from Palestine in 1928 for the Royal College of Surgeons in London (Vallois, 1936), before being transferred to the University of Berkeley in 1939 and ultimately reaching the Peabody Museum in 1962. The anthropological material from Shukba would therefore have followed an almost identical path to that of the material from El Wad (see point: 2.1.1 Natufian sites - El Wad) and was partially studied by the same anthropologists (Keith, 1931, 1932).

The Shukba site, the inaugural Natufian site to be excavated, is regrettably lacking in comprehensive documentation. The presence of a considerable quantity of tools is indicative of a residential settlement. However, the apparent absence of architectural features and the lack of grinding tools suggest that this may have been a temporary encampment. Despite the current anthropological collection, at least eight Natufians have been discovered. Three individuals, all corresponding to an immature age, would have been the subject of secondary burials, two of them being associated with the primary burial of an adult. The remaining graves are individual in nature and were situated in a clustered formation within the northeast section of the primary hall.

2.1.2. PRE-POTTERY NEOLITHIC A SITES (PPNA)

2.1.2.1. JERF EL AHMAR

Figure 19 Geographical situation of Jerf el Ahmar archaeological site.

Jerf el Ahmar is an archaeological site located in modern Syria, in the middle valley of the Euphrates River. It was discovered by Tom McClellan in the 1980s and later explored by M.C. Cauvin, M. Molist and A. Taha (1987-1988). Due to the construction of the Tchrine hydraulic dam, its excavation was a crucial rescue operation. D. Stordeur and B. Jamous supervised this project, which was completed by a Franco-Syrian team between 1995 and 1999 (Stordeur, 2015). The waters of the aforementioned reservoir have been swallowing the site since 2001.

The site is located on the left bank of the Euphrates, on the slope of a double hill formed by calcareous rocks that have been cut by the erosion of an ancient watercourse, eventually forming a characteristic relief that allows the site to be divided into two parts, the East Eminence and the West Eminence. In this way, the settlement is bounded on one side by the

Euphrates River and on the other by the hills associated with the Jebel esh Sheikh Anan Mountain range (Stordeur & Margueron 1998; Stordeur 2015).

The geological deposit in question was formed on a deposit that can be divided into three distinct phases. The initial phase comprises levels with calcareous components integrated in an alluvial deposit that drains materials derived from the erosion of these Palaeogene-era reliefs. The oldest and most remote phase is linked to the Oligocene, while the most recent phase is linked to the Upper Eocene. The second stage is associated with the erosion caused by the presence of a wadi, which separates the aforementioned hills. Lastly, the formation of marly-calcareous colluvium in the form of Upper Eocene hill pebbles represents the third stage, as proposed by Stordeur and Margueron (1998).

The excavation of over 1,000 m² and subsequent study by an interdisciplinary team have enabled us to ascertain the fundamental characteristics of this significant settlement. The settlement was occupied between 9,500 and 8,700 cal BC, corresponding to the PPNA period and, more specifically, the Mureybetien facies (Stordeur, 2015). The twelve layers of ecological and architectural development that overlap in each of the two tiny natural mounds on which the settlement is located have been documented through a combination of stratigraphic and architectural investigation. The levels have been divided into four periods, which are distinguished by known differences in architectural style. The initial three phases are typified by structures that are essentially circular in design. Therefore, only unicellular dwellings with rounded shapes are observed during the initial phase (levels VII/E and IV/E). The initial construction of internal walls, which delineate the remaining circular or semi-rectangular interiors of the buildings, is observed in the middle phase (levels III/E and I/E). The documentation also includes the initial structures to be designated as community usage, based on their construction and geographical characteristics. These semi-buried structures exhibit a circular layout, with walls enclosing the areas on all sides. It has been postulated that these structures may be interpreted as multipurpose edifices, which could be utilised for a plethora of purposes, including meetings, storage, and craft activities (Strodeur, 2015).

Two significant structural alterations can be identified during the period of occupation. The buildings initially exhibit a circular floor plan, which will be documented when the occupants change. This will demonstrate that the floor plan gradually transitions to a rectangular configuration. Although technological advancements are associated with this transformation, it is evident that social and economic changes also played a pivotal role. The second variation pertains to the number of rooms. All of the residential structures are unicellular at the outset of the occupation, but over time, more of the same structures will be observed, with varying numbers of pieces, until a total of five are present in the higher levels (Strodeur, 2015).

A diverse spectrum of PPNA burial customs has been unearthed during excavations at Jerf el Ahmar, illuminating the complex social and ritualistic practices of these prehistoric agrarian societies (Stordeur & Abbès, 2002).

One of the most notable characteristics of the Jerf el Ahmar burials is the considerable variation observed in both body placement and burial treatment. Archaeological investigations have revealed the presence of both individual and collective/multiple burials at the site (Stordeur & Brenet, 2014). The bodies in the individual burials were arranged in a range of orientations, including extended, slightly flexed, and firmly flexed. The bodies were positioned in a variety of ways, including on their stomach or back, and on their side (Stordeur & Abbès, 2002; Stordeur & Brenet, 2014). This variation suggests the possibility of unique funeral practices among the PPNA community.

The practice of inhume multiple individuals in a single grave, with as many as six or more bodies sometimes laid to rest together, represents a fascinating aspect of communal burial practices (Stordeur & Brenet, 2014). It may be posited that the intricate social systems, familial ties and common beliefs about the afterlife exhibited by the PPNA society are reflected in these group burials. Further insight into the mortuary customs and beliefs of this period can be obtained from the grave goods discovered alongside the Jerf el Ahmar burials. Archaeological evidence includes stone tools, animal remains, personal ornaments (such as pendants and beads), and proof of the use of ochre pigment (Stordeur & Abbès, 2002; Stordeur & Brenet, 2014). The existence of grave goods at Jerf el Ahmar indicates that the people of this region had highly developed belief systems and social hierarchies, as evidenced by the ornate burial treatments observed in certain individuals. Furthermore, the spatial configuration of the tombs within the site offers insights into the rituals and social structure of the PPNA community. The concentration of burials in specific locations suggests the existence of distinct familial or social groupings within the larger community (Stordeur & Brenet, 2014).

2.1.3. PRE-POTTERY NEOLITHIC B SITES (PPNB)

3.1.2.1. DJA`DE EL MUGHARA

Figure 20 Geographical situation of Dja'de el-Mughara archaeological site.

The site of Dja'de el-Mughara is situated on the left bank of the Euphrates River, upstream from the Qara Qosak bridge, within the province of Aleppo in the region of Djézireh. The tell is situated on a medium-sized Quaternary terrace, comprising pebbles and conglomerate rocks, at the boundary between two distinct environments: the alluvial plain of the Euphrates and the steppe hinterland of Djézireh. The tell, which is relatively low-lying, reaches an elevation of 6 metres above the current plain (Coqueugniot, 1999).

The excavation was initiated in 1991 as an operation of the French permanent mission in El Kowm-Mureybet, under the administrative direction of D. Stordeur and with the support of the DGAM. The excavation was initially conducted as a rescue operation as part of an international campaign established to preserve the Euphrates sites that were at risk of destruction due to the construction of the Tishrine dam (Coqueugniot, 1999).

The research project began with two survey campaigns, conducted in 1991 and 1992, with the objective of elucidating the chronological and cultural significance of the Dja'de el Mughara site. To this end, a series of comprehensive surveys were conducted on the southwestern portion of the tell, facing the Euphrates, which enabled the definitive attribution of the previously discovered Neolithic levels to the early PPNB (Coqueugniot 1992). A further survey was conducted in 1993 on the north-eastern aspect of the site, overlooking the Djézireh plain. This uncovered a primary burial from the Early Bronze Age III/IV (Coqueugniot et al. 1998). The subsequent set of excavations started in Dja'de in 1995 under the scientific responsibility of E. Coqueugniot, and from 1996 onwards, under his full direction (Coqueugniot 1998a). The excavations were conducted until 2010, at which point the prevailing circumstances in Syria precluded the possibility of the team returning to the field.

The site of Dja'de el-Mughara was ultimately not inundated when the Tishrine dam was filled during the winter of 1999-2000. Consequently, the excavations were able to proceed apace. In 2007, as a result of the discovery of 75 polychrome geometric wall paintings in the final PPNA levels, the archaeological mission at Dja'de el-Mughara was granted autonomous status and a four-year programme was initiated to continue the excavations, restore the paintings and highlight this heritage (Coqueugniot, 2007).

Dja'de has yielded a comprehensive and uninterrupted sequence spanning the transition from the PPNA to the early PPNB (from 9310 to 8290 cal BC). This is represented on the site by 9 m of archaeological deposits (Coqueugniot, 2007, 2010). The site has been subdivided into five phases of occupation, the first three of which date to the pre-ceramic Neolithic period and span almost the entire 9th millennium BC, with no interruption.

The Dja'de 1 occupation phase has been dated by 14C to the period between 9310 and 8830 cal. From a cultural perspective, this phase can be situated at the conclusion of the PPNA. The architectural style of this period is characterised by a combination of rectangular structures with large stone walls and paved floors, and circular buildings. Additionally, evidence of lightweight structures has been uncovered during this period (Coqueugniot, 2010). Two constructions exhibit a divergence from the architectural patterns. First, a large community-type building, similar to those discovered in particular on the contemporary sites of Mureybet and Jerf El Ahmar (Stordeur et al., 2001), was unearthed in 2002.

This structure is semi-buried, circular in shape, with an interior diameter of 7.5 m and three radial blocks 2 m high that divide the space into several apses. Its distinctive architectural style contrasts with other constructions of the same period, and its decoration is noteworthy. Notably, two of the blocks dividing the interior space are the surface is covered with polychrome geometric paintings applied to a white coating composed of crushed limestone. The second structure that is exceptional for this phase of the PPNA is a monumental wall, measuring 1.10 m in width and 70 cm in height. The structure comprises two facing elements: a larger slab laid on its edge and a smaller, rectangular slab laid on its edge (1.3 m x 45 cm). The interior of the structure is filled with limestone and chalky stones. The function of this structure remains unclear. Its position on the periphery of the tell could suggest that it was a surrounding wall, but its low height would make it only a symbolic delimitation at most (Coqueugniot, 2008). The bone industry is characterised by a high level of diversity and abundance. With regard to portable art, grooved stones and two engraved slabs appear to be emblematic of this period (Coqueugniot, 2006).

DJA'DE 2

The second occupation phase, designated Dja'de 2 or DJ II, has been radiocarbon dated to a range of 8800 to 8500 cal. BC. This is the initial phase of the early PPNB, known from Dja'de el Mughara (Coqueugniot, 2010).

The architectural style of this phase is markedly distinct from that of the preceding one, and the presence of certain elements allows for the proposition of a subdivision of Dja'de 2 into three sub-phases. In terms of architectural design, the buildings are rectangular in shape and comprise a number of large rooms. The floors are constructed from beaten earth, which is sometimes covered with a bed of small, multicoloured sandstone pebbles. The first Dja'de 2 sub-phase is characterised by the presence of burnt house layers. One noteworthy aspect of the sub-phase is the presence of butchery waste spread across expansive exterior surfaces.

The taxonomic diversity is low, with many of the remains belonging to large herbivores, primarily aurochs and equines. The fragmentation of the bones is significant, and the burial process was likely rapid, occurring on expansive surfaces (Gourichon, 2004). At the conclusion of this phase (DJ IIc), the emergence of "grill-plans" is observed. These are defined as small, low, parallel walls of minimal height constructed within external areas. It is possible that their use differed from that accepted for the PPNB of Çayönü (Özdoğan, 1999). Alternatively, these low walls may have served at Dja'de el Mughara as supports for sleeping platforms or food drying platforms (Coqueugniot, 2007; Chamel, 2014).

DJA'DE 3

The final phase of the Pre-Pottery Neolithic period at Dja'de el Mughara is the second part of the Early PPNB, which is dated from 8540 to 8290 cal BC. The Dja'de 3 phase is the most extensively documented.

The architectural style of this period is characterised by small, rectangular structures with a single cell. The walls are constructed from compacted soil, with a frame of small stones, while the floors are made from beaten earth on stone rafts. The houses are situated in isolation, with considerable outdoor areas that have retained evidence of the activities of their inhabitants. The site also comprises combustion structures, post holes that may have been used to maintain light or temporary structures, low walls in a 'grill-plan' configuration, and numerous waste pits. An accumulation of soils, designated "en millefeuille," indicates a rapid, potentially seasonal, occupation rhythm (Coqueugniot, 2010).

Dja’de 3 also yielded a particularly distinctive building, designated the "**House of the Dead**." This designation is analogous to the term "skull building" as observed in Çayönü (M. Özdoğan & A. Özdoğan, 1998). The presence of numerous burials beneath the floors of this structure, in addition to the numerous deposits associated with it, provides a rationale for this appellation. The lithic industry comprises pedunculated arrowheads of the Byblos point type, Aswad points and their derivatives, crafted from a bipolar naviform debitage (Coqueugniot, 2010). The presence of milling and grinding equipment is notable, with the majority of these items crafted from vacuolated basalt. This primary source of material is located approximately 25 km from Dja'de (Chamel, 2014). Portable art forms have also been identified, including incised pebbles and figurative representations of humans, some of which appear in a funerary context.

DJA’DE 4 AND 5

The site was subsequently abandoned during the Middle and Recent PPNB periods. A new occupation of the tell is attested during the Ceramic Neolithic period, at the beginning of the 7th millennium BC. This is the Dja'de 4 phase, which is associated with the pre-Halaf culture. A modest settlement comprising three levels of clustered structures and a multitude of pits was unearthed during this period. The presence of numerous ceramic shards within these pits serves to confirm the belonging of this village to the pre-Halaf culture. However, the duration of this occupation of the tell is believed to have been relatively limited (Coqueugniot 1998a, 2000).

3.1.2.2. ABU HUREYRA

Figure 21 Geographical situation of Abu Hureyra archaeological site.

The site of Abu Hureyra is located on one of the low terraces overlooking the Euphrates, about 130 km east of the city of Aleppo. It is a trapezoidal tell, oriented north-south, 480 m long and 290 m wide. Located close to a dead branch of the Euphrates, which once supplied the site with water, Abu Hureyra is ideally situated at the interface of two environments: above the Euphrates alluvial plain to the north and below the arid steppe to the south (Moore 1975, Moore et al. 2000).

The site of Abu Hureyra, like many others in the region, was discovered during reconnaissance missions carried out in the 1960s in the floodplain of the future Tabqa Dam (Van Loon, 1967). A surface survey had revealed several ceramic sherds, as well as numerous examples of lithic industry similar to that found at the site of Bouqras (Van Loon, 1967; Contenson & Van Liere, 1966). In fact, the Middle Euphrates sector had already yielded some Neolithic settlements, such as Mureybet, dated to the beginning of the Neolithic sequence, or Bouqras, dated to the end of this period. The aim of A. Moore and his team was to find a site that would fill the gaps in the Neolithic chronology, if possible, with a long occupation (Moore, 1975; Moore et al., 2000).

A rescue excavation under the direction of A. Moore in 1971 was decided to last for two years. The aim was to obtain a complete Neolithic sequence. Seven trenches were dug over the entire surface of the tell, six of them down to the natural subsoil. The spacing of the trenches reflects the desire to obtain as complete a picture as possible of the extent of the occupation of the tell. During the first campaign in 1972, five trenches (A, B, C, D and E) were excavated, revealing a pre-ceramic Neolithic occupation. At the end of the campaign, a much older Epipaleolithic occupation was discovered at the bottom of trench E. The 1973 excavations made it possible to widen this trench in order to better understand the sequence of occupations and to enlarge A, B and C in order to have a clearer view of the buildings uncovered during the 1972 campaign. Two further trenches (F and G) were also opened outside the previously favoured north-south axis to test the extent of occupation in other parts of the tell (Moore, 1975, Moore et al., 2000).

The site was flooded by the waters of the Tabqa Dam in April 1974. Surveys of the surrounding area were carried out in 1975 to place the site in its chronological and geographical context (Moore et al., 2000).

Abu Hureyra was occupied over a very long period, but not continuously. In fact, two villages followed each other with a gap of about 1000 years between them (Moore et al. 2000). The first settlement, Abu Hureyra 1, is called "Mesolithic" by A. Moore corresponds to the later/end Natufian. It is dated between 11.500 and 9650 cal. BC. The village, was established closer to the Euphrates to the north, was found on only 49 m² at the bottom of trench E190 (Moore et al., 2000). The occupation can be divided into three phases: The phase 1A corresponds to the implantation of pits, together with numerous postholes, perhaps used to support light structures (Moore et al., 2000); Phase 1B produced no pits, but a series of dark-coloured occupation floors and areas of hearth. It appears that light structures were built on one level; Phase 1C for the first village does not bring much change, except for the appearance of clay floors, still with hearths (Moore, 1975; Moore et al., 2000).

The site was then abandoned for almost 1000 years during the PPNA period, only to be reoccupied in the Pre-Ceramic and then Ceramic Neolithic with the establishment of a new village, Abu Hureyra 2. The inhabitants first cleared the surface of the tell and levelled the upper layers of the previous village before settling on a larger area, this time to the south. This occupation can be divided into three phases (Moore et al., 2000): Abu Hureyra 2A, called

"Early Aceramic", is dated to c. 8650 to 7350 cal. BC and corresponds to the middle PPNB. This phase revealed numerous rectangular structures built of raw bricks, most of them multicellular, with plastered floors. The area of the village is estimated to have been about 8 ha (Moore et al., 2000).

The next phase, 2B, called "Later Aceramic", represents the largest extension of the site with 16 ha. It is dated from 7350 to 6200 cal. BC, the most recent PPNB. There are no major changes between this phase and the previous one in terms of architecture and lithic industry; those that are observed concern the subsistence economy, since there is a shift from the intensive hunting of gazelles to the breeding of small ungulates.

The last phase of the Neolithic is characterised by a change in the form of occupation of the site, which is reduced in size (about 7 ha). This is the "Developed Neolithic", phase 2C, dated from 6200 to 6000 cal. BC, or the Ceramic Neolithic. In **phase 2A**, domesticated einkorn wheat was found, followed shortly by domesticated emmer wheat at a lower frequency. Rye remains morphologically wild, and hulled barley exists in both domesticated and wild forms. The question of the domestication of lentils and chickpeas is raised for this phase but not resolved. The assemblages still consist mainly of steppe and lowland plants, at over 85% (Moulins, 1997; Helmer et al., 1998). Gathering is therefore still the main means of obtaining food. Of this 85% of plants, about half are small nutritious plants such as clover and alfalfa. Towards the middle of phase 2A, there is a progressive increase in the frequency of einkorn and domestic barley in the assemblage (Moulins, 2000).

The faunal spectrum of Abu Hureyra 2A remains essentially the same as that of AH1, reflecting an unchanged environment, despite the considerable time lag between these two phases of occupation (Helmer et al. 1998). The abundance of gazelle also remains the same as in AH1. Onagers and aurochs are not very abundant, accounting for 2 to 3% of the assemblages. The remains of fallow deer and wild boar are even rarer. Small game hunting continues to decline, with only 1% of hare remains in the assemblages and some fox remains (Legge & Rowley-Conwy 2000). The major change in phase 2A concerns caprine. In fact, goats appear for the first time at the beginning of phase 2A. The frequency of goats thus increases to 30% at the beginning of the sequence, before decreasing to 12% at the end. The ratio of goats to sheep is 5:1 at the beginning of 2A, then equalises at the end of the sequence (Legge 1996, Legge & Rowley-Conwy 2000). The massive appearance of this new species is a very strong argument for domestication of goats.

The burials at Abu Hureyra come from the seven trenches opened during the 1972 and 1973 excavations. However, only the burials from four trenches (B, D, E and G) were examined and described in the monograph published in 2000 (Moore et al. 2000). Skeletons dated to phase 2A were discovered in trenches B and D.

In trench B, few deposits are dated to the beginning of Phase 2A, providing only one, B273, the mandible of an immature individual aged between 4.5 and 6 years at the time of death. It was found in a clay-filled level and represents the oldest deposit from the reoccupation of the site during the Abu Hureyra 2 phase (Molleson, 2000).

The Phase 2B - 8/1 building was initially constructed as a single large room measuring 7.25 x 5 m. A mudbrick partial wall was then built along a north-east/south-west axis, dividing the building into two unenclosed rooms, a small and a large one (Moore et al., 2000). The small room yielded numerous human remains for both Stage 1 and Stage 2, either whole skeletons, body parts, or isolated or grouped skulls. This diversity of burial practices in the same ensemble led the site anthropologist to propose the function of this room as a "charnel room", i.e. a room used to expose bodies in the process of decomposition before burial of whole bodies or parts of them (Moore & Molleson 2000).

Room 3 of Phase 8/2 of Trench B referred to 'charnel room' by the anthropologist at Abu Hureyra (Moore & Molleson, 2000). This term has also been used at other sites, like Bouqras and Tell Sabi Abyad (Verhoeven, 2000, Merrett & Meiklejohn, 2007). This room is described at Abu Hureyra as having served as a depository for bodies during the life of the building. It appears that the bodies were either placed directly on the floor or in very shallow pits, as the fire that caused the abandonment of the building burned only one side of the bones and skulls that were present in the room at the time (Moore & Molleson 2000). Two hypotheses have been put forward as to the function of this room: it may have been a place where bodies were prepared before burial, or it may have been the final resting place of the deceased. Other hypotheses have been put forward, such as that the bodies were exposed to the open air to allow the flesh to decompose (Moore & Molleson 2000). However, the fact that complete or incomplete skeletons were found in this room does not necessarily mean that they were defleshed. In fact, many of these deposits appear to be undisturbed primary burials that were probably covered by sediment quite quickly.

The other deposits of phase 2A come from trench D, located on the western slope of the tell. Only phases 2 and 3 yielded burials.

In phase 2 a rectangular building with one room was excavated. Two burials were discovered within it: deposit 73-852 is located in a small pit (146) and contains the body of an immature individual aged between 6 months and 1 year at death, as well as an adult craniofacial block. The immature was buried in a flexed position with its head facing east. This deposit is accompanied by a caprine mandible and other faunal bones that may have come from the filling of the pit (Moore et al., 2000). The second deposit is located to the north-east of the room and contains an immature individual that died between 6 and 8.5 years of age and was deposited in a hypercontracted position in a rectangular pit.

The trunk is seen from the front, the upper limbs are bent on the trunk and the lower limbs, at least one of them, are bent very much to the right of the trunk. It is accompanied by four stone beads. The rectangular shape of the pit is quite unusual, as most burial pits of this period are generally oval in shape. In addition, the degree of contraction of the individual's lower limbs suggests the presence of a flexible container, such as a sack, in which it would have been placed (Moore et al., 2000, Moore & Molleson, 2000).

3.1.2.3. TELL ASWAD

Figure 22 Geographical situation of Tell Aswad archaeological site.

Tell Aswad is a black hill formed of volcanic deposits, with a maximum elevation of 4.5 m above the surrounding plain in its southern region. Its length is 275 m from north to south, and its width is 250 m from east to west, encompassing an area of approximately 5 ha. The tell is situated in the central Levant region, approximately thirty kilometres east of Damascus, in close proximity to the village of Jdeidet el-Khass. Geological data indicates that the Damascus basin, in which the site is situated, was previously half-covered by a large lake during the Late Pleistocene period. This lake was subsequently filled by alluvium during the Holocene epoch. Two residual lakes remain: that of Aateibé to the north and that of Hijjané to the south (Contenson et al., 1979, Contenson, 1995). The archaeological and palynological evidence indicates that the vegetation in the vicinity of the site was that of a forest-steppe, comprising a variety of trees and shrubs, including almond and pistachio trees. On the shores of the lakes, which were situated in closer proximity to the site during the Neolithic period than they are today, a diverse range of flora flourished, including poplars, ash, and willows, as well as a vast array of aquatic and hygrophilous plants (Contenson et al., 1979).

In 1967, Dr. Contenson engaged the excavation of Tell al Khazzami, workers from the neighbouring village of Tell Aswad presented him with flints from surface collections on the tell, prompting him to develop a more profound interest in this site.

Further collections yielded a plethora of flints analogous to those from the earliest stratum of Tell Ramad. However, no pottery sherds were recovered, suggesting a pre-ceramic occupation. In 1971, the Tell Ramad mission was terminated, and the DGAM proposed to Contenson that the funds previously allocated to that project be redirected towards an excavation at Tell Aswad. It was then resolved that two test pits should be opened on the two highest points of the tell, to the east and west, at a distance of approximately one hundred metres. This was done in order to gain a better understanding of the stratigraphy of the tell from the summit to the virgin soil. During the initial campaign, the two test pits were excavated on 16 m² each by stripping 25 cm.

Contenson employed the lithic industry in conjunction with the 14C dates to define the Aswadian, which is situated within the PPNA horizon (M.C Cauvin, 2006). However, no other site exhibiting the defining characteristics of the Aswadian was identified in the subsequent years. The re-examination of the lithic series also prompted significant questions regarding the veracity of this period. In order to address these questions, the site was reopened for excavation by Stordeur and Jammous from 2001 until 2006 (Stordeur 2003a). The initial two excavation campaigns concentrated on the areas previously investigated by test pits opened in 1971-1972.

Following the excavations conducted by Contenson, the tell was subjected to approximately twenty notches along its periphery in 1973, during the October War. These notches were created for the purpose of installing military batteries. Two of the notches were situated at the locations of the former test pits, thus enabling the excavators to gain direct insight into the stratigraphy (Stordeur 2003a). Additionally, squares were opened on the highest points near the notches. Sector B was opened on the site of the former East test pit, where a notch could be exploited down to virgin soil. Sector C was conducted at the location of the West test pit, which had been destroyed, leaving only the lowest level of the structure.

The excavations revealed the presence of structures constructed from a combination of building earth, wood, and reeds, with plaster used as a flooring material. In addition, rectilinear walls constructed from unfinished brick were discovered across all levels of the excavation. Some of the constructed elements have interior fittings that appear to have been designed for storage or arrangement purposes. The space alternates between built zones and exterior areas at different levels. The latter feature pits and combustion structures (Stordeur, 2003a). The most significant discovery resulting from these new excavations, in addition to the revision of the dating of the site, is the identification of three distinct burial areas. The oldest of these extends over 126 m², and it yielded a total of 22 burials, in addition to four skulls that exhibit clear evidence of overmodelling. The most recent group, which is of a smaller size, comprises 10 primary and secondary burials, as well as five overmodeled skulls. The areas mentioned before have been dated to the end of the Middle PPNB or the beginning of the Recent PPNB (Stordeur et al., 2006; Stordeur & Khawam, 2007; Stordeur et al., 2010).

In order to propose a dating for the site of Tell Aswad, it was necessary to undertake a number of steps. From the initial excavation campaign, it became evident that two distinct levels could be discerned within the stratigraphic sequence. The upper level is characterised by a grey, ashy hue, while the lower level displays a brown, clayey composition. The virgin soil is characterised by a homogeneous and compact yellow clay, which has been interpreted as a lake sediment. In 1972, Contenson proposed a connection between the site and the PPNB of Jericho based on the lithic industry, clay figurines and funerary practices. Nevertheless, he qualified this hypothesis by noting that the 14C dates were not yet available at the time (Contenson 1972; M.-C. Cauvin 2006). Subsequently, the stratigraphy of Aswad was divided into three phases: level IA, level IB and level II. All three levels are observed in the eastern borehole, while only level II is present in the western borehole. The calibrated 14C dates for these levels are as follows (Contenson, 1995): Level IA: 9000-8500 BC (PPNA) | Level IB: 8500-8000 BC (EPPNB) | Level II: 8000-7500 BC (MPPNB).

The stratigraphic succession of 18 levels, was revealed by the excavations conducted by Stordeur and Jammous. A total area of 1000 m² was subjected to exploration. The aforementioned layers can be classified into three distinct phases.

For stage I, all the graves are in pits, although sometimes they are only shallow excavations, followed by the spreading of a white coating over the entire surface intended for burials. It can also be argued that the site is "consecrated" by a founding act, which consists of placing four overmodeled skulls in a small, prepared basin. All the burials corresponding to this stage were excavated in this preparatory layer.

Stage II of the cemetery was inaugurated by the addition of a thick layer of earth. The researchers do not know whether this gesture corresponds to a temporary cessation of the use of the cemetery due to the expansion of the village to the east, or to a temporary interruption of its use. The original graves were covered by an addition of earth and this covering had the direct consequence of making them inaccessible, or at least hidden. But one tomb remains visible, the one with the overmodeled skulls; it is not covered by this layer, on the contrary, it emerges from it, as we will see (Strodeur, 2006).

Other types of preparation layers, this time closely linked to a given burial complex, are sometimes arranged: white bedding, yellow silt beds, red dyes. Stage II is also characterised by multiple, repeated and complex gestures following the burials. While three tombs (probably among the oldest) are completely enclosed by the mass of soil brought back, others contain burnt elements in their fill. This use of combustion then increases and becomes more precise. Calcined lenticular deposits cover at least seven graves. They are of different sizes, sometimes mixed together, and may have been spread during new burials or the reopening of graves. None of these deposits covers the whole area (Strodeur, 2006).

The area is then bordered to the west by small hearths, arranged in a northwest-southwest circular arc, with a dual function. When lit, they could indicate the space dedicated to the dead. However, there are also faunal remains and small objects, especially figurines that can be interpreted as offerings. Other types of fireplaces are associated with specific burials. In particular, the tomb with the overmodeled skulls, enriched with new burials, is carefully covered with a dome of earth rich in burnt plant remains and surrounded by a low wall and hearths. The two states of the area are therefore clearly individualised by their preparation and by the signalling of the place they occupy (Strodeur, 2006).

In all phases the joints are close to the face. The bodies are placed on the left side. The orientation almost always follows a main east-west axis, with the head facing east. It is also sometimes oriented northeast/southwest. There is therefore a systematic choice, which suggests that there is a code that runs through the successive states of the burial area. If in some burials the orientation is south-north, with the head to the south, the researchers note that these are very specific contexts (Strodeur, 2006).

3.1.2.4. TELL RAMAD

Figure 23 Geographical situation of Tell Ramad archaeological site.

Tell Ramad is located at the foot of Mount Hermon, about 900 metres above sea level, about 20 kilometres south-west of Damascus and 3 kilometres south-east of Qatana. The site lies on the northern side of a basaltic plateau in Wadi Qatana, which has its bed at the interface between Neogene conglomerates and basaltic deposits (Contenson & van Liere, 1964). The wadi carries water in winter and spring; in early summer it stops flowing in May. The tell measures 175 metres east-west and 1 50 metres north-south. The thickness of the deposits can reach 6 metres.

Contenson and van Liere conducted excavations at Tell Ramad in 1963 and 1965, and Contenson excavated there from 1966 to 1973. A total of eight field seasons were spent testing the site. The site was divided into 10x10m squares using a grid system. NE, NW, SW and SE are the four quadrants into which each 10x10m square is divided.

There are three main periods of occupation. The basaltic virgin soil served as the foundation for the community. Up to two metres of black, clay soil formed the lower levels (Phase I), where a series of semi-subterranean dwellings with plastered ovens and mud walls were discovered. The artefacts include flint tools, some obsidian blades and querns, hammerstones, mortars and basalt pestles. Tools and spatulas are examples of bone artefacts; polished stone bowls were made of limestone. Clay figures of humans and animals are quite common. Plastered skulls with red ochre on the top and lime on the face have also been found. The first phase dates back to around 6200 BC (van Zeist & Bakker-Herres, 1982).

The Phase II levels reveal more complex architectural elements: rectangular houses with plastered floors and mud-brick walls supported by stone foundations. The dwellings had a single room and were divided by small streets and courtyards. It seems that a reduced version of the skull cult persisted. In terms of objects, the white unfired bowls (vaisselle blanche) are the most distinctive feature of the Phase II levels. Tell Ramad, often called the Hill of Ashes, takes its name from the very pale layers of Phase II. The date of this phase is around 5950 BC.

The Pre-pottery Neolithic B culture of is represented by Phases I and II. Contenson (1971) posits that the animal bones recovered from both PPNB phases are those of wild animals, thereby indicating that animal husbandry was not practised. It is noteworthy that, based on the limited research conducted thus far on animal bones from the Aceramic Neolithic period in the Damascus Basin, there is no evidence of domestic animals. Further comprehensive analysis of the faunal remnants is eagerly awaited.

Phase II is only recorded on the western side of the tell, at the highest point, and in pits dug into the underlying strata. The defining characteristic of this period is the presence of true ceramics, which are typically handcrafted, exhibit a rough surface, and frequently display dark colouring. The phase III is composed of partially or mostly redeposited phase II material. Given that the charcoal was determined to originate from a later period, a phase II date (5930 BC) was derived from a radiocarbon assay of a phase III sample. The pottery from Phase II has been dated to the end of the sixth millennium BC, based on comparisons with similar material from other Southwest Asian sites. Bones from domestic goats, sheep, cattle, and dogs were recovered from phase III levels.

Tell Ramad is alsso home to the biggest collection of plastered skulls. A total of around twenty-three skulls were found in three different caches: eight skulls were recovered from the initial cache, three skulls were retrieved from the second cache, and at least a dozen skulls were identified in the third cache (Contenson, 2000). The first assemblage, classified as Level I, comprised the skulls of five girls, two men, and one adolescent male, estimated to be between 13 and 14 years of age. This assemblage dates to approximately 6200 BC. The Level II caches yielded additional findings, including the plastered skulls of two girls and one male, along with twelve unidentified individuals, which are dated to approximately 6000 BC.

The Tell Ramad skulls exhibit a number of distinctive characteristics. All teeth were extracted post-mortem, yet the mandible remained connected (Ferembach, 1970). The eyes were composed of greyish plaster, with the iris and pupil protruding in pure white. The neck was also plastered, and the cranium exhibited a prominent red patch at the vertex in Ramad I (Contenson, 1967). In the Level II, the entire cranium was painted red (Contenson and van Liere, 1966).

It seems likely that the plastered skulls were exhibited to the general public at Tell Ramad. The initial cache, comprising eight skulls. The skulls were located outside of a structure and measured 80 x 40 centimetres. Similarly, it is conceivable that the three skulls from the second cache, which were situated against a stone foundation containing human collarbones (Contenson & van Liere, 1966), were intended for display. Subsequently, an oval cage constructed from mud bricks and a substantial plaster vessel were utilized to house the skulls of Cache 3. They were arranged in minute clusters, with substantial clay balls serving to separate them. Both the initial and concluding caches included clay figurines coated in a layer of plaster (Contenson, 1967). These were integral components of the assemblage or represented an alternative form of funerary offerings.

3.1.2.5. TELL HALULA

Figure 24 Geographical situation of Tell Halula archaeological site.

The research project at Tell Halula was conducted between 1991 and 2011 and comprised a systematic programme of archaeological excavations at the site. The excavations have enabled the establishment of the stratigraphic sequence of the settlement and have provided insights into the characteristics of the main horizons of a town that dates to the period of consolidation of the Neolithicisation process in the Northern Levant area.

The location is situated approximately 150 km east of the modern city of Aleppo, within the middle valley of the Euphrates. It is considered to be one of the most significant archaeological sites in Southeast Asia between the 8th and 6th millennia BC, due to its considerable size of approximately 8 hectares and the notable thickness of its archaeological layers, which reach a depth of 15 metres.

The characterisation of the primary occupations and the definition of the type of occupation of the space, along with the architectural elements, economic strategies and technological transformations associated with them, have been made possible by the fieldwork and investigations conducted by the SAPPO-GRAMPO team of the Department of Prehistory of the Autonomous University of Barcelona, under the direction of Dr. Miquel Molist. The archaeological excavation has identified over forty phases of occupancy (FO), carried out over an area of approximately 2,500 m². This indicates that there was essentially continuous habitation from 7,800 to 5,700 cal BC. The historical eras to which these findings are attributed include the MPPNB-LPPNB (FO 1–20), PN, which encompasses the Pre-Halaf period (FO 21–35), and the Neolithic–Chalcolithic transition, symbolised by the Halaf and Obeid civilisations (FO 36–38) (Molist et al., 2013; Molist & Vicente, 2013).

OCUPATION DURING THE PREPOTTERY NEOLITHIC B PERIOD

The results of the surveys and excavations indicate that the village is of considerable size, encompassing approximately 7.5 hectares over the course of its historical designation. The data obtained from the excavation activities conducted in the southern portion of the village (sector 2/4) clearly demonstrate the existence of a well-structured constructed space. The most comprehensive documentation for this historical period can be found in this region.

The village in the PPNB period would have, according to current knowledge, a distribution of housing units in alignments, arranged in parallel according to a dominant axis, which is to the west. There are ample spaces between the alignments, which constitute the front spaces of the houses, access points to them and open areas where a significant portion of domestic production activities are carried out. In each alignment, different housing units are juxtaposed, oriented essentially north/south, with small circulation spaces (ranging from 0.40 cm to 1.5 m) between them, forming a dense structure. The houses exhibit a striking uniformity in their morphology, characterised by a rectangular, multi-cellular floor plan with three, four or five rooms, distributed according to an orderly plan that is repeated in the different units.

One of the most notable characteristics of the residences is the size of the main room, which ranges from 18 to 22 square meters. The walls and flooring have been meticulously treated with lime plaster and coating. It has been established on multiple occasions that this room has been decorated. In one instance (house FEC/phase XI), a set of schematic figures was discovered on the floor of a room in the vicinity of the house, which serves to illustrate the remarkable degree of conservation observed in this particular instance. A total of 23 female figurines were distributed across an equally symbolic representation of the previously mentioned red-painted figures. The representation was that of a square with internal stripes (Molist et al., 2013).

A wastewater evacuation system is in place, and the presence of niches and benches in some houses has also been observed. The complementary rooms are of a smaller dimension, exhibit a more varied morphology and construction quality. For example, the walls and floors may or may not have a lime plaster, and the presence of built silos or homes is also variable. In short, the set of structures and/or spatial distributions of material remains indicate complementary functions, such as storage, tool manufacturing processes, grain drying, etc. In the front part of the house, in front of the door, another room has been revealed in some of the constructions. This room is of a more fragile and temporary constitution than in the manner of a "diwan" or porch. It contains some domestic structures, including homes and silos (Molist, 1998; Molist, 2001; Molist, 2013; 2014; Molist and Gomez, 2015).

A set of architectural elements has been identified that suggest the potential for the construction of collective infrastructure in these settlements, while also indicating a degree of planned organisation in the layout of the interior space. The most impressive of the architectural elements is the stone wall, which has been preserved to a height of approximately 4 metres and has been uncovered by the excavation team in a continuous length of approximately 30 meters. However, the results of the global analysis, which included geo-electrical prospecting and soundings, indicate that the wall is located in the western part of the settlement and that its shape is elliptical, exceeding 200 metres in length. The function of this construction has been compared to the famous wall of Jericho. It was proposed that this building could be a collective structure. This construction is exceptional, as although earthwork works are known in contemporary sites, the significant finds discovered in Tell Halula constitute the earliest evidence of monumental architecture in the actual Syria (Molist, 2013; 2014).

The exploitation of plant resources is evident from the earliest periods in the Euphrates valley, with the emergence of incipient agriculture involving the domestication of diverse morphologically distinct wheat species, including T*riticum aestivum/durum*, *Triticum* *monococcum*, and others. But the existence of wild-type varieties such as *Triticum Dicoccoides*, barley (*Hordeum spontaneum*), either as the result of a harvest, or in the form of agricultural exploitation, but on wild morphology. Furthermore, there is evidence of the cultivation of legumes (such as peas and lentils) and fruit trees (including olives and plums). The results of the analyses indicate the presence of a diverse range of significant species, including Pistacia, Quercus, Fraxinus, and Populus. These findings suggest the existence of vegetation adapted to a climate with slightly higher humidity than the current conditions. Additionally, the C13 isotope analyses (Araus et al., 2001) have demonstrated that the soil possesses characteristics conducive to the cultivation of rainfed crops.

The verification of the **domestication process** of the main animal species that provided food (goat, sheep, pig and ox) constitutes a significant contribution to the settlement in general and to these older phases in particular. This is due to the fact that Tell Halula is one of the few settlements in the eastern Levant area where it has been possible to follow these domestication processes continuously and progressively over time. This allows for the observation of the incorporation of the four main domestic species, the consolidation and productive diversification of livestock strategies, and the gradual decline in hunting activity. Tell Halula archaeological site is notable for its demonstration of the rapid domestication of goats, sheep, pigs and oxen, which occurred within a timespan of 200 to 300 years. Consequently, it can be stated with certainty that by 8500 BP in the Euphrates valley area, the principal animal species providing sustenance were already domesticated.

A review of the 20 occupation phases defined at Tell Halula, which span the PPNB period, reveals that burial structures have been documented in eight of them, spanning from occupation phase 7 to 14. In total, more than a hundred graves have been excavated, typically situated within the domestic structures, and particularly in the area immediately preceding the entrance to the primary living space. The funerary structures at Tell Halula are characterised by the predominance of individual and primary burials, in which the deceased are interred in a pit dug directly into the beaten earth floors documented in the main room of the houses.

The predominant finding was the presence of a single primary skeleton in the largest proportion of burial pits. In contrast, only twelve graves yielded evidence of the remains of more than one individual. The burial pits were excavated into the clay floor and coated with lime plaster. The bodies were positioned with both lower and upper limbs flexed. Additionally, several fetal positions were observed, though only in the case of neonates and infants. In some burials, remains of vegetable fibres, sacks, mats, or baskets were found, suggesting that the bodies may have been covered. All pits were sealed with adobe, probably originally visible on the surface. The number of burial pits per house varied from five to 13, with an average of 8.5 pits per house (Estebaranz et al., 2007).

In nearly all cases (111/114), the interments at Tell Halula were situated in the vicinity of the entrance to the primary chamber. The main room of the house can be divided into two distinct areas, both enclosed by the same structural wall. The first of these is the 'entrance/burial' area, and the second is the 'main/domestic' area. The use of these terms does not imply that people did not reside or engage in domestic activities within the entrance/burial area of a house. There is no evidence to suggest that people did not sleep, live, and engage in the same activities in both areas. Rather, these terms are used to highlight the physical differences in floor construction and the spatial positioning of specific social acts, which were materialised below the floor in one area of the larger room but not in others (Guerrero, 2009).

In contrast to the funerary practices observed at other Middle PPNB sites, the burials at Tell Halula are characterised by a seated position. With the exception of a few fetal burials, most of the burials are flexed, with the legs drawn up tightly to the body and the arms flexed and folded around the chest. The exceptional state of preservation of some of the burials allows us to reconstruct the sequence of steps involved in the construction of the burial pits and the subsequent internment of the individuals. The construction of the burial pits was carried out in a similar manner. In the initial stage of the process, a circular-oval opening was excavated in the clay floor of the entrance area, with dimensions sufficient to accommodate the interment of the individual. Subsequently, the pit was extended in a downward direction by the removal of soil, frequently resulting in the formation of straight walls, thus ensuring that the depth of the pit was sufficient to accommodate the burial below the floor level. While there is variation, the base of the burial pit was often concave or flat. The tightly flexed burial was then lowered into the hole. Excavations have revealed that more than 50% of the pits still have empty spaces between the skeleton and the walls or are partially filled with very soft sediment. In contrast, less than 30% of the burial pits are filled with compacted sediment, suggesting that these pits were deliberately filled (Guerrero, 2009).

OCCUPATION DURING THE LATE NEOLITHIC/HALAF PERIOD

The residential units are rectangular in shape and incorporate both technological and layout innovations. The use of stone as a construction material has seen a notable increase within the category, particularly in the context of plinths and foundations. Conversely, lime is seldom employed as a plastering material. Plastering is employed in only a few rooms, while the most prevalent flooring method is beaten earth. The distribution of rooms is markedly irregular. It is significant to note that a novel architectural style has emerged that deviate from the original theory associating it with temples (Molist, 1998).

The advent of ceramics is widely regarded as the most significant technological innovation to emerge from the early agricultural societies. The rapidity with which this new material was adopted and developed is testament to its transformative impact. In Southwest Asia, this innovation is evidenced by the emergence of ceramics in the context of a completed transition to sedentary lifestyles and the advent of new economic practices. The earliest known examples of ceramics in this region date to around 7,000 cal BP, appearing in several cultural regions, including the central Anatolian plateau, the Mediterranean coastal zone, and northern Mesopotamia. The advent of ceramics in these regions marks a pivotal technological shift.

The oldest phase has yielded an intriguing level of habitat with a rectangular, multicellular architectural style that has largely survived to the present day, along with the notable presence of graves situated beneath the floors of the rooms. The middle phase is distinguished by a series of excavated structures, primarily pits, which were initially utilized as silos and subsequently as a waste accumulation area. As in the preceding phase, the most recent phase has yielded evidence of built settlements, graves, and pits that cover part of the upper region of the settlement (Gómez-Bach, 2011). This period marks the final stable occupation of the settlement.

3.1.2.6. NEMRIK 9

Figure 25 Geographical situation of Nemrik 9 archaeological site.

In the period between 1985 and 1987, an archaeological mission from the University of Warsaw in Poland, led by Stefan K. Kozłowski, conducted excavations at a PPN site, Nemrik 9, situated in the northern Iraqi Dohuk governorate. The research was conducted in close collaboration with the State Organisation of Antiquities and Heritage, led by Dr. Moayed Said Damerji, as part of the global Saddam's Dam Salvage Project. The location, situated at an elevation of between 340 and 345 meters above sea level, encompasses an area of approximately 1.8 hectares. It is positioned on the third terrace of the Tigris River, at a distance of approximately 1,500 meters from the river's current course and approximately 4,300 meters from the base of the Kurdish Mountains. The site is situated between 65 and 70 metres above the current river valley. A multitude of wadi valleys, extending in a north-south orientation, traverse the heavily denuded third terrace, thereby dividing it into numerous peninsulas. One such peninsula is where the site of Nemrik 9 is located. It is bordered to the east and west by two wadis, which are up to 30 metres deep (Kozłowski, 1989).

As stated by Kozłowski (2002), the discovery of human remains has been a consistent occurrence at Nemrik throughout the majority of the settlement phases, spanning from Phase II (10,000–9,900 BP) to Phase V (before 8,400 BP). However, most individuals have been identified as belonging to two specific periods: phase IIIb (9100–8900 BP) and phase IVb (before 8600 BP). One of the humans remains can be dated to the Post-Assyrian era, while the other two were discovered in a tomb that is likely to have been constructed during the Middle Assyrian period (Sołtysiak et al., 2015).

A significant number of disarticulated human bones and partially articulated skeleton components were excavated under the floorboards of a considerable proportion of known phase II–V homes. The majority of bones were recovered from several graves that contained the remains of up to six individuals (houses 1A, 2A, 4A, 8A, 19, all dated to the phase IIIb), while a few isolated disturbed primary or secondary inhumations were also identified (houses 3, 6, 10, 18). It seems likely that many burial trenches were repeatedly uncovered before additional skeletal remains were deposited, resulting in the rearrangement of bones that had already been interred. However, the stratigraphic evidence is inconclusive due to the mixed character of the pit fill. The depth of each burial pit was recorded as being up to 50 cm below the surface of the ground (Sołtysiak et al., 2015).

Given the absence of articulated skeletons across the various layers, despite the occasional grouping of bones from a single individual, it is more probable that these pits held secondary graves rather than primary burials that were disrupted by frequent usage of a burial site. The majority of the artefacts discovered in the pit fill are flint implements of a diminutive size. They appear to have been misplaced during domestic activities or inadvertently mixed in with the pit fill. The only potential grave goods are a few stone tools and tool pieces or beads, which are found in particularly high quantities beneath the floor of house 1A (Sołtysiak et al., 2015).

Several articulated skeletons were recovered from basic pit burials in a tiny cemetery (approximately 150 m^2) situated in the south-western corner of the site, close to the area where people had previously resided. The cemetery was dated to Phase IVb. With the exception of a few flint implements, which may have been inadvertently included, no burial items were identified in these shallow pits. The legs were observed to be flexed, and the bodies were positioned on their sides (Kozłowski, 2002; Sołtysiak et al., 2015).

Despite the lack of completeness and poor preservation of the human remains from Nemrik, some information about these early farmers in the upper Tigris River valley can be obtained. Firstly, between approximately 9000 and 8600 cal BP, there was a modification in burial practices. In the past, the remains were typically interred beneath home floors and were likely left exposed for an extended period prior to burial. While solitary graves were also identified, it was notable that skull burials and clusters of mixed components from multiple individuals were prevalent. Subsequently, single individuals were buried in pit graves without extended exposure at an extramural cemetery. Given the significant divergence in the age-at-death profile between the two temporal groupings, it can be inferred that this shift in burial practices was considerably more widespread (Kozłowski, 2002; Sołtysiak et al., 2015).

The farmers who were inhumed in Nemrik's Pre-Pottery Neolithic strata did so under challenging circumstances and with limited access to food preparation techniques. It is, however, remarkable that their tooth wear pattern did not deviate much from subsequent eras, despite the restricted capacity to boil food in the absence of pottery. The dental attrition levels indicate that the diet of the Nemrik inhabitants was relatively softer than that of the Bronze Age inhabitants at Tell Barri. The reasons behind this somewhat unexpected temporal pattern in tooth wear cannot be further investigated without a stable isotopic study (Sołtysiak et al., 2015).

3.1.2.7. ALI KOSH

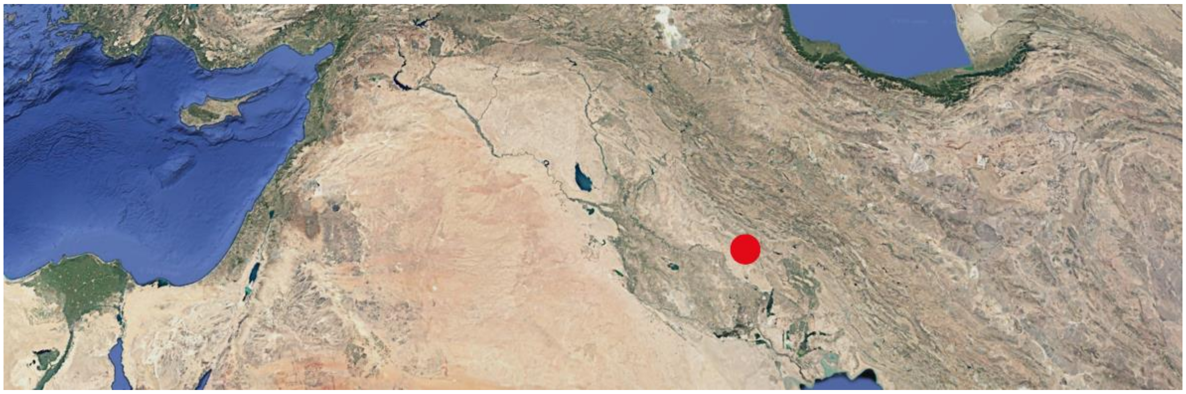


Figure 26 Geographical situation of Ali Kosh archaeological site.

The Deh Luran Plain in south-west Iran is the location of the Neolithic archaeological site of Ali Kosh, situated at an elevation of approximately 150 metres above sea level. The mound is approximately four meters above the surrounding fields and contains approximately seven meters of dense archaeological deposits. In 1903, a French team undertook the inaugural investigation of Ali Kosh (Gautier and Lampre, 1905). It is currently regarded as one of the most instructive sites in the region, providing evidence of early agricultural communities in the eastern arm of the Fertile Crescent. However, subsequent excavations conducted by F. Hole in the early 1960s (Hole et al., 1969) have provided further insights.

In May 2017, Hojjat Darabi constructed a brief stratigraphical trench with the objective of updating the site's chronology and gathering material for research on subsistence tactics (Darabi, 2017). A dense cluster of 13 human tombs was identified at a depth of approximately 4–5 metres below the surface during the recent small-scale excavation. The investigation of the site was not possible due to time constraints. Several of the corpses were dismembered using large slabs of the surrounding earth prior to being transported to the archaeological workshop at Razi University in Kermanshah.

A total of 11 individuals were identified through the analysis of three bone clusters. However, it should be noted that several of these clusters only included cranial and/or mandibular remains, with a lack of postcranial components. Block B yielded a disarticulated mandible

(H7), another disarticulated cranium (H4), an incomplete skeleton (H5), and a partially preserved skeleton (H2) atop three incomplete and disarticulated skeletons (H10, H11, and H12). The final block, C, yielded a skull (H6), which exhibited minor postcranial skeletal remnants (Sołtysiak and Darabi, 2017).

The unintentional discovery of the burial site permits only a restricted comprehension of the associated traditions. The bodies of the three individuals (H2, H5, H6) whose articulations were preserved were found in a squatting posture, with both limbs hyperflexed, hands and knee joints near the face, and feet and elbows near the pelvis. Given that all the long bones were positioned vertically between the skull and the os coxae, it seems plausible that some form of bundling with linens or ropes may have been necessary to secure them in place. Furthermore, the presence of multiple disarticulated teeth and bones suggests that prolonged cemetery usage may have been a contributing factor (Sołtysiak and Darabi, 2017).

The available assemblage comprises a minimum of seven crania, mandibles and postcranial components. Notwithstanding the fragmentation and postmortem alteration of all crania, the most striking feature was the conspicuous artificial distortion. As a result of the application of a band around the skull along the front parietal and occipital regions, creating a conical protuberance around the lambda, circumferential alteration was evident in all instances (Frieß & Baylac, 2003).

The age-at-death profile of the Ali Kosh sample appears to be markedly tilted. Even after accounting for the very small sample size, there is a noticeable lack of infants and just one individual in the oldest age group, which may result in an under-representation of age groups with the highest mortality rates. The absence of dental caries indicates that a diet low in fermentable sugars may be advantageous (Sołtysiak, 2014). Moreover, the skull of one individual (H6) exhibited extensive obliteration of microporosity at multiple locations, indicating a markedly low prevalence of cranial porosities. Conversely, the temporal line was conspicuously pronounced in two individual, both presumed to be females, displaying clear vascularization above, suggestive of potential mechanical strain on the temporal muscle.

2.1.4. POTTERY NEOLITHIC SITES

4.1.2.1. TEPECIK-ÇIFTLIK

Figure 27 Geographical situation of Tepecik-Çiftlik archaeological site.

Tepecik-Çiftlik which was first identified during the survey of the Central Anatolian region conducted by Ian Todd in 1966, is located 1 km from the district centre (38°10’20’’N 34°29’38’’) in the lowlands of the Çiftlik district of Niğde province. (Bıçakçı, 2001; Bıçakçı et al., 2011, 2017).

Excavations of the village were planned under the direction of Associate Professor Erhan Bıçakçı of the Prehistory Department of Istanbul University. The alluvial layers from the nearby mountains and the pumice and ash from volcanic eruptions created the Çiftlik plain, which is about 1500 metres above sea level (Bıçakçı et al., 2007; 2011: 26; Kuzucuoğlu, 2013). At a height of 9.60 metres above the plain, the egg-shaped mound measures 300 by 170 metres (Bıçakçı et al., 2011). During the excavations, Early Chalcolithic, Neolithic Pottery, Neolithic Pre-Pottery and Late Roman-Early Byzantine levels were discovered (Bıçakçı et al., 2007, 2011, 2017).

The fifth, fourth and third levels have yielded a wealth of information about the Neolithic period (Bıçakçı et al., 2011, 2017). The fifth floor has a few architectural elements, mostly pits and fires, which emphasises the value of outdoor recreation. Furthermore, the presence of burials suggests that the site was used as a cemetery (Bıçakçı, 2012). A configuration with clearly identifiable buildings was seen on the fourth level. On the other hand, many houses in the early and late stages of the third level show elements that change over time, such as settlement patterns and house layouts. Levels 3, 4 and 5 are dated to 6800-6100 cal BC according to the 14C study (Bıçakçı, 2012).

The main features of the constructions of the **third level**, which belong to the second part of the 7th millennium BC, are comparable. There are two phases in this level. The structures are built with stone foundations and mud walls. Ovens and silos are typical features of the free-standing buildings. A subphase of this level shows a new type of structure known as the "oven building". The ovens in the buildings became more important during this period and were crucial in shaping the settlement pattern. Each building has a storage unit and at least one oven. Free-standing buildings with large spaces between them were built separately in the early stages of this level. Clusters of buildings formed as new buildings were built in open spaces and the open spaces became smaller (Bıçakçı et al., 2012).

Most of the settlement consisted of open spaces on the **fourth level**, which dates from around the middle of the seventh millennium BC. The buildings were constructed with mud walls on stone foundations. The best preserved structure on this level is a square building complex. It was originally built as a single unit, with smaller rooms added later. The complex is surrounded by open spaces with a variety of work and service areas. This building complex provides most of the information about the fourth level. A severe fire destroyed many of the bones and obsidian tools, charred remains of wood and plant seeds found in the building (Bıçakçı et al., 2011, 2017).

In the middle of the site, the **fifth and sixth levels** were uncovered. There was an open space in this part of the village. Most of the area was covered with waste pits containing animal bones and waste from obsidian production, as well as shallow pits filled with ashes. Very few architectural remains have been found in these layers.

However, one of these architectural remains is from a five-storey building with a square floor plan and stone walls. The bones of at least 42 different individuals were found in the 2.5 m2 area of the structure. The discovery of primary and secondary graves near this building suggests that this area of the community served as a "cemetery".

Neolithic and Chalcolithic faunal remains indicate that hunting and animal husbandry were common activities, and that the society valued the consumption of animals (Bıçakçı et al., 2007; Campana and Crabtree, 2017). According to archaeobotanical data, numerous plant species, mainly cereals and legumes, could have been eaten at the site. Accordingly, new research has found both primary and secondary evidence for plant foods, such as grains, seeds, storage silos, hand mills and grinding slabs (Bıçakçı et al., 2007, 2011; Řídký, 2009). It can be argued that, from a technological point of view, pottery production at the site would have gradually evolved into more complex and sophisticated forms over time. Daily life also included activities related to obsidian (Balcı, 2016; Bıçakçı et al., 2011, 2017; Godon, 2012).

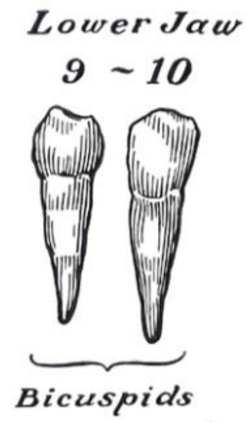
A deep trench was excavated in the western part of the site to determine the oldest layers of the village and to understand the stratigraphy of the mound. In this trench, layers from the Pre-Pottery Neolithic and Early Pottery Neolithic periods were discovered. The discovery of these layers showed that the settlement was also occupied throughout the Pre-Pottery Neolithic period, although no building remains were found in this limited area.

Indeed, Tepecik-Çiftlik is not far from some of the sources of obsidian known to have been widely used in the Near East in prehistoric times. It is well documented that obsidian cores and tools from nearby sources, including the well-known Mt. Göllüdağ, were 'exported' to places as far away as the Levant and Cyprus (Binder, 2002; Şevketoğlu, 2006, 2008; Balkan-Atlı and Binder, 2011). According to workshops found in the settlement, the production and consumption of obsidian played an important role in daily life (Bıçakçı, 2012; Balcı, 2016). Given the quality and range of objects (including seals) found in the archaeological excavations, it is likely that the people of Tepecik-Çiftlik were heavily involved in the management and control of obsidian supplies. In addition, the site has unexcavated PPN layers and is close to obsidian sources which may provide valuable information in the future.

The preferred burial technique was primary burial in simple pits (Büyükkarakaya et al., 2009: 128, 2012 Büyükkarakaya, 2017a, b). However, ten jar (pot) burials for infants were also excluded from the third, fourth and fifth levels. The BB area is one of the few constructions of level 5 that have been discovered, and the earliest burials are from this level. In addition to the burial of the BB group, twelve main and four secondary tombs were found in the open areas of this level. Burials within residential areas and other structures are not observed until the fourth level. Most burials on the fourth level were found in the “AY” and “BA” buildings attached to the “AK” complex (Bıçakçı et al., 2011). Although older children and adults are sometimes found in the AY building, the majority of individuals identified in these buildings are infants under the age of 12 months. This level yielded a total of 33 primary burials and two secondary burials. Almost every grave on the third level, which marks the end of the Neolithic in the village, was in an open grave.

There is considerable regional and population-level variation in the funerary practices of the Near Eastern Pre-Pottery and Pottery Neolithic periods (Croucher, 2012). The diversity of mortuary practices and customs at Tepecik-Çiftilik also reveals details about the symbolic world of the population, including their belief system and ideas about death and dying. Furthermore, the burial practices of the settlement are comparable to those of other modern pre-Pottery Neolithic groups (Boz and Hager, 2013; Büyükkarakaya, 2017a, b; Büyükkarakaya and Erdal, 2014; Croucher, 2012; Öztan, 2010).

In 2009, the BB collective burial was discovered in the main trench of the site, and the excavation of the burial was completed in 2010. As the stratigraphy of the settlement and radiocarbon dating of burnt wood samples place it between 6850 and 6650 cal BC, it is located in level 5. Skeletal samples from the BB collective burial were radiocarbon dated, placing the level between 6750 and 6635 and 6690 and 6595 cal BC. The laboratory of the Anthropology Department of Hacettepe University has all the human remains from the BB Tomb.



CHAPTER 3. METHODS

3. CHAPTER 3. METHODS

One of the main objectives of this study was to explore a more comprehensive understanding of the origins of these early sedentary societies in Southwest Asia. To this end, the sample was drawn from excavations conducted during previous campaigns, as well as diverse environmental conditions and countries, and curated by distinct institutions. To address these issues, Dr. Alejandro Pérez-Pérez, Dr. Ferran Estebaranz-Sánchez and Dra. Laura M Martínez first cast dental moulds that now correspond to the dental collection of the Anthropology Unit of the University of Barcelona (coordinated and directed by Dra. Laura M. Martínez and Dr. Alejandro Pérez-Pérez), which includes samples from 7 sites in Southwest Asia: Abu Hureyra, Dja'de El Mughara, El Wad, Jerf el Ahmar, Kebara, Shukba, Tell Aswad, Tell Halula and Tell Ramad. (Estebaranz et al., 2009, 2012; Martínez et al., 2016). In recent years, new dental casts have been obtained from other sites and other regions within the area under study: Nemrik 9 (actual Iraq), Ali Kosh (actual Iran) (Sołtysiak, 2015, 2017) and Tepecik-Çiftlik (actual Türkiye) (Büyükkarakaya, 2008, 2019).

The use of dental moulds serves to eliminate potential complications arising from the transport of both archaeological and human remains. Additionally, it also facilitates the preservation of replicas of these materials which might otherwise have been destroyed during the numerous conflicts in the region (concerns exists on the state of preservation of some of the Syrian samples here analysed). The consolidation of all the samples in a single location simplifies the study process, thereby facilitating a comprehensive understanding of the subject matter. Concurrently, the method permits a variety of tests to be conducted without the potential for irreparable damage to the original sample.

3.1. CASTING PROCEDURE

3.1.1. TOOTH SELECTION

In the initial stage of the study, all the available teeth, unworn and worn, were moulded. The dental casts were obtained from the entire lower and upper dental arch, encompassing teeth from I1 to M3 from all age groups from infants to adults, as long as the tooth was well preserved and had not at risk of being damaged during the moulding process. This approach was adopted to ensure the opportunity to carry out various dietary and morphological analyses in the future, when new analytical techniques become available.

3.1.2. TOOTH CLEANING

The teeth of each individual were cleaned in order to remove any grit or dust that may have adhered to the enamel surface as a result of the taphonomic process. The enamel surfaces were cleaned with a cotton swab with pure acetone to eliminate any consolidant residue, that could be on the surface of the tooth crown. Once the acetone in evaporated, a 70% ethanol dilution was applied to eliminate the acetone residues, that could affect the adhesion of the mould-making silicone to the tooth surface. Subsequently, the same procedure is repeated, with a brief interval to assure the evaporation.

3.1.3. TOOTH MOULDING AND CASTING

Subsequently, dental silicone was applied on the tooth surface in accordance with the standardised processes outlined by Alejandro Pérez-Pérez research group (Galbany et al., 2004, 2006). Polyvinylsiloxane AFFINIS Perfect Impressions (Coltene®) (A two-component impression material based on addition-curing Polyvinylsiloxane) was used to obtain a negative of the dental surface. A regular body impression material provides a good surface reproduction without harming or changing the tooth's structure.

After mixing it with the mixing thin tip to remove air bubbles before contact with the enamel surface the product is applied to the tooth surface. To ensure optimal preparation and utilisation of the product, it is first necessary to insert the cartridge into the dispenser and then to remove the safety cap. Thereafter, a small quantity of both products should be poured onto a piece of paper until the same quantity of both components is obtained, with a uniform viscosity. This will guarantee that the mixture will be ideal for a perfect print. The universal mixing tip should then be attached to the cartridge and turned ¼ clockwise. Subsequently, the dispenser should be pressed gently and consistently, taking care to avoid abrupt movements that may result in the formation of bubbles.

Figure 28 AFFINIS Perfect Impressions (Coltene®) Kit (Box, tips, cartridges and dispenser).

In order to produce the positives once the moulds have been made, it is necessary to wait at least thirty minutes after extraction before starting the casting process, as the polyvinylsiloxane needs to rest to achieve an optimum consistency. The positives were obtained at the Biology Faculty lab with a white polyurethane FEROPUR PR-55 WHITE (Feroca®). The product has two components that once they are mixed, harden at room temperature and is applied on the tooth crown. The product is comprised of a colourless resin (polyol) and a yellowish hardener (isocyanate), both of which are uncharged. To guarantee the optimal preparation and utilisation, components A and B are combined in equal proportions (50/50) (in volume) in a third flask, and the mixture is balanced and not agitated to facilitate the incorporation of the product without the formation of bubbles. Once the product has been mixed, it should be transferred into the negatives using a single-use *Pasteur Pipette*. Prior to polymerisation, the negatives containing the mixture should be subjected to centrifugation for one minute at 1000 rpm. This process serves to eliminate any potential air bubbles that may have formed in the positive. Following a five-minute period, the polyurethane is solid, and the casts can then be readily removed from the negatives.

3.2. 3D SCAN AND MESH PROCESSING

3.2.1. 3D SCANNING

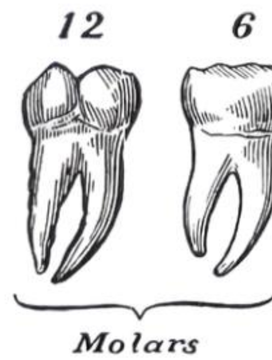
The dental replicas were digitised on one hand with a **DAVID SLS-2** structured light 3D surface scanner, utilising the maximum resolution setting. To digitise the entire surface, eight scans were performed with a rotation angle of 30°, utilising the rotating turntable to obtain a comprehensive 360° image. The images were automatically aligned by superimposing common regions. The calibration scale length was set at 30 mm, which is the recommended value for scanning small objects. The scans were then unified to form a closed mesh, which was exported to a .ply file, the most commonly used format in 3D digitisation work. On the other hand, a **Shining EinScan-SP** structured white light 3D surface scanner was also used to digitise the entire surface, eight scans were performed using the rotating turntable to obtain a comprehensive 360° image. The scans were then unified to form a closed mesh with a maximum resolution setting and finally was exported to a .ply and .obj files.

Figure 29 3D model of the Shining EinScan-SP structured light 3D surface scanner, with the two cameras and projector connected with an arm to the turntable where the samples are positioned.

3.2.2. 3D MESH PROCESSING

The 3D meshing process comprised (1) the isolation of each tooth, (2) the reconstruction of the interproximal surfaces, (3) the orientation of the mesh, and (4) the cutting with a horizontal plane from the lowermost point. The initial processing step entailed the isolation of each joint piece's tooth by the interproximal surfaces. Meshlab v.1.3.3 (ISTI-CNR, University of Pisa) software was used to isolate each tooth as the walls of the interdental regions are devoid of contents and in contact with one another, it was necessary to recreate these sections for each tooth while minimising the alteration to the crown's natural shape.

In order to align the dental crowns with the XYZ axis system and thereby account for the triangles of the occlusal surface in an appropriate manner. Subsequently, the bucco-lingual direction is aligned with the Y axis, the disto-mesial direction with the X axis, and the occlusal surface is oriented upwards regarding the Z axis. Lastly, a horizontal plane was created with the “Trim with Plane” tool in Geomagic Wrap 2014 (3D Systems, Morrisville, USA), designed for the modelling of 3D components. This tool was employed to excise the reoriented crowns, with the XY plane used to cut and define the lowest point of the foveas on the occlusal surface, obtaining an enamel cup.



CHAPTER 4. CHANGES IN TOOTH SIZE

CHAPTER 4.
4. CHANGES IN TOOTH SIZE

4.1. INTRODUCTION

Over the years the study of morphological distances (biodistances) has not ceased to be used despite the consolidation of techniques such as ancient DNA or isotope analysis (Fernández et al., 2014; Feldman, 2019; Lazaridis et al., 2022). The fact that biodistances constitute a non-invasive analytical technique that is utilised as a phenotypic proxy to clarify the phylogenetic relationships between population groups or individuals. This means that morphological study has continued to grow and evolve over the years, moving from a set of classical measurements performed with physical gauges to the 3D analysis of human remains (Pinhasi, 2008, 2015; von Cramon-Taubadel et al., 2011; Galland et al., 2016; May, 2018).

As explained more extensively in the introductory section, one of the most important events in human history is the change in subsistence strategies, the shift from hunting and gathering to farming and pastoral economy. Agriculture was adopted in several areas of the world during the Holocene, which replaced the end of the Pleistocene around 12.000 cal BP. (Ferrio et al., 2011, 2012). The global warming had a significant impact on northern regions, leading to a melting of ice and subsequent changes in lake levels and the Mediterranean coastline , as well as a reduction in open areas in favour of forested areas (Willcox et al. 2008). It was during this climatic change that the process known as neolithization emerged in the Southwest Asia region, particularly in the Middle Euphrates River Valley, coinciding with the earliest chronologies of archaeological sites such as Jerf el Ahmar (Stordeur & Abbès, 2002). The inhabitants of this region occupied settlements ranging from large agrarian villages, even towns, to small seasonal camps (see point: 1.2.2 Chronological context - Chronological terms). These communities appear to have been supported by a wide range of economic patterns, including various combinations of herding, farming, and foraging (Henry, et al., 2016).

The emergence of an economy based on agriculture and pastoralism cannot be attributed to a single theory, such as those proposed by Childe (1928), Brainwood (1960), or Rowley-Conwy (1987). Rather, it is a complex phenomenon that arose due caused by multiple factors. Diet has long been a crucial factor in human adaptation, varying with climatic conditions and the resource availability of the population. Tooth size and enamel thickness are considered key data for tracing dietary and ecological adaptations in the Hominini lineage (Alrousan, 2009).

The climatic and environmental change and the subsequent economic transition from hunting/fishing and gathering to a food production economy based on agriculture and husbandry and/or new processing techniques (Eshed et al., 2006) occurs synchronically to occurs synchronically to a reduction and/or morphological changes in craniofacial and dentition , both in **Southwest Asia** (Smith, 1986, Brace et al., 1987; Kaifu, 1997; Erdal, 1999, Le Luyer & Bayle, 2017; Pinhasi et al., 2008, Alrousan, 2009, Pinhasi 2008, 2015, May et al., 2018; Menéndez & Buck, 2022) and **other regions** (Smith, 1972; Carlson & van Cerven, 1977; y'Edynak & Fleisch, 1983; Formicola, 1987; Jacobs, 1994; Le Luyer & Bayle, 2017; Pokhojaev et al., 2019; Nava et al., 2021; Godinho et al., 2023; Martin et al., 2023).

This reduction and morphological change of the masticatory apparatus would be a consequence of this dietary change, either as a result of a selective directional pressure due to a reduction in mastication forces (Pinhasi et al., 2008; von Cramon-Taubel, 2011; Katz et al., 2017; Le Luyer & Bayle, 2017; May et al., 2018; Pokhojaev et al., 2019; Martin et al., 2024) or as a result of morphological simplification of the crown to reduce the incidence of pathologies associated with this dietary change – such as caries (Calcagno, 1986; Calcagno & Gibson, 1988). In this scenario there would have been a population continuity (Carlson & van Cerven, 1977; y'Edynak & Fleisch, 1983; Formicola, 1987; Galland et al., 2016; Irish & Usai, 2021). Other scenarios suggest that this morphological change was due to some level of population discontinuity between the Mesolithic and Neolithic (Nava et al., 2021; Godinho et al., 2023; Martin et al., 2024).

A method for determining biological affinities, kinship, and inbreeding amongst populations is the systematic examination of genetically determined anatomical characteristics. The degree of phenetic similarity between individuals can be used as an indication of their genetic relatedness (Ullinger et al., 2005; Hanihara, 2008; López-Onaindia & Subirà, 2017; López-Onaindia et al., 2017, 2019, Maaranen et al., 2022).

Non-metric dental traits (NMDT) are commonly used since they are highly genetically determined (Scott & Turner, 1997; Higgins et al., 2011; Hughes et al., 2013; Hlusko, 2016), have no sexual dimorphism, and are generally considered to be neutral to selection (Turner, 1984; Hanihara, 1992; Irish, 1997; Scott & Turner, 1997). In addition, enamel is the hardest organic tissue in the human body, so the representativeness, preservation and structural integrity of teeth in the archaeological record tends to be high (Maaranen et al., 2022).

This chapter of the **study aims** to examine tooth size by taking a broader view of the populations of Southwest Asia. This will allow us to make a large-scale comparison between ancient skeletal groups in the same geographical area. The populations examined include those from the Sinai Peninsula, the Levant, the Euphrates Valley, the Zagros Mountains and the Anatolian Peninsula. The **second aim** of the study is to analyse the biological affinities, kinship and consanguinity between populations using the systematic examination of genetically determined anatomical patterns.

4.2. MATERIAL AND METHODS

4.2.1. MATERIAL

The study analysed dental remains from 32 archaeological sites in Southwest Asia. The sites were selected on the basis of a temporal framework that aligns with the precise moment of this climatic and ecological shift. Consequently, the study includes 8 Natufian, 4 PPNA, 16 PPNB and 4 Pottery Neolithic sites. Furthermore, the archaeological sites from the Northern Fertile Crescent (Ibáñez et al., 2017) have been subdivided into (phyto)ecological and/or geographically differentiated regions for the purpose of comparing regionalised patterns (Horwitz & Tchernov, 2000; Palmisano et al., 2021). The archaeological sites (N=32) were grouped according to geographical region, as follows: Levant/Mediterranean (n=20), Middle Euphrates/Anti-Taurus (n=4), Sahara-Arabian desert Region (n=4), Zagros Mountains (n=2) and South/Central Anatolia/Taurus (n=2).

The analyzed dental collections are curated in different laboratories or institutions. It is also interesting to highlight the different nature of the samples analyzed. Thus, in some cases, high-resolution casts obtained with Ferropur 55 or epoxy resin (Galbany et al., 2006) have been analyzed, corresponding to the dental collection of the Anthropology Unit of the University of Barcelona (coordinated and curated by Dra. Laura M. Martínez and Dr. Alejandro Pérez-Pérez) that includes samples from 7 sites in the Southwest Asia: Abu Hureyra, Dja'de El Mughara, El Wad, Jerf el Ahmar, Kebara, Shukba, Tell Aswad, Tell Halula, Tell Ramad (Estebaranz et al., 2009, 2012; Martínez et al., 2016; Sołtysiak, 2015, 2017).

There is a second set of samples that were able to be analyzed and measured directly on the original teeth, including:

- Tepecik-Çiftlik (Büyükkarakaya, 2008, 2019) and Gre Filla, curated by Dr. Büyükkarakaya from the Human Behavioral Ecology and Archeometry Laboratory (IDEA Lab) and Dr. Serpil Eroğlu both from the Department of Anthropology, Hacettepe University.
- The Kharaysin sample, curated by Dr. Juan José Ibañez from the Archaeology of Social Dynamics (ASD) and hosted at the Institución Milá i Fontanals de Investigación en Humanidades (CSIC-IMF).
- Nemrik 9 and Ali Kosh sites curated by Dr. Arkadiuz Sołtysiak in Warsaw University which were moulded/casted and replicated in University of Barcelona.

Finally, there is a third set of sites from which the measurements have been obtained from other scientific articles and previously online published resources (Pinhasi et al., 2008, 2015; N= 274): Abu Gosh (n=22), Abu Hureyra (n=18), Abu Madi (n=4), Ain Mallaha (n=37), Areq el Ahmar (n=2), Atlit Yam (n=7), Banana (n=7), Basta (n=3), Hatoula (n=7), Hayonim (n=19), Jericho (n=20), Kefar Haroresh (n=89), Lod (n=3), Nahal Betzet (n=4), Nahal Oren (n=16), Neve Yan (n=2), Rekefet (n=4), Tell Roin (n=4), Yiftahel (n=6).

SITE	N	DATATION BP	PERIOD	REGION	HOST INST.	C14 REF.
El Wad	98	12500	Nat	Levant/Med.	UB[6]	Weinstein-Evron, 1991
Ain Mallaha	37	11590	Nat	Levant/Med.	-	Pinhasi, 2015
Kebara	71	11500	Nat	Levant/Med.	UB	Byrd, 1994
Shukba	28	11500	Nat	Levant/Med.	UB	
Areq el Ahmar	2	11500	Nat	Levant/Med.	-	Garfinkel, 1999
Hayonim	19	11220	Nat	Levant/Med.	-	Eshed et al. 2005
Rakefet	4	10980	Nat	Levant/Med.	-	Eshed et al. 2005
Hayonim	19	10900	Nat	Levant/Med.	-	Eshed et al. 2005
Nahal Oren	16	10900	Nat	Levant/Med.	-	Eshed et al. 2005
Jerf el Ahmar	15	10650	PPNA	Middle Euphrates	UB	
Nahal Oren	16	10490	Nat	Levant/Med.	-	Eshed et al. 2005
Ain Mallaha	225	10400	Nat	Levant/Med.	UB	Pinhasi, 2015
Hatoula	7	10030	PPNA	Levant/Med.	-	Pinhasi, 2015
Tell Aswad	53	9730	PPNB	Saharo-Arabian desert	UB	Contenson 1973; Stordeur et al. 2010:58
Dja'de	61	9560	EPPNB	Middle Euphrates	UB	Coqueugniot, 2014
Jericho	20	9551	PPNA	Levant/Med.	-	Pinhasi, 2015
Gre Filla	60	9500	PPNA	Anatolia	HU[7]	
Nemrik 9	35	8900	PPNB	Zagros Mountains	UW[8]	Kozlowski 1994:261f
Yiftahel	6	8870	PPNB	Levant/Med.	-	Pinhasi, 2015 | Garfinkel 1987
Ali Kosh	26	8850	PPNB	Zagros Mountains	UW	
Jericho	20	8710	PPNB	Levant/Med.	-	Pinhasi, 2015
Kefar Hahoresh	89	8650	PPNB	Levant/Med.	-	Garfinkel, 1999 | Goring-Morris, Boaretto, Weiner 2001
Abu Gosh	22	8650	PPNB	Levant/Med.	-	Garfinkel, 1999 | Hershkovitz PC
Basta	3	8650	PPNB	Saharo-Arabian desert	-	Pinhasi, 2015
Banana	7	8650	PPNB	Levant/Med.	-	Hershkovitz PC
Tell Halula	136	8500	PPNB	Middle Euphrates	UB	Molist et al., 2013

[6] UB – Universitat de Barcelona
[7] Hacettepe Üniversitesi
[8] University of Warsaw

Kharaysin	15	8350	PPNB	Levant/Med.	ASD-CSIC[9]	
Abu Hureyra	18	8330	PPNB	Middle Euphrates	-	Pinhasi, 2015
Nahal Betzet	4	8330	PPNB	Levant/Med.	-	Garfinkel, 1999
Abu Madi	4	8250	PPNB	Saharo-Arabian desert	-	Hershkovitz PC
Tell Halula	5	8050	PN	Middle Euphrates	UB	Molist et al., 2013
Tepecik-Çiftlik	255	8050	PN PN	South/Centr. Anatolia	IDEAlab[10]/HU	Bıçakçı et al., 2007
Tell Ramad	77	7950	PPNB	Saharo-Arabian desert	-	Contenson, 2000:21
Atlit Yam	7	7755	PN	Levant/Med.	-	Garfinkel, 1999
Tell Roim West	4	7300	PN	Levant/Med.	-	Pinhasi, 2015
Lod	3	7050	PN	Levant/Med.	-	Pinhasi, 2015
Neve Yan	2	6565	PN	Levant/Med.	-	Garfinkel, 1999
TOTAL	1482					

Table 3 Archaeological sites, number of samples (N), chronology, period and region.

The total initial sample consisted of 2.408 teeth (Annex 1): I1 (n=198), I2 (n=192), C (n=285), Pm3 (n=320), Pm4 (n=329), M1 (n=473), M2 (n=377), M3 (n=234). However, only permanent postcanine teeth were measured (premolars and molars). In addition, teeth that presented an occlusal wear stage ≥ 3 according to Smith's categorization (Smith, 1984) were also excluded, to reduce the effect of wear on the dimensions of the dental crown (Hillson, 2005; Gkantidis, 2020), especially in mesiodistal diameters (Table 2).

The final sample is composed of:

[9] Archaeology of Social Dinamics – CSIC
[10] IDEAlab - Human Behavioral Ecology and Archaeometry Laboratory, Hacettepe Üniversitesi

Tooth type	Pm3	Pm4	M1	M2	M3
MAXILAR	133	143	212	151	88
MANDIBULAR	222	228	328	298	158
TOTAL	355	371	540	449	246

Table 4 Number of teeth studied in the final sample by tooth type.

4.2.2. METHODS

2.2.4.1. TOOTH MEASUREMENTS

Tooth size was estimated by measuring both the maximum buccolingual (BL) and mesiodistal (MD) diameters (i.e., tooth width and length) using the standard procedure previously described by Moorrees et al. (1957) and latterly applied by other authors (Pinhasi, 2015; Croix, 2020; Lukacs, 2022; López-Onaindia, 2023). The measurements were recorded in millimetres using a digital calliper with a sensitivity of 0.01 mm at the greatest distance between the contact points on the proximal surfaces. As posited by Silvana et al. (1985), the occlusal view of the teeth is the optimal method for obtaining dental measurements.

Each well-preserved pots-canine tooth was measured by a single observer (AEDR). In cases where interproximal wear or disease (e.g. caries) resulted in a reduction of the overall crown length, all dimensions were excluded from the analysis. Similarly, in those cases where occlusal wear or pathology resulted in a reduction of the overall crown height below the point where the maximal breadth dimension was previously positioned, all buccolingual dimensions were eliminated.

2.2.4.2. NON-METRIC DENTAL TRAITS (NMDT)

In the present study, 23 non-metric dental traits of the permanent dentition (13 for upper and 9 for lower teeth) were assessed according to the Arizona State University Dental Anthropology System (ASUDAS) (Turner et al., 1991) (see table 1, Point: 1.4 Non-Metric Dental Traits). Each available tooth was scored, and any characteristic that was obscured by significant enamel deterioration, wear, or decay was excluded from the sample. Although NMDTs are affected by tooth wear and pre and post-mortem tooth loss, the traits selected for this study are still observable despite moderate attrition (Irish, 2005). In addition, they are easily distinguishable and exhibit a high degree of genetic variation in expression (Irish, 2005). To eliminate potential inter-observer error, a single investigator (AEDR) documented each trait observation.

Non-metric traits could only be calculated for those sites (N=11) where we had the original teeth or high-resolution casts: El Wad, Kebara, Shukba, Jerf el Ahmar, Abu Hureyra, Dja'de El Mughara, Tell Aswad, Tell Halula, Tell Ramad, Tepecik-Çiftlik spanning 4 different periods (Natufian, PPNA, PPNB, and Neolithic).

Scott & Turner (1997) used the individual count approach to determine trait frequencies. In the present study, one tooth was selected for analysis from each individual. In cases where the right dentition was absent, the sample from the left dentition was employed. For individuals exhibiting different expressions in the left and right dentition, the most relevant trait was selected for the analysis. To simplify multivariate statistical analysis, trait expression was classified based on its presence or absence, as in previous studies (Sjøvold, 1977; Ortiz, 2013; López-Onaindia et al., 2017; Maaranen, 2022).

The study of ASUDAS traits is of particular interest due to the high degree of genetic heritability exhibited by the traits, their evolutionary stability, and their variation between populations. The quantitative approach to the debate on population replacement in Southwest Asia during the transition to early agricultural and sedentary livestock-keeping societies will be facilitated by the study of ASUDAS traits. (Horwarth et al., 2014; Irish & Usai, 2021; Martin et al., 2023).

2.2.4.3. STATICAL ANALYSIS

A database with all the NDMT and tooth size measurements was created for subsequent analysis. The bucco-lingual and mesio-distal dimensions (in mm) of all permanent tooth classes were analysed using IBM SPSS Statistics 23 and Microsoft Excel 2016 software programmes. Furthermore, intra-observer errors were considered to prevent any data transmission failures (Henson, 2020).

A normality test was performed for each tooth-type. The Kolgomorov-Smirnov test was used to determine whether each tooth measurement had a normal or non-normal distribution over time periods ($p <0 .05$).

To assess patterns of dentition reduction, general linear models of dimensional change over time were computed for the entire group of specimens from the Natufian, PPNA, PPNB, and Pottery Neolithic. The same analysis was also computed for different geographic areas (Levant/Mediterranean, Middle Euphrates/Anti-Taurus, Sahara-Arabian desert Region, Zagros Mountains and, South/Central Anatolia/Taurus).

Post hoc range tests and pairwise multiple comparisons were also performed to determine whether statistical differences existed among populations. The post hoc analyses were performed for each tooth type using buccolingual and mesiodistal distances as a dependent variable. Due to the large number of paired means, a Tukey's Honestly Significant Difference test was used (HSD, $p < 0.05$). Furthermore, graphs have been created for each of these significant metrics across several chronologies to provide a visual representation of the data relevance (Pinhasi et al., 2008).

For non-metric dental traits, the traits were standardized by presence or absence (Maraneen, 2022) to carry out a frequency analysis. This allowed for a cross-table study to examine the relationship of the data between different periods (Natufian, PPNA, PPNB, Neolithic) and in different geographical areas (Middle Euphrates, Levant, Desert, Anatolia and, Zagros). Also, a Chi-square amount sites, and time periods ($p < 0.05$) were performed to see that relationship.

4.3. RESULTS

DENTAL SIZE

The Kolmogrov-Smirnov test for normality was not significant for any tooth type ($p > 0.05$) for the buccolingual measurements, except for the lower Pm3 ($p = 0,006$) and lower M3 ($p = 0.005$). As for the mesiodistal results, significance is found in different teeth such as: lower Pm3 ($p = 0.000$), lower Pm4 ($p = 0.000$) and upper M1 ($p = 0.003$).

The general linear model suggests that there are significant differences between buccolingual measurements both between different time periods and in different geographic regions independently of each other (p-value < 0,05).

In the *post hoc* test, significant differences were found in the *P*-value between the different periods only in the buccolingual measurements. In most of them, it was the Natufian period that differed from the rest. Significant differences were observed in lower Pm3 between Natufian and PPNA (Tukey's HSD $p = 0.014$), PPNB (Tukey's HSD $p < 0.001$) and Pottery Neolithic (Tukey's HSD $p < 0,001$); lower Pm4 between Natufian and PPNB (Tukey's HSD p = 0,040), PN (Tukey's HSD $p = 0,037$); lower M1 between Natufian and PPNA (Tukey's HSD $p = 0,033$), PPNB (Tukey's HSD $p = 0,000$) and Pottery Neolithic (Tukey's HSD $p = 0,000$); lower M2 between Natufian and PPNB (Tukey's HSD p < 0,001) and Pottery Neolithic (Tukey's HSD $p = 0,009$); upper Pm3 between Natufian and PPNB (Tukey's HSD $p = 0,006$); upper Pm4 between Natufian and PPNB ($p = 0,002$); upper M1 between Natufian and PPNB (Tukey's HSD $p < 0,001$), Neolithic (Tukey's HSD $p = 0,001$); upper M2 between Natufian and PPNB (Tukey's HSD $p = 0,007$) and Pottery Neolithic (Tukey's HSD $p = 0,005$).

LOWER					**UPPER**				
Pm3	Natufian	PPNA	PPNB	PN	**Pm3**	Natufian	PPNA	PPNB	PN
PPNA	**0.014**		.996	.834	PPNA	.883		.072	.136
PPNB	**<0.001**	.996		.728	PPNB	**0.006**	.072		1.000
PN	**<0.001**	.834	.728		PN	.100	.136	1.000	
Pm4	Natufian	PPNA	PPNB	PN	**Pm4**	Natufian	PPNA	PPNB	PN
PPNA	.195		.930	1.000	PPNA	.880		.069	.144
PPNB	**0.04**	.930		.824	PPNB	**0.002**	.069		1.000
PN	**0.037**	1.000	.824		PN	.087	.144	1.000	
M1	Natufian	PPNA	PPNB	PN	**M1**	Natufian	PPNA	PPNB	PN
PPNA	**0.033**		.991	.982	PPNA	.854		.644	.334
PPNB	**<0.001**	.991		.725	PPNB	**<0.001**	.644		.674
PN	**0.009**	.982	.725		PN	**0.001**	.334	.674	
M2	Natufian	PPNA	PPNB	PN	**M2**	Natufian	PPNA	PPNB	PN
PPNA	**.053**		.939	.975	PPNA	.838		.878	.642
PPNB	**<0.001**	.939		.998	PPNB	**0.007**	.878		.821
PN	**.009**	.975	.998		PN	**0.005**	.642	.821	

Table 5 Significant differences were observed in each tooth by period. Significant *P* values in bold.

An analysis of the dimension change was made to see the percentage of change on tooth dimensions among the different populations over time, comparing the Natufian period with the others.

$$Average\ Rate\ of\ Change = \frac{f(b) - f(a)}{f(b)} \cdot 100$$

An average rate of change was calculated, with ***b*** representing the average measurement of the Natufian period for each of the teeth and ***a*** representing the average measurement of the other periods (PPNA, PPNB and PN).

In the lower Pm3 buccolingual measurements, a decrease in the mean of the buccolingual measurements with respect to the Natufian period was demonstrated. The greatest change was observed in the PN period, with a decrease of 8.34% compared to the Natufian period. This decrease was also significant in the PPNA (8.10%) and PPNB (6.91%) periods. With regard to lower P4, a decrease of 4.34% was observed in the PPNA period, 3.28% in the PPNB and 4.81% in the PN. With regard to the lower M1, a decrease in the mean was observed, amounting to 5.21% in the PPNA, a decrease of 3.94% was observed in the PPNB, while a decrease of 4.93% was observed in the PN. A decrease of 6.22% in the PPNA, 4.18% in the PPNB and 4.36% in the PN period was observed for lower M2. Thus, the greatest decrease is found in the PPNA with respect to the Natufian in both premolars and molars.

Regarding the upper dentition, a decrease of 4.34% was observed in the upper Pm3 in comparison to the Natufian, while a decrease of 3.28% was noted in the PPNB and a decrease of 2.58% in the PN. A decrease of 2.27% is observed in the upper Pm4 of the PPNA, 4.86% in the PPNB and 4.65% in the PN. Regarding upper M1, a decrease of 3.74% is observed in the PPNA, 4.49% in the PPNB and 3.32% in the PN. Finally, for upper M2, the PPNA shows a decrease of 2.87% with respect to the Natufian, while the PPNB and PN exhibit decreases of 5.17% and 6.83%, respectively.

LOWER				UPPER			
Tooth	**Period**	**Period**	**% of decrease**	**Tooth**	**Period**	**Period**	**% of decrease**
		PPNA	8.10%			PPNA	**4.34%**
P3	Natufian	PPNB	6.91%	P3	Natufian	PPNB	3.28%
		PN	**8.34%**			PN	2.58%
		PPNA	4.43%			PPNA	2.27%
P4	Natufian	PPNB	3.28%	P4	Natufian	PPNB	**4.86%**
		PN	**4.81%**			PN	4.65%
		PPNA	**5.20%**			PPNA	3.74%
M1	Natufian	PPNB	3.94%	M1	Natufian	PPNB	**4.49%**
		PN	4.93%			PN	3.32%
		PPNA	**6.22%**			PPNA	2.83%
M2	Natufian	PPNB	4.18%	M2	Natufian	PPNB	5.17%
		PN	4.36%			PN	**6.83%**
		PPNA	4.38%			PPNA	5.46%
M3	Natufian	PPNB	2.47%	M3	Natufian	PPNB	2.95%
		PN	**10.77%**			PN	**16.38%**

Table 6 Average rate of change between tooth and periods. Major differences are marked in bold for each tooth type.

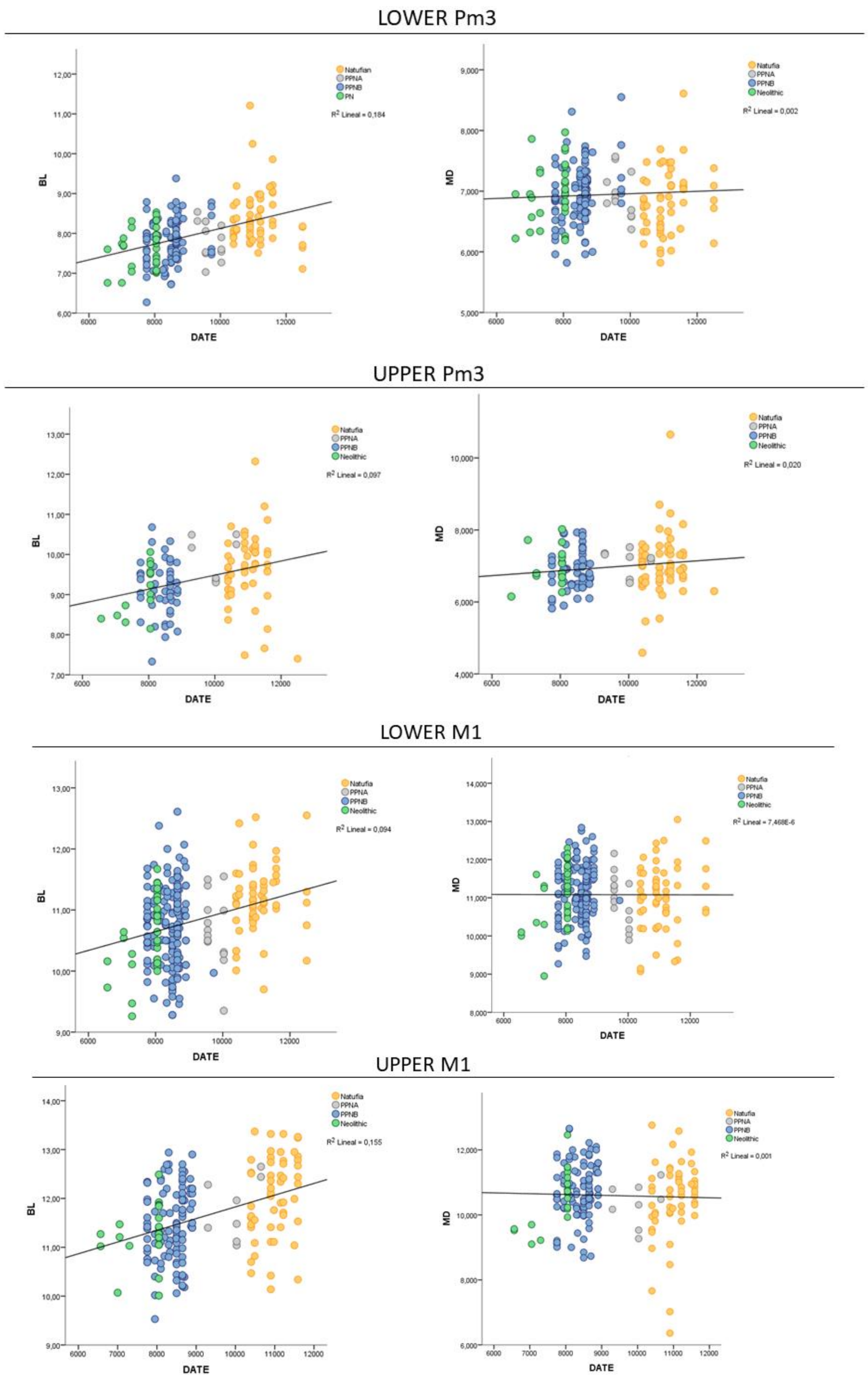


Figure 30 Tooth diameter through time of the upper and lower Pm3 and M1) in buccolingual and mesiodistal measurements. Yellow-Natufian, Grey-PPNA, Blue-PPNB, Green-Pottery Neolithic. To see the graph of all teeth, see supplementary information Annex 2

UPPER					LOWER				
Tooth	**Period**	**Period**	**Sd**	**Sig.**	**Tooth**	**Period**	**Period**	**Sd**	**Sig.**
		PPNA	.285	.883			PPNA	.179	**.014**
Pm3	Natufian	PPNB	.149	**.006**	Pm3	Natufian	PPNB	.097	**.000**
		PN	.219	.100			PN	.130	**.000**
		PPNA	.271	.880			PPNA	.206	.195
Pm4	Natufian	PPNB	.127	**.002**	Pm4	Natufian	PPNB	.108	**.040**
		PN	.192	.087			PN	.152	**.037**
		PPNA	.287	.854			PPNA	.177	**.033**
M1	Natufian	PPNB	.127	**.000**	M1	Natufian	PPNB	.094	**.000**
		PN	.191	**.001**			PN	.129	**.000**
		PPNA	.393	.838			PPNA	.221	.053
M2	Natufian	PPNB	.186	**.007**	M2	Natufian	PPNB	.111	**.000**
		PN	.239	**.005**			PN	.147	**.009**
		PPNA	.560	.666			PPNA	.251	.960
M3	Natufian	PPNB	.213	.374	M3	Natufian	PPNB	.135	.089
		PN	.560	**.008**			PN	.212	**.000**

Table 7 One way ANOVA p*ost hoc* values in tooth dimensions. Significant *p-values* are marked in bold.

NON-METRIC DENTAL TRAITS

Regarding the results of the non-metric characters analysed, we observe that only two ASUDAS characters [Cusp 5 (Metaconule) of the upper M2 and Mesial/Distal Accessory Cusps of the upper premolars show significant differences p = 0.012 and p = 0.014, respectively] in frequency between the different periods. For the Cusp 5 (metaconule), significant differences are observed between the Pottery Neolithic period and the other periods. In the case of Cuspid 5 (Metaconule), only 7% of the Tepecik-Çiftlik individuals present this characteristic of the whole sample, therefore this trait is only present in the Anatolian sample. For the Mesial/Distal Accessory Cusp of the upper premolars significant differences are between all the periods considered. A total of 36% of the individuals from Tell Halula of the PPNB show this characteristic, whereas 43% of the individuals from Jerf el Ahmar belonging to the PPNA of the same region show this characteristic. In addition, 37% of the individuals from the

Tepecik-Çiftlik assemblage of the Anatolian region and the Pottery Neolithic assemblage show this characteristic, as do 25% of the individuals from Kebara of the Levant region and the Natufian period.

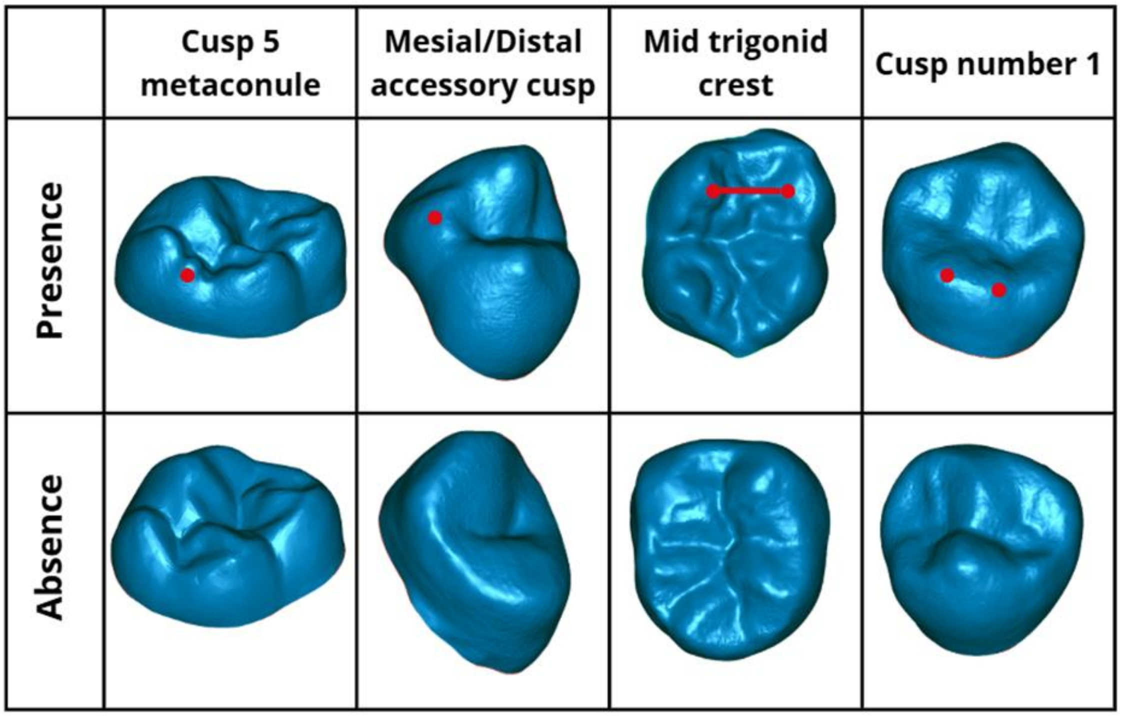


Figure 31 Example of presence and absence of the ASUDAS traits that show significant values.

Similarly, the results of the ASUDAS frequencies across different geographically differentiated regions show that there are significant differences only in the Mid-Trigonid Crest of the lower M2 (p = 0.028), the Cusp Number 1 of the lower premolars (p = 0.038) and the Cusp 5 (Metaconule) of the upper M2 (p = 0.012). Therefore, only 5.88% of the ASUDAS traits show significance by period and only 8.82% of the ASUDAS traits show significance by geographical area.

Regarding the Mid-Trigonid Crest, it was observed that 50% of the Kebara individuals from the Natufian period in the Levantine region exhibited this trait, in comparison to 27% and 39% from Dja'de el Mughara and Tell Halula, respectively, both from the Euphrates Valley region and PPNB period. In the case of Cusp Number 1, El Wad and Kebara from the Levantine area of the Natufian period present 10% and 11% of the trait, respectively. In contrast, Tell Aswad from de desertic area and the PPNB period presents 29% of the trait, while Tepecik-Çiftlik, from the Anatolian area and belonging to the Neolithic Pottery, presents 24% of this trait. Finally, Cuspid 5 (Metaconule), also by geographical area only 7% of the Tepecik-Çiftlik individuals present this characteristic vs the no presence in other regions and periods.

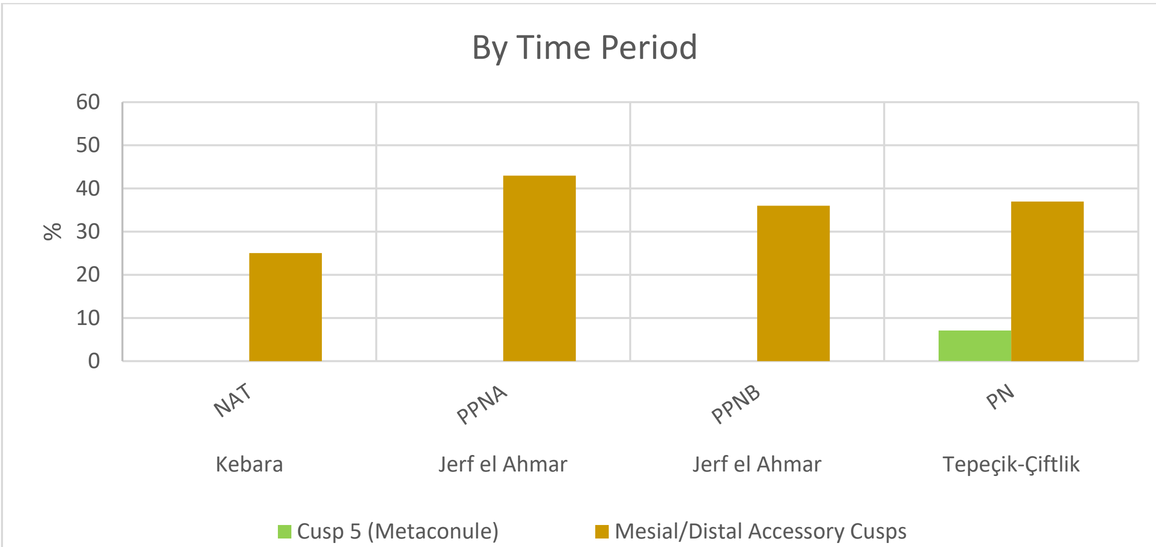


Figure 32 Percentage of the presence of metaconule (green) and mesial distal accessory cusps (brown) on molars by time period, percentage express the frequency from 0 to the highest value.

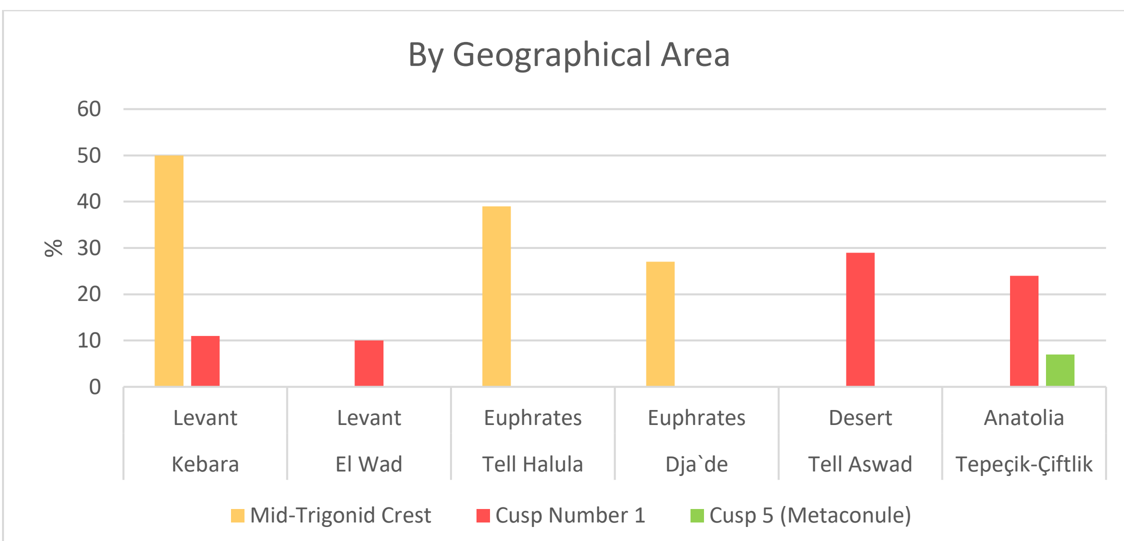


Figure 33 Percentage of the presence of Mid trigonid crest (yellow), Cusp number 1 (red) and, metaconule (green) by geographical area, percentage express the frequency from 0 to the highest value.

4.4. CONCLUSION AND DISCUSSION

During the transition between the Pleistocene and the Holocene, a series of changes occurred concurrently in the natural and social-ecological environments. These included a shift in climate, an ecological transformation, a socio-ecological change in food production (from hunter-gatherers to farmers and pastoralists), and a biological change marked by the reduction of masticatory anatomical structures. These changes occurred simultaneously in time and in the same region. This sequence of events has traditionally been interpreted as evidence of a causal relationship in which climate change would have triggered an ecological change that would have forced the populations of Southwest Asia to adopt a new system of food production, which would have ultimately caused a change in diet that would have had a marked impact on the reduction of tooth size in these populations (Larsen, 1997; Erdal, 1999; Estebaranz 2004; Pinhasi 2008, 2015). Although this reductionist model is very tempting, the truth is that the explanation of the existence of these events is currently more complex than the aforementioned suggested model (Maher et al., 2011). Firstly, it is inaccurate to suggest that there was a unidirectional and gradual climate change; rather, there were climatic oscillations with periods of climatic maxima followed by rapid periods of environmental deterioration (Maher et al., 2011).

Tooth size is highly relevant in biological anthropology, particularly in relation to adaptation and evolution. It has been extensively studied, and it is a well-established fact that there has been a reduction in dental size over the course of evolution (Estebaranz et al., 2004). Several studies have been conducted in the Eastern Mediterranean region in recent years, including Pinhasi's (2008, 2015) focusing on the Levantine area and Erdal's (1999) study of the Anatolian region suggesting that exist a tooth reduction from neolithic to bronze age. This research provides an insight into the whole area of Southwest Asia from the Levantine area, through the Euphrates valley, Sinai Peninsula, Zagros Mountains, and Anatolian Peninsula, as far as dental size and non-metric dental traits are concerned.

The results in the present study indicate that there is an accentuation of dental reduction in the transitional societies from hunter-gatherers to the first populations of farmers and agriculturalists in the Southwest Asia. Not only in the populations of the Levant, but also in whole populations of the whole studied region (Levant, Euphrates, Sinai, Zagros and Anatolia). However, the results obtained in the general linear model analysis suggest that this reduction in teeth is more important only in the buccolingual dimensions.

The most optimal approach to dental assessment is the occlusal perspective of the teeth, as proposed by Silvana et al. (1985). The authors suggested that the process of gracilization was driven by the need to maintain masticatory pressure despite a reduction in muscle mass. This isevidenced by a comparative analysis of Upper Palaeolithic and Neolithic populations. In contrast, Formicola (1987) conducted a comparative analysis of the tooth sizes of Neolithic and Epigravetian inhabitants in Liguria. He concluded that a combination of factors, including dietary modifications, the emergence of new technologies, and biological functional requirements, were responsible for the observed shift in tooth size. The relaxation of selective pressures in favour of larger teeth was facilitated by each of these conditions. The evolutionary changes in the masticatory apparatus of people in some populations of Southwest Asia and Europe from hunter-gatherer to Bronze Age were examined by Pinhasi et al. (2008, 2015) and Pokhojaev (2019) and the analysis revealed a reduction in the mandibular form and the bucco-lingual dimensions of the tooth.

Assessing the potential benefits or adaptations of the tooth size reduction specifically in the buccolingual measures is challenging. In the context of human evolution, the modifications to the human masticatory complex have occurred over a relatively brief span of time (Hillson, 2005). Several evolutionary models have been proposed to explain the reduction in these regions. One such model is the probable mutation effect (Brace, 1963; Brace & Mahler, 1971; Pinhasi et al., 2008), which suggests that, in the absence of selection pressure, spontaneous mutations will occur and result in a reduction and simplification of dental morphology. The adoption of a Neolithic lifestyle resulted in significant alterations to food practices and a relaxation of the selective pressure favoring larger, more complex teeth. It is anticipated that all dental measurements will decrease overall or exhibit homogeneous variance. It has been postulated that the advent of pottery and the subsequent alterations in food production, enabled using pottery, may have resulted in a relaxation of selective forces on the masticatory system. This, in turn, may have precipitated a probable mutation effect, which would have led to a reduction in tooth size (Brace, 1963, 1971). This theory would make sense if the changes in the dentition of agricultural societies started with the onset of pottery production in 7th millennia. However, the findings of the present study indicate that this change originated at an earlier period, as there is already a decrease in comparison to the Natufian in the PPNA and PPNB periods around 10th millennia.

The increasing population density effect (Macchiarelli & Bondioli, 1986) postulates that a sedentary lifestyle resulted in a marked decline in nutrition and health. As a result, the size of the body as a whole and therefore the size of the teeth would have decreased. In this model, it is anticipated that there would be a general decrease in body size and all dental measurements. In a similar approach, Pinhasi (2015) has also examined the mandibles of several individuals in the same area of the present study and asserts that the mandibles of the farmers are not merely diminutive replications of the chronologically earlier groups but rather exhibit allometric scaling. The MANOVA analysis indicates that while some mandibular dimensions increase in size, others decrease, suggesting a mosaic pattern of change. It would be beneficial for future studies to include postcranial measurements from diverse sites and periods to assess the validity of this theory.

The selective compromise effect (y'Edynak & Fleisch, 1983; Calcagno & Gibson, 1991) posits that populations with larger teeth are more susceptible to dental crowding and caries, which applies pressure on smaller teeth. However, it is hypothesised that the selection for larger teeth with stronger enamel was driven by the need to withstand extreme wear, which was caused by the consumption of abrasive foods, often the product of new Neolithic cooking techniques. This concept posits that dental reduction or uniform trend, and general enamel thickening represent the outcomes of a compromise between these two selection forces. To date, no published information is available on malocclusion and dental diseases in the Levantine populations. The prevalence of caries, periapical lesions, and antemortem tooth loss in the Natufian and Neolithic populations was found to be similar by Eshed et al. (2006).

However, the study also revealed that the Natufians exhibited a significantly higher incidence of periodontal disease compared to the PPN period (Pinhasi, 2008).

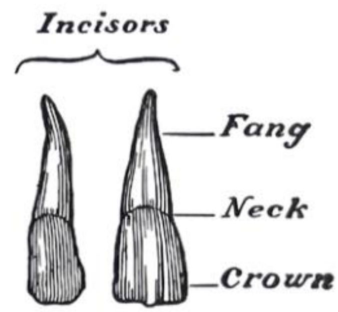
There is no evidence to suggest that Periodontal Disease is associated with alterations in dietary habits or general oral hygiene practices. However, given the Natufian period's intensive utilization of occlusal pressures during the mastication of abrasive foodstuffs, it is most probable that this is the result of physiological factors.

The evidence of variations in the two groups' wear patterns lends further support to this statement. In contrast, the PPN populations display a more inclined wear pattern and the presence of cupped wear on occlusal surfaces (Eshed et al., 2006; Pinhasi, 2008). In contrast, the Natufians exhibit uniformly distributed flat wear. After the transition to agriculture, analogous modifications in the wear pattern were observed in Japan (Kasai and Kawamura, 2001), Nubia (Smith, 1984), and other locations. It is postulated that this transition reflects a reduction in agricultural diets. It can be reasonably deduced from the available evidence that variations in mastication demands result in modifications to the observed wear patterns. This may be associated with the observed decline in buccolingual dimensions of most of the dentition and specific mandibular measurements. This lends support to the "Masticatory-Functional Hypothesis" proposed by Carlson and Van Gerven (1977), which posits that the craniofacial complex of early agriculturalists underwent a simultaneous alteration in response to a reduction in the functional demands placed on the masticatory complex.

The Arizona State University Dental Anthropology System (ASUDAS) is a tool used for the analysis of non-metric dental features, which provides insight into the phenotypic differences between populations (Scott & Turner, 1997), in this case from various time periods and geographical locations. This chapter focuses on certain traits that demonstrate notable differences across different chronological periods, including Cusp 5 (Metaconule) in the upper M2 and Mesial/Distal Accessory Cusps of upper premolars. The occurrence of Cusp 5 in 7% of the Tepecik-Çiftlik population during the Pottery Neolithic period of Anatolia also suggests a possible evolutionary divergence in tooth morphology that is unique to this time and place.

As mentioned above, the geographical study reveals significant regional variations in characteristics such as the lower M2's Mid-Trigonid Crest and the lower premolars' Cusp Number 1. The differences in Cusp Number 1 between geographical areas and chronological periods, in addition to the Mid-Trigonid Crest, which is more prevalent among Kebara individuals from the Natufian era in the Levantine area, show that these traits might have been influenced locally by genetic drift or evolutionary influences.

It is remarkable that the frequencies of ASUDAS traits exhibit notable but limited geographical and temporal significance, with only a small percentage of traits demonstrating significant differences (two and three traits over the 23 in total). This suggests that while certain traits facilitate accurate differentiation, overall dental morphological variations may be comparatively slight over specific timeframes or geographical regions. This could be indicative of a combination of genetic continuity and constrained environmental influences. The results of the ASUDAS trait analysis demonstrate that certain dental morphological differences exist between various prehistoric populations. These differences are influenced by the historical and geographical settings of the populations in question. Notable markers of evolutionary or cultural differentiation include traits such as the mid-trigonid crest in the lower M2 and cusp 5 in the upper M2. The limited number of characteristics exhibiting notable variations underscores the intricate nature of human evolutionary dynamics, suggesting that further comprehensive studies are needed to enhance our understanding of the influences affecting dental morphology. This study contributes to a more comprehensive understanding of the ways in which ancient societies interbred over time and adapted to their surrounding environments.



CHAPTER 5. CHANGES IN TOOTH TOPOGRAPHY

CHAPTER 5.

5. CHANGES IN TOOTH TOPOGRAPHY

5.1. INTRODUCTION

The changing environment that took place during the Young Dryas (see point: 1.2.2 Chronological context - Climatic Change); the carrying capacity of the ecosystems lowered by Stadial Climate Unpredictability, which reduced the number of resources available to the hunter-gatherer population (Molleson, 1994, Cappers, 2002); the impact of human activity on the distribution and productivity of wild C3 cereal grasses, as well as the yearly variations in the amount of pistachio and acorns produced, which were harvested by hunter-gatherers, had an important impact on human adaptations (Munro, 2004); to mitigate the challenges associated with resource scarcity, Late Natufian populations transitioned from a hunting-gathering to a farming lifestyle during this climatic and ecological transition and the subsequent environmental crisis (Bar-Yosef & Belfer-Cohen, 1992; Hillman, 1996; Miller, 1996; Belfer-Cohen & Bar-Yosef, 2000; Isaar & Zohar, 2009).

Following the Younger Dryas, the Holocene transition was marked by a rapid increase in temperature (approximately 7°C) and precipitation (Alley, 2000; Robinson et al., 2006; Weninger et al., 2009; Maher et al., 2011; Ferrio et al. 2011; Ibáñez et al. 2017). The Pre-Pottery Neolithic A period (11,600–10,500 cal BP) was characterised by an increase in regional population, which was linked to an increase in site quantity and size. Simultaneously to this climatic and social change, hunting and gathering wild fruits and seeds are still practised in numerous locations in Southwest Asia, alongside the simultaneous emergence of domesticated grains and legumes (Kuijt, 1994; Weninger et al., 2009; Zeder, 2011). These propitious environmental conditions would prevail for several millennia until the advent of the PPNB (PrePottery Neolithic B, 10,500–8,750 cal BP) period. During the PPNB period, the basis for sustenance underwent a significant transformation due to an increased reliance on domesticated crops and animals, including cattle, pigs, goats, and sheep (Bar-Yosef & Meadow, 1995; Peters et al., 2005; Zeder, 2005).

Dental variations between different taxa like hominin, including tooth size, dental proportions, dental topography, and enamel thickness, are often employed to indicate shifts in nutritional patterns. However, these variations can also be indicative of environmental changes or a combination of environmental and dietary shifts and, consequently different climatic changes may affect to the availability of food resources (Lucas et al., 2008; Onoda et al., 2011 Ungar and Sponheimer, 2011).

To carry out a quantitative study of human teeth (also exist in different taxa), different techniques are used, such as the study of tooth size, shape studies, macro- and microwear studies, etc. In this case, dental topography analysis is used.

Summarizing the point: 1.5.2 Dental topography. This method employs Geographic Information Systems (GIS) (Zuccotti et al., 1998; Ungar and Williamson, 2000) to analyse three-dimensional tooth structure quantitatively and to correlate shape with diet (Ungar, 2004; Godfrey et al., 2012; Ledogar et al., 2013; Winchester et al., 2014; Berthaume, 2016a; Berthaume and Schroer, 2017). Dental topography has also been employed to predict enamel surface morphology based on the form of the enamel-dentin junction (Skinner et al., 2010; Guy et al., 2015), to examine niche partitioning and other evolutionary forces (Boyer et al., 2012; Godfrey et al., 2012; Berthaume and Schroer, 2017), and to describe and assign new species (Boyer et al., 2012), in addition to the deduction of dietary ecology (Berthaume, 2018). In the ancient populations of Southwest Asia, we used four dental topographic metrics. Despite the consumption of comparable dietary items, there may be variations in dental behaviour between species and even within the same species. This is due to the utilisation of different masticatory motions or loads. Consequently, the varying characteristics of tooth morphology in response to nutritional factors are quantified by the use of topographic factors. To illustrate, low-cusped crowns will exhibit a lower relief index (RFI) (Boyer 2008), which is calculated as the ratio of the tooth's three-dimensional (3D) projection area on the occlusal plane to its two-dimensional (2D) surface area (Teaford and Ungar, 2000; Boyer, 2008; Allen et al., 2015; Pampush et al., 2018).

The computation of the crown's curvature is achieved through the utilisation of Dirichlet normal energy (DNE), as proposed by Bunn et al. (2011). Teeth with curved surfaces, such as taller cusps, typically exhibit greater sharpness and a higher DNE, which is a measure of surface variety. Tooth occlusal complexity (OPCR) (Evans et al., 2007), defined as the average number of dental elements, is potentially correlated with the selective compromise effect (Y'Edynak & Fleisch, 1983; Calcagno & Gibson, 1991). The number of dental elements or triangles can be calculated by adding together the changes in triangle patch directions (OPCR; orientation patch count rotated). Previous research has indicated that occlusal surfaces with greater patch counts are associated with greater tooth complexity. This is because higher OPCR values indicate more complex teeth (Pineda-Muñoz et al., 2017; Berthaume et al., 2020; Avià et al., 2022). To quantify the degree of exposure of a surface to ambient illumination when observed from the occlusal direction, Berthaume (2019) developed the dental topographic metric denominated as ambient occlusion (PCV; Part de Ciel Visible). The foveae, or sides of enamel caps, exhibit lower PCV values due to their reduced exposure to light. Conversely, the cusp tips, crest, and blade edges demonstrate greater exposure to light and consequently higher PCV values. It has been demonstrated that there is a correlation between PCV and hard object feeding efficiency. Populations whose diets are characterised by a higher proportion of fibrous elements will exhibit lower PCV values than those whose diets are comprised predominantly of hard items, where the cusps are subjected to significant illumination (Berthaume, 2016; Berthaume et al., 2020).

5.2. MATERIAL AND METHODS

5.2.1. MATERIAL

The study analyzed 105 dental remains (first and second lower molars) from 10 archaeological sites in Southwest Asia (El Wad, Kebara, Dja'de el Mughara, Abu Hureyra, Tell Aswad, Tell Ramad, Tell Halula, Ali Kosh, Nemrik 9 and, Tepecik-Çiftlik) (See table 5). The sites are limited to different chronological periods: Natufian, Prepottery Neolithic B and, Pottery Neolithic as any PPNA first or second lower molars were unworn and well preserved to conduct the topographic study. In addition, these archaeological sites from the Northern Fertile Crescent (Ibáñez et al., 2017) have been divided into (phyto)ecological and/or geographically differentiated regions to compare regionalized patterns (Horwitz & Tchernov, 2000; Palmisano et al., 2021): Levant/Mediterranean, Middle Euphrates/Anti-Taurus, Saharo-Arabian desert Region, Zagros Mountains, and South/Central Anatolia/Taurus.

Archaeological Site	Chronological period	Geographical area	Number of samples M1L	Number of samples M2L
El Wad	Natufian	Levant	5	3
Kebara	Natufian	Levant	5	2
Dja'de el Mug.	PPNB	Euphrates	5	-
Abu Hureyra	PPNB	Euphrates	6	5
Tell Aswad	PPNB	Desert	1	3
Tell Ramad	PPNB	Desert	6	8
Tell Halula	PPNB	Euphrates	17	4
Ali Kosh	PPNB	Zagros	1	2
Nemrik 9	PPNB	Zagros	6	3
Tepecik-Çiftlik	Pottery Neo.	Anatolia	7	16
TOTAL	-	-	59	46

Table 8 Content of the materials analysed in dental topography study.

The dental collections that were subjected to analysis are situated in a variety of laboratories and institutions. The samples were obtained from seven sites in Southwest Asia. Abu Hureyra, Dja'de el Mughara, El Wad, Jerf el Ahmar, Kebara, Shukba, Tell Aswad, Tell Halula, Tell Ramad (Estebaranz et al., 2007). The collections analysed, correspond to the dental collection curated at the Anthropology Unit of the University of Barcelona (coordinated and directed by Dra. Laura M. Martínez and Dr. Alejandro Pérez-Pérez). Additionally, a second set of samples was obtained and curated by Dr. Arkadiuz Sołtysiak at the University of Warsaw and subsequently analyzed at the University of Barcelona. The third set of samples was curated by Dr. Ali Metin Büyükkarakaya from the Human Behavioral Ecology and Archeometry Laboratory (IDEA Lab), Department of Anthropology, Hacettepe University, specifically the Tepecik-Çiftlik from the Anatolian peninsula and was obtained during my research stay there.

5.2.2. METHODS

The samples were cleaned to remove any grit and depositional material with cotton isotopes soaked in pure ethanol. Silicone moulds were then obtained using Affinis® Regular Body (Coltène-Whaledent) polyvinylsiloxane. The positive casts were obtainedusing Ferropur PR-55 polyurethane (Ferroca® Composites, Spain) in accordance with the procedures outlined by Galbany (2016). Three-dimensional scans were acquired using structured white light 3D scanning technology, specifically the Shining Einscan SP, with a resolution of 0.05mm. The 3D meshes were exported in the polygonal format (.ply). The scanned samples were processed with Geomagic Studio/Wrap 2014 by isolating each tooth and repairing the interproximal surfaces. Subsequently, the models were imported to Meshlab (ISTI-CNR Research Centre, University of Pisa) for orientation, with the occlusal face of the tooth positioned perpendicular to the Z-axis (Pampush et al., 2016; Avià et al., 2022). Finally, each tooth mesh was orientated and cut by the lowermost point of the lowermost fovea (Berthaume, 2019) and simplifying the mesh to 10,000 polygons (Winchester, 2016; Avià te al., 2022).

Morphotester software was employed to calculate three topographic parameters: the relief index (RFI) (Boyer, 2008; Avià et al., 2022), Dirichlet normal energy (DNE) (Bunn et al., 2011) and orientation patch count rotated (OPCR) (Evans et al., 2007). On the other hand, to calculate the ambient occlusion (PCV; Percentage du Ciel Visible) Cloud Compare 3D software was used (Berthaume, 2019a).

The statistical analysis was conducted using the statistical software SPSS statistics 23.0 (IBM, Armonk, NY, USA). According to the Shapiro-Wilk test, dental topographic factors were not normally distributed by chronological period and geographical area ($p < 0.05$). One-way ANOVA on each variable (DNE, RFI, OPCR, PCV) by chronological period and geographical area were used using Tukey's honestly significance test (HSD) to determine significant variation during the transition from the last hunter-gatherers to the first agricultural populations by chronological period and geographical areas. Two discriminant analyses were conducted with the objective of identifying the optimal method for differentiating between the groups, in one hand we used chronological period groups, in the other hand we used regionalized areas groups. A Linear Discriminant Analysis (LDA) was conducted on the correlation matrix to ascertain the patterns of topographic variation that explained the observed variation in different groups. Using Addinsoft XLSTAT 2020.5.

5.3. RESULTS

The final sample consisted of M1L (N=59) from eight archaeological sites and M2L (N= 46) from seven archaeological sites were included in the dental topographic analysis Table 6 provides descriptive dental topography data.

The dental topographic metrics showed significant differences among different chronological periods/geographical areas.

Site	Tooth	N	DNE		RFI		OPCR		PCV	
			mean	SD	mean	SD	mean	SD	mean	SD
El Wad	M1	5	197,552	53,105	1,417	,094	100,600	13,684	,726	,025
	M2	3	191,707	17,982	1,388	,064	88,250	6,758	,728	,010
Kebara	M1	5	227,787	79,933	1,552	,125	99,500	12,257	,697	,034
	M2	2	215,418	56,565	1,414	,008	102,312	32,438	,726	,009
Dja'de el Mughara	M1	5	216,299	29,042	1,383	,024	144,775	16,116	,754	,008
	M2	0	-	-	-	-	-	-	-	-
Abu Hureyra	M1	6	200,152	56,043	1,479	,092	115,062	21,020	,722	,024
	M2	5	142,927	13,642	1,462	,085	81,350	14,018	,727	,014
Tell Aswad	M1	1	219,764	-	1,668	-	100,125	-	,680	-
	M2	3	214,304	84,101	1,502	,155	101,750	21,328	,715	,038
Tell Ramad	M1	6	200,139	31,950	1,420	,0339	114,500	21,323	,728	,007
	M2	8	159,817	36,616	1,432	,055	86,250	11,748	,728	,023
Tell Halula	M1	17	191,514	48,598	1,448	,132	104,220	12,920	,728	,029
	M2	4	181,671	54,492	1,445	,125	99,625	16,425	,740	,0351
Tepecik-Çiftlik	M1	7	189,481	26,337	1,608	,050	90,107	9,037	,645	,0124
	M2	16	173,777	33,452	1,517	,112	86,671	9,406	,680	,029
Ali Kosh	M1	1	234,831	-	1,412	-	130,250	-	,732	-
	M2	2	173,964	17,183	1,372	,003	107,375	24,395	,745	,009
Nemrik 9	M1	6	188,819	22,173	1,556	,083	83,125	13,019	,703	,020
	M2	3	175,851	49,829	1,523	,050	80,833	5,706	,716	,020

Table 9 Descriptive dental topography data by site and tooth type.

The one-way ANOVA revealed statistically significant differences by period (ANOVA; $p < 0.05$) (see Annex 3 for the complete statistical results). In contrast, Tukey's HSD procedure indicated that the **first lower molars** for the DNE and OPCR exhibited no significant differences (Tukey's HSD p > 0.05). This suggests that, although the ANOVA test revealed some differences, they were not strong enough to be detected by the post-hoc test. Therefore, there are no notable discrepancies between the Natufian, PPNB, and Pottery Neolithic periods. Conversely, the RFI index revealed significant differences between the PPNB and Pottery Neolithic periods (Tukey's HSD $p = 0.005$). Furthermore, the PCV index revealed significant differences between the Neolithic period and the other periods (PPNB/Natufian) (Tukey's HSD $p < 0.001$) (Figure 34).

The **second lower molars** for the DNE and OPCR exhibited no significant differences (Tukey's HSD $p > 0.05$), indicating that there are no notable discrepancies between the Natufian, PPNB, and Pottery Neolithic periods. Conversely, the RFI index demonstrated statistically significant differences between the Natufian and Pottery Neolithic periods (Tukey's HSD $p = 0.048$). Furthermore, the PCV index demonstrated significant discrepancies in the *p*-value between the Neolithic period and the rest of periods, with the PPNB exhibiting the greatest divergence (Tukey's HSD $p < 0.001$) followed by the Natufian period (Tukey's HSD $p =0.002$) (Figure 34).

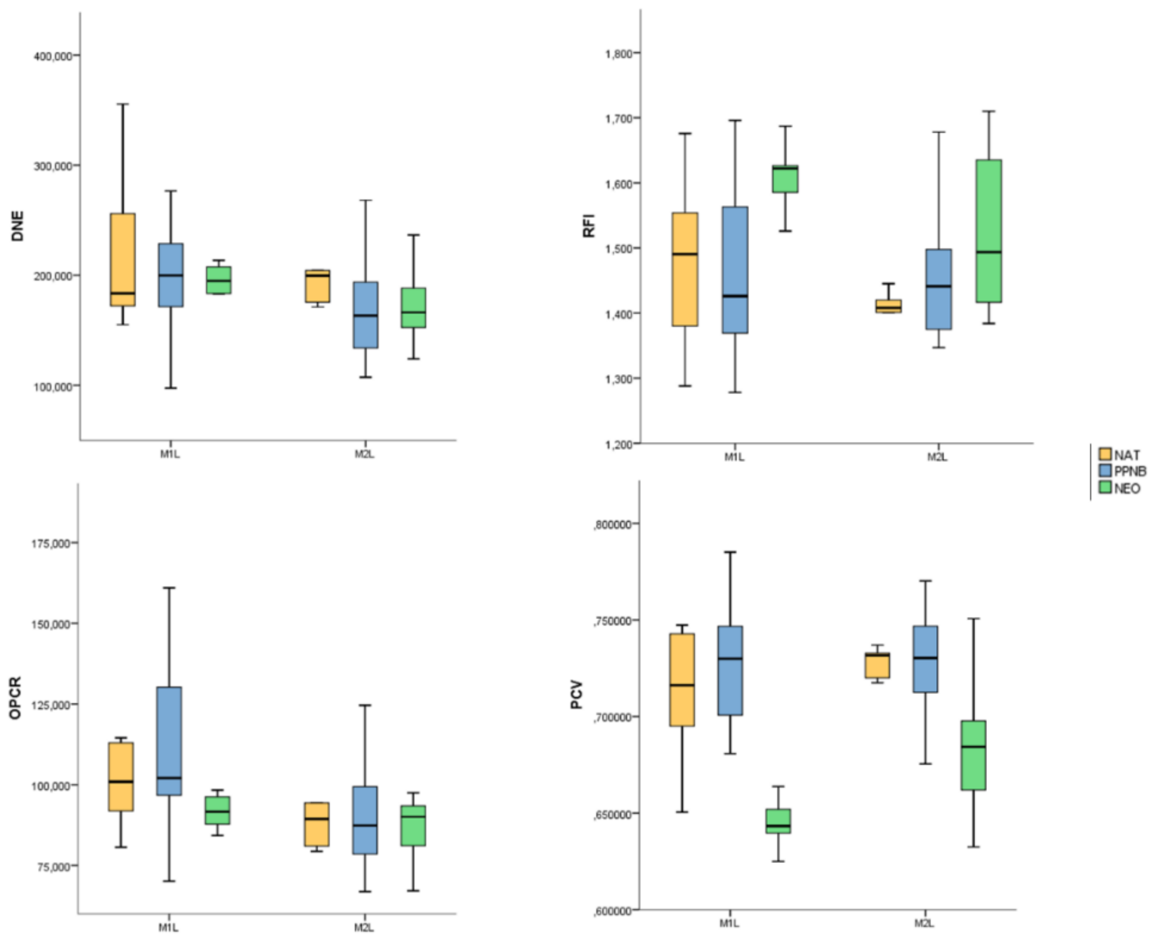


Figure 34 Box plots of DNE, RFI, OPCR and, PCV in M1L and M2L by period.

The one-way analysis of variance (ANOVA) also revealed statistically significant differences in the *P*-value by geographical area (Please refer to the Annex 4).

In Tukey's HSD procedure no significant differences were observed in the **first lower molars** for the DNE index (Tukey's HSD $p > 0.05$). In contrast, a significant difference was observed between the Euphrates and Anatolia regions with regard to the RFI index (Tukey's HSD $p = 0.005$). Additionally, the OPCR index indicates notable disparities between the Euphrates and Anatolia regions (Tukey's HSD $p = 0.035$) and the Euphrates and Zagros regions (Tukey's HSD $p = 0.033$). In conclusion, the PCV index demonstrates significant differences between the Anatolian and other geographical areas (Levant, Euphrates, Desert, Zagros) (Tukey's HSD $p = 0.000$) with respect to the lower first molars.

The **second lower molars** for the DNE, RFI and OPCR index did not reveal statistically significant differences in the *P*-value by geographical area (Tukey's HSD $p > 0.05$). In contrast, a significant difference was observed between Anatolia and other geographical areas [Levant (Tukey's HSD $p = 0.008$), Euphrates (Tukey's HSD $p = 0.000$), Desert (Tukey's HSD $p = 0.001$), Zagros (Tukey's HSD $p = 0.008$) with respect to the lower first molars.

The one-way analysis of variance (ANOVA) also revealed statistically significant differences in the *P*-value by geographical area (complete statistical results are in the Annex 4). Tukey's HSD procedure showed no significant differences among areas in the **first lower molars** for the DNE index (Tukey's HSD $p > 0.05$). In contrast, significant difference was observed in the RFI index between the Euphrates and Anatolia regions (Tukey's HSD $p = 0.005$). Additionally, the complexity OPCR value indicates notable disparities between the Euphrates and Anatolia regions (Tukey's HSD $p = 0.035$) and the Euphrates and Zagros regions (Tukey's HSD $p = 0.033$). Finally, the PCV value demonstrates significant differences between the Anatolian and other geographical areas (Levant, Euphrates, Desert, Zagros) (Tukey's HSD $p = 0.000$) with respect to the lower first molars.

Regarding the **second lower molars** there were no statistically significant differences in the DNE, RFI and OPCR values by geographical area (Tukey's HSD $p > 0.05$). In contrast, significant differences were observed between Anatolia and other geographical areas [Levant (Tukey's HSD p = 0.008), Euphrates (Tukey's HSD p = 0.000), Desert (Tukey's HSD p = 0.001), Zagros (Tukey's HSD p = 0.008) with respect to the lower first molars.

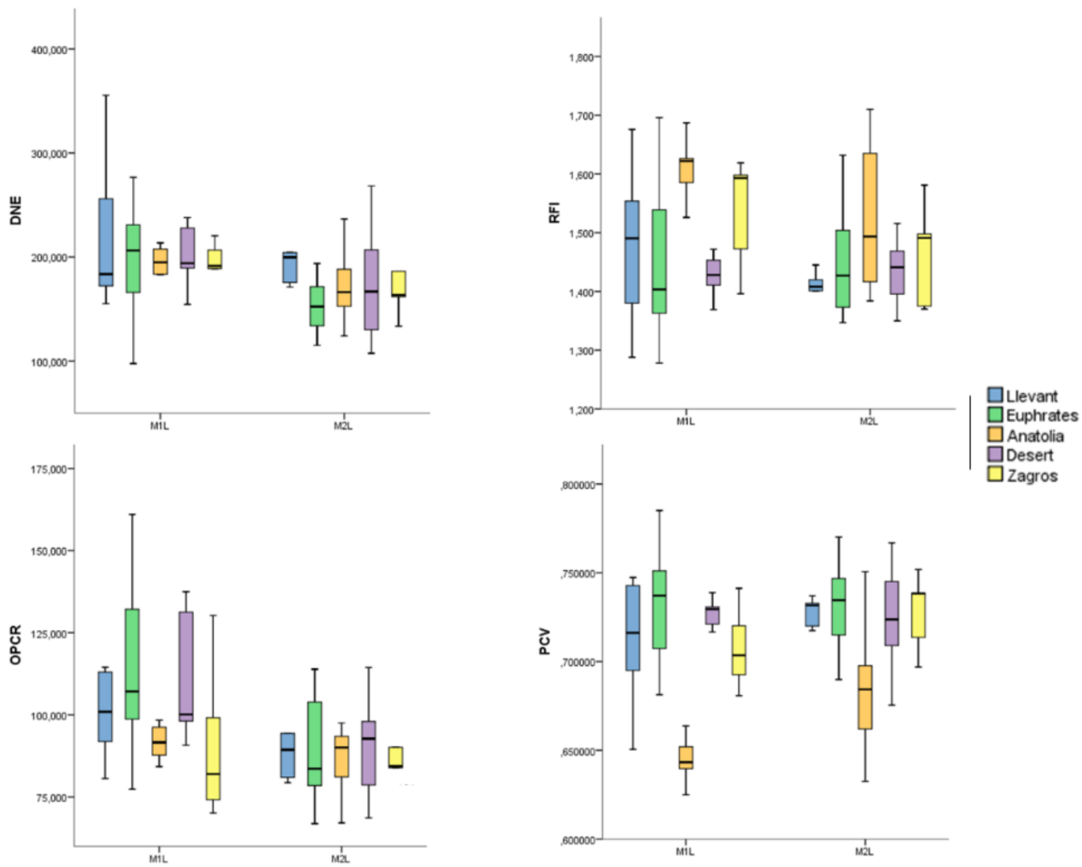


Figure 35 Box plots of DNE, RFI, OPCR and, PCV in M1L and M2L by geographical area.

The results of the linear discriminant analysis (LDA) of the topographical samples from the aforementioned areas, are presented graphically in Figure 36 and 37, with data organized by period and geographic area. The LDA revealed highly significant differences between **chronological periods** in both studied teeth (M1L and M2L) according to the morphological-related topographic parameters (Wilks' $\lambda = 0.160$; $F = 19.893$; $p < 0.0001$ on M1L and, Wilks' $\lambda = 0.220$; $F = 11.336$; $p < 0.0001$ on M2L). The first two discriminant functions (DF1 and DF2) collectively accounted for 96.46% (in lower M1) and 90.08% (in lower M2) of the total variance.

In the case of the lower M1, the LDA demonstrated an accuracy rate of 83.05% in correctly categorizing the individuals of each chronology (post-hoc correct classification). Most misclassifications were observed between the Natufian and PPNB categories. In this instance, nine of the ten individuals assigned to the Natufian category were not correctly classified. In the Lower M2, the LDA correctly classified the samples of each chronology in the correct category 80% of the time (post-hoc correct classification). Most misclassifications were observed between the Natufian and PPNB categories, as well as between the Pottery Neolithic and PPNB categories. In both instances, three individuals were misclassified. However, the proportion of misclassified Natufian specimens was higher, due to the small sample size. In Lower M1 DF1 (96.465% of variance; eigenvalue 4.390) significantly differentiated between periods.

The LDA revealed highly significant differences between **geographical areas** in both studied teeth (M1L and M2L) according to the morphological-related topographic parameters (Wilks' $\lambda = 0.124$; $F = 9.577$; $p < 0.0001$ on M1L and, Wilks' $\lambda = 0.208$; $F = 4.909$; $p < 0.0001$ on M2L). The first two discriminant functions (DF1 and DF2) collectively accounted for 92.49% (in M1L) and 88.04% (in M2L) of the total variance.

In the case of the lower M1, the LDA has demonstrated an accuracy rate of 61.02% in correctly categorizing the individuals of each geographical area (post-hoc correct classification). The majority of misclassifications were observed between the Desertic sites and Euphrates categories. Specifically, all the individuals assigned to the Desert category were not correctly classified (were all misclassified as Euphrates). In Lower M1 DF1 (96.465% of variance; eigenvalue 4.390) significantly differentiated between periods. In the Lower M2, the LDA correctly classified the samples of each geographical area in the correct category 50% of the time (post-hoc correct classification). Most misclassifications were observed between the Euphrates and Desert categories. Only 22.22% of the Euphrates individuals were correctly classified.

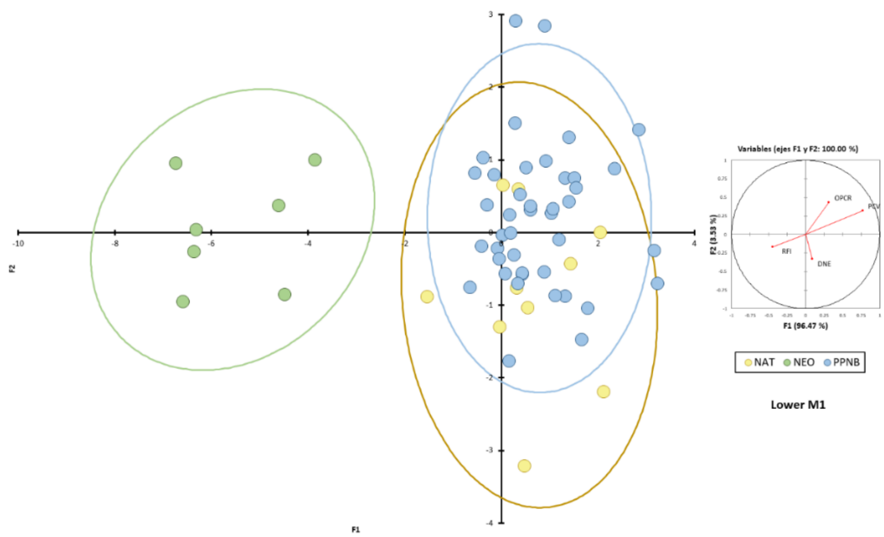


Figure 36 Linear Discriminant Analysis (LDA) for lower M1 by periods (DF1 96.47% and DF2 3.53%)

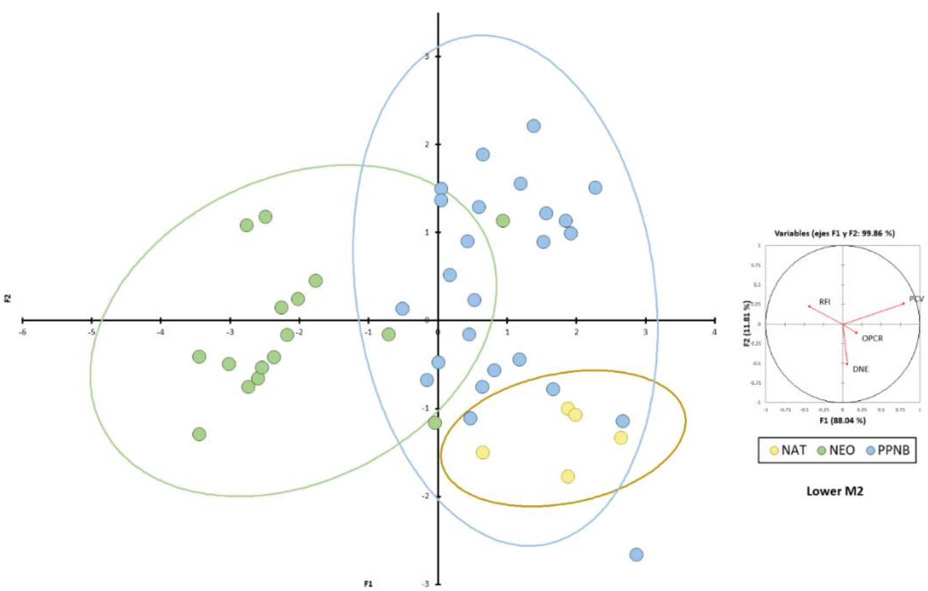


Figure 37 Linear Discriminant Analysis (LDA) for lower M2 (DF1 88.04% and DF2 11.81%)

5.4. CONCLUSION AND DISCUSSION

This study examines the morphology of unworn teeth throughout time and geographical areas. In primates, like other mammals, there is a strong relationship between tooth shape, size, and diet. From a biomechanical perspective, teeth are tools that play an important role in food processing (grinding or crushing) and item breakdown. Natural selection is likely acting on tooth shape through one or more of these functions, that depend on diet or dietary items. During the transition from hunter-gatherers to Neolithic, major dietary changes occurred in relation with several climatic transitions and cultural changes. Climatic changes influenced the availability of resources, and the findings demonstrate that the distinctive environmental challenges associated with Stadial Climate Unpredictability significantly reduced the capacity of ecosystems, which had an immediate impact on human populations that relied on these resources (Molleson, 1994; Cappers, 2002). The transition from hunting and gathering to early agricultural lifestyles among Late Natufian societies can be attributed to resource constraints, which represent a pivotal evolutionary response to ecological pressures (Bar-Yosef & Belfer-Cohen, 1992; Miller, 1996; Hillman, 1996).

Discriminant analysis applied for exploring dental morphology showed pronounced differences in dental topography metric measurements through various epochs and spatial distributions. The findings suggest that the dental variables related with tooth curvature and crown complexity (DNE and OPCR respectively) did not produce meaningful differences, thus the lower molars studied did not change in cusp heights or the depth of the foveas, nor between the complexity of crown counted by the number of locations (patches) where foods are likely to fracture (Berthaume et al., 2020). Complexity is correlated with the number of occlusal features (i.e., cusp, crests, crenulations), and in primates is not indicative of different diets probably because there is a lower level of variation in dental complexity within primates and humans compared to other mammalian clades. On the other hand, the RFI and PCV indices pointed out some changes from the Natufian to the later Neolithic contexts (PPNB and pottery Neolithic). Neolithic samples exhibited a higher RFI, with tooth morphology characterized by higher cusps (3D area) relative to the tooth surface (2D area) compared to

PPNB samples. This pattern was observed in both the first and second lower molars. Additionally, PPNB samples displayed lower and more rounded cusps compared to the Neolithic samples from Anatolia. This suggests a trend from the lower, rounded cusps of the PPNB period to the highest, sharper cusps seen in the Neolithic. These changes may reflect different adaptations to dietary items and habits probably associated with an adaptive response, thus emphasizing the very profound impact made on the subsistence patterns of the people through organism domestication and the agricultural system development (Zeder, 2005; Peters et al., 2005). Moreover, there were no significant differences between the Natufian and PPNB periods indicating that the change in tooth morphology was associated with major dietary changes related to animal and plants domestication. However, we have to consider that these Neolithic samples are from Anatolia, a different region of the PPNB and Natufian samples.

An important turning point came with the transition to the Holocene, which was clearly characterized with a relative climatic improvement that eased population increases and human settlements' expansion (Alley, 2000; Robinson et al., 2006; Weninger et al., 2009). Even though hunting and gathering were still in use, the emergence of domesticated crops made it possible to start more intricate agricultural societies. The prominent dental features which are associated with certain forms of resource exploitation give clues on how these changes are manifest in the shape of the dental structures (Lucas et al., 2008; Ungar & Sponheimer, 2011). The occurrence of different dental topographic metrics among the samples is not only indicative of the distribution of the diets of most recent populations but also wider ecocritical possibilities across the region of Southwest Asia (Berthaume, 2018).

The results of the linear discriminant analysis (LDA), with 80% of correct classification, provide further insight into the relationship between morphological variation and chronological categorization. The misclassification between the PPNB and Natufian populations indicates the existence of subtle morphological dental changes throughout this period of transition. In evaluating dental adaptations and ecological strategies, this underscores the importance of considering sample size and geographical heterogeneity (Godfrey et al., 2012; Berthaume & Schroer, 2017).

On the other hand, an LDA was also conducted at the geographical area level to assess whether the observed morphological changes in the dentition are associated with the different geographical and climatic zones that exist. The results demonstrate that the geographic areas of Anatolia and the Levant are significantly more distant from one another than the Desert, Euphrates and Zagros. It is noteworthy that the geographic area of Anatolia encompasses the entire sample from the Neolithic Ceramic period, while the geographic area of the Levant largely corresponds to the Natufian chronological period. This may explain why the majority of misclassifications (38.98% on M1L and 50% on M2L) align with geographical areas of the same period, suggesting that changes in dentition may have occurred over time rather than being influenced by regional differences.

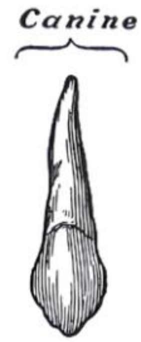
Dental topography can provide insight into genetic adaptations beyond the mere reflection of food patterns. Both environmental stressors and evolutionary reactions can affect phenotypic features, such as the growth and form of teeth, which are influenced by genetic variables (Ungar et al., 2011). The notion that dental characteristics are not merely dietary responses but also serve as markers of population history and migratory patterns is substantiated by the interplay between genetics and dental morphology. Our understanding of the way that environmental factors and genetic composition have interacted to produce human adaptations over time can be enhanced by employing genetic analysis to elucidate the relationships between variations in dental topography and the genetic origins of diverse populations.

The observed distance between the Neolithic pottery individuals and the others may be attributed to the fact that they all originate from the Tepecik-Çiftlik site, which is situated on the Anatolian peninsula. Yaka (2020) already addresses the question of the Anatolian Early Neolithic sites, noting that despite their proximity, each site is represented in a different genetic cluster. Nevertheless, the genetic distance between the Anatolian Neolithic and the Neolithic of Europe and the Caucasian hunter-gatherers is significant, as is the distance between the Anatolian Neolithic and the Levantine Neolithic and the early Iranian first farmers (Kiliç, 2016, 2017; Feldman et al., 2019). The diversity is so great that Tepecik-Çiftlik has no such genetic affinity with Çatalhoyuk, which is about 160 kilometres away.

Regional gene flow is evident between 7500 and 6500 BC (Yaka, 2020). It can be posited that the effect of this gene flow may account for the observed increase in genetic diversity in Neolithic populations during the transition from the Aceramic Neolithic to the Ceramic Neolithic in Anatolia. This transition, or rather this change, is contemporaneous with the emergence of more complex societies with a different social organisation (Özbaşaran, 2011; Baird, 2012). In contrast, Tepecik-Çiftlik represents a genetic outlier in comparison to the other contemporary sites. The discrepancy may be attributed to the inferior quality of the genomic data or the presence of a distinct genetic structure, corroborated by the material record at the site itself, which differs from those of other sites of comparable chronology (Bıçakçı, 2012).

Furthermore, the genomic data of Late Pleistocene individuals from central Anatolia exhibit a distinctive genetic profile that is significantly associated with both early Neolithic farmers in the region and contemporary Anatolian populations, as reported by Feldman et al. (2019). The adoption of agricultural methods in Anatolia may have resulted from local evolution and adaptation rather than a large-scale external migration, as evidenced by the researchers' discovery that these early farmers exhibited genetic similarities with local foragers rather than with people from the Near East. Also, Feldman et al. (2019) posited that genetic continuity is pivotal in comprehending the cultural transition towards agriculture. Their argument is based on the premise that a gradual transition, facilitated by both cultural and technological exchanges, is more plausible than a sudden population shift. They support this assertion by demonstrating that the early farmers shared a significant proportion of their ancestry with these earlier hunter-gatherer cultures.

This hypothesis is further supported by the dental topographical analysis made in this study, which reveals that the dental topography of Tepecik-Çiftlik is markedly distinct from that of other Neolithic Aceramic populations in different sub-regions.



CHAPTER 6. CHANGES IN WEAR RATES

CHAPTER 6.

6. CHANGES IN WEAR RATES

6.1. RETHINKING WEAR RATE ANALYSIS: A NEW DENTIN EXPOSURE PROXY AND ITS APPLICATIONS TO ANCIENT CHINESE POPULATIONS

This part of the chapter is an article (Published) which introduces a novel methodology for the analysis of dentin exposure in molars, thereby enhancing the study of dental wear in prehistoric Chinese populations. It is proposed that dental wear can be defined as an age-dependent physiological process, influenced by the hardness and abrasiveness of the foods consumed. This assertion is supported by previous studies (Kaifu et al., 2003; Romero et al., 2019). Conventional techniques for wear analysis frequently underestimate the true age of individuals, as they are based on discrete scores that do not adequately reflect variations in wear rates according to the lifestyle and diet of each population (Gilmore & Grote, 2012).

This study focuses on human remains from Chinese archaeological sites, including Houtaomuga, Banlashan, Dunping and Jiayi, and analyses 275 individuals. The methodology employed incorporates three-dimensional (3D) scanning and the measurement of exposed dentin surfaces, thereby overcoming the limitations of previous methods. This continuous measurement model permits the evaluation of wear rates across multiple molars, thereby facilitating a more precise and comprehensive understanding of tooth wear patterns over time.

The findings indicate that the highest rates of wear occur during childhood, with a subsequent gradual increase in dentin exposure as molars become functionally active. Moreover, the observed wear rates vary considerably between the populations under study, reflecting differences in dietary habits and environmental conditions. Populations with diets that are more abrasive, which are typically associated with arid environments, exhibited more pronounced tooth wear. In contrast, the Dunping population, which is situated in a region with greater ecological diversity, demonstrated considerably lower wear rates.

This novel methodology not only facilitates a more accurate characterization of tooth wear rates but also provides insights into the ecological conditions and dietary practices of ancient populations. It can be concluded that the analysis of dentin exposure through 3D modelling provides a reliable method for estimating age at death in archaeological and paleontological contexts. This therefore enriches the field of bioarchaeology and its focus on the cultural and dietary practices of past societies.

Journal of Archaeological Method and Theory (2024) 31:2053–2081
https://doi.org/10.1007/s10816-024-09664-7

RESEARCH

Rethinking Wear Rate Analysis: a New Dentin Exposure Proxy and its Applications to Ancient Chinese Populations

Shiyu Yang[1,2,7] · Laura M. Martínez[2,3] · Alejandro Romero[4] · Susana Carrascal[2,3,5] · Jie Guo[1] · Albert E. Dyowe[6] · Quanchao Zhang[1] · Alejandro Pérez-Pérez[2,3]

Accepted: 30 July 2024 / Published online: 16 August 2024

Abstract

Assessing age through dentin exposure often leads to underestimated age due to assumptions of constant molar wear rate. New methods for age-related dentin exposure accrual could facilitate cross-population comparisons independent of dietary habits and sociocultural strategies. We analyzed 3D dentin exposure surfaces in four Chinese archaeological samples to reveal variations in dentin exposure rates linked to socioeconomic practices. Linear regression models of dentin exposure areas across molar rows showed significant correlations, with the first molars exhibiting steeper slopes and smaller intercepts compared to the second molars, which had intermediate values, and the third molars showing the highest intercepts and lowest slopes. The first molar contributed most to overall dentin exposure in the molar quadrant, while the second molar wore faster post-eruption. Among populations, Banlashan, predominantly agriculturalist; Houtaomuga, focused on fishing; and Jiayi, a nomadic hunting society, displayed similar wear rate patterns. In contrast, Dunping, a Bronze Age nomadic settlement situated on a high-altitude plateau, exhibited distinctively lower wear rates. These observed dentin exposure rates aligned with ecological and dietary constraints, enabling interpopulation comparisons using the proposed 3D dentin exposure proxy. Moreover, the statistical model allows for comparing wear rates across populations relative to dietary habits and potentially estimating age at death for isolated archaeological specimens, whether humans or animals. The precision of this physiological age estimation depends on the regression models used, necessitating further research with specimens of known age at death.

Keywords Dentin exposure · Wear rates · Age at death · Northern China · Neolithic to early Bronze Age

Quanchao Zhang and Alejandro Pérez-Pérez contributed equally to this work.

Extended author information available on the last page of the article

Introduction

Dental wear is a physiological, age-dependent process of gradual enamel loss and dentin exposure largely determined by dietary abrasiveness (Kaifu et al., 2003; Romero et al., 2019). After the dental crown reaches full functional occlusion, enamel surfaces progressively wear down due to tooth-to-tooth attrition and tooth-to-food abrasion. These processes involve hard, microscopic particles from both intrinsic sources, such as silica-based phytoliths from edible monocotyledon plants, and extrinsic sources, such as gritty particles incorporated into food during processing (Lucas & van Casteren, 2015; Schmidt, 2010).

Traditional wear scoring systems rely on discrete cusp enamel wear and dentin exposure stages (Broca, 1879; Murphy, 1959). Gross dental wear scores on molar teeth allow classifying individuals into broad age categories (Lovejoy, 1985). However, age estimations based on discrete scores of dentin exposure (Gilmore & Grote, 2012) tend to underestimate actual individual ages (Miles, 2001), since they frequently assume constant molar wear rates, independent of the population's lifestyle and diet (Brothwell, 1963). Overall, in populations with low wear rates, dentin exposure scores were expected to provide less accurate age estimations because interindividual variation in wear could obscure the age-related signal (Cuesta-Torralvo et al., 2021; Gilmore & Grote, 2012).

The dentitions of geographically and temporally diverse prehistoric hunter-gatherer populations exhibited higher wear scores than those of agriculturalist groups due to their less refined, tougher foods consumed (Deter, 2009; Kaifu et al., 2003). Furthermore, dietary proclivities and technical methods of food processing induced significant variation in the percentages of dentin exposure in both Arctic (Clement & Hillson, 2012; Górka et al., 2016) and mesothermal (Richards & Brown, 1981; Romero et al., 2019) hunter-gatherers. Although molar crown shape changes with age due to wear, the models were likely ineffective for determining wear rates and age at death in skeletal remains because of the high variability in molar wear within modern human populations (Benazzi et al., 2008; Cuesta-Torralvo et al., 2021). Smith (1984) also noted that the angle of the occlusal plane of molar teeth was sensitive to interpopulation differences in food toughness, independent of the variation in wear scores. Notwithstanding the age and diet interdependence, making inferences of age at death or dietary habits based on molar wear rates required that one of the two factors remain constant (Rose & Ungar, 1998: 352). In this context, we need novel methods to estimate dentin exposure rates, rather than averaging measures of dental wear scores of skeletal samples for which the age distribution is unknown.

In this study, we employed a three-dimensional (3D) dentin exposure analysis approach, using a continuous measure of dentin exposure on molar tooth rows (M_1-M_2-M_3). This enabled us to derive wear rates through regression models of dentin exposure, allowing for comparisons among archaeological populations.

Materials and methods

We studied human skeletal remains from the Chinese prehistoric sites of Houtaomuga, Banlashan, Dunping, and Jiayi, curated in the *Human Skeletal Collections* at the School of Archaeology (Jilin University, China). The total sample analyzed consisted of 275 individuals (52.1% of the available skeletons), including 107 females, 137 males, and 31 subadult unsexed individuals (Table 1). The variation in sample sizes across sites resulted from differences in skeletal preservation and environmental conditions affecting the burials. Detailed criteria for sample selection are outlined in the sample processing section. The remains from the Jiayi cemetery, located in an extremely arid desert environment, were better preserved than those from Houtaomuga, placed close to a river margin with moist soils. Specimens lacking erupted permanent molars or not in functional occlusion were excluded from the study sample. The proportion of infants lacking erupted first molars was higher in Houtaomuga compared to the other sites (Xiao, 2014). We chose permanent, fully erupted mandibular molars (M_1, M_2, and M_3) with measurable patches of occlusal dentin exposure.

Before this research, skeletal samples from Banlashan and Dunping were aged and sexed by one of us (SY) using a combination of skeletal markers. These included dental eruption patterns, decay stages of the pubic symphysis and ilium auricular surfaces, cranial suture closure stages, and upper and lower limb bone epiphyseal fusion. The standard skeletal markers we employed are described by Buikstra and Ubelaker (1994), as well as for Chinese skeletal remains by Wu et al. (1984) and Shao (1985). These markers are also detailed by He (2015) and Xiao (2014).

Archaeological and Ecological Background

Around 5500 BCE, during the Late Neolithic, a significant cooling event occurred in the ecologically fragile zone of northern China. This event stimulated the development of agricultural practices, marked by the introduction of tools such as stone plows (Teng, 2013). However, in the Great Wall area, subsistence patterns gradually

Table 1 Available skeletal and dental samples by site, sex, and tooth type

Site	Period	ka BP	N_t	N_s				N_m $(D>0)$			
				♀	♂	?	All	M_1	M_2	M_3	All
Houtaomuga A	Neolithic	12–2.7	29	1	9	3	13	11	9	1	21
Banlashan	Neolithic	7.5–5	44	16	8	1	25	17	11	–	28
Dunping	Bronze	2.5–2.3	83	22	40	0	62	16	8	–	24
Houtaomuga B	Bronze-Iron Age	2.7–1.7	88	15	23	1	39	34	27	5	66
Jiayi	Bronze-Iron Age	2.8–2.3	284	53	57	26	136	100	69	20	189
		All	528	107	137	31	275	178	124	26	328

ka BP thousands of years before present, *Nt* total number of burials, *Ns* well-preserved individuals by sex, *Nm* dental sample of lower molar teeth with dentin exposure ($D>0$)

GS(2016)2882

Fig. 1 Map of Chinese provinces indicating the location of the four sites studied: Houtaomuga (Neolithic to Liao and Jin dynasties, 12,000 BCE–1781 ACE, Jilin Province), Banlashan (Late Neolithic, 3200–3050 BCE, Liaoning Province), Dunping (Bronze Age, 546–283 BCE, Gansu Province), Jiayi (Late Bronze to Early Iron Age, 800–300 BCE, Xinjiang Province)

shifted from agriculture to a nomadic lifestyle during the transition from the Neolithic to the Bronze Age. Eventually, animal husbandry became the predominant economic strategy in many regions (Yang & Cao, 2007). During this transition, human populations from northern China exhibited a wide gradient in subsistence patterns, ranging from the nomadic civilizations of the Eurasian grasslands to the agricultural civilizations of the Central Plains. The dietary habits of these ancient populations varied greatly in terms of food consistency and abrasive potential. Both Dunping and Jiayi had nomadic economies, but their geographical environments and ecological constraints were completely different.

The Houtaomuga cemetery is located on the shores of Xinhuang Lake in Yonghe Village, Da'an City, in Jilin Province, south of the Songnen Plain, close to the intersection of the Nenjiang and Songhua rivers (Fig. 1). From an archaeological perspective, the Houtaomuga site spans seven phases, from the Early Neolithic period (12,000 BCE) to the Liao and Jin dynasties (960–1279 ACE) (Wang, 2018; Xiao, 2014). The subsistence strategy in northeastern China during the Neolithic was mainly based on fishing activities (Gao, 2021; Zhu, 2019). Carbon and nitrogen stable isotopic analyses (^{13}C, ^{15}N) indicated that freshwater fish were the major component of the diet of Houtaomuga during the Neolithic (A phase) (Kunikita et al., 2017). However, during the Bronze to the Early Iron Age (2700 BCE–1781 ACE), Houtaomuga (B phase) showed a nomadic lifestyle, mostly based on animal husbandry and seasonal harvesting (Kunikita et al., 2017; Wang, 2018; Xiao, 2014).

The Banlashan site is a Late Neolithic rubble mound cemetery located at Chaoyang in Liaoning Province in northeastern China (Fig. 1). It dates back to 3200–3050 BCE and belongs to the late period of the Hongshan culture. Analyses of ^{13}C and ^{15}N of the human skeletons suggested that the Banlashan people mainly consumed C4 plant foods and/or animals that ate C4 plants while few wild C3 plants were consumed and animal protein accounted for a high proportion of their diet (Zhang et al., 2017a, 2017b). Paleo-ethnobotany and zoo-archaeology studies have shown that foxtail millet (*Setaria italica*) and proso millet (*Panicum miliaceum*) were widely cultivated and were the main sources of plant foods (Sun & Zhao, 2013; Sun et al., 2016). Fishing, hunting of wild boars, deer and rabbits, and domestic pig livestock also occupied a significant portion of their food procurement activities (Chen, 2014; Suo & Li, 2013).

The Dunping cemetery in Zhang County in Gansu Province (Fig. 1), situated on a plateau with an altitude ranging between 2000 and 3000 m, is surrounded by mountains, rivers, and valleys (Mao et al., 2019). The environment in this area was highly diverse, with overall cold and dry climatic conditions, although the valley alluvial plains were expansive and lush (Jiang, 2011). The Dunping population occupied an array of ecosystems differing in land formation, climatic conditions, and natural resource availability. The archaeological assemblage of the Dunping cemetery belongs to the West-Rong culture system of the northern Bronze culture belt in the Warring States period, dated by ^{14}C to 546–283 BCE, a transitional period from a nomadic tradition to a farming culture (Mao et al., 2017, 2019).

The Jiayi population, located in the Turpan basin deep within the interior of the Eurasian continent, experienced extreme drought, high temperatures, and frequent sandstorms (Cheng et al., 2006), which favored fast-drying foods. The nomadic Jiayi population processed foods without water, resulting in hard, long-term preservation, and easy-to-carry *Ta-er-mi* (塔尔米) traditional food. This food was the preferred for migrating herdsmen (Liu et al., 2009), as also documented at the Yanghai cemetery (Liu, 2020) in Xinjiang, along the Silk Road, where unearthed tools were consistently used for processing coarse foods such as *Mi* cake (糜饼) and millet. The Jiayi cemetery in Turpan, Xinjiang Province (Fig. 1), has been dated to 800–300 BCE, both by typology and ^{14}C AMS (Wang, 2017; Xiao, 2018), from the *Subeixi* Late Bronze Age to the Early Iron Age archaeological cultures in the Xinjiang Uygur Autonomous Region. It is the only prehistoric culture found in the Turpan basin. Numerous tools have indicated a mainly hunting economy with small-scale farming (Wang et al., 2014). Environmental studies on Jiayi cemetery identified 14 plant remains, including weeds, such as wild foxtail millet (*Setaria viridis*), common reed (*Phragmites australis*), cockspur grass (*Echinochloa crusgalli*), and grains such as barley (*Hordeum vulgare*) and common millet (*Panicum miliaceum*). This evidence suggests that the Jiayi population supplemented their mainly nomadic and hunting economy with a small proportion of agricultural planning (Jiang et al., 2021; Li et al., 2013). The vegetation of northeastern China is highly sensitive to variations in the East Asian Monsoon (Zhou et al., 2002). Low-temperature events occurred eight times from 9200 to 600 cal. BP (Li et al., 2011). These events led to climatic

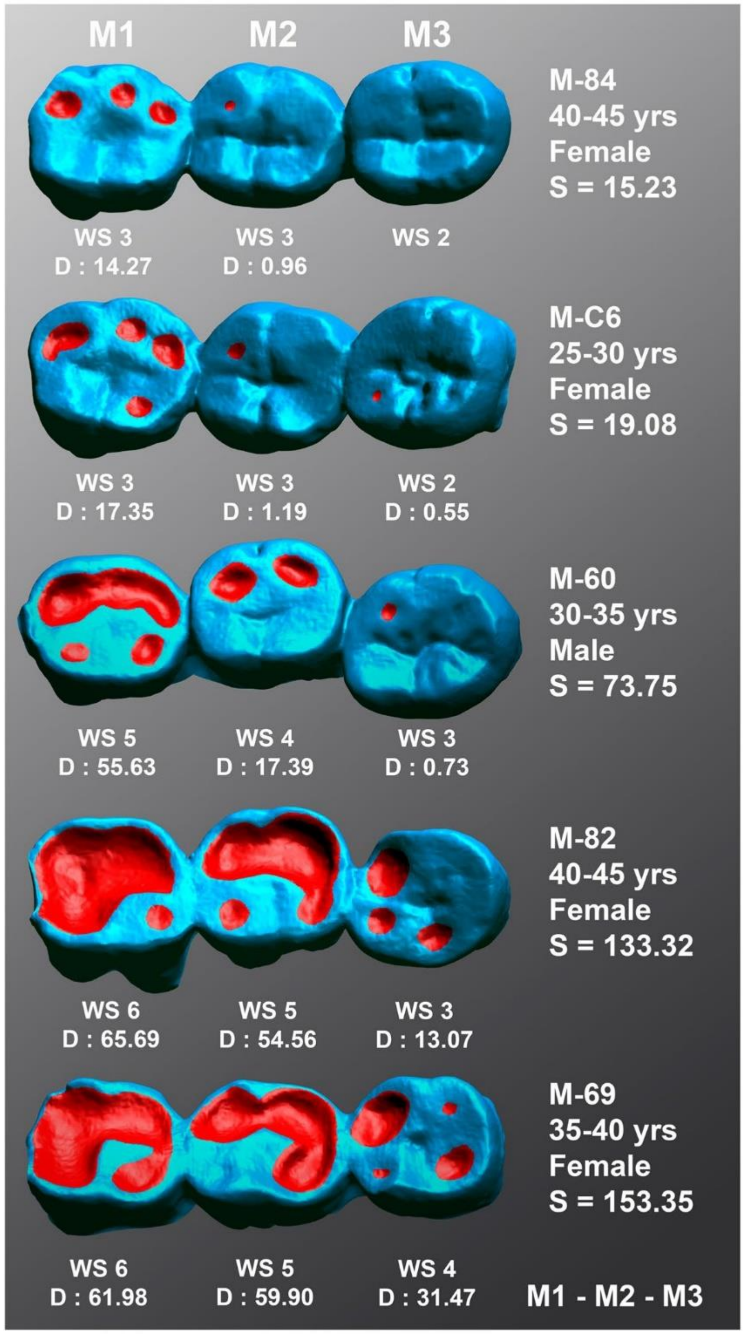
Fig. 2 Meshes of selected molar quadrants (M_1-M_2-M_3 from left to right) from adult individuals at Jiayi, ▶ displaying dentin exposure (red surfaces) ranging from lightly worn (top) to heavily worn (bottom). The wear score (WS) according to Smith's (1984), areas of dentin exposure (*D*) by tooth type, and the total sum of dentin exposure areas for the quadrant (*S*) are depicted. Specimen reference numbers and estimated age (years) are included; WS and *D* values for each tooth are indicated under respective molars. Mesial (left); buccal (top)

instability that may have contributed to changes in economic, social, and cultural conditions, as well as in the pathogen milieu. This could explain the high prevalence of linear enamel hypoplasia (Chen & Rong, 1998) observed in the Houtaomuga population, with an incidence of up to 72.73% during phases II and IV (Merrett et al., 2016; Xiao, 2014).

Sample Processing and Measuring

We molded dental quadrants, including lower molar teeth, following standardized protocols (Galbany et al., 2006) with 3M™ light-body polyvinylsiloxane impression material. We used Feropur PR55 polyurethane by Feroca™ for the positive casts of the molar teeth. Before polymerization, we centrifuged the molds for approximately 1 min at 800 rpm to prevent the formation of air bubbles. We obtained digital 3D meshes of all molar quadrants using a 3D EinScan SP2 Shinning™ scanner in *non-texture* mode, capturing eight scans per quadrant at 45° angles. We scanned each cast three times, capturing occlusal, buccal, and lingual views, and automatically fused them using the *surface topography* mode into a single point-cloud mesh. Afterward, we applied a slight smoothing filter to eliminate outlier points and exported the meshes to both a polygon (PLY) and an ASCII object (OBJ) file formats.

We derived two measures of occlusal dentin exposure for each molar tooth: a wear score (WS), recorded from the original molar using the eight-stage classification by Smith (1984), and the area of the dentin exposure surfaces on each molar (D, mm^2) (Fig. 2) using the *Shining* digital software. Additionally, we computed the overall sum of the dentin exposure surfaces for the molars in a mandibular quadrant ($S = D_{M1} + D_{M2} + D_{M3}$, mm^2). Both *D* and *S* represent 3D measures of surface topography and are measured in square millimeter units. We assigned an *S* value for a given quadrant only when the specimen met three conditions. First, the M_1 tooth had to be present and show dentin exposure; otherwise, we discarded the complete specimen. This condition allows the inclusion of subadult individuals in the sample, provided they have a fully erupted and worn first molar. Note that the focus is on the permanent molar tooth, not the individual. Secondly, the M_2 tooth was either present, showing or lacking dentin exposure (the absence of dentin exposure was recorded as a zero *D* value), or it had not yet erupted, in which case a zero *D* value was assigned. Third, and last, the M_3 was either present (in which case the M_2 should also be present) or absent exclusively due to not having yet erupted. We recorded a zero *D* value for the lack of dentin exposure in an observable molar tooth, while we considered a missing value when the tooth was absent not because of a lack of eruption. When a tooth row showed a missing value due to the absence of one or more molar teeth, and the cause of that absence was not attributed to non-eruption, we discarded


M1
M2
M3
M-84
40-45 yrs
Female
S = 15.23
WS 3
D : 14.27
WS 3
D : 0.96
WS 2
M-C6
25-30 yrs
Female
S = 19.08
WS 3
D : 17.35
WS 3
D : 1.19
WS 2
D : 0.55
M-60
30-35 yrs
Male
S = 73.75
WS 5
D : 55.63
WS 4
D : 17.39
WS 3
D : 0.73
M-82
40-45 yrs
Female
S = 133.32
WS 6
D : 65.69
WS 5
D : 54.56
WS 3
D : 13.07
M-69
35-40 yrs
Female
S = 153.35
WS 6
D : 61.98
WS 5
D : 59.90
WS 4
D : 31.47
M1 - M2 - M3

the entire quadrant and did not assign an S value. We treated each quadrant as an independent specimen to maximize sample sizes and because bilateral differences in dentin exposure within individuals are not likely to affect the regression models.

Statistical Modeling of Dentine Exposure

We refrained from conducting direct statistical comparisons of dentin exposure metrics between samples because the wear is an age-related variable that strongly depends on the age distribution of the skeletal samples considered. Instead, we developed least square regression models (Linear, Quadratic, and Power) of D onto both WS and S to analyze the regression of the two scoring proxies (WS and D) and to assess the contribution of the continuous measure of dentin exposure to the overall dentin exposure of the molar quadrant. Additionally, we used nonlinear regression models (Compound and Power) to examine the association between the estimated skeletal age (Age) and the 3D dentin exposure (D). Finally, we employed a Power regression model of D onto S (Eq. (1)) to estimate the relative contribution of each molar to the overall dentin exposure of the mandibular quadrant.

$$S = a\,D^b \tag{1}$$

$$\ln S = \ln a + b \ln D \tag{2}$$

This choice was made because the Power function can be directly transformed into a Linear function (Eq. (2)) by taking the logarithm (in this case, the natural logarithm) of the two variables ($\ln D$, $\ln S$). The intercept ($\ln a$) predicts the $\ln S$ value attained at the onset of the dentin exposure contribution of each molar tooth, and the slope (b) reflects the rate at which $\ln D$ contributes to the overall dentin exposure $\ln S$.

A physiological age (E) of an individual (based on the overall dentin exposure S) can be estimated if a significant regression model can be obtained between E and S. For this purpose, we tested several models and finally selected a linear one (Eq. (3)). By combining Eqs. (1) and (4), we can estimate a model-based age at death from the dentin exposure of each molar (Eq. (3)), as well as the expected dentin exposure (D) at any given age (Eq. (4)). Note that E is not the actual age at death of an individual but a predicted physiological age based on a given dentin exposure.

$$E = c + bS = c + baD^b \tag{3}$$

$$D = \sqrt[b]{\frac{E - c}{ba}} \tag{4}$$

Dentin Exposure Rates

From the ln-transformed Linear regression models of the three molars, we deduced average population overall wear rates for the age intervals between the onsets of dentin exposure for two consecutive molars. These age intervals, derived from molar eruption ages in modern *Homo sapiens* (Ash & Nelson, 2003), were a juvenile 6-year interval, from M_1 (5.5 years) to M_2 (11.5 years), and a subadult 7-year interval, from M_2 (11.5 years) to M_3 (18.5 years). Gilmore and Grote (2012) provide slightly smaller estimates of the age intervals: a 5.29-year juvenile interval for an average molar eruption age of 6.02 years for M_1 and 11.31 years for M_2, and a 6.56-year subadult interval, with an average eruption age of 17.87 years for M_3. It is worth noting that molar eruption ages can vary significantly among populations, particularly for M_3. We adopted the age intervals indicated by Ash and Nelson (2003); if these ranges were to be smaller or greater, the computed wear rates would represent under- or overestimations of actual rates, respectively.

We also computed wear rates for an overall age interval from the eruption of M_1 (5.5 years) to an adult age (E_m years) at which M_1 and M_2 exhibit equal dentin exposure areas (the D value of M_2 matched that of M_1). This interval encompasses both the juvenile and subadult intervals, as well as an adult period whose length may vary depending on the variation of wear rates within the intervals. We did not compute a separate wear rate for the adult interval alone because some samples lacked M_3 teeth showing dentin exposure.

While molar eruption undeniably occurs earlier than the onset of dentin exposure, we use molar eruption ages to define the age intervals. Thus, the span between eruption and the onset of dentin exposure of one molar is included at the beginning of the age interval considered for computing wear rates. We assume that the interval between the eruptions of two consecutive molars does not differ significantly from the interval between the onsets of dentin exposure for those same molars if the wear rate remains consistent within the short span from eruption to dentin exposure onset. Lower molar crown formation, crown eruption, and root completion ages in modern humans support consistent age intervals for average developmental events of consecutive molars (Ash & Nelson, 2003).

For each age interval, using the intercept ln a for each molar in the regression models in Eq. (2), $\ln S = \ln a + b \ln D$, for each molar, we computed two dentin exposure rates.

$$r_i = \frac{\ln a_{i+1} - \ln a_i}{12\,t} \tag{5}$$

$$w_i = \frac{a_{i+1} - a_i}{t} \tag{6}$$

The r (Eq. (5)) wear rate value is a monthly (divided by 12) percent (%) rate (r) of dentin exposure for a given age interval in years (t). This equation derives from the *compound interest rate* function $S_{i+1} = S_i e^{12rt}$, where the overall dentin exposure at the end of the interval (S_{i+1}, accrued capital) is a function of the wear rate (r, interest rate), the elapsed time (t, duration of the investment in years), and the dentin exposure at the beginning of the interval (S_i, invested capital). The accrued dentin exposure is a function of time that depends on the rate of accumulation in the same way as invested capital. In contrast, the w (Eq. (6)) wear rate (mm^2/year) represents the yearly change in dentin exposure for the age intervals considered (juvenile, subadult, or otherwise). The values ln a and a are obtained from the Linear model $\ln S = \ln a + b \ln D$ for each molar. Thus, r_1 and w_1 are wear rate measures for the juvenile interval, r_2 and w_2 refer to the subadult age interval, and r_m and w_m refer to the age interval from the eruption of M_1 to the adult E_m age at which M_1 and M_2 show the same D_m value of dentin exposure. To compute r_m and w_m, the D_m dentin exposure at age E_m is required and can be computed by equalizing the dependent variable (ln S) of the linear regression models ($\ln S = \ln a + b \ln D$) of two consecutive molars ($\ln S_{M1} = \ln S_{M2}$, Eq. 7). From this, we can compute the D_m value independently of the wear rates (Eq. (8)). The predicted age (E_m) at which M_1 and M_2 show the same dentin exposure areas (D_m) is used to define an adult age interval. This interval goes from $\ln S_{M3}$ to $\ln S_m$ (from age E_{M3} to E_m) ($\ln S_m = \ln a + b\ D_m$), in the same way that the subadult interval goes from $\ln S_{M2}$ to $\ln S_{M3}$ (from age E_{M2} to E_{M3}), and the juvenile interval goes from $\ln S_{M1}$ to $\ln S_{M2}$ (from age E_{M1} to E_{M2}). For each age interval, the wear rates are expressed as a percentage (%) of dentin exposure per month (r) or in mm^2 per year (w), so the length of the interval is not relevant for comparative purposes.

$$\ln a_{M1} + b_{M1} \ln D_m = \ln a_{M2} + b_{M2} \ln D_m \tag{7}$$

$$D_m = e^{\frac{\ln a_{M1} - \ln a_{M2}}{b_{M2} - b_{M1}}} \tag{8}$$

For comparative purposes, we computed the same dentin exposure rates for the *Coimbra International Exchange Collection*, XVIII-XIX c. from Portugal (Cunha & Wasterlain, 2007).

Estimation of Age at Death

The estimation of the age at death of any individual derives from a regression model between eruption ages and the dentin exposure area of the first molar. We used the eruption ages (E_i) of all three molars (5.5 for M_1, 11.5 for M_2, and 18.5 for M_3) as the dependent variable and the corresponding dentin exposure areas of M_1 as the independent variable. The D_i values were computed from Eq. (1) as $D_i = \sqrt[b]{\frac{S_i}{a}}$. We tested three regression models (Linear, Power, and Compound) to predict age at death (E) from the variables D, ln D, S, and ln S for the M_1 to determine which model and variable better predicted the available skeletal age (A). Eventually, the linear model $E = c + b(aD^b)$ was adopted (Eq. (3)). The estimated ages (E) for all individuals were correlated with the physiological skeletal age (A) available for the combined Chinese sample. For such an estimation of age at death to be reliable, the predicted ages need to be not only highly correlated (association) but also very close to the actual ages (precision). The estimation of the precision of an age prediction was not the objective of the present research, since only rough age estimation ranges of skeletal age were available, rather than precise ages, nor to say actual ages.

Measurement Error and Statistical Analyses

A single observer (SY) made all the D measurements by manually outlining the dentin exposure patches on the occlusal molar crown surface. Measuring errors may arise either by erroneously defining the dentin patch boundaries or by under or over-representing dentin patches. For testing possible biases in dentin exposure characterization between observers, a second observer (APP) reanalyzed the complete Jiayi specimens, the largest and best-preserved sample. APP independently applied the specimen selection criteria and measured again the newly selected specimens from the Jiayi samples. We performed paired t-test for sample mean comparisons between observers and computed anew the same wear rates for the duplicated sample.

A t-test (Eq. (9)) was used to compare slope values (b_i, b_j) between two samples (n_i, n_j) for the linear regression models $\ln S = \ln a + b \ln D$.

$$t = \frac{b_i - b_j}{\sqrt{e_i^2 + e_j^2}};\ d.f. = ni + nj - 4. \tag{9}$$

We used SPSS v.27 (IBM, Armonk, NY, USA, licensed to UB) for all statistical analyses. The significance level was set to $\alpha = 0.05$.

Results

A sample of 328 lower molars showed dentin exposure (Table 1). However, the sample sizes by molar type decreased from M_1 to M_3 in all the groups considered (Table 2). Since the posterior molars erupt later than the preceding molars, not all analyzed quadrants showed dentin exposure on M_3 or M_2, significantly reducing their sample sizes. Banlashan and Dunping lacked M_3 molars with dentin exposure.

Table 2 Summary statistics of the dentin exposure area by site, tooth, and sex

		Female			Male			All		
		N	Mean	SD	N	Mean	SD	N	Mean	SD
Banlashan	M_1	10	20.11	19.42	7	39.63	31.82	17	28.15	26.27
	M_2	5	14.78	22.80	6	23.59	32.45	11	19.59	27.49
Dunping	M_1	8	21.81	16.92	8	21.88	20.92	16	21.84	18.38
	M_2	5	14.38	6.47	3	25.83	20.39	8	18.68	14.22
Houtaomuga	M_1	14	31.05	21.23	30	49.15	26.72	45	42.50	26.65
	M_2	9	22.02	23.10	27	33.25	27.49	36	30.44	26.60
	M_3	3	5.40	2.67	3	6.04	3.41	6	5.72	2.76
Jiayi	M_1	38	36.46	25.08	46	52.87	27.13	100	42.00	27.90
	M_2	27	23.93	24.42	36	32.95	24.18	69	29.23	24.54
	M_3	10	13.71	10.67	8	16.26	14.05	20	14.83	11.39

N sample size, *Mean* average dentin exposure area (D, in mm^2), *SD* standard deviation of D

Houtaomuga A only showed one M_3 molar with dentin exposure and Houtaomuga B had five. These small sample sizes for M_3 led us to treat Houtaomuga as a single sample. Dentin exposure areas decreased from front to back (M_1–M_3), reflecting the later eruption age of the posterior molars. Males showed somewhat higher average D values than females for the three molars in all the populations considered (Table 2). We did not attempt comparisons of dentin exposure areas among groups due to the significant dependence of dentin exposure on the age distributions within each group, which varied considerably across samples. Furthermore, the dentin exposure areas (D) did not follow a normal distribution (Kolmogorov−Smirnov test, K–S) for M_1 ($N=178$, K–S$=0.135$, $P<0.001$) and M_2 ($N=124$, K–S$=0.124$, $P<0.001$), whereas for M_3, the test was not significant ($N=28$, K–S$=0.152$, $P=0.124$), likely due to its reduced sample.

Interobserver Measurement Error

Despite following the same sample selection criteria, the Jiayi sample selected by SY was larger ($N=164$; 88 M_1, 59 M_2, 17 M_3) than that measured by APP ($N=125$; 66 M_1, 40 M_2, 19 M_3) who discarded some cases for being damaged, heavily worn, or not showing clearly defined dentin exposure patches. All the t-test comparisons between observers, using paired measurements, were significant ($P<0.001$). In all cases, SY showed larger dentin exposure measurements than APP by tooth type: M_1 ($N=66$), $t=6.167$, 12.7% difference between observers; M_2 ($N=40$), $t=3.255$, 16.5%; M_3 ($N=19$), $t=3.436$, 37.5%. Despite the differences in average D values being significant, the measurements by the two observers were highly correlated: $r=0.983$ for M_1 ($F=1795.370$, $P<0.001$), $r=0.965$ for M_2 ($F=511.545$, $P<0.001$), and $r=0.777$ for M_3 ($F=25.828$, $P<0.001$). The parameters of the linear regression models of ln D over ln S (ln S = ln a + b ln D) by tooth type showed similar ln a and b values in both observers (Table 3). The slopes (b) of the models did not significantly differ between observers ($P=0.930$ for M_1, $P=0.974$ for M_2, and $P=0.954$ for M_3). The differences between the intercepts (ln a), a key factor for computing the wear rates, only differed between observers in 0.071 mm^2 for M_1, − 1.822 mm^2 for M_2, and 1.021 mm^2 for M_3. These differences resulted in dentin exposure rate divergences (Table 3) ranging from − 0.25 to 0.21%/month for the r_i values and from − 0.36 to 0.47 mm^2/year for the w_i values. All the dentin exposure rates computed for the age intervals considered were consistent in the two observers.

Dentin Exposure as a Wear Indicator

Overall trends of increasing dentin exposure (D) with wear score (WS) were observed in all molars for the combined sample (Fig. 3). However, when WS = 8, wear significantly impacted the molar root, and the dentin exposure area decreased. By tooth type (excluding the wear score value of 8), and for the entire sample, all three tested least square regression models between WS (independent variable) and D (dependent variable)—Linear, $D=b$ WS; Quadratic, $D=b$ WS $+ b_1$ WS^2; and Power, $D=$ WS^b—showed high significance

Table 3 Comparison of dentin exposure parameters between independent observers (SY and APP indicated as subindices) by tooth type (M_1, M_2, M_3)

	M_1	M_2	M_3		APP	SY	Dif
$\ln a_{APP}$	−0.108	2.852	3.942	r_1	4.11	4.36	−0.25
$\ln a_{SY}$	−0.190	2.952	3.922	r_2	1.51	1.35	0.16
a_{APP}	0.898	17.322	51.522	r_3	5.62	5.71	−0.09
a_{SY}	0.827	19.144	50.501	r_m	1.23	1.02	0.21
b_{APP}	1.111	0.465	0.302	w_1	2.74	3.05	−0.31
b_{SY}	1.138	0.490	0.334	w_2	5.70	5.23	0.47
t-test	0.088	0.032	0.058	w_3	8.44	8.28	0.16
P	0.930	0.974	0.954	w_m	4.21	4.57	−0.36

ln a and *b* intercept and slope (respectively) of the regression model $\ln S = b + \ln D$, *a* dentin exposure in mm^2 at the intercept, *t-test* parameter of the statistical test comparing the slopes of the two observers, *P* significance probability of the test (non-significant), r_1 wear rate (%/month) for the juvenile interval, r_2 wear rate (%/month) for the subadult interval, r_3 wear rate (%/month) for an adult interval from M_3 eruption to the E_m age (when M_1 and M_2 match their dentin-exposed surfaces), r_m wear rate (%/month) for the interval from the eruption of M_1 to the adult E_m age, w_1 wear rate (mm^2/year) for the juvenile interval, w_2 wear rate (mm^2/year) for the subadult interval, w_3 wear rate (mm^2/year) for an adult interval, w_m wear rate (mm^2/year) for the interval from the eruption of M_1 to the adult E_m age

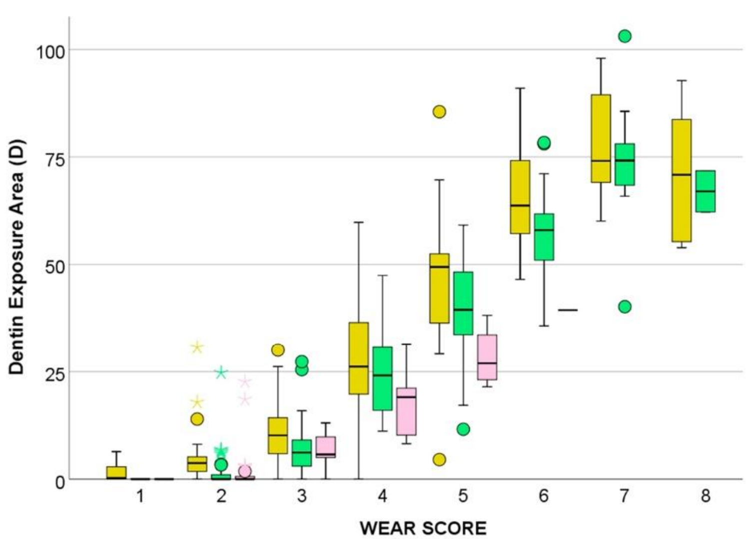


Fig. 3 Box plots of 3D dentin exposure areas categorized by wear score (from 1 to 8) and tooth type: M_1 (gold), M_2 (green), and M_3 (pink). Outliers are indicated by circles (95% confidence interval) or 5-point stars (99% confidence interval)

Table 4 Standardized least square regression models (Linear, Quadratic, Power)1 of the wear score (WS, independent variable) on the 3D dentin exposure (*D*, dependent variable)2 by site and tooth type

Site	Tooth	*N*	Model	R^2	*e*	*F*	*P*	*b*	b_1
Banlashan	M_1	17	Linear	0.866	14.316	103.579	< 0.001	8.676	1.813
			Quadratic	0.969	7.161	231.437	< 0.001	− 0.453	
			Power	0.985	0.382	1072.404	< 0.001	2.321	
	M_2	11	Linear	0.793	15.626	38.222	< 0.001	7.710	1.995
			Quadratic	0.964	6.860	120.599	< 0.001	− 2.416	
			Power	0.778	1.211	35.059	< 0.001	1.815	
Dunping	M_1	16	Linear	0.791	13.306	56.745	< 0.001	6.697	1.302
			Quadratic	0.828	12.479	33.785	< 0.001	1.000	
			Power	0.937	0.740	223.568	< 0.001	2.215	
	M_2	8	Linear	0.796	11.070	27.325	< 0.001	4.560	1.711
			Quadratic	0.889	8.819	24.041	< 0.001	− 3.654	
			Power	0.982	0.398	388.541	< 0.001	1.888	
Houtaomuga	M_1	44	Linear	0.894	16.458	361.762	< 0.001	9.375	1.852
			Quadratic	0.947	11.736	377.010	< 0.001	− 0.934	
			Power	0.989	0.385	3725.412	< 0.001	2.269	
	M_2	35	Linear	0.822	16.667	156.688	< 0.001	7.598	2.130
			Quadratic	0.936	10.161	240.012	< 0.001	− 3.738	
			Power	0.949	0.704	626.776	< 0.001	2.034	
	M_3	6	Linear	0.923	1.894	60.301	< 0.001	2.059	0.187
			Quadratic	0.927	2.070	25.336	0.005	1.468	
			Power	0.981	0.255	263.473	< 0.001	1.621	
Jiayi	M_1	97	Linear	0.915	14.457	1027.777	< 0.001	9.728	1.458
			Quadratic	0.951	11.010	921.239	< 0.001	1.599	
			Power	0.982	0.466	5320.577	< 0.001	2.303	
	M_2	69	Linear	0.861	14.281	421.953	< 0.001	8.053	1.750
			Quadratic	0.930	9.420	529.592	< 0.001	− 1.015	
			Power	0.941	0.818	907.205	< 0.001	2.129	
	M_3	20	Linear	0.805	8.401	78.256	< 0.001	4.710	1.019
			Quadratic	0.841	7.786	47.617	< 0.001	0.607	
			Power	0.844	1.018	102.994	< 0.001	1.923	
All	M_1	174	Linear	0.896	15.143	1491.552	< 0.001	9.376	1.627
			Quadratic	0.946	10.994	1493.100	< 0.001	0.484	
			Power	0.981	0.469	9040.788	< 0.001	2.289	
	M_2	123	Linear	0.832	15.249	604.281	< 0.001	7.653	1.909
			Quadratic	0.928	9.780	822.346	< 0.001	− 2.269	
			Power	0.931	0.811	1563.317	< 0.001	2.062	
	M_3	26	Linear	0.767	8.140	82.140	< 0.001	4.259	1.175
			Quadratic	0.824	7.212	56.232	< 0.001	− 0.298	
			Power	0.857	0.906	150.438	< 0.001	1.868	

R^2 coefficient of determination, *e* standard error of the estimation, *F* statistic for the regression model, *P* probability of significance, *b* slope of the standardized regression models

[1]Linear, $D = b\text{WS}$; Quadratic, $D = b\text{WS} + b_1\text{WS}^2$, Power:$D = \text{WS}^b$

[2]Smith's (1984) score of 8 and the teeth lacking dentin exposure ($D=0$) were not considered for the regressions. The models with the highest R^2 and *F* values within each tooth are shown in bold

($P < 0.001$) (Table 4). The Linear model consistently exhibited the lowest performance, displaying a large dispersion of data (mean error), although still statistically significant. This implies that a nonlinear model might provide a better prediction of D from WS. The nonlinear regressions by samples largely overlapped for M_1 (Fig. 4A). However, for M_2, the Dunping sample ($N = 8$) displayed a somewhat flatter curve (Fig. 4B). Regarding M_3, only Jiayi ($N = 20$) and Houtaomuga ($N = 6$) data could be plotted (Fig. 4C). The Power function exhibited the smallest standard error of the estimation (e) and explained the highest percentage of the total variance (R^2, coefficient of determination) in all samples except for the M_2 of Banlashan (Table 4). Despite the macroscopic scoring of wear being a standard bio-archaeological practice, discrete wear scores appear to artificially compress a wide range of variability in a continuous measure of dentin exposure.

Dentin Exposure as an Age Estimator

The actual ages at death of the studied individuals were unknown. However, archaeologically estimated ages derived from skeletal markers enabled the testing of the hypothesis of a nonlinear relationship of the variable D over time. Since the bio-archaeological estimations of age at death provided age ranges instead of precise ages, for simplification of this analysis, we used the midpoint of the estimated age interval for each individual as a rough measure of skeletal age, rather than the actual, unknown age at death. Nevertheless, D increased in all molars as individuals aged and exhibited a significant correlation ($P < 0.001$) with both wear scores ($r = 0.907$ for M_1, $r = 0.914$ for M_2, and $r = 0.778$ for M_3) and archaeologically estimated ages ($r = 0.623$ for M_1, $r = 0.431$ for M_2, and $r = 0.002$ for M_3, $P = 0.992$); this last correlation was not significant for M_3.

Both the Compound ($D = a\ b^{\text{Age}}$) and the Power ($D = a\ \text{Age}^b$) regression models between D and Age were highly significant (Table 5) using the Linear models derived from the ln-transformed variables. Overall, the Compound models ($\ln D = \ln a + \text{Age} \ln b$) showed larger R^2 values (75.2–98.9%) than the Power ones ($\ln D = \ln a + b \ln \text{Age}$) (48.2–96.5%). The Compound model explained a larger percentage of the total variance than the Power model for most analyses (6 of the 10 tests made), except for Dunping M_2, Houtaomuga M_1 and M_3, and Jiayi M_3. For the complete joint sample, the Compound model performed better for M_1 ($N = 165$) and M_2 ($N = 113$), while the Power model performed somewhat better for M_3 ($N = 23$). The Linear model ($D = a + b$ Age, not shown in Table 5) always performed the least in all groups, suggesting that a nonlinear model better explained the relationship between age and dentin exposure.

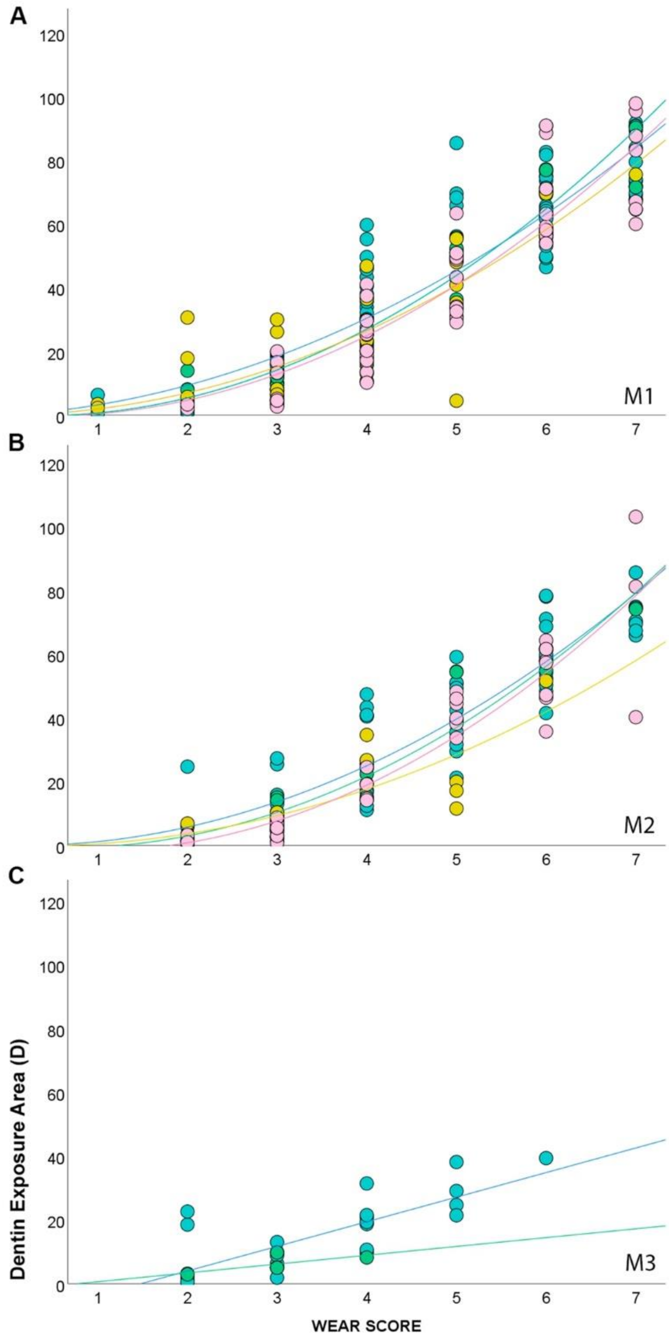


Fig. 4 Plots of dentin exposure areas (mm^2) (*Y*-axis) by wear scores (from 1 to 7, *X*-axis) across sites (Banlashan in green, Dunping in gold, Houtaomuga in pink, Jiayi in blue), and tooth type (**A** M_1, **B** M_2, **C** M_3). Exponential regression lines are displayed for each site. Wear score 8 was excluded as it pertains to the root of the molar teeth after the complete wear of the crown. M_3 data were unavailable for Dunping and Houtaomuga

Table 5 Standardized least square regression models (Compound, Power)[1] of the skeletal age (Age, independent variable) on the 3D dentin exposure area (*D*, dependent variable), by site and tooth

Site	Tooth	*N*	Model	R^2	*e*	*F*	*P*	*b*
Banlashan	M_1	17	**Compound**	0.978	0.469	707.430	<0.001	1.097
			Power	0.932	0.820	220.217	<0.001	0.855
	M_2	11	**Compound**	0.567	1.691	13.106	0.005	1.053
			Power	0.482	1.850	9.318	0.012	0.481
Dunping	M_1	16	**Compound**	0.932	0.772	204.207	<0.001	1.090
			Power	0.914	0.866	158.935	<0.001	0.803
	M_2	8	Compound	0.958	0.615	158.596	<0.001	1.078
			Power	0.965	0.555	195.821	<0.001	0.773
Houtaomuga	M_1	44	Compound	0.959	0.732	1002.728	<0.001	1.139
			Power	0.962	0.701	1097.214	<0.001	1.085
	M_2	35	**Compound**	0.848	1.212	188.989	<0.001	1.102
			Power	0.838	1.249	176.135	<0.001	0.840
	M_3	6	Compound	0.881	0.645	36.842	0.002	1.057
			Power	0.925	0.512	61.489	<0.001	0.492
Jiayi	M_1	88	**Compound**	0.953	0.744	1765.687	<0.001	1.119
			Power	0.939	0.848	1339.230	<0.001	1.002
	M_2	59	**Compound**	0.818	1.313	260.244	<0.001	1.087
			Power	0.780	1.444	205.292	<0.001	0.780
	M_3	17	Compound	0.673	1.513	32.873	<0.001	1.062
			Power	0.701	1.447	37.477	<0.001	0.608
China (all)	M_1	165	**Compound**	0.940	0.826	2583.000	<0.001	1.117
			Power	0.936	0.856	2396.850	<0.001	0.996
	M_2	113	**Compound**	0.800	1.341	446.759	<0.001	1.086
			Power	0.777	1.413	390.971	<0.001	0.766
	M_3	23	Compound	0.700	1.328	51.321	<0.001	1.061
			Power	0.726	1.270	58.204	<0.001	0.581

The models with the highest R^2 and *F* values within each tooth are shown in bold

R^2 coefficient of determination, *e* standard error of the estimation, *F* statistic for the regression model, *P* probability of significance, *b* slope of the standardized regression models

[1]Compound, $D = b^{\mathrm{Age}}$; Power, $D = \mathrm{Age}^b$

Group Comparisons Using the Power Function

The Linear regression models $\ln S = \ln a + b \ln D$ (derived from the Power model) showed highly significant ($P < 0.005$) R^2 values (ranging from 0.720 to 0.984) for all the molars and samples (Table 6), except for Houtaomuga M_3 ($N = 6$, $R^2 = 0.004$, $P = 0.910$) and for the Coimbra comparative sample M_3 ($N = 6$, $R^2 = 0.631$, $P = 0.059$). These results are indicative that *D* is a reliable predictor of *S* provided the sample sizes for each molar are large enough.

The slopes (*b*) of the linear model for M_1 were significantly larger than one ($P < 0.001$) in all four Chinese samples (Table 7), ranging from 1.167 to 1.198.

Table 6 Linear least square regression models between ln *S* (dependent variable) and ln *D* (independent variable) by site and tooth type (ln $S = \ln a + b \ln D$)

		N	*r*	R^2	*e*	*F*	*P*
Banlashan	M_1	17	0.992	0.984	0.154	909.6	< 0.001
	M_2	11	0.849	0.720	0.534	23.2	< 0.001
Dunping	M_1	16	0.987	0.973	0.196	508.7	< 0.001
	M_2	8	0.915	0.836	0.258	30.7	0.001
Houtaomuga	M_1	44	0.987	0.973	0.182	1535.6	< 0.001
	M_2	35	0.925	0.856	0.256	195.7	< 0.001
	M_3	6	0.060	0.004	0.584	0.014	0.910*
Jiayi	M_1	97	0.985	0.971	0.219	3174.2	< 0.001
	M_2	69	0.892	0.795	0.341	260.2	< 0.001
	M_3	20	0.857	0.734	0.280	49.7	< 0.001
China (all)	M_1	174	0.987	0.974	0.201	6350.0	< 0.001
	M_2	123	0.885	0.784	0.350	438.0	< 0.001
	M_3	26	0.758	0.575	0.365	32.5	< 0.001
Coimbra[1] (Portugal)	M_1	123	0.977	0.955	0.262	2586.0	< 0.001
	M_2	37	0.717	0.514	0.754	37.0	< 0.001
	M_3	6	0.795	0.631	0.550	6.9	0.059*

N sample size, *r* Pearson's correlation coefficient, R^2 coefficient of determination, *e* standard error of the regression model, *F* statistic for the regression, *P* significance probability of the regression model

*Non-significant *P* values

[1]Coimbra International Exchange collection, Coimbra (Portugal)

These slopes did not differ significantly among the samples (*t*-test, *P* ranging from 0.399 to 0.899). The slopes of the linear models varied greatly for M_2, with the Dunping sample showing the highest value ($b = 0.812$), significantly differing from the other three samples (Table 7): Banlashan ($b = 0.425$, $P = 0.039$), Jiayi ($b = 0.454$, $P = 0.019$), and Houtaomuga ($b = 0.470$, $P = 0.029$). The slopes for these three samples did not differ significantly from each other ($P = 0.636$ for the Banlashan-Houtaomuga comparison, $P = 0.717$ for Houtaomuga-Jiayi, and $P = 0.757$ for Banlashan-Jiayi).

The regression models by tooth type and site for the ln-transformed variables showed a strong relationship between the intercepts (ln *a*) and the slopes (*b*). The M_1 teeth had the largest slopes and the smallest intercepts, the M_2 teeth had intermediate slope and intercept values, and the M_3 teeth had the largest intercepts and the lowest slopes. For M_2, the Dunping sample showed distinct values for *b* and ln *a* (Table 7). This overall trend is consistent with the greater intercept values and smaller slopes of later erupting molars.

For the joint sample (Table 7, Fig. 5 top left), M_1 showed the largest slope ($b = 1.173$) and the smallest intercept ($\ln a = -0.296$), followed by M_2 ($b = 0.458$, $\ln a = 2.950$), and then M_3 ($b = 0.337$, $\ln a = 3.876$). Consequently, the three regression lines tended to converge to a point where all molars would show the same *D* values. This indicates that the three molars do not expose their dentin at the same

Table 7 Linear least square regression models between ln S (dependent variable) and ln D (independent variable) by site and tooth type (ln S = ln a + b ln D)

Genus		*ln a*	t_i	P_i	*b*	e_s	t_s	P_s
Banlashan	M_1	-0.357	-3.0	0.009	1.181	0.039	30.2	<0.001
	M_2	2.994	13.8	<0.001	0.425	0.088	4.8	<0.001
Dunping	M_1	-0.215	-1.5	0.166*	1.160	0.051	22.6	<0.001
	M_2	1.609	3.9	0.008	0.812	0.147	5.5	0.001
Houtaomuga	M_1	-0.365	-3.4	0.002	1.198	0.031	39.2	<0.001
	M_2	2.874	28.0	<0.001	0.470	0.034	14.0	<0.001
	M_3	4.115	4.5	0.011	0.064	0.536	0.12	0.910*
Jiayi	M_1	-0.284	-3.9	<0.001	1.167	0.021	56.3	<0.001
	M_2	3.026	35.0	<0.001	0.454	0.028	16.1	<0.001
	M_3	3.956	33.7	<0.001	0.329	0.047	7.1	<0.001
China (all)	M_1	-0.296	-5.9	<0.001	1.173	0.015	79.7	<0.001
	M_2	2.950	44.9	<0.001	0.458	0.022	20.9	<0.001
	M_3	3.876	27.8	<0.001	0.337	0.059	5.7	<0.001
Coimbra[1] (Portugal)	M_1	0.080	2.3	0.024	1.027	0.020	50.6	<0.001
	M_2	1.792	11.4	<0.001	0.735	0.121	6.1	<0.001
	M_3	2.545	8.6	0.001	0.657	0.251	2.6	0.059*

ln a intercept of the linear model for ln $D=0$, t_i Student's t statistic for the null hypothesis ln $a=0$, P_i significance probability for the null hypothesis ln $a=0$, b slope of the regression model, e_s standard error of the slope, t_s Student's t statistic for the null hypothesis $b=0$, P_s significance probability for the slope

*Non-significant P values

[1]Coimbra International Exchange collection, Coimbra (Portugal)

rates; overall, M_3 wears at a faster, non-constant rate compared to M_2, and M_2 wears faster than M_1. This overall pattern was observed in all the samples considered. The regression slopes and intercepts for M_1 were almost identical across all four skeletal collections (Table 7, Fig. 5 top right). For M_2, however, the Dunping sample showed a significantly larger slope and a smaller intercept compared to the other sites (Table 7, Fig. 5 bottom left). Sample sizes for M3 were too small for population comparisons (Table 7, Fig. 5 bottom right). Assuming identical dentin exposure onset ages in all four Chinese samples, Dunping exhibited less dentin exposure at the eruption of M_2 than the other samples, indicating reduced wear rates for this sample. The combined sample of all Chinese specimens showed an ln a value of 2.950, equivalent to $a=19.1$ mm^2 of dentin exposure for M_1 at the onset of dentin exposure for M_2. These values were 2.994 (20.0 mm^2) for Banlashan, 2.874 (17.7 mm^2) for Houtaomuga, and 3.026 (20.6 mm^2) for Jiayi, while Dunping showed a reduced intercept value of 1.609 (5.0 mm^2) (Table 7).

Wear Rates Within Age Intervals

Overall wear rates were higher in the juvenile interval ($r_1=4.51$%/month and $w_1=0.834$ mm^2/year) than in the subadult interval ($r_2=1.29$%/month and $w_2=0.420$

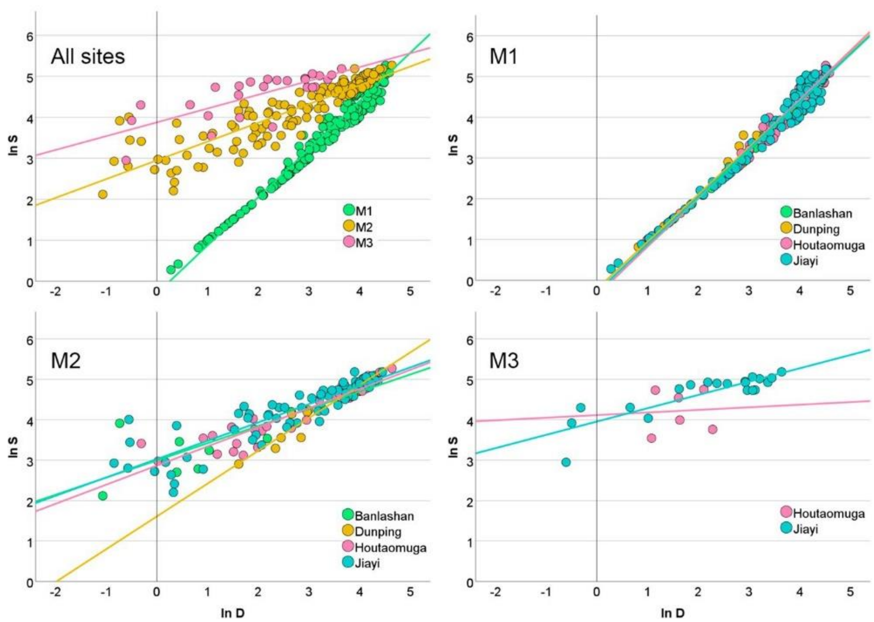


Fig. 5 Contribution of dentin exposure (ln *D*, *X*-axis) to cumulative dentin exposure (ln *S*, *Y*-axis) by molar type (M_1, M_2, M_3) and sites; intercepts with the vertical axis (ln *a*) for ln $D=0$ ($D=1$ mm^2) are indicated. Top left: joint sites by tooth type (M_1 green, M_2 gold, M_3 pink); top right: M_1 by site (Banlashan green, Dunping gold, Houtaomuga pink, Jiayi blue); bottom left: M_2 by site; bottom right: M_3 by site

Table 8 Wear rate estimations *r* (%/month) and *w* (mm^2/year) derived from the linear regression model $E=c+pD$ using the data in Table 7. r_1 and w_1 show the dentin exposure rates for the 6-year interval from 5.5 to 11.5 years (juvenile interval); r_2 and w_2 show the dentin exposure rates for the 7-year interval from 11.5 to 18.5 years (subadult interval); r_m and w_m show the dentin exposure rates for the interval from 5.5 years to the E_m adult age; D_m is the dentin exposure of M_1 and M_2 at age E_m; E_m is the age at which *D* is equal in M_1 and M_2; S_m is the predicted *S* value at age E_m; *c* is the intercept and *p* is the slope of the regression model $E=c+pD_{M1}$

	r_1	r_2	r_m	w_1	w_2	w_m	D_m	E_m	S_m	c	p
Banlashan	4.65	–	1.41	3.21	–	4.21	84.14	36.51	131.35	5.127	0.373
Dunping	2.53	–	0.17	0.70	–	1.19	188.93	300.93	352.48	3.928	1.572
Houtaomuga	4.50	1.48	1.66	2.84	6.22	5.34	85.56	32.22	143.32	5.869	0.308
Jiayi	4.60	1.11	1.24	3.31	4.52	4.65	103.79	41.81	169.63	5.273	0.352
China (all)	4.51	1.10	1.25	3.06	4.16	4.29	93.68	40.92	152.82	5.233	0.381
Coimbra[1]	2.38	0.90	0.33	0.82	0.96	2.89	351.78	82.71	446.44	5.714	0.438

[1]Coimbra International Exchange Collection, XVIII-XIX c., Coimbra (Portugal)

mm^2/year), indicating that M_1 wore fast when it was the only molar involved in food processing. After the eruption of M_2, the overall rates of dentin exposure decrease in the subadult interval. Houtaomuga and Jiayi exhibited this same trend and similar wear rates for both periods. Banlashan and Dunping had no third molars with dentin exposure, so we computed wear rates only for the juvenile period (Table 8). Banlashan showed wear rates similar to those of Houtaomuga and Jiayi, whereas Dunping showed smaller wear rates ($r_1 = 2.53\%$/month and $w_1 = 0.240$ mm^2/year). The reduced wear rates in Dunping resulted in an increased D_m value (188.93 mm^2) at age E_m compared to the other samples (Table 8). With smaller wear rates, M_1 and M_2 require a longer time to reach the same D_m value, consequently resulting in greater dentin exposure areas at age E_m. The E_m age for Dumping was 300.93 years, clearly beyond life expectancy (which indicates reduced wear rates for this sample), followed by Jiayi (41.81 years), Banlashan (36.51 years), and Houtaomuga (32.22 years). The comparative Coimbra sample showed an E_m age of 82.71 years, indicating smaller wear rates than the Chinese samples except for Dunping.

Dentin Exposure and Age-at-Death Estimation

The estimation of age at death (E) for the combined Chinese sample required prior knowledge of how to predict E from D (Eq. (3)). The three regression models tested (Linear, Power, Compound) used the molar eruption ages (E) as the dependent variable (5.5 years for M_1, 11.5 years for M_2, and 18.5 years for M_3). As the independent variable, we used the dentin exposure area (D, in mm^2) to predict age (E). The D values were computed using Eq. (4): D was 1.00 mm^2 for M_1, 15.92 mm^2 for M_2, and 35.05 mm^2 for M_3. Only the Linear model ($E = c + pD$) for the non-ln-transformed E and D variables yielded a statistically significant regression for predicting age at death from the dentin exposure of M_1 ($p = 0.381$, $c = 5.233$; $R^2 = 0.999$, $F = 1370.5$, $P = 0.017$; $E = 5.233 + 0.381D$). We used this model to estimate the E_m age at which both the M_1 and M_2 teeth showed the same D_m value (obtained from Eq. (8)). Thus, the equation $E_m = 5.233 + 0.381D_m$ predicted an E_m value of 40.92 years to reach a D_m dentin exposure value of 93.68 mm^2 of dentin exposure in the whole Chinese sample. By population (Table 8), the E_m ages were 36.51 years ($D_m = 84.14$ mm^2) for Banlashan, 32.22 years ($D_m = 85.56$ mm^2) for Houtaomuga, and 41.81 years ($D_m = 103.79$ mm^2) for Jiayi, all three samples closely resembling each other. However, Dunping showed an E_m age of 300.93 years ($D_m = 188.93$ mm^2), a value beyond life expectancy, indicating that Dunping exhibited the smallest dentin exposure rates.

The overall r_m and w_m wear rates, encompassing all age periods (juvenile, subadult, and adult until the E_m age), were 1.25%/month and 4.16 mm^2/year, respectively. However, these values for Dunping were considerably smaller, 0.17%/month and 1.19 mm^2/year, respectively, clearly deviating from the other samples (Table 8). The contemporaneous, European sample from Coimbra showed a w_m of 2.89 mm^2/year, a value 46% smaller than that observed for Houtaomuga (Table 8). The average E_m age at which M_1 and M_2 showed the same dentin exposure was 82.71 years for Coimbra, a much larger value than for the combined Chinese sample (40.92 years). As expected, for smaller wear rates, higher ages at which the two molars would match their dentin exposure areas are observed.

Discussion

Several significant results are drawn from the present research. Firstly, we demonstrate that molar dentin exposure throughout life follows a distinct statistical model. While various regression functions were significant, the Power function provided the smallest least square deviations, with the advantage that linear equations can be derived by applying a logarithmic transformation of the *D* and *S* data. Secondly, we show that the slopes of the regression models differed among the lower molars analyzed within a tooth quadrant, indicating that dentin exposure rates differ in molar teeth, with M_1 exhibiting the smallest rate and M_3 the largest. Finally, we suggest that differences in the intercept and slope values of the regression models, and in the derived wear rates, are indicative of activity patterns related to food abrasives, chewing forces, and masticatory biomechanics. The proxy proposed for analyzing wear rates has the advantage of dealing with a continuous variable, rather than discrete scores of dentin exposure. We measure 3D dentin exposure surfaces because dentin wears down in a third dimension (dentin wears faster than enamel) that a 2D measure does not consider. A 3D scanning equipment, increasingly affordable, provides easy-to-implement and fast tools for making a 3D measure of dentin exposure surfaces by defining the dentin patch perimeter in the same way as for obtaining a 2D measure.

Wear Rate Differences Among Population

Our analysis of populations from various cemeteries spanning extensive geographical regions and representing different time periods, distinct climatic conditions, resource availability, and food processing techniques yielded significant results. We observed high dentin exposure rates, which were overall similar despite their heterogeneity (with a w_m wear rate of 4.21 mm^2/year in Banlashan, 4.65 in Jiayi, and 5.34 in Houtaomuga). This homogeneity is consistent with the consumption of hard and tough diets in most samples, likely including extrinsic abrasives incorporated into foodstuffs during food processing. The combination of cold, arid, and dry environmental conditions is likely the primary cause of the high wear rates observed in these Chinese samples. However, the Dunping site, whose inhabitants occupied much more diverse habitats, clearly differed from the other sites, showing wear rates in line with the Coimbra sample. The methodological approach used distinguished Dunping from the other sites, revealing a significantly higher slope for the linear regression model for M_2. This finding is consistent with the warmer, less arid, although more diverse, habitats and ecological conditions reported for Dunping inhabitants, who occupied an array of ecosystems ranging from forested to grassland and desert environments. The diet of the nomadic population from Dunping, a Bronze to Early Iron Age site, might have been less abrasive compared to that of the other samples, including the earlier Neolithic samples (Banlashan, Houtaomuga A) and the contemporaneous Bronze to Early Iron Age samples (Jiayi, Houtaomuga B). However, no comparisons between Houtaomuga A and B could be made. The Houtaomuga sample exhibited the highest dentin exposure rates and E_m age, despite their linear regression slopes for M_2 did not differ significantly from the other Chinese samples. This observation is consistent with the broad environmental conditions reported for this site.

As designed, the 3D dentin exposure areas of molar teeth proved to be a good proxy for characterizing molar wear rates, allowing for interpopulation comparisons. The wear rate calculations proposed depend only on the knowledge of the length of equivalent age intervals for the compared samples. This new methodological approach to dentin exposure characterization, designed here for the Chinese samples, shows that the overall 3D dentin exposure area (S) is a Power function of molar dentin exposure (D). Dentin exposure of the three molars (S) increases as the molars erupt and come to full functional occlusion, thus contributing to molar crown wear. The observed trends in the three molars matching their dentin exposure areas support the hypothesis that the posterior molars wear faster than the preceding molars, at least for the studied modern human samples.

Although the first molar contributes the most to the overall dentin exposure, as it erupts earlier than the other molars, dentin exposure rates are necessarily faster in the rearmost molars, as suggested by the fact that their dentin exposure surfaces eventually match that of the first molar. The second molar wears faster than the first one, and the third one wears even faster than the second one, as their regression functions also eventually intersect. Greater enamel thickness within molars may provide greater resistance to wear (Macho & Spears, 1999). Grine (2002, 2005) found that enamel thickness increases along the molar row in modern human molars but did not detect significant differences among permanent molars. Smith et al. (2006) found that upper molars showed significantly greater average enamel thickness than lower ones and that average enamel thickness increased significantly from M_1 to M_3 in both molar rows. Thus, the distal change in enamel thickness might be functionally related to higher bite forces exerted distally along the tooth row. Mahoney (2013) showed that, for the decidual dentition, thicker enamel on molars where bite forces are greater, combined with a reduced proportion of dentin, should facilitate the highest bite forces along the tooth row, independently of crow size. Our research shows that the thicker enamel and reduced size of the posterior lower molars have not fully compensated for the greater bite loadings on the posterior dentitions. Thus, dentin exposure rates remain faster on the posterior lower molars compared to the anterior ones.

Dietary Interpretations

The new proxy described here is a promising approach for between-group comparisons of dentin exposure rates to characterize overall dietary habits or ecological conditions. However, researchers must meet some methodological requirements: the three molars in a tooth row need to be characterized (either for being present or not yet erupted), and only molars showing dentin exposure can be considered. Samples are frequently scarce or poorly preserved, and fragmentation by tooth type quickly reduces sample sizes, especially for the third molar when wear rates are small. Our initial available sample of 528 skeletons ultimately resulted in a sample of 26 M_3

teeth (20 from Jiayi and 6 from Houtaomuga). The other two sites, Banlashan and Dunping, lacked M_3 teeth either because they had not yet erupted, showed no dentin exposure, were damaged, or were lost *postmortem*. Short life expectancies and reduced wear rates, common in modern humans, cause M_3 to rarely show dentin exposure before death, as seen in the Coimbra sample. Despite these difficulties, the 3D dentin exposure proxy proves to be consistent and reliable for comparing wear rates among populations with distinct socioeconomic practices or varying dietary habits. The Chinese samples studied showed striking similarities in their molar wear rate patterns, with the exception of Dunping. This consistency is indicative of highly abrasive diets under harsh environmental conditions, unrelated to their distinct socioeconomic lifestyles—whether hunter-gatherers, agriculturalists, or nomadic pastoralists with a shift to a greater focus on secondary animal products. Despite there seeming to be no clear association between dentin exposure rates and site-specific lifestyles and economies, similarities in food processing across populations might explain the resemblances. Practices such as grinding or otherwise processing millet grain, or using certain cooking technologies, could swamp signatures related to different types of diets. Despite archaeological reconstruction revealing few food processing artifacts in the sites studied, the nomadic populations might have used small millstones seasonally. Communalities in foodstuffs consumed and food preparation technology might have a greater effect on dentin exposure than the type of subsistence strategy. This conclusion requires confirmation with larger and more dietary distinct populations.

Future research on the proposed methodology for characterizing dentin exposure rates on molar teeth should focus on intra- and interpopulation comparisons among hunter-gatherer, agriculturalist, and pastoralist modern human populations. This will test whether socioeconomic strategies and diets can be discriminated against by measuring 3D dentin exposure rates of molar teeth, thereby determining if distinct sociocultural practices can be identified using wear rates. Research also needs to demonstrate that dentin exposure models are independent of the age distribution within the available samples, ensuring that sample sizes remain representative. Additionally, studies should focus on non-human species with varying life expectancies to determine which statistical model better explains dentin exposure with age.

Estimation of Age at Death

Finally, the dentin exposure models designed here might also contribute to resolving the challenges associated with estimating the physiological age at death of isolated archaeological or paleontological specimens. A biological estimation of age, reflecting physiological factors affecting skeletal markers, may not strongly correlate with the actual chronological ages of an individual. Dentin exposure serves as a physiological, diet-related indicator of age rather than an exact predictor of age. However, the 3D dentin exposure approach offers a statistical model for age prediction that, while dependent on both diet and physiological constraints, could provide an age-dependent sequence of archaeological remains. This could be particularly valuable for specimens of unknown ages at death.

Skeletal samples from primate populations, including humans, with known ages are scarce. Comparisons between actual ages at death and age predictions based on dentin exposure are necessary to validate this proxy as a reliable age indicator. We anticipate that the correlation between dentin exposure-based ages and actual ages would be significant, but the precision of age predictions—measured by the distance between actual and predicted ages—would vary depending on the statistical model used and the strength of the relationship between physiological age and chronological age. Precision in age estimations also depends on factors such as sample heterogeneity, underscoring the need to segment samples based on relevant criteria.

Conclusions

The 3D dentin exposure area of each lower molar tooth in various modern human archaeological samples shows a significant association with the overall dentin exposure in the respective quadrant. This correlation allows for determining the intercept value of regression models as an indicator of molar dentin exposure onset ages. These findings help predict dentin exposure rates across age intervals, identify the age at which two molars reach similar dentin exposure areas, and estimate age at death using model-based approaches. The study reveals dentin exposure as a nonlinear, age-dependent process, shedding light on ecological conditions and dietary habits among the studied populations. Specifically, Chinese populations from Banlashan, Houtaomuga, and Jiayi exhibit high molar dentin exposure rates indicative of their environmental conditions. In contrast, the Dunping site sample shows significantly lower wear rates across all molars, consistent with their highly diverse ecological habitats.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10816-024-09664-7.

Acknowledgements The authors want to thank Mr. Ruilin Mao (Gansu Institute of Cultural Relics and Archaeology), Dr. Zenglong Xiong (Jinan University), Mr. Long Wang (Academy of Turfanology), and Dr. Lixin Wang (Jilin University) for providing the materials for this study.

Author Contribution S.Y. and J.G. studied the skeletal collections in China, and S.Y. made the dental molds and measured the scans. L.M. and A.R. contributed to the development of the methodological procedures. A.E.D. helped with the molding and scanning procedures. Q.Z. and A.P-P. funded the project. A.P-P. designed the research and made the interobserver error analyses. S.Y. wrote the initial draft, and A.P-P. wrote the paper. S.Y., L.M., and A.R. greatly contributed to the final manuscript. All authors reviewed the manuscript.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature. This research was supported by the Chinese Fundamental Research Funds for the Central Universities [Projects:*On the origins of Chinese civilization, No. 2020YFC1521607, and Migration, Cultural Integration and Environmental Adaptation of Ancient Populations along the Belt and Road Based on the Bio-archaeological Perspective, No. 2022CXTD17]; theGraduate Innovation Fund of Jilin University and China Scholarship Council Grant[fellowship 2022134 to SY]; theBio-archaeological Study on Human Skeletons Unearthed from Dunping Cemetery in Zhang County, Gansu Province[23XWB046]; and the SpanishMinisterio de Ciencia e Innovación(MCIN) and ERDFA way of making EuropeEU [PID2020-112963GGB-I00 grant to APP, Ref. MCIN/AEI/10.13039/501100011033], as well as theMargarita Salaspostdoctoral contract, funded by the SpanishMinisterio de Universidades,a Next GenerationEU grant to SC.*

Data Availability Raw data is provided in the supplementary information file.

Declarations

Competing Interests The authors declare no competing interests.

References

Ash, M., & Nelson S. (2003). *Wheele's dental anatomy, physiology and occlusion*. Sounders Ed.

Benazzi, S., Bonetti, C., Cilli, E., & Gruppioni, G. (2008). Molar crown height: Not always a reliable method for the evaluation of age-at-death. *Journal of Archaeological Science, 35*(8), 2371–2378. https://doi.org/10.1016/j.jas.2008.03.005

Broca, P. (1879). Instructions relatives à l'étude anthropologique du système dentaire. *Bulletins de la Société d'anthropologie de Paris*, III° Série. *Tome, 2*, 128–163. https://doi.org/10.3406/bmsap.1879.5212

Brothwell, D. R. (1963). *Digging up bones. British Museum Natural History, London*. Oxford University Press.

Buikstra, J. E., & Ubelaker, D. H. (1994). Standards for data collection from human skeletal remains. *Arkansas Archaeological Survey Research Series* N. 44, Arkansas.

Chen, J. (2014). *A research on faunal remains excavated from Haminmangha site in Inner Mongolia and related problem study*. Master dissertation, Jilin University, Changchun. https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD201402&filename=1014212419.nh. Accessed 13 June 2024

Chen, H., & Rong, W.S. (1998). The linear enamel hypoplasia of deciduous tooth. *Journal of Prevention and Treatment for Stomatological Diseases*, *3*, 59–60. https://kns.cnki.net/kcms2/article/abstract?v=VtJuiS_38noNIBZhMr5cvrCzj8HzbMKBwah8JA9nRVJtIseaTZIgLzksfT0PqC_CTvh_FqDAxlAedfGCYfDCEp5gbzaGJiDDNmOEycK-dNM-3V9nf0BOXQ==&uniplatform=NZKPT&language=CHS

Cheng, J., Zan, L., & Zhang, X. W. (2006). The Holocene vegetation and climate changes in the Turpan Basin of Xinjiang, China. In W. Dong (Ed.), *Proceeding of the Tenth Annual Meeting of the Chinese Society of Vertebrate Paleontology* (pp. 283–294). China Ocean Press.

Clement, A., & Hillson, S. (2012). Intrapopulation variation in macro tooth wear patterns – A case study from Igloolik, Canada. *American Journal of Physical Anthropology, 149*, 517–524. https://doi.org/10.1002/ajpa.22153

Cuesta-Torralvo, E., Pacheco, D., Martínez, L. M., Romero, A., Umbelino, C., Avià, Y., & Pérez-Pérez, A. (2021). Three-dimensional proxies to dental wear characterization in a known age-at-death skeletal collection. *Journal of Archaeological Method & Theory, 28*(4), 1261–1275. https://doi.org/10.1007/s10816-020-09496-1

Cunha, E., & Wasterlain, S. (2007). The Coimbra identified osteological collections. In G. Grupe & J. Peters (Eds.), *Skeletal series and their socio-economic context* (pp. 23–33). Verlag Marie Leidorf GmbH, Rahden/Westf.

Deter, C. (2009). Gradients of occlusal wear in hunter-gatherers and agriculturalists. *American Journal of Physical Anthropology, 138*, 247–254. https://doi.org/10.1002/ajpa.20922

Galbany, J., Estebaranz, F., Martínez, L. M., Romero, A., De Juan, J., Turbón, D., & Pérez-Pérez, A. (2006). Comparative analysis of dental enamel polyvinysiloxane impression and polyurethane casting methods for SEM research. *Microscopy Research Techniques, 69*(4), 246–252. https://doi.org/10.1001/jemt.20296

Gao, Y. (2021). *Cultural evolution and social development in Northeast China before 3,000 BC*. PhD Dissertation, Jilin University, Changchun. https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CDFDLAST2022&filename=1022426458.nh. Accessed 6 Aug 2024

Gilmore, C. C., & Grote, M. N. (2012). Estimating age from adult occlusal wear: A modification of the miles method. *American Journal of Physical Anthropology, 149*(2), 181–192. https://doi.org/10.1002/ajpa.22106

Górka, K., Romero, A., & Pérez-Pérez, A. (2016). Dental-macrowear and diet of Tigara foragers from Point Hope, northern Alaska. *Anthropologischer Anzeiger, 73*, 257–264. https://doi.org/10.1127/anthranz/2016/0613

Grine, F. E. (2002) Scaling of tooth enamel thickness, and molar crown size reduction in modern humans: Research letter. *South African Journal of Science*, *98*, 503—509. https://hdl.handle.net/10520/EJC97533. Accessed 6 Aug 2024

Grine, F. E. (2005). Enamel thickness of deciduous and permanent molars in modern *Homo sapiens*. *American Journal of Physical Anthropology, 126*, 14–31. https://doi.org/10.1002/ajpa.10277

He, L. T. (2015). *Stress for ancient population of Jiayi cemeteries in Turpan, Xinjiang Province*. Master's Dissertation, Jilin University, Changchun. https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD201502&filename=1015589698.nh. Accessed 6 Aug 2024

Jiang, C. N. (2011). *Researches on the archaeological culture and ethnicity of Bronze Age in the Region of Gansu & Qinghai*. Master's Dissertation, Dongbei Normal University, Changchun. https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD2012&filename=1012294136.nh. Accessed 6 Aug 2024

Jiang, H. E., Lv, E. G., & Zhang, Y. B. (2021). A consideration of the lifestyle of the ancient Yanghai people in Turpan. *Journal of the Turpan Studies*, *1*, 41–47+154. https://doi.org/10.14087/j.cnki.65-1268/k.2021.01.005

Kaifu, Y., Kasai, K., Townsed, G. C., & Richards, L. C. (2003). Tooth wear and the "design" of the human dentition: A perspective from evolutionary medicine. *American Journal of Physical Anthropology, 37*, 47–61. https://doi.org/10.1002/ajpa.10329

Kunikita, D., Wang, L. X., Onuki, S., Sato, H., & Matsuzaki, H. (2017). Radiocarbon dating and dietary reconstruction of the Early Neolithic Houtaomuga and Shuangta sites in the Song-Nen Plain, Northeast China. *Quaternary International, 441*, 62–68. https://doi.org/10.1016/j.quaint.2017.01.031

Li, C., Wu, Y., & Hou, X. (2011). Holocene vegetation and climate in Northeast China revealed from Jingbo Lake sediment. *Quaternary International, 229*(1–2), 67–73. https://doi.org/10.1016/j.quaint.2009.12.015

Li, Y., Li, X., Cao, H. Y., Li, C. C., Jiang, H. E., & Li, C. S. (2013). Grain remains from archaeological sites and development of oasis agriculture in Turpan, Xinjiang. *Chin Sci Bull, 58*(S1), 40–45. https://doi.org/10.1360/tb-2013-suppl017

Liu, J. (2020). *The social life of the former Yanghai people: Yanghai I cemetery from the Perspective of social archaeology*. Master's Dissertation, Xinjiang Normal University, Xinjiang: Urumqi. https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD202102&filename=1021554648.nh. Accessed 6 Aug 2024

Liu, Y. M., Cao, J., & Wang, X. (2009). Study on nutritional compoents of Ta-er-mi from a traditional food of Kazakh in Xinjiang. *Science & Technology Food Industry*, *30*(3), 310–312. https://doi.org/10.13386/j.issn1002-0306.2009.03.093

Lovejoy, C. O. (1985). Dental wear in the Libben population: Its functional pattern and role in the determination of adult skeletal age at death. *American Journal of Physical Anthropology, 68*(1), 47–56. https://doi.org/10.1002/ajpa.1330680105

Lucas, P. W., & van Casteren, A. (2015). The wear and tear of teeth. *Medical Principles and Practice, 24*, 3–13. https://doi.org/10.1159/000367976

Macho, G. A., & Spears, I. R. (1999). Effects of loading on the biomechanical behavior of molars of *Homo*, *Pan*, and *Pongo*. *American Journal of Physical Anthropology*, *109*, 211–227. https://doi.org/10.1002/(SICI)1096-8644(199906)109:2<211::AID-AJPA6>3.0.CO;2-B

Mahoney P. M. (2013). Testing functional and morphological interpretations of enamel thickness along the deciduous tooth row in human children. *American Journal of Physical Anthropology*, *151*, 518–525. https://doi.org/10.1002/ajpa.22289

Mao, R. L., Yang, Y. G., & Jiang, C. N. (2017). The excavation of Dunping cemetery in Zhangxian County, Gansu in 2014. *Archaeology*, *8*, 35–51. https://kns.cnki.net/kcms/detail/detail.aspx?FileName=KAGU201708003&DbName=CJFQ2017. Accessed 6 Aug 2024

Mao, R. L., Yang, Y. G., Zhao, W. C., Fu, W. X., & Cao, X. X. (2019). The excavation of Dunping cemetery in Zhangxian County, Gansu in 2015. *Cultural Relics*, *3*, 19–37. https://doi.org/10.13619/j.cnki.cn11-1532/k.2019.03.002

Merrett, D. C., Zhang, H., Xiao, X., Zhang, Q., Wei, D., Wang, L., Zhu, H., & Yang, D. Y. (2016). Enamel hypoplasia in northeast China: Evidence from Houtaomuga. *Quaternary International, 405*, 11–21. https://doi.org/10.1016/j.quaint.2015.06.004

Miles, A. E. W. (2001). The miles method of assessing age from tooth wear revisited. *Journal of Archaeological Science, 28*, 973–982. https://doi.org/10.1006/jasc.2000.0652

Murphy, T. (1959). The changing pattern of dentin exposure in human tooth attrition. *American Journal of Physical Anthropology, 17*(3), 167–178. https://doi.org/10.1002/ajpa.1330170302

Richards, L. C., & Brown, T. (1981). Dental attrition and age relationships in Australian Aborignals. *Archaeology in Oceania, 16*, 94–98.

Romero, A., Ramírez-Rozzi, F. V., Cuesta-Torralvo, E., & Pérez-Pérez, A. (2019). Age-related tooth wear in African rainforest hunter-gatherers. *American Journal of Physical Anthropology, 170*(4), 622–628. https://doi.org/10.1002/ajpa.23934

Rose, J. C., & Ungar, P. S. (1998). Gross dental wear and dental microwear in historical perspective. In Alt, K. W., Rosing, F. W., Teschler Nicola, M. (Eds.). *Dental Anthropology: fundamentals, limits, prospects* (pp. 349–386) Gustav-Fischer. https://doi.org/10.1007/978-3-7091-7496-8_19

Schmidt, C. W. (2010). On the relationship of dental microwear to dental macrowear. *American Journal of Physical Anthropology, 142*(1), 67–73. https://doi.org/10.1002/ajpa.21197

Shao, X. Q. (1985). *Anthropometric manual*. Shanghai Lexicographical Publishing.

Smith, B. H. (1984). Patterns of molar wear in hunger-gatherers and agriculturalists. *American Journal of Physical Anthropology, 63*(1), 39–56. https://doi.org/10.1002/ajpa.1330630107

Smith, T. M., Olejniczaka, A. J., Reidc, D. J., Ferrelld, R. J., & Hublin, J. J. (2006). Modern human molar enamel thickness and enamel-dentine junction shape. *Archives of Oral Biology, 51*, 974–995. https://doi.org/10.1016/j.archoralbio.2006.04.012

Sun, Y. G., & Zhao, Z. J. (2013). A comprehensive study on the plant remains from Weijiawopu site of Hongshan culture. *Agricultural Archaeology, 3*, 1–5.

Sun, Y. G., Zhao, Z. J., & Ji, P. (2016). The research of plant remains from Haminmangha prehistorical settlement site. *Huaxia Archaeology*, *02*, 45–52. https://doi.org/10.16143/j.cnki.1001-9928.2016.02.006

Suo, X. F., & Li, S. B. (2013). Neolithic animal remains in Liaoxi area. *Steppe cultural relics*, *1*, 43–49. https://doi.org/10.16327/j.cnki.cn15-1361/k.2013.01.001

Teng H. (2013). The environmental changes and the rise and decline of "culture" — Taking the West Liaohe River Basin in North China as the research object. (环境变迁与"文化"的兴衰——以中国北方西辽河流域为考察对象). *Knowledge, 1*, 29–33. https://doi.org/10.16435/j.cnki.cn22-1273/c.2013.01.002

Wang, C. (2017). *Archaeobotanical studies at the Jiayi cemetery and naked barely processing of early Iron Age in east part of Xinjiang*. Master's Dissertation, University of Chinese Academy of Sciences, Beijing.

Wang, L. (2018). Studies on the remains of the Neolithic Age in Houtaomuga site and relevant issues. *Acta Archaeologica Sinica*, *2*, 141–164. https://kns.cnki.net/kcms/detail/detail.aspx?FileName=KGXB201802001&DbName=CJFQ2018. Accessed 6 Aug 2024

Wang, L., Xiao, G. Q., Liu, Z. J., Lv, E. G., & Wu, Y. (2014). Brief report on excavation of Jiayi cemeteries in Turpan, Xinjiang. *Journal of the Turpan Studies*, *1–19*, 157–161. https://doi.org/10.14087/j.cnki.65-1268/k.2014.01.015

Wu, R. K., Wu, X. Z., & Zhang, Z. B. (1984). *Anthropometric methods*. Science Press.

Xiao, X. M. (2014). *A research on the human skeletons of Houtaomuga site, Da'an City, Jilin Province*. Ph.D. Dissertation, Jilin University, Changchun. https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CDFDLAST2015&filename=1015504223.nh. Accessed 6 Aug 2024

Xiao, G. Q. (2018). *The review and study of Jia Yi Cemetery in Turfan, Xinjiang*. Master's Dissertation, Northwest University, Xi'an. https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD201901&filename=1018119811.nh. Accessed 6 Aug 2024

Yang, J., & Cao, J. E. (2007). The culture development of ancient nomadic people in northern frontier of China. *Jilin University Journal of Social Science Edition*, *5*, 140–146. https://doi.org/10.15939/j.jujsse.2007.05.019

Zhang, X. L., Liu, G. X., Wang, M. H., & Lv, P. (2017a). Carbon and nitrogen stable isotope analysis of human skeletons unearthed from Xinglonggou site. *Cultural Relics in Southern China, 4*, 185–195. https://kns.cnki.net/kcms/detail/detail.aspx?FileName=LFWW201704030&DbName=CJFQ2017. Accessed 6 Aug 2024

Zhang, Q. C., Zhang, Q., & Han, T. (2017b). The stable isotope analysis of human skeletons from Banlashan cemetery, Chaoyang City, Liaoning province. In Xiong, Z. L., Fan, S. Y., Wu, Y. L., et al. (Eds.) *The excavation of Banlashan site of Hongshan archaeological culture in Chaoyang city,* *Liaoning Province* (vol. 2, pp. 31–34+2) Archaeology. https://kns.cnki.net/kcms/detail/detail.aspx?FileName=KAGU201702001&DbName=CJFQ2017. Accessed 6 Aug 2024

Zhou, G. S., Wang, Y. H., & Jiang, Y. L. (2002). Global change and water-driven IGBP-NECT, northeast China. *Earth Science Frontiers*, *9*(1), 198–216. https://kns.cnki.net/kcms/detail/detail.aspx?FileName=DXQY200201038&DbName=CJFQ2002. Accessed 6 Aug 2024

Zhu, M. (2019). *The Neolithic Age settlement and social from evolution in the Nenjiang River Basin*. Master Dissertation, Liaoning Normal University, Shenyang. https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD202001&filename=1019041217.nh. Accessed 6 Aug 2024

Authors and Affiliations

Shiyu Yang[1,2,7] · Laura M. Martínez[2,3] · Alejandro Romero[4] · Susana Carrascal[2,3,5] · Jie Guo[1] · Albert E. Dyowe[6] · Quanchao Zhang[1] · Alejandro Pérez-Pérez[2,3]

✉ Quanchao Zhang
py2000sdqy@sina.com

✉ Alejandro Pérez-Pérez
martinez.perez-perez@ub.edu

Shiyu Yang
yangshiyu2016@163.com

Laura M. Martínez
lmartinez@ub.edu

Alejandro Romero
arr@gcloud.ua.es

Susana Carrascal
susana.carrascal@gmail.com

Jie Guo
2890432476@qq.com

Albert E. Dyowe
albertepitie@gmail.com

1 School of Archaeology, Jilin University, Av. Qianjin 2699, 130012 Changchun, China

2 Dept. Biologia Evolutiva, Ecologia i Ciències Ambientals (BEECA), Universitat de Barcelona (UB), Av. Diagonal 643, 08028 Barcelona, Spain

3 Institut d'Arqueologia (IAUB), Universitat de Barcelona, Barcelona, Spain

4 Dept. Biotecnología, Universidad de Alicante (UA), Alicante, Spain

5 Dept. Biologia Animal, Biologia Vegetal i Ecologia (BABVE), Universitat Autònoma de Barcelona (UAB), Bellaterra, Spain

6 Dept. Prehistòria, Universitat Autònoma de Barcelona (UAB), Cerdanyola del Vallès, Spain

7 School of Archaeology and Literature, Chongqing Normal University, Av. 37 Daxuechenh Road, Shapinba, Chongqing 401331, China

6.2. EVALUATING A DENTIN EXPOSURE PROXY FOR WEAR RATES ESTIMATIONS ON MESOLITHIC AND NEOLITHIC POPULATIONS FROM THE NEAR EAST AND THE IBERIAN PENINSULA: A COMPARATIVE ANALYSIS.

The development of a new statistical indicator to measure dentine exposure rates in molars was evaluated as a potential reliable resource for inter-population comparisons on Yang et al. (2024).The analysis made in the following article (accepted) is focused on the dietary and socio-economic practices of ancient human populations from the Mesolithic and Neolithic periods in Southwest Asia and the Iberian Peninsula (Portugal and Spain), regions that showed distinct patterns of food production and ecological constraints.

By comparing attrition rates between the groups studied, clear regression models were obtained, which were aligned with previous dietary hypotheses, regardless of the age distribution of the specimens in the samples. The results revealed significant trends in wear rates across different periods and socio-economic practices. Dentine exposure rates, comparing molar eruption ages, were found to be higher in Mesolithic populations, mainly hunter-gatherer populations, compared to Neolithic populations, which were agriculturally oriented. Modern and contemporary samples exhibited the lowest attrition rates, while Natufian specimens demonstrated dentine exposure rates more closely similar to later Neolithic than “contemporary” Mesolithic samples from the same geographical area. In conclusion, the 3D proxy for dentine exposure rates permitted the comparison of archaeological samples, which were under-represented, thus offering a clear perspective for hypothesis testing in relation to dietary habits, lifestyle changes over time, or ecological constraints during the transition from a predominantly hunting and gathering lifestyle to a settled, agriculture-based Neolithic society.

Journal of Archaeological Science: Reports 61 (2025) 104936

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Evaluating a dentin exposure proxy for wear rates estimations on mesolithic and neolithic populations from the near East and the Iberian Peninsula: A comparative analysis

Susana Carrascal [a,b,c], Ferran Estebaranz-Sánchez [c], Albert E. Dyowe-Roig [d], Shiyu Yang [a,e], Claudia Umbelino [f], Bérénice Chamel [g], Miquel Molist [d], María Eulàlia Subirà [b], Alejandro Pérez-Pérez [a,c], Laura M. Martínez [a,c,*]

[a] Dept. Biologia Evolutiva, Ecologia i Ciències Ambientals (BEECA), Universitat de Barcelona (UB), Av. Diagonal 643, Barcelona 08028, Spain
[b] Dept. Biologia Animal, Biologia Vegetal i Ecologia (BABVE), Universitat Autònoma de Barcelona (UAB). Edifici C, Facultat de Biociències, 08193 Bellaterra, Barcelona, Spain
[c] Institut d'Arqueologia de la Universitat de Barcelona (IAUB), Fac. Geografia i Historia. Universitat de Barcelona (UB), Barcelona 08001, Spain
[d] Dept. Prehistòria, Universitat Autònoma de Barcelona (UAB), Edifici B. Campus de la UAB, 08193 Bellaterra (Cerdanyola del Vallès), Spain
[e] Present Address: School of Archaeology and Literature, Chongqing Normal University, Av. 37 Daxuechenh Road, Shapinba, Chongqing 401331, China
[f] Dept. of Anthropology, Universidade de Coimbra, Coimbra, Portugal
[g] Laboratoire Archéorient, Maison de l'Orient et de la Méditerranée. 7, rue Raulin, F-69365 Lyon cedex 07, France

ARTICLE INFO

Keywords:
Molar
Wear
Dentine
Mesolithic
Neolithic
Diet
Chewing

ABSTRACT

A new statistical proxy of analyzing dentin exposure rates of molar teeth, proposed as a reliable indicator for inter-population comparisons, was tested in relation to dietary habits and socioeconomic practices in ancient human populations from Mesolithic and Neolithic periods in the Near East and the Iberian Peninsula (Portugal and Spain) with distinct patterns of food production and ecological constraints. The comparisons of wear rates among groups provided distinct regressions models consistent with previous dietary hypotheses, independently from the age distribution of specimens within the samples. We found clear trends in wear rates among time-periods and socioeconomic practices. Dentine exposure rates between molar eruption ages showed higher values for the Mesolithic, mainly hunter-gatherer populations than the Neolithic, agriculturalist ones. The modern and contemporary samples showed the lowest wear rates, while the Natufian specimens showed dentin exposure rates more closely resembling the posterior Neolithic than the contemporaneous Mesolithic samples from the same geographical area. Overall, the 3D dentin exposure rates proxy allowed the comparison of archaeological, scarcely represented samples, offering clear insights into hypotheses testing in relation to dietary habits, lifestyle shifts through time, or ecological constraints in the transition from a predominantly hunting and gathering lifestyle to a settled, agriculture-based Neolithic society.

1. Introduction

Ecological constraints and socioeconomic practices have significantly influenced human diets, leading to variations in dental wear rates across past populations (Smith 1984, Oxilia et al. 2018). During the Natufian period in the Near East, a warm and stable climate enabled a diet heavily reliant on wild nuts, cereals and legumes, which included hard, minimally processed foods, potentially causing significant dental wear due to the abrasiveness of the grains (Mahoney 2006). The subsequent Neolithic revolution in the Levant brought about agricultural advancements and the domestication of plants and animals, leading to a more varied diet and softer foods (Shavit & Sharon 2023). The same dietary changes arrived to Europe later (Araus et al. 2024), eventually also reducing dental wear. In modern times, the evolution of food processing technologies, such as refined milling techniques and the introduction of processed and cooked foods, significantly decreased dental wear rates. Overall, ecological and climatic changes have driven shifts in diet and dental health, from the abrasive, unprocessed foods of early agricultural societies to the more refined and less wear-inducing diets of contemporary populations (Alday 2012; Pérez & Arribas 2013).

* Corresponding author.
E-mail address: lmartinez@ub.edu (L.M. Martínez).

https://doi.org/10.1016/j.jasrep.2024.104936
Received 10 September 2024; Received in revised form 9 November 2024; Accepted 15 December 2024
Available online 25 December 2024

2. Cultural and ecological transitions

2.1. The near East Natufian and Neolithic populations

The Natufian period in the Levant, ca. 13,000–9,600 BCE, occurred during a time of significant climatic instability at the end of the last Ice Age (Richter et al. 2017). As the climate warmed and ice sheets retreated after the Younger Dryas (10,900–9,700 BCE), the Levant featured dryer environments, with expanding oak (*Quercus calliprinos*) and pistachio (*Pistacia lentiscus*) woodlands and wild cereals like barley (*Hordeum vulgare* ssp. *spontaneum*) and emmer wheat (*Triticum dicoccum*), crucial to the Natufian diet (Henry 1989). The abundance of resources supported a semi-sedentary lifestyle, with communities likely moving seasonally to exploit different resources, leading to the development of more permanent settlements (Richter 2017; Weide et al. 2018). Abu Hureyra in modern-day Syria, although outside the Levant, provides a continuous record of human occupation from the Epipaleolithic (15,000–9,600 BCE) to the Pre-Pottery Neolithic (9,600–5,800 BCE) period (Smith et al. 2022). Initially, a seasonal settlement reliant on hunting gazelles (*Gazella dorcas*) and gathering wild cereals, the site reflects a broader transition to agriculture similar to the Levant. By 9,500 BCE, Abu Hureyra had evolved into a more permanent settlement with mud-brick houses and increasing reliance on domesticated crops and animals, indicating a shift from foraging to agriculture (Smith et al. 1984). The main domestic plants were emmer and einkorn wheat (*Triticum monococcum*), barley (*Hordeum vulgare*), peas (*Pisum sativum*), and lentils (*Lens culinaris*). Among animals species, sheep (*Ovis aries*), goat (*Capra aegagrus hircus*), and eventually cattle (*Bos taurus*) and pigs (*Sus scrofa domesticus*) were present. Climatic conditions at Abu Hureyra, like those in the Levant, became more stable and warmer post-Younger Dryas, promoting plant growth and animal life. The Euphrates River, enabling a diverse range of plant and animal resources, although less forested, sustained the region's semi-arid steppe environment. Both regions saw a shift towards semi-sedentary lifestyles and early plant domestication, laying the groundwork for agriculture (Bar-Yosef 1998; Smith et al. 2022).

In the Near East, the Neolithic Revolution marked a crucial shift to settled agricultural communities, driven by the more stable and warmer climate of the Holocene epoch around 9,600 BCE. Increased precipitation expanded vegetation zones, including grasslands and forests, which provided abundant food resources for early Neolithic communities. The Euphrates and Tigris river valleys offered fertile floodplains ideal for early agriculture, with wild crops gradually becoming the basis of cultivation. Alongside plant domestication, the period saw the full domestication of sheep, goats, and cattle, supporting the sedentary lifestyle of these communities. During the Pre-Pottery Neolithic B (PPNB) period in Syria (Akkermans 2004), large, permanent settlements with well-constructed buildings and communal spaces emerged, reflecting the shift to a more settled way of life. This transition brought significant social changes, including complex hierarchies, trade networks, and communal organization. The ability to store surplus food spurred population growth and larger communities. As agriculture became central, Neolithic communities modified the landscape through practices like forests clearing, irrigation, and terracing, which eventually led to environmental challenges, such as soil depletion and deforestation (Akkermans & Schwrtz 2003).

2.2. The Mesolithic to Neolithic transition in Europe

The transition from hunter-gatherer societies to agriculture in Europe shares some broad similarities with the Natufian–Neolithic transition in the Near East but also reveals key differences in climate, ecology, and cultural developments. Both regions experienced significant climatic changes, leading to warmer, more stable conditions that expanded forests and grasslands, increasing food availability. However, agriculture began much earlier in the Near East during the Natufian period, transitioning into the Neolithic by 9,000 BCE. In contrast, Europe's Mesolithic period persisted longer, with agriculture emerging around 5,500 BCE in Iberia. This shift in Europe was gradual and less uniform, involving interactions between indigenous Mesolithic hunter-gatherers and incoming Neolithic farmers from the Near East (Bicho et al. 2017). While Natufian sites show early plant cultivation and permanent structures, Mesolithic European sites generally do not. Agriculture in the Near East involved local domestication, whereas in Europe, migrating Neolithic populations introduced it. Mesolithic adaptations in the Iberian Peninsula reflect diverse environmental contexts. The Portuguese sites of Sado and Muge relied heavily on riverine and estuarine resources (Bicho et al. 2010; Bicho et al., 2013), similar to how Natufian sites exploited the Levantine corridor's resources. These coastal and river estuary locations offered abundant aquatic resources like fish, shellfish, and waterfowl, supporting more permanent settlements. In contrast, the Mesolithic site of La Oliva in Spain, despite also having evidences of shell middens, focused more on terrestrial resources within a continental environment (Gibaja et al. 2017a). This area, characterized by a mosaic of forests and grasslands, supported game animals like red deer (*Cervus elaphus*) and wild boar (*Sus scrofa*), which were vital for subsistence, highlighting a more mobile, hunting-focused lifestyle (Cubas et al. 2016; Zilhão 2001).

Neolithic settlements in the Iberian Peninsula and the Near East share the broad transition from hunter-gatherer to agricultural communities but differ significantly due to distinct ecological contexts. Near Eastern Neolithic settlements, concentrated in the Fertile Crescent, benefited from a Mediterranean climate and the fertile alluvial soils of the Tigris and Euphrates rivers, ideal for crop cultivation. In contrast, the Iberian Peninsula featured varied topography and climates, from Mediterranean coastal areas to cooler, wetter interiors. Agriculture arrived in Iberia around 5,500–5,000 BCE, influenced by migrating Neolithic farmers. Iberia's ecological diversity led to regional variations in Neolithic adaptations, with coastal areas adopting farming more readily than the challenging interior landscapes. Unlike the irrigation-based agriculture of the Near East, Iberian farming was mostly rainfed, limiting agricultural scale in some regions. While Iberian Neolithic settlements were near fertile land or rivers, they did not reach the size and complexity of those in the Near East (Alday Ruiz 2012).

The diet of post-Neolithic populations in Western Europe was more complex and varied than that of Neolithic societies, involving significant dietary changes due to advances in agriculture, food processing, and external influences from trade and conquest. By the Early Medieval period, 6th–11th centuries CE, agriculture provided a highly diverse diet (McClatchie et al. 2015) that included various grains (wheat, barley, rye), vegetables (onions, garlic, leeks), and fruits (apples, pears), and continued consumption of meat, dairy, and eggs. Improved food processing techniques, such as using mills for finer flour, led to softer bread and more palatable foods, and preservation methods like salting, smoking, and drying allowed for food storage and contributed to a more refined diet compared to the coarser, harder textures of the Neolithic diets (Pérez & Arribas 2013).

2.3. Dental wear and diet

Dental wear is a classical indicator of diet and lifestyle in ancient populations (Petraru et al. 2022), revealing insights into food consumption, preparation methods, and health of ancient communities (Molnar 1971; Molnar et al. 1983; Scott & Turner 1988), as well as non-dietary activities (Lukacs & Pastor 1988). The study of molar wear is crucial in bioarchaeology, offering a window into human adaptation to environmental and climatic conditions (Smith 1984; Walker and Erlandson, 1986). Dental wear is also an age-dependent process (Maat, 2001), involves enamel and dentin removal due to mechanical actions driven by dietary abrasiveness (Kaifu et al. 2003; Hilson et al. 2005; Romero et al. 2019). This wear results from various mechanisms (Kaidonis 2008): *attrition* (tooth-to-tooth contact), *abrasion* (tooth-to-food contact with abrasive particles like silica phytoliths), and *erosion* (chemical demineralization) (Smith & Knight 1984). These processes vary depending on diet and chewing activities, creating distinct wear patterns (Kaidonis et al. 2012). Wear is not uniform across teeth, with variation influenced by tooth morphology, function, and eruption sequence, particularly in molars. Dental wear affects not just tooth conservation during lifetime but also life-history patterns, such as tooth loss and bone resorption (Hillson 1996; Hillson et al. 2005).

The dual nature of dental wear, being both age- and diet-dependent, as well as affected by extra-masticatory use (Walsh 2022), complicates the interpretation of occlusal dentin exposure rates, as these measures are influenced by the age distribution of archaeological samples (Molnar 1971; Górka et al. 2015; Vieira et al., 2015). In contrast, Yang et al. (2024) propose a 3D dentin exposure proxy, applied to Neolithic to Bronze Age Chinese populations, that allows inter-population comparisons independent of age distributions. The significance of this proxy lies in its applicability to samples with unknown age distributions.

The goal of this research is to test the 3D dentin exposure proxy's effectiveness in characterizing the shift from hunter-gatherer to agricultural practices in the Near East and Iberian Peninsula. The study aims to analyze regional discontinuities in dietary practices during the Mediterranean transition from forager to agriculture. A reliable measure of molar wear rates would help characterize dietary and lifestyle shifts accompanying the Neolithic revolution, using skeletal populations with distinct diets and socioeconomic practices from Epipaleolithic to Neolithic periods (Eshed et al. 2006).

3. Materials and methods

3.1. Study sample

We reviewed dental cast collections from Mesolithic and Neolithic populations in the Iberian Peninsula and the Near East (Fig. 1), housed at the *Universitat de Barcelona* (UB) and the *Universitat Autònoma de Barcelona* (UAB). These cast collections were gathered through research collaborations and projects on dental wear coordinated by Dr. A. Pérez-Pérez (UB) and Dr. M. E. Subirà (UAB). For comparative purposes, we also analyzed dental casts of two modern samples: an Early Medieval sample from Catalunya (Spain), 6–11th c. CE, and a contemporary skeletal collection from Coimbra (Portugal), 18–19th c. CE. This research was part of various national and international archaeological and anthropological projects led by Dr. S. Carrascal, Dr. A. Malgosa, and Dr. M. Molist from UAB; Dr. B. Chamel and Dr. E. Coqueugniot (*Maison de l'Orient et de la Méditerranée*, Lyon); and Dr. C. Umbelino (*Universidade de Coimbra*, Portugal).

The skeletal sample studied (Table 1) included 323 individuals (N_i) with 1,674 M teeth (N_t). We analyzed molar quadrant, irrespective of side (left or right) or jaw (maxilla or mandible). Molar quadrants with dental crown damage or pathologies like carious lesions were excluded, resulting in a final sample of 544 quadrants (N_q) with 930 M teeth (N_{qt}). Selection criteria for including a molar quadrant followed Yang et al. (2024). A quadrant had to include a first molar with dentin exposure, with other molars either showing patches of dentin exposure or not yet erupted. Molars without dentin exposure were recorded as having zero exposure areas. Unidentifiable or missing molars (lost *ante-mortem* or *post-mortem*) were excluded. Due to poor preservation in some archaeological samples, analyzing multiple molar quadrant per individual increased the available sample size from 323 individuals to 544 quadrants, though it reduced the available molar sample from 1674 to 930. Final sample sizes varied by site, making site-specific comparisons impractical. Therefore, samples were grouped by geographic areas and periods, resulting in seven groups.

3.2. Portuguese Mesolithic

The Mesolithic sample from Portugal included 123 quadrants with 246 M teeth from two closely related shell middens, Sado and Muge, located on riverbanks and dating to the Mesolithic period (5,400–3,900 BCE) (Meiklejohn et al. 2009; Bicho et al. 2010; Bicho et al., 2013). The Sado Valley sample, originating from shell middens (Arapouco, Cabeço das Amoreiras, Cabeço do Pez), was initially excavated between 1960 and 1962 near Lisbon. However, this sample was limited ($N_i = 10$ individuals, $N_q = 20$ quadrants), with most quadrants ($N_q = 14$) coming from Cabeço do Pez. In contrast, the Muge Complex in the Tagus Valley (Cabeço da Amoreira, Cabeço da Arruda, Moita do Sebastiao) was better represented, with 103 quadrants, most of which came from Moita do Sebastiao ($N_q = 79$). Cabeço da Arruda was discovered in 1863 by Portuguese archaeologist Carlos Ribeiro, while the other two sites, Cabeço da Amoreira and Moita do Sebastião were identified one year later, in 1864.

3.3. Spanish Mesolithic

The Mesolithic sample from Spain included 28 quadrants with 54 M teeth. The El Collado in Oliva, Valencia (Spain), initially excavated between 1987 and 1988, dates to 6,630–6,250 BCE (Gibaja et al. 2015, 2017a). Fourteen burials were unearthed across a 143 m^2 area, yielding 21 quadrants with 40 M teeth. The site's dating has been debated (Hernández Pérez & Soler Mayor 1997; Bernabeu Aubán & Orozco Köhler 1991). The La Braña site, located in Valdelugueros, León (Spain), dates to 5,900–5,650 BCE (Vidal Encinas et al. 2010). Excavated by Vidal Encinas after its discovery in 2006, the site revealed two Mesolithic burials (LB-1 and LB-2) from the La Braña-Arintero Cave, providing 7 quadrants with 14 M teeth.

3.4. Spanish Middle Neolithic

The Spanish Middle Neolithic sample consists of 83 quadrants with 162 M teeth from eleven sites in Catalunya, northeast Spain, dating between 4,694 and 3,294 cal. BCE. Among these, 25 quadrants are from Puig d'en Roca (Maroto & Soler 2000), and 19 are from Sant Pau del Camp (Molist et al. 2012). The remaining Neolithic sites, with fewer individuals, included numerious sites: Can Gambús (Masclans 2017; Gibaja et al. 2017b), Mines de Gavà (Villalba et al. 1986; Bordas et al. 2009), Ca l'Estrada (Subirà et al. 2015), Camí de Can Grau (Pou et al. 1995), Can Roqueta II, 4,230–3750 cal. BCE (Oliva et al. 2008; Fontanals-Coll et al. 2015), Hort de Can Torras, 3607–3522 cal. BCE (Coll & Roig 2005; Fontanals-Coll et al. 2015), Pantà de Foix (Cebrià et al. 2013), Pla del Riu (Guitart 1987), and Segudet (Yáñez de Aldecoa 2003) (Table 1).

3.5. Near East Natufian / Epipaleolithic

Key Natufian sites in Israel include Mugharat El-Wad ($N_q = 16$), on Mount Carmel, dating from 11,000 to 8,730 cal. BCE (Weinstein-Evron 1991), and Me'arat Kebara ($N_q = 7$), dating from 12,550 to 11,050 cal. BCE (Arensburg & Belfer-Cohen 1998). The Shuqba Cave site ($N_q = 3$), in the West Bank, Palestine, dates from 12,500 to 9,500 cal. BCE, and was the first identified Natufian site showing the transition from mobile to sedentary lifestyles (Weinstein-Evron 2003). Tell Abu Hureyra ($N_q = 3$), in Syria, dating from 11,500 to 10,500 cal. BCE, shows phases reflecting the shift from hunting and gathering to agriculture, though it is outside the core Natufian region (Akkermans & Schwartz 2003). Abu Hureyra, while not a Natufian site, is included for its parallel early agriculture development. The final Near East Natufian/Epipalaeolithic sample included 29 quadrants with 66 M teeth from these four sites.

3.6. Near East Pre-Pottery Neolithic B

The PPNB (Pre-Pottery Neolithic B) samples from Syria included 31 quadrants with 47 M teeth from four sites. Excavations at Dja'dé El Mughara ($N_q = 6$), dating from 8,800 to 8,000 cal. BCE, located in

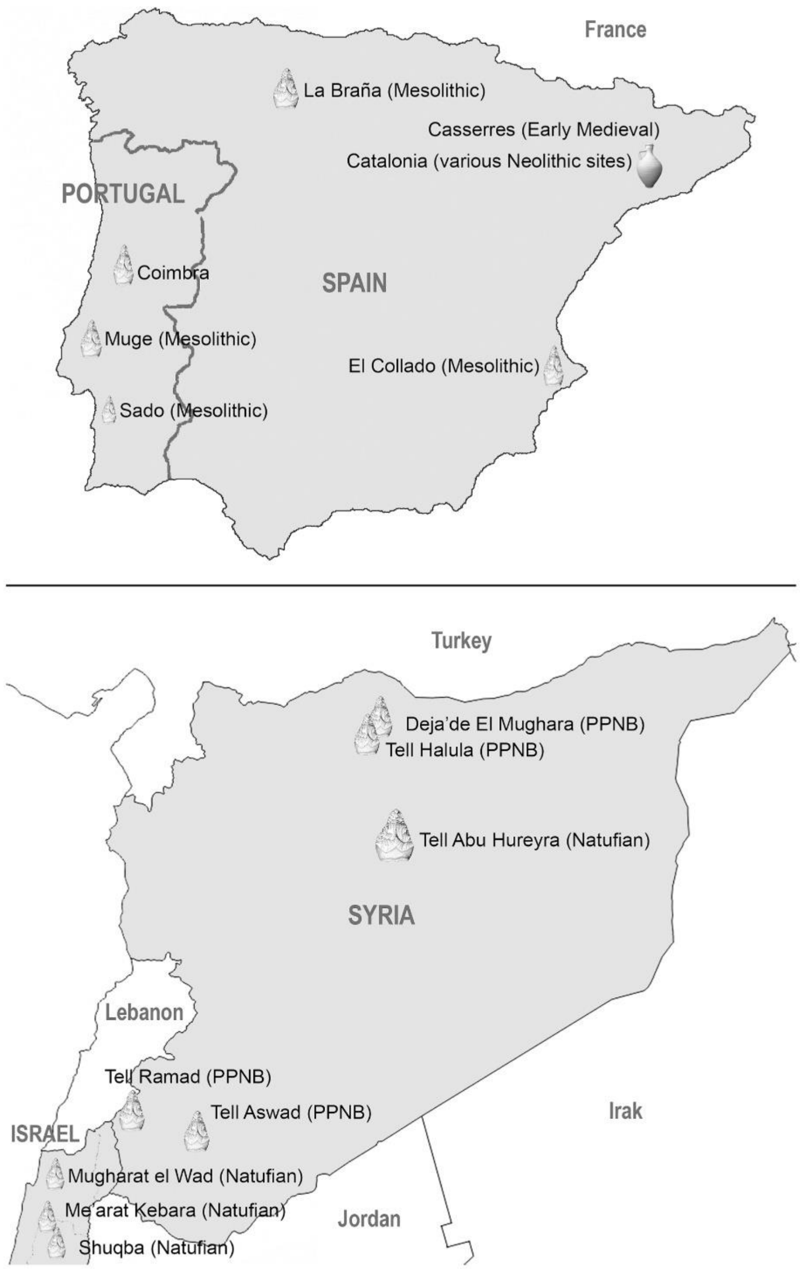


Fig. 1. Geographic location of the Mesolithic and Neolithic sites studied in the Iberian Peninsula (top) and the Near East (bottom)-Natufian, Mesolithic and pre-pottery site locations indicated with a lithic tool, and Neolithic site locations shown with a pottery amphora.

Table 1
Samples studied from Mesolithic and Neolithic periods in the Iberian Peninsula (Portugal, Spain) and the Near East (Syria, Israel, West Bank Palestine). Site names, chronology, geographic location, and repositories (Rep.) of the cast collection (UB, UAB) are indicated. Numbers of the individuals analyzed (N_i), molar teeth available (N_t), molar quadrants selected (N_q), and teeth studied in the selected quadrants (N_{qt}) are provided.

Chronology	N_i	N_t	N_q	N_{qt}
1. Portugal Mesolithic	**67**	**314**	**123**	**246**
Sado, 5000 BCE	*10*	*54*	*20*	*40*
Arapouco	2	8	3	6
Cabeço das Amoreiras	1	3	1	1
Cabeço do Pez	5	37	14	29
Sado	2	6	2	4
Muge, 5400–3900	*57*	*260*	*103*	*206*
Cabeço da Amoreira	3	11	4	8
Cabeço da Arruda	17	85	34	57
Moita do Sebastiao	37	172	79	141
2. Spain Mesolithic	**14**	**78**	**28**	**54**
El Collado, Valencia, 6630–6250 BCE	12	58	21	40
La Braña León, 5900–5650 BCE	2	20	7	14
3. Spain Middle Neolithic (Catalunya)	**49**	**251**	**83**	**162**
Ca l'Estrada, 4694–4491 BCE	1	6	2	4
Camí Can Grau, 3800–3500 BCE	2	12	4	8
Can Gambús-1, 3766–3356 BCE; CG-2, 3200–23300 BCE	5	18	6	14
Can Roqueta, 4310–4220 BCE	3	24	8	17
Horts de Can Torras, 3698–3620 BCE	3	27	9	17
Mines de Gavà, 3400–2360 BCE	1	3	1	2
Pantà de Foix, 3620–3294 BCE	2	6	2	3
Pla del Riu, 4038–3640. BCE	2	12	4	9
Puig d'en Roca, 4045–3642 BCE	9	75	25	44
Segudet, 4320–4050 BCE	1	9	3	6
Sant Pau del Camp, 4250–3700 BCE	20	59	19	38
4. Near East Natufian / Epipaleolithic	**24**	**68**	**29**	**66**
Tell Abu Hureyra, Syria, 11500–10500 cal. BCE	3	6	3	6
Mugharat El-Wad, Israel, 11000–8730 cal. BCE	13	40	16	40
Me'arat Kebara, Israel, 12550–11050 cal. BCE	6	16	7	14
Shuqba, West Bank Palestine 12500–9500 cal. BCE	2	6	3	6
5. Near East PPNB Neolithic (Syria)	**31**	**47**	**31**	**47**
Dja'dé el Mughara, 8800–8000 cal. BCE	6	14	6	14
Tell Aswad, 8700–7500 cal. BCE	5	9	5	9
Tell Halula, 7800–6300 cal. BCE	4	5	4	5
Tell Ramad, 7230–6800 cal. BCE	16	19	16	19
6. Spain Early Medieval, Accés Est Casserres, Catalunya, V-XI ACE	**52**	**295**	**126**	**188**
7. Coimbra Portugal contemporary, XIX-XX ACE	**86**	**621**	**123**	**167**
	323	**1674**	**544**	**930**

northern Syria on the Euphrates River's eastern bank, revealed evidence of wild plant use, hunting, and early cereal cultivation (Coqueugniot 2000, 2011). Tell Ramad site, dating from 7,230 to 6,800 cal. BCE (Ferembach 1969) is the most represented site ($N_q = 16$), situated near the Diyala River in eastern Iraq. It revealed early agriculture, including domesticated two-row barley (*Hordeum vulgare*) and einkorn wheat (*Triticum monococcum*), alongside circular mudbrick structures, storage pits, and distinct pottery, making the transition to settled agricultural communities. Tell Aswad ($N_q = 5$), dating from 8,700 to 7,500 cal. BCE (Stordeur 2003; Stordeur & Abbès, 2002), located 30 km northeast of Damascus, Syria, uncovered circular mudbrick houses, storage pits, and artifacts such as stone tools and pottery. It is notable for its early evidence of domesticated emmer wheat (*Triticum dicoccum*) and barley. Tell Halula ($N_q = 4$), dating from 7,800 to 6,300 cal. BCE (Aurenche 2005; Estebaranz-Sánchez et al., 2007), in the middle Euphrates valley, Syria, is one of the largest known Neolithic sites. Excavations, led by Dr. Miquel Molist revealed early agricultural practices, domestication plants like wheat, barley, and flax (*Linum usitatissum*), and domesticated animals including cattle, sheep, and goats (Akkermans 2004). Despite the extensive human remains uncovered (Estebaranz-Sánchez et al., 2007), very few quadrants were preserved.

3.7. Spanish Early Medieval and Portuguese contemporary comparative samples

The Spain Early Medieval site of *Accés Est Casserres* (Berguedà, Catalunya, Spain), dating from the 6th to the 11th century CE, served as a comparative collection. This period encompasses the arrival of the Visigoths and the conflicts between the Franks and the Muslims (Carrascal 2021). By 2021, 211 individuals from 184 burials had been documented at this site, and the sample analyzed included 126 quadrants with 188 M teeth. A modern sample was sourced from the Portuguese *Coimbra International Exchange Collection*, dating from the 18th to 19th centuries (Cunha & Wasterlain 2007). Housed at the University of Coimbra, this collection constitutes of skulls with documented sex and age at death, making it invaluable for anthropological and forensic research, including comparative skeletal anatomy, pathology, population genetics, and forensic anthropology; Yang et al. (2024) previously examined the molar dentin exposure of the lower dentition in this sample. The current study extends that analysis to include the upper dentition; the final sample consisted of 123 quadrants with 167 M teeth of 86 individuals, with evenly represented age groups ranging from 6 to 90 years old.

3.8. Sample processing and analysis

Prior to this research, we had already molded the molar quadrants using Colténe^{TM} Affinis regular body (UB) and 3M^{TM} light-body polyvinylsiloxane (UAB) materials, adhering to standardized protocols (Galbany et al. 2006). High-resolution casts of the complete dental crowns in each molar quadrant were made using polyurethane Feropur PR55 (Feroca^{TM}, Spain). The dental casts were digitized with a 3D EinScan SP scanner (Shinning^{TM}) from occlusal, buccal, and lingual views, using *non-texture* mode with eight captures per scan at 45° angles.

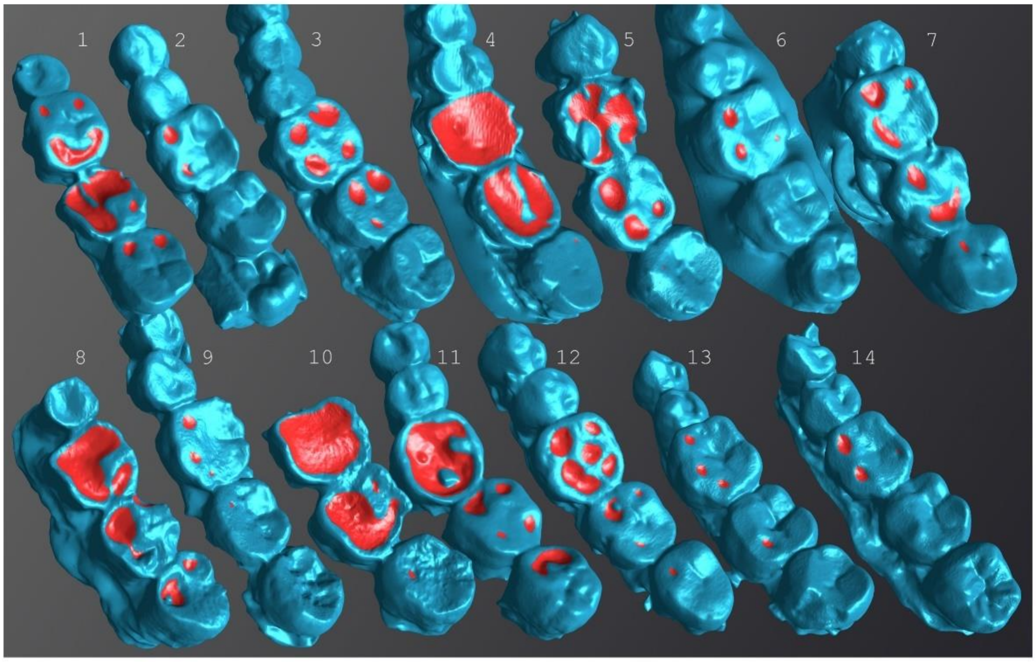


Fig. 2. 3D point-cloud meshes (bleu) of selected specimens from the archaeological sites analyzed; the measured dentin exposure surfaces are shown in red. All specimens correspond to lower, left quadrants: upper row, 1. Arapouco 1A P4-M3; 2. Cabeço do Pez 62518 P3-M3; 3. Cabeço d'Arruda 81.19.103 I1-M3; 4. El Collado 20.14 I1-M3; 5. La Braña 2 P4-M3; 6. Puig d'en Roca 14 I1-M3; 7. Can Gambús 137 P4-M3; lower row, 8. El Wad 153 P4-M3; 9. Abu Hureyra 11 P3-M3; 10. Dja'dé 77 M1-M3; 11. Accés Est Casserres 88 P4-M3; 12. Accés Est Casserres 22 P4-M3; 13. Coimbra 370 P3-M3; 14. Coimbra 433 P3-M3. The meshes are not all at identical scales. The red colored surfaces show dentin-exposed areas on the occlusal surfaces of the molar teeth indicaive of the measured surfaces with the Shinning software.

The 24 scans were then automatically fused into a single point-cloud mesh model, with a slightly smoothing filter applied to remove outliers. The meshes were exported in polygon (.ply) and ASCII object (.obj) file formats.

Dentin exposure areas (in mm^2) were measured directly from the 3D meshes (Fig. 2) using the Shinning software's *measure* mode. The software automatically calculated the total dentin exposed area (D) for each tooth by summing the surfaces of all defined patches on the occlusal plane. For molars without dentin exposure or those not yet erupted, D was recorded as zero. Additionally, for each molar, we calculated the sum of the dentin exposure areas of all characterized molars in the quadrant, denoted as $S = D_{M1} + D_{M2} + D_{M3}$. Quadrants with unmeasurable dentin exposure were excluded from the analysis. This method ensured that all M1 teeth included in the study exhibited some degree of dentin exposure ($D_{M1} > 0$), while M2 and M3 could have zero exposure if no dentin was exposed or the tooth had not yet erupted (Yang et al., 2024).

3.9. Statistical approach

We tested various regression models (Linear, Quadratic, Compound, Power) to determine which best predicted the overall dentine exposure area (S) from the dentin exposure (D) of each molar. The slope (*b*) of each regression indicated the rate of S accumulation as D increase, while the intercept (*a*) represented the S value when D was zero. The coefficient of determination (R^2) was used to assess the precision of the models, indicating the percentage of total variance explained. The ANOVA F statistic and its significance (*P*) were employed to compare the models.

The slope comparisons between samples and groups were conducted using a *t*-test (Equation (1), with degrees of freedom (*d.f.*) equal to $n_1 + n_2 – 4$. The *P* value was derived from the two-tail *t* distribution, computed as $P = \text{T.DIST.2 T}(t, d.f.)$ in MS-EXCEL.

$$t = \frac{ABS(b_1 - b_2)}{\sqrt{SE_{b1}^2 + SE_{b2}^2}} \quad (1)$$

Slope comparisons were made by molar between mandibular and maxillary quadrants within each group, and between groups for the combined samples of upper and lower molars. All statistical analyses were performed using IBM SPSS v. 27 (licensed to UB), with the significance level set at $\alpha < 0.05$.

3.10. Dentin exposure rates

As described by Yang et al. (2024), we used the regression model intercepts to estimate the wear rates of each molar quadrant during the intervals between the onsets of dentin exposure for each molar. Molar eruption ages for modern *Homo sapiens* were taken from Ash & Nelson (2003)—5.5 years for M1, 11.5 years for M2, and 18.5 years for M3—to compute the lengths of the M1–M2 juvenile interval (6 years) and an M2–M3 subadult interval (7 years). While variations in molar eruption ages exist (Gilmore & Grote, 2012), these differences are of little relevance if the intervals between eruption ages remain consistent across modern humans populations. Therefore, we applied the same intervals across all samples: 6 years (5.5 to 11.5 years) for the juvenile interval,

Table 2
Basic statistic of 3D dentin exposure by site. Dentin exposure by site and tooth type (M1, M2, M3) for the combined samples of upper and lower quadrants. N: sample size; mean: average of the 3D dentin exposure (D) in mm^2; s.d.: standard deviation of D.

	M1			M2			M3		
Site	**N**	**mean**	**s.d.**	**N**	**mean**	**s.d.**	**N**	**mean**	**s.d.**
Accés Est Casserres	112	17.891	17.974	54	13.431	15.745	22	10.990	10.413
Arapouco	2	33.395	18.901	2	31.530	9.687	2	7.910	4.285
Ca l'Estrada	2	20.200	4.186	2	3.370	1.810	–	–	–
Cabeço da Arruda	31	35.181	25.961	19	26.671	21.622	7	26.420	27.962
Cabeço das Amoreiras	5	42.016	28.349	2	45.580	3.239	2	2.434	0.245
Cabeço do Pez	14	34.645	21.697	11	15.656	11.184	4	9.505	14.305
Camí Can Grau	4	22.170	6.668	3	1.213	0.199	1	0.680	–
Can Gambús 1 & 2	6	31.161	25.889	5	20.812	19.324	3	7.340	3.027
Can Roqueta	8	36.127	19.602	7	4.403	3.255	2	1.555	0.686
Coimbra	123	6.890	9.312	38	3.953	5.312	6	3.216	3.006
Dja'dé el Mughara	6	74.590	7.345	6	54.237	15.889	2	12.175	9.907
El Collado	21	30.434	28.670	14	17.452	19.006	5	8.894	6.635
Horts de Can Torras	9	17.490	14.221	5	5.866	5.453	3	2.480	1.621
La Braña	7	40.500	13.727	5	10.238	12.065	2	0.643	0.067
Me'arat Kebara	7	8.623	4.462	5	1.886	1.882	2	1.425	0.488
Mines de Gavà	1	30.530	–	1	2.860	–	–	–	–
Moita do Sebastiao	70	39.226	18.979	58	13.540	12.084	13	5.539	8.790
Mugharat el-Wad	16	39.125	15.926	16	17.164	15.095	8	10.954	8.552
Pantà de Foix	2	8.940	3.606	1	3.160	–	–	–	–
Pla del Riu	4	31.898	24.874	3	30.393	26.693	2	8.685	0.700
Puig d'en Roca	25	17.130	9.795	16	6.455	3.981.	3	4.053	5.072
Sado (*unspecified*)	2	28.880	5.869	2	4.555	0.276	–		
Sant Pau del Camp	19	25.241	17.331	14	6.359	7.055	5	2.198	1.348
Segudet	3	27.810	5.080	3	6.160	3.475	–	–	–
Shuqba	3	62.750	36.426	3	37.240	24.819	–	.	–
Tell Abu Hureyra	3	28.807	22.211	3	4.946	3.957	–	–	–
Tell Aswad	5	26.088	22.788	3	12.067	9.001	1	4.420	–
Tell Halula	4	9.910	6.448	1	3.150	–	–	–	–
Tell Ramad	16	10.821	10.676	3	1.200	0.641	–	–	–

and 7 years (11.5 to 18.5 years) for the subadult interval, acknowledging that the M3 may erupt later in present-day humans.

Yang et al. (2024) computed two dentin exposure rates for these intervals: a direct wear measure, calculated as $(S_1 - S_2)/t$ in mm^2/year, and a relative dentin exposure rate (r) as shown in Equation (2). This per-one rate, representing growth ($r > 0$) or decay ($r < 0$) of S, was calculated per month rate, with t being the number of years in the age interval and n the number of intervals within a year ($n = 12$ for monthly calculations). Equation (2) derives from equation (3), the continuous compound growth rate function.

$$r = \frac{\ln(S_1) - \ln(S_0)}{nt} \quad (2)$$

$$S_1 = S_0 e^{-rnt} \quad (3)$$

Although non-continuous, compounded exponential growth is commonly used in social sciences to estimating storage and investment benefits (Connolly et al. 2001; Hember et al. 2012), it tends to underestimate future value of exponential growing variable (Almenberg & Gerdes 2012). Alternatively, a continuous exponential growth trend, defined as $S_1 = S_0 e^{rt}$, where S_1 accrues based solely on r (the exponential growth rate) and t (the time interval length in years), better reflects continuous processes like dentin exposure accumulation (Shimojo et al. 2010; Han et al. 2014). In evolutionary ecology, this continuous compounded function has been extensively studied (Weis et al. 2000; Pandey et al, 2017). The overall dentin exposure (S) growth follows this continuous model, with the wear rate (r) representing a percent increase in dentin exposure, expected to decreases with age.

4. Results

The basic statistics (sample size, mean, and standard deviation) for the 3D dentin exposure area (D, in mm^2) by site are shown in Table 2. We did not compare dentin exposure areas among sites due to the heterogeneity and small sizes of most samples, making meaningful comparison impossible. Additionally, the average D values by site are heavily influenced by unknown age distribution within each sample. Since D increases with older age distributions, average values are not informative. This applies to the average D values of the seven groups considered (Table 3). Although these groups had large sample sizes, D did not follow a Normal distribution in any group (K-S test, $P < 0.001$), which is expected when the age distribution is highly heterogeneous, samples sizes are small, or the variable is age dependent. Sample sizes ranged from 28 (Spanish Mesolithic) to 124 (Portuguese Mesolithic) for M1, from 13 (Near East Neolithic) to 94 (Portugal Mesolithic) for M2, and from 3 (Near East Neolithic) to 28 (Portugal Mesolithic) for M3. As expected,

Table 3
Basic statistic of the 3D dentin exposure by group. Dentin exposure by periods tooth type (M1, M2, M3) for the combined samples of upper and lower quadrants. N: sample size; mean: average of the 3D dentin exposure (D) in mm^2; s.d.: standard deviation of D.

	M1			M2			M3		
Sample group	**N**	**mean**	**s.d.**	**N**	**mean**	**s.d.**	**N**	**mean**	**s.d.**
1. Portugal Mesolithic	124	37.549	21.256	94	17.315	15.706	28	11.273	17.718
2. Spain Mesolithic	28	32.950	25.893	19	15.553	17.432	7	6.537	6.749
3. Spain Middle Neolithic	83	23.250	16.117	60	8.043	10.711	19	3.883	3.387
4. Near East Natufian	29	33.139	23.170	27	15.208	16.889	10	9.048	8.547
5. Near East PPNB Neolithic	31	25.508	27.726	13	28.336	27.519	3	9.590	8.314

sample sizes decreased from M1 to M3, as the later-erupting molars (M2 and M3) are less frequently observed. Additionally, not all molar quadrants showed dentin exposure on M2, and especially on M3, further reducing sample sizes due to methodological constraints in molar selection. In all groups and teeth examined, except for the Near East PPNB Neolithic M2, the average 3D dentin exposure area of M1 was greater than that of M2, and M2 was greater than M3, consistent with the six-years offset of molar eruption ages. Despite these limitations, both Mesolithic groups from Portugal and Spain, as well as the Natufian sample, showed higher average D values for M1 than the Neolithic samples from both geographic zones, as well as the Medieval Catalan and the contemporaneous Coimbra samples, which had the lowest average D values. However, this trend was not observed for M2 or M3. Such comparisons are not informative due to the unknown age distribution of the samples, given the age-dependent nature of dentin exposure.

4.1. Regression models by jaws

The sample sizes for the upper quadrants were smaller than for the lower ones, likely due to differences in bone preservation and recovery at the sites, as we studied all available remains, except for the Coimbra sample, where we selected a representative subset (see methods). The linear regression model $\ln S = \ln a + b \ln D$ (*Power* function) for both maxillary bones by groups showed significant associations ($P < 0.05$) between logarithmic transformed variables ln D and ln S for all molars, explaining a large proportion of total variance (R^2), although less so when the sample sizes were small (Table 4). These models tested the hypothesis of equality of the regression slopes (b) between the upper and lower quadrants, yielding non-significant P-values for most comparisons by tooth type—15 of the 19 comparisons made. Some comparisons could not be made due to the small sample sizes for Near East Neolithic M2 (N = 1) and M3 (N = 0). Significant differences in slope (b) between upper and lower jaw teeth were found for the Spain Neolithic M1 sample ($P = 0.036$, $N_U = 34$, $N_L = 49$, $\delta = 0.082$, the absolute difference between slopes); the Portugal Mesolithic M3 sample ($P = 0.034$, $N_U = 7$, $N_L = 21$, $\delta = 0.164$); and the Coimbra contemporaneous M3 sample ($P = 0.031$, $N_U = 2$, $N_L = 4$, $\delta = 1.459$), the smallest sample. Based on these results, we combined the upper and lower quadrants to create larger samples for population comparisons.

4.2. Regression models by groups

For the combined jaw quadrants, the four models tested (*Linear*, *Quadratic*, *Compound*, *Power*) showed highly significant regressions between D and S in most groups and molars (Table 5). The *Linear* model did

Table 4
Slope comparisons between upper and lower quadrants. X: maxillary quadrants; M: mandibular quadrants. N: sample size; R^2 : coefficient of determination (percentage of total variance explained by the regression model); ln *a*: intercept of the model; *b*; slope of the linear regression; e_b : standard error of the regression model; t_b : statistic for the slope; P_b : probability of significance of the slope ($H_0 : b = 0$). δ: difference between the slopes compared; e_δ : standard error of the difference between the slopes compared; $t\delta$: statistic of the comparison; $P\delta$: probability of significance of the difference between slopes ($H_0 : b_1 = b_2$). α = 0.05.

Sample	Tooth	Jaw	N	R^2	ln *a*	*b*	e_b	δ	e_δ	t_δ	P_δ
Near East Natufian	M1	U	7	0.990	0.006	1.078	0.070	0.056	0.096	0.582	0.566
		L	22	0.968	−0.110	1.134	0.066				
	M2	U	6	0.781	2.464	0.505	0.202	0.068	0.212	0.321	0.751
		L	21	0.902	2.561	0.573	0.063				
	M3	U	2	1.000	2.624	0.412	0	−0.057	0.106	0.523	0.626
		L	8	0.799	3.678	0.355	0.109				
Near East Neolithic	M1	U	8	0.995	−0.104	1.078	0.044	0.028	0.054	0.520	0.607
		L	23	0.992	−0.700	1.106	0.031				
	M2	U	1								
		L	12	0.901	2.336	0.624	0.095				
	M3	U	–								
		L	3	0.707	3.443	0.618	0.618				
Spain Mesolithic	M1	U	14	0.990	0.068	1.021	0.043	0.100	0.079	1.269	0.216
		L	14	0.980	−0.120	1.121	0.066				
	M2	U	6	0.267	3.010	0.251	0.452	0.131	0.464	0.282	0.782
		L	13	0.734	3.206	0.382	0.106				
	M3	U	2	1.000	3.885	0.199	0	0.022	0.203	0.108	0.921
		L	5	0.450	4.130	0.177	0.203				
Spain Neolithic	M1	U	34	0.991	−0.012	1.051	0.024	0.082	0.038	2.134	***0.036***
		L	49	0.984	−0.199	1.133	0.030				
	M2	U	22	0.664	2.771	0.419	0.106	0.053	0.115	0.462	0.626
		L	38	0.871	2.770	0.472	0.044				
	M3	U	5	0.438	3.702	0.200	0.333	0.142	0.344	0.413	0.685
		L	14	0.758	3.738	0.342	0.085				
Spain Medieval	M1	U	41	0.991	−0.058	1.076	0.023	0.052	0.032	1.634	0.105
		L	71	0.987	−0.096	1.128	0.022				
	M2	U	13	0.941	2.121	0.684	0.074	−0.121	0.083	1.455	0.152
		L	41	0.920	2.455	0.563	0.038				
	M3	U	3	0.997	3.278	0.590	0.043	−0.134	0.095	1.407	0.171
		L	19	0.793	3.248	0.456	0.085				
Portugal Mesolithic	M1	U	55	0.982	−0.088	1.096	0.029	0.046	0.049	0.931	0.354
		L	69	0.961	−0.220	1.142	0.040				
	M2	U	40	0.770	3.028	0.404	0.054	0.058	0.068	0.848	0.399
		L	54	0.833	2.917	0.462	0.042				
	M3	U	7	0.950	3.759	0.370	0.054	−0.164	0.073	2.249	***0.034***
		L	21	0.694	4.256	0.206	0.049				
Portugal Coimbra	M1	U	56	0.973	0.113	0.997	0.032	0.053	0.041	1.285	0.201
		L	67	0.980	0.043	1.050	0.026				
	M2	U	17	0.420	1.908	0.664	0.371	0.167	0.395	0.423	0.675
		L	21	0.807	1.622	0.811	0.136				
	M3	U	2	1.000	2.724	−0.749	0.000	1.459	0.264	5.527	***0.031***
		L	4	0.885	2.568	0.710	0.264				

Table 5

Regression models between S and D by group and tooth type. N: sample size; R^2 : coefficient of determination (percentage of total variance explained by the model); *P*: significance of the regression model ($H_0 : b = 0$). The non-significant *P*-values are shown in bold, as well as the highest R^2 values by tooth type.

		Linear		*Quadratic*		*Compound*		*Power*	
Group	**N**	**R²**	***P***	**R²**	***P***	**R²**	***P***	**R²**	***P***
Portugal Mesolithic									
M1	124	0.771	*<0.001*	0.800	*<0.001*	0.759	*<0.001*	**0.948**	*<0.001*
M2	94	0.813	*<0.001*	**0.827**	*<0.001*	0.630	*<0.001*	0.660	*<0.001*
M3	28	**0.732**	*<0.001*	**0.732**	*<0.001*	0.494	*<0.001*	0.559	*<0.001*
Spain Mesolithic									
M1	28	0.880	*<0.001*	0.883	*<0.001*	0.823	*<0.001*	**0.975**	*<0.001*
M2	19	0.685	*<0.001*	**0.692**	*<0.001*	0.406	0.003	0.410	0.003
M3	7	0.179	**0.344**	0.180	**0.673**	0.255	**0.248**	**0.345**	**0.165**
Spain Middle Neolithic									
M1	83	0.887	*<0.001*	0.902	*<0.001*	0.804	*<0.001*	**0.973**	*<0.001*
M2	60	0.818	*<0.001*	**0.832**	*<0.001*	**0.530**	*<0.001*	0.675	*<0.001*
M3	19	0.589	*<0.001*	**0.606**	*<0.001*	**0.556**	*<0.001*	0.582	*<0.001*
Near East Natufian									
M1	29	0.864	*<0.001*	0.864	*<0.001*	0.826	*<0.001*	**0.959**	*<0.001*
M2	27	0.903	*<0.001*	**0.924**	*<0.001*	0.647	*<0.001*	0.811	*<0.001*
M3	10	0.655	*<0.001*	**0.751**	0.008	0.526	0.018	0.679	0.003
Near East PPNB Neolithic									
M1	31	0.952	*<0.001*	0.981	*<0.001*	0.799	*<0.001*	**0.985**	*<0.001*
M2	13	0.970	*<0.001*	**0.978**	*<0.001*	0.763	*<0.001*	0.825	*<0.001*
M3	3	0.559	**0.463**	**1.000**	*<0.001*	0.447	**0.534**	0.500	**0.500**
Spain Early Medieval									
M1	112	0.900	*<0.001*	0.917	*<0.001*	0.761	*<0.001*	**0.976**	*<0.001*
M2	54	0.889	*<0.001*	**0.893**	*<0.001*	0.688	*<0.001*	0.851	*<0.001*
M3	22	0.444	*<0.001*	0.568	*<0.001*	0.368	0.003	**0.644**	*<0.001*
Portugal Coimbra									
M1	123	0.835	*<0.001*	0.845	*<0.001*	0.59	*<0.001*	**0.955**	*<0.001*
M2	38	0.640	*<0.001*	**0.658**	*<0.001*	0.446	*<0.001*	0.514	*<0.001*
M3	6	0.683	*<0.001*	**0.694**	0.005	0.518	0.008	0.631	**0.059**

not show a significant association for the Spain Mesolithic M3 sample (N = 7, *P* = 0.344) and the Near East PPNB Neolithic M3 samples (N = 3, *P* = 0.673). The *Quadratic* model was not significant only for the Spanish Mesolithic sample (N = 7, *P* = 0.165). Finally, the *Power* regression model was not significant for the Near East PPNB Neolithic M3 sample (N = 3, *P* = 0.500), the Spanish Mesolithic M3 (N = 7, *P* = 0.344) sample, and the Portuguese Coimbra contemporaneous M3 samples (N = 6, *P* = 0.059). All the non-significant associations affected the M3 molar, which had the smallest sample sizes. The highest coefficients of determination (R^2) by group and tooth type were observed in 12 (57.1 %) of the 21 M analyzed for the *Quadratic* model, 8 (38.1 %) for the *Power* model, 2 (9.5 %) for the *Compound* model, and 1 (4.8 %) for the *Linear* model. All the M1 teeth showed greater R^2 values for the *Power* model, while the other molars closely followed a *Quadratic* model, except in two cases. These may reflect the differing rates of dentin exposure of the second and third molars, as shown by Yang et al. (2024). For comparative purposes and since all the *Power* associations for M2 were also highly significant, we adopted our previous approach (Yang et al., 2024) and centered subsequent analyses on the *Power* model. The dispersion ranges of the coefficients of determination (R^2) for the *Power* models were [0.955, 0.985] for M1, [0.410, 0.851] for M2, and [0.345, 0.679] for M3. The percentage of total variance explained by the model

Table 6

Linear models of the *Power* regression equations by group and tooth type for the combined jaw sample. ln *a*: intercept of the linear model for ln D = 0; $a = e^{\ln a}$, e_a : standard error of the intercept; t_i : Student t statistic for ln *a* = 0; P_i : significance probability for the intercept; *b*: slope of the linear regression model; e_b : standard error of the slope; t_s : Student t statistic for *b* = 0; P_s : significance probability for the slope.

Group	Tooth	*N*	ln *a*	*a*	e_a	t_a	P_a	*b*	e_b	t_b	P_b
Portugal Mesolithic	M1	124	−0.143	0.867	0.082	−1.738	0.085	1.117	0.024	47.373	***<0.001***
	M2	94	2.964	19.375	0.086	34.412	***<0.001***	0.439	0.033	13.368	***<0.001***
	M3	28	4.139	62.740	0.086	47.955	***<0.000***	0.247	0.043	5.73	***<0.000***
Spain Mesolithic	M1	28	−0.016	0.984	0.107	−0.151	0.881	1.077	0.034	32.154	***<0.001***
	M2	19	3.087	21.911	0.272	11.362	***<0.001***	0.390	0.114	3.435	***0.003***
	M3	7	4.039	56.770	0.216	18.719	***<0.001***	0.198	0.122	1.625	0.165
Spain Neolithic	M1	83	−0.121	0.886	0.061	−1.996	***0.049***	1.100	0.020	54.041	***<0.001***
	M2	60	2.757	15.753	0.078	35.442	***<0.001***	0.463	0.042	10.968	***<0.001***
	M3	19	3.712	40.936	0.096	38.657	***<0.001***	0.349	0.072	4.870	***<0.001***
Near East Natufian	M1	29	−0.086	0.918	0.148	−0.579	0.568	1.125	0.045	25.001	***<0.001***
	M2	27	2.513	12.342	0.135	18.673	***<0.001***	0.580	0.056	10.364	***<0.001***
	M3	10	3.182	24.095	0.261	12.193	***<0.001***	0.537	0.131	4.110	***<0.003***
Near East Neolithic	M1	31	−0.086	0.918	0.073	−1.176	0.249	1.103	0.026	43.126	***<0.001***
	M2	13	2.335	10.329	0.256	9.124	***<0.001***	0.626	0.087	7.210	***<0.001***
	M3	3	3.443	31.281	1.317	2.614	0.233	0.618	0.618	0.999	0.500
Spain Early Medieval	M1	112	−0.082	0.921	0.043	−1.895	0.061	1.109	0.017	66.900	***<0.001***
	M2	54	2.365	10.644	0.079	29.990	***<0.001***	0.599	0.035	17.246	***<0.001***
	M3	22	3.263	26.128	0.173	18.835	***<0.001***	0.473	0.079	6.010	***<0.001***
Portugal Coimbra	M1	123	0.080	1.083	0.035	2.278	***0.024***	1.027	0.020	50.852	***<0.001***
	M2	38	1.792	6.001	0.153	11.686	***<0.001***	0.735	0.119	6.173	***<0.001***
	M3	6	2.545	12.743	0.297	8.563	***0.001***	0.657	0.251	2.618	0.059

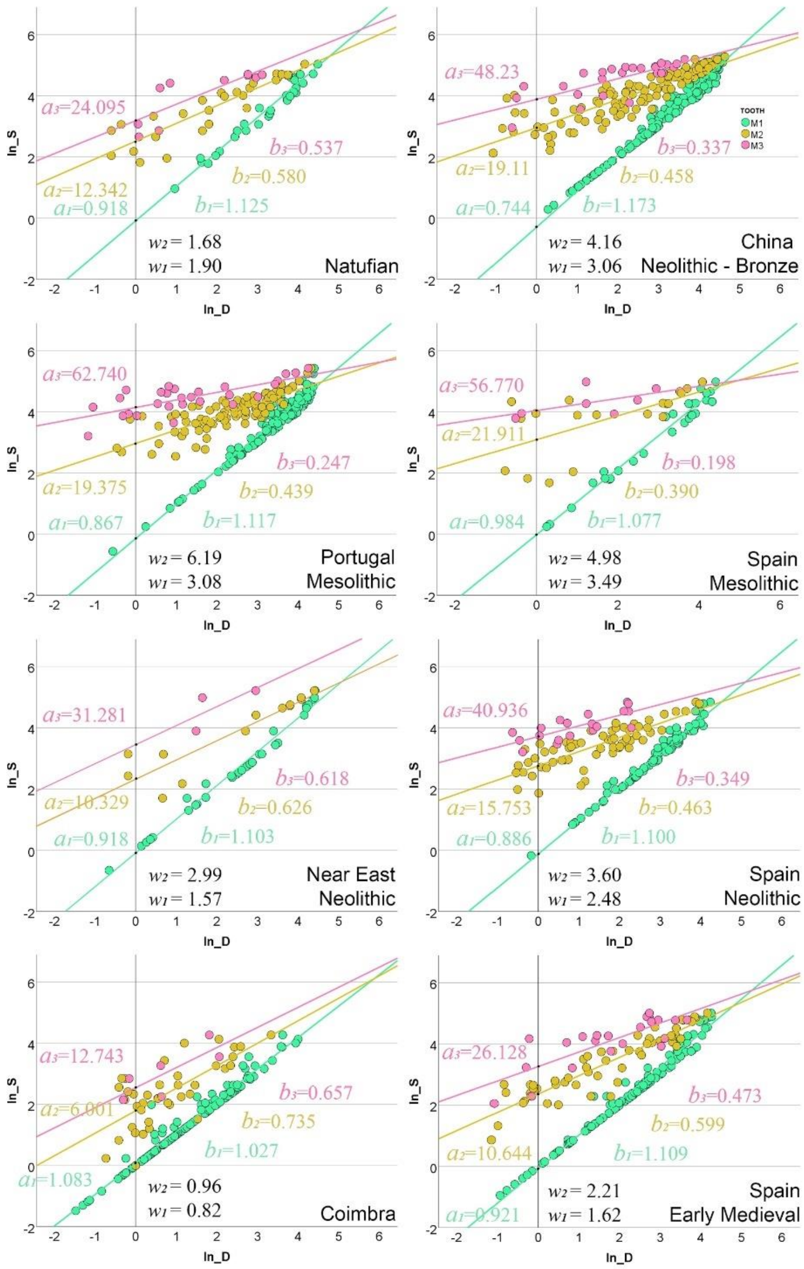


Fig. 3. Linear regression $\ln S = \ln a + b \ln D$ by molar types and by groups. The intercepts a_i (mm^2) and slopes (b) are indicated, as well as the w_1 (juvenile 5.5-11.5 years) and w_2 (subadult 11.5-18.5 years) wear rates (mm^2/month).

decreased from M1 to M3 in all groups, corresponding with the decreasing samples sizes from M1 to M3.

The slopes of the regression models for all the groups decrease from M1 to M3 (Table 6). The decrease in slopes from M1 to M2 was highly significant ($P \leq 0.017$) across all groups, while the decrease from M2 to M3 was only significant for the Portuguese Mesolithic sample. This suggests that, regardless of the statistical model used, S accrues at different rates depending on how many molars contribute to the overall dentin exposure. This is consistent with the fact that the regression models for the three molars eventually intersect (Fig. 3), reaching the same D value and thus equally contributing to S. If the regression models did not cross, it would suggest that S accrued at a constant rate, independent of how many molars contributed to the overall dentin exposure, which is unlikely given the results obtained. All the intercepts ($\ln a$) by group of the *Power* regression models for M1 were negative ($\ln a < 0$), as at the onset of dentin exposure, when S approaches 1 mm^2, $\ln a$ may take negative values ($S < 1$)—except for the Coimbra sample ($\ln a = 0.080$). A negative ln-transformed intercept is consistent with S being nil (no dentin exposure) before the onset of dentin exposure for this tooth. The intercepts for M1 did not significantly differ from zero, except in the Spanish Neolithic ($N = 83$, $P = 0.049$) and Portuguese Coimbra ($N = 123$, $P = 0.024$) samples. For M2 and M3, the intercepts significantly differed from zero in all groups except for the Near East Neolithic M3 ($N = 3$, $P = 0.233$), the smallest sample. The dispersion ranges of the intercepts were [-0.143, 0.080] for M1, [1.792, 3.087] for M2, and [2.545, 4.139] for M3. In all samples, the intercept for M1 was smaller than for M2, and this was smaller than for M3, reflecting the progressive nature of dentin exposure and the sequential eruption of molars.

4.3. Dentin exposure rates by groups

The magnitude of the differences in intercept values (a, mm^2) between consecutive molars depends on the dentin exposure rates for the population considered. A larger difference in $a_{M2} - a_{M1}$ indicates greater dentin exposure rates during a given age interval, while a smaller difference suggests lower rates. All seven groups followed the pattern $a_{M2} - a_{M1} < a_{M3} - a_{M2}$, even though the subadult interval was longer (7 years) than the juvenile one (6 years). This resulted in higher wear rates (mm^2/year) during the subadult period than during the juvenile period ($w_2 > w_1$), except in the Near East Natufian sample, which showed similar wear rates for both periods (Table 7). This suggests that dentin exposure (S) does not accrue at a continuous rate over time but increases as molars erupt and come into occlusion. However, the percentage contribution to S of each molar decreases over time as dentin exposure accumulates ($r_2 < r_1$). Although this may seem contradictory, it simply reflects that the percentage contribution of each molar's D value becomes smaller as the overall S value increases, which is uninformative about whether D remains constant, grows, or decreases over time.

The Portuguese and Spanish Mesolithic samples had the largest percentage contributions to S over the entire age interval (w_3), at 2.74 and 2.60 % per month, respectively, followed by the Neolithic samples and then the Natufian (Table 7). The Spanish Early Medieval sample showed w values similar to, though slightly higher than, those of the Natufian, while the modern Coimbra sample had much lower rates (Fig. 2). These results suggest that Mesolithic populations had higher dentin exposure rates than both the earlier Natufian and the later Neolithic populations in both geographic areas. In particular, the Portuguese Mesolithic sample had the highest wear rates during the combined interval (w_3), at 4.76 mm^2/year, followed by the Spanish Mesolithic sample at 4.29 mm^2/year. Both groups had higher w values in the subadult period than in the juvenile one. The Neolithic samples showed lower dentine exposure rates for the combined period, with 3.08 mm^2/year for Spain and 2.34 mm^2/year for the Near East. The other samples had even lower rates: 1.94 mm^2/year for the Spanish Early Medieval, 1.78 mm^2/year for the Near East Natufian, and 0.90 mm^2/year for Coimbra, the most recent sample, while the Early Medieval sample had wear rates similar to those of earlier Neolithic samples. In the Near East, the Natufian and Neolithic samples clearly differed: during the juvenile period, the Natufian specimens wore their molars somewhat faster that the Near East Neolithic but slower than the Spanish Neolithic sample, while in the subadult period, the Neolithic specimens wore their molars at faster rates than the Natufian (Fig. 4).

For the juvenile age interval, the Portuguese and Spanish Mesolithic samples showed similar dentin exposure rates, though the Portuguese Mesolithic had a higher wear rate during the subadult period (Fig. 4). The Spanish Mesolithic specimens had greater wear rates than the Spanish Neolithic ones in both age intervals, and these, in turn, had greater wear rates than the Near East Neolithic sample. The Natufian sample had lower wear rate values than the Neolithic ones, closely resembling the Early Medieval sample. The modern Coimbra sample had the lowest wear rate values in both age intervals.

Overall, the observed wear rates suggest that the Natufian's mixed diet, which relied heavily on hunting and gathering, resulted in lower wear rates than those seen during the Mesolithic period, which relied on hunting and gathering, and the Neolithic period, more dependent on agriculture. The dentin exposure rates indicate that the Natufian population does not fit neatly into either the Mesolithic or the Neolithic categories in terms of molar use related to food chewing or other masticatory activities. Additionally, while the Spanish and Portuguese Mesolithic samples both had high wear rates in both age periods, they differed in that the Portuguese Mesolithic had higher wear rates during the *juvenile* period. Finally, the Neolithic samples from Spain and the Near East had similar wear rates, with slightly higher values in the Spanish sample in the *juvenile* period (Fig. 4).

When testing the significance of the differences in slopes and intercepts of the regressions among groups by tooth (Table 8), several significant ($P < 0.05$) differences were observed, most notably with the modern Coimbra sample, whose M1 slope significantly differed from all other samples. Coimbra had the smallest M1 slope (Table 6) and greatly reduced dentin exposure rates (Table 7). The M1 intercepts of Coimbra also significantly differed from all the other samples. For M2, the Coimbra slope only differed significantly from those of the two Mesolithic (Portugal and Spain) and the Spanish Neolithic samples, as did the intercepts, except for the Near East Neolithic. M3 comparisons showed

Table 7

Comparisons of slopes and wear rates among the groups considered. The t-tests compare the slopes of M1, M2 and M3 for the combined maxillary bones. The dentin exposure rates of %/month and mm^2 /year refer to the molar eruption intervals M1-M2 ($r_{1\text{-}2}$, $w_{1\text{-}2}$), M2-M3 ($r_{2\text{-}3}$, $w_{2\text{-}3}$), and M1-M3 ($r_{1\text{-}3}$, $w_{1\text{-}3}$).

	$b_{M1} \leftrightarrow b_{M2}$		$b_{M2} \leftrightarrow b_{M3}$		%/month				mm^2/year		
Group	$t_{M1\text{-}2}$	$P_{M1\text{-}2}$	$t_{M2\text{-}3}$	$P_{M2\text{-}3}$	r_1	r_2	r_3	w_1	w_2	δ_{j-i}	w_3
1. Portugal Mesolithic	16.62	***0.000***	3.54	***0.001***	4.32	1.40	2.74	3.08	6.19	3.10	4.76
2. Spain Mesolithic	5.77	***0.000***	1.15	0.263	4.31	1.13	2.60	3.49	4.98	1.49	4.29
3. Spain Neolithic	13.69	***0.000***	1.37	0.176	4.00	1.14	2.46	2.48	3.60	1.12	3.08
4. Near East Natufian	7.59	***0.000***	0.30	0.765	3.61	0.80	2.09	1.90	1.68	−0.22	1.78
5. Near East Neolithic	5.25	***0.000***	0.09	0.931	3.36	1.32	2.26	1.57	2.99	1.42	2.34
6. Spain Early Medieval	13.11	***0.000***	1.46	0.149	3.40	1.07	2.14	1.62	2.21	0.59	1.94
7. Portugal Coimbra	2.42	***0.017***	0.28	0.780	*2.38*	*0.90*	*1.58*	*0.82*	*0.96*	0.14	*0.90*

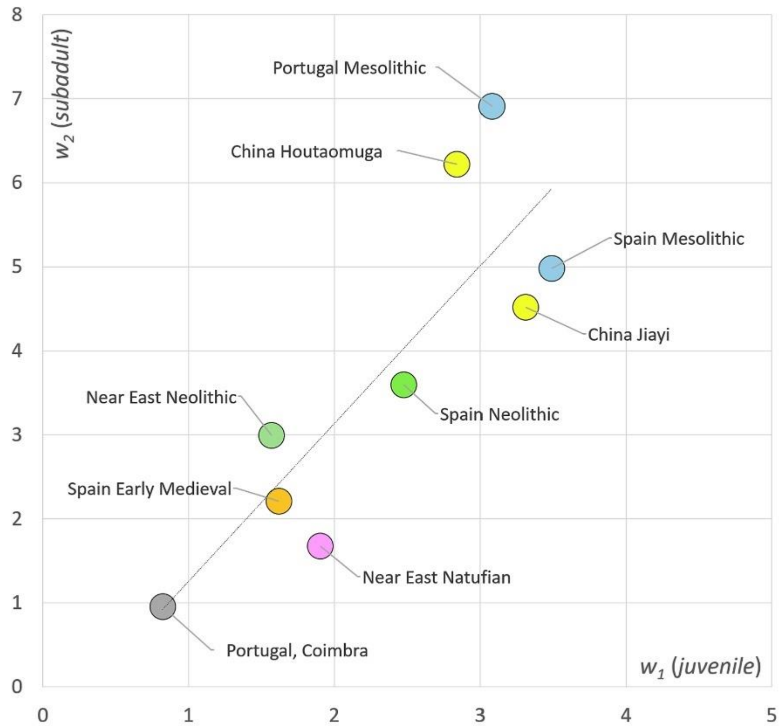


Fig. 4. Bivaried plot of the wear rates (mm^2/year) for the juvenile (w1, X-axis) and the subadult (w2, Y-axis) age-intervals of all the groups studied (names shown in the plot).

Table 8
Comparison of the slopes of the linear models among the groups considered. Tests (*t*-test) for the null hypotheses $H_0 : b_i = b_j$ (upper diagonal matrix) and $H_0 : a_i = a_j$. (lower diagonal matrix). The shaded areas indicate the comparisons of Coimbra and the Early Medieval groups with the rest of the samples. The significant *P*-values are shown in bold ($P \leq 0.05$).

b / ln *a*		P-MES		Coimbra		S-MES		S-NEO		S-MED		NE-NEO		Natufian	
		t	*P*	*t*	*P*	*t*	*P*	*t*	*P*	*t*	*P*	*t*	*P*	*t*	*P*
P-MES	**M1**	–		2.881	**0.004**	0.961	0.338	0.544	0.587	0.272	0.786	0.396	0.693	0.157	0.876
	M2			2.397	**0.018**	0.413	0.681	0.449	0.654	3.326	**0.001**	2.010	**0.047**	2.169	**0.032**
	M3			1.610	0.118	0.379	0.707	1.216	0.231	2.513	**0.016**	0.599	0.554	2.103	**0.043**
Coimbra	**M1**	2.501	**0.013**	–		1.268	0.207	2.581	**0.011**	3.124	**0.002**	2.317	**0.022**	1.990	**0.048**
	M2	6.678	**0.000**			2.094	**0.041**	2.155	**0.034**	1.096	0.276	2.155	0.034	1.179	0.243
	M3	7.409	**0.000**			1.645	0.134	1.180	0.251	0.699	0.491	1.180	0.251	0.424	0.679
S-MES	**M1**	0.942	0.348	0.853	0.395	–		0.583	0.561	0.842	0.401	0.607	0.546	0.851	0.399
	M2	0.431	0.667	4.150	**0.000**			0.601	0.550	1.753	0.084	1.646	0.111	1.496	0.142
	M3	0.430	0.670	5.541	**0.000**			1.066	0.298	1.892	0.070	0.667	0.530	1.894	0.081
S-NEO	**M1**	0.215	0.830	2.858	**0.005**	0853	0.396	–		0.343	0.732	0.091	0.927	0.508	0.613
	M2	1.783	0.077	5.619	**0.000**	1.166	0.247			2.453	**0.016**	1.680	0.098	1.657	0.101
	M3	3.313	**0.002**	5.656	**0.000**	1.383	0.180			1.160	0.253	0.432	0.671	1.258	0.220
S-MED	**M1**	0.659	0.511	2.922	**0.004**	0.572	0.568	0.523	0.602	–		0.193	0.847	0.333	0.740
	M2	5.126	**0.000**	3.328	**0.001**	2.549	**0.013**	3.531	**0.001**			0.288	0.774	0.288	0.774
	M3	4.534	**0.000**	3.424	**0.002**	2.804	**0.010**	2.269	**0.029**			0.233	0.818	0.418	0.679
NE-NEO	**M1**	0.519	0.604	2.050	**0.042**	0.540	0.591	0.368	0.714	0.047	0.962			0.423	0.674
	M2	2.329	**0.022**	1.821	0.075	2.013	0.054	1.577	0.119	0.112	0.911	–		0.445	0.659
	M3	0.527	0.602	0.891	0.392	0.447	0.671	0.204	0.841	0.136	0.893			0.128	0.901
Natufian	**M1**	0.337	0.737	1.092	0.277	0.383	0.703	0.219	0.827	0.026	0.979	0.000	1.000	–	
	M2	2.818	**0.006**	3.534	**0.001**	1.890	0.066	1.565	0.121	0.946	0.347	0.615	0.542		
	M3	2.618	**0.013**	2.629	**0.017**	2.530	**0.025**	1.906	0.068	0.259	0.798	0.194	0.850		

fewer significant differences; for the slope, Coimbra only differed from the Portuguese Mesolithic, while for the intercept, it differed from all the samples except the Near East Neolithic. On the other hand, the M1 slope and intercept of the Early Medieval Catalan sample only differed significantly from Coimbra, indicating that the Early Medieval sample more closely resembled the other samples than Coimbra. For M2, significant differences in both slope and intercept were observed between the Portugal Mesolithic and both the Natufian and Near East Neolithic samples. Finally, the M3 intercepts significantly differed between the Portugal Neolithic and both the Natufian and the Spanish Neolithic samples, though the slope only significantly differed from the Natufian. No other significant differences in slopes were detected. Overall, the Mesolithic samples had significantly high dentine exposure rates, particularly the Portugal Mesolithic, followed by the Spanish Mesolithic and Neolithic samples, with no significant differences between the two Neolithic samples.

5. Discussion

The Natufian culture (circa 12,500–9,500 BCE) is notable for its semi-sedentary lifestyle, advanced stone tool technology, and the early plant and animal domestication in the Levant, particularly Israel, Palestine, and Lebanon (Weinstein-Evron 1991, 2009). Patricia Smith analyzed dental attrition in the Natufian in the early 1970 s (Smith 1972). She noted that the age-attrition correlation is the major component of tooth wear. However, the limited accuracy of age estimations for adults with rapid attrition rates "may bias the findings considerably". Therefore, it is crucial to have samples of known age, a condition rarely met with skeletal material from early sites. Alternatively, attrition gradients within individual specimens, such as differences between molar eruption ages, can be used for intergroup comparisons (Smith, 1972). Smith employed a 5-point wear score for measuring attrition, but only scores 1 (enamel faceting), 2 (dentin exposure), and 3 (secondary dentin exposure) were used. Her findings showed a similar correlation coefficient between M1 and M2 at the Natufian sites of Eynan ($r = 0.80$) and El Wad ($r = 0.82$), but significantly different correlation at Kebara ($r = 0.70$, $P < 0.01$). This difference persisted when examining M2 and M3 pairs, with $r = 0.51$ at Kebara, 0.86 at El Wad and 0.84 at Eynan. These results indicated that the attrition gradients at El Wad and Eynan were very similar but differed from Kebara, suggesting a diet of different consistency at Kebara. Eshed et al. (2006) supported Smith's conclusion that the low rate of attrition at Kebara Cave is typical of a hunting-based population consuming non-abrasive foods within the framework of a hunting/gathering economy (with a possible increased reliance on grains), as opposed to El Wad and Eynan, whose more severe attrition suggested a more abrasive diet. Smith et al. (1984) later confirmed that the attrition rate varied among Natufian groups, being most severe at El Wad and Eynan and least severe at Kebara and Hayonim Cave. Natufian hunter-gatherers in northern Israel exploited a diverse range of animal and plant foods from both sedentary and more mobile settlements (Bar-Yosef 1998), while Early Neolithic people practiced a hunting-farming economy from increasingly sedentary settlements (Garfinkel 1987). Despite the expectation that the removal of plant seed coats would reduce phytoliths, enamel pits were significantly larger among farmers than hunter-gatherers, and scratches were wider among farmers than hunter-gatherers, suggesting that the diet became harder during the Neolithic period, likely due to reliance on stone-ground plant foods containing grit particles harder than enamel (Mahoney 2006).

The absence of known ages at death for most skeletal remains complicates dental wear studies, making an age-independent measure of dental wear necessary (Elgart 2010; Molnar et al. 1983; Rose & Ungar 1998; Scott 1979; Smith 1972). Traditionally, wear rates comparisons across populations have utilized the principal axis technique (Benfer & Edwards 1991; Scott 1979). This method assesses wear on M1 when M2 erupts and on M2 when M3 erupts. Assuming a constant wear rate during these known-age intervals, the slope of the regression model between the wear scores of the two molars indicates the wear rate, with a steeper slope implying a high rate (Scott 1979). In this study, we employ this technique, incorporating the proxy by Yang et al. (2024) to examine changes in overall 3D dentin exposure area (S) within fixed age intervals (*juvenile* and *subadult*) based on molar eruption ages. Wear rates, both in mm^2/year (w) and % per month (r), were calculated for these intervals and compared across populations. The innovation of this procedure lies in using the overall 3D dentin exposure area of the three molars (S) rather than a single molar. We used the intercepts from the regression models of each molar to derive the dentin exposure area of M1 at the onset of M2 dentin exposure and the combined dentin exposure area of M1 and M2 at the onset of M3 dentin exposure.

We show that regression models by tooth type were highly significant across the intervals considered. During the *juvenile* interval, M1 was the sole contributor to S, while both M1 and M2 contributed during the subsequent *subadult* interval. Wear rates increased during the *subadult* period compared to the *juvenile* one in all samples except Coimbra and the Near East Natufian, which exhibited the lowest dentin exposure rates, with the Portuguese Mesolithic sample showing the greatest increase. This likely reflects either a shift in food processing (Deter 2009), diet composition (Godinho et al. 2023), or a broader range of foods, including more abrasive items (Romero et al. 2012), as the three molars come into occlusion. Consequently, the overall accrual of dentin exposure was curvilinear rather than linear. S best fitted a *Power* model for D by molar type, indicating a non-constant rate of dentin exposure accumulation within a molar quadrant (Yang et al. 2024). We observed the same wear pattern in the present research for M1 across all seven groups considered. However, for M2 or M3, the *Quadratic* function explained the highest percentage of variance, likely due to smaller sample sizes of rear molars. Despite variations in R^2 values, all functions were highly significant.

The overall wear rates were similar during the Portuguese Mesolithic (4.76 mm^2/year), characterized by a high intake of seafood (as indicated by the numerous shellmiddens in the sites), and the Spanish Mesolithic (4.29 mm^2/year), not so intensively associated to shellmiddens. These wear rates were comparable to those reported for the Chinese Neolithic to Bronze Age population at Houtaomuga (4.66 mm^2/year) and Jiayi (3.69 mm^2/year) (Yang et al., 2024), which inhabited cold, arid environments. However, the high wear rates observed in the Mesolithic populations do not suggest similar environmental conditions to those of the Chinese populations during the transition from the Late Neolithic (5500–3200 BCE) to the Early Iron Age (2700 BCE–1781 ACE) (Wang 2018; Yang et al. 2024). Instead, these rates reflect the heavy loads, highly demanding, and poorly processed diets typical of the European Mesolithic.

The Mesolithic *Concheiros* in Portugal were seasonal settlements located in the estuaries of the Muge valley and the Sado River near Lisbon. Muge (Roche, 1972a: pp. 135–137; Lentacker 1986) and Sado (Arias et al. 2021) provided evidence of both marine and terrestrial animal food consumption. The faunal assemblages at Muge included various species, with cockles (*Cerastoderma* edule), peppery furrow shell (*Scrobicularia plana*), rabbits (*Oryctolagus cuniculus*), wild boar (*Sus scrofa*), and red deer (*Cervus elaphus*) being the most abundant. The Spanish Mesolithic site of El Collado (Gibaja et al. 2015, 2017a) also contained shell middens similar to those found at the Portugal sites, but shell consumption might have been less significant there than at Muge and Sado, indicating a greater reliance on terrestrial foods (Garcia-Guixé et al. 2006). The wear rate during the subadult interval was smaller in the Spanish Mesolithic sample (3.49 mm^2/year) compared to the Portuguese Mesolithic sample (6.19 mm^2/year), suggesting a more abrasive subadult diet in the latter, although the differences were not significant. This trend in food resource exploitation could be attributed to the seasonality of hunting and gathering activities or to lower mollusk production in the Mediterranean compared to the Atlantic region.

There is a consensus that abrasives foods were consumed by Neolithic populations (Mahoney 2006), with plant phytoliths and grit from plant-grinding stone tools being primarily responsible for the variations observed between hunter-gatherers and early farmers. Accordingly, our findings show higher wear rates in the PPNB Neolithic (2.34 mm^2/year) compared to the Natufian (1.78 mm^2/year), likely due to the consumption of abrasives from various sources, such as contaminant grit, less processed foods, mineral-rich shells, or dry fish, which accelerated enamel and dentin wear (Alrousan et al. 2013; Yang et al. 2024).

In the Iberian Peninsula, Middle Neolithic populations were agriculture-based settlers consuming cultivated plants and livestock (Price 2000; Alday 2012), whereas Mesolithic populations were hunter-gatherers with temporary settlements in marine estuaries (Bicho et al. 2017). However, the lower wear rates observed in the Neolithic populations compared to Mesolithic ones suggest a less abrasive or processed diet in the Neolithic populations, despite the use of stone mills, which likely introduced abrasive particles into the foods, especially cereals. The Spanish Neolithic sample had a lower wear rate (3.08 mm^2/year) than the Spanish Mesolithic populations (4.29 mm^2/year). Similarly, the Near East PPNB Neolithic samples exhibited a low wear rate (2.34 mm^2/year), indicating a less abrasive diet in the Near East. Neolithic populations during the PPNB period were fully settled, with developed crops and livestock (Mahoney 2006), whereas the Natufian period was characterized by nomadic hunter-gatherers. The first domesticated crops appeared in the Early PPNB period, between 8,700 and 8,200 BCE (Nesbitt 2002). The results suggest that the Natufian lifestyle was associated with softer diets compared to the Neolithic PPNB period.

The transition to a Neolithic lifestyle, marked by full sedentarization, animal domestication, and increased reliance on edible plant remains (Galili et al. 1993; Garfinkel 1987) such as emmer wheat and pulses, indicates a greater emphasis on farmed foods. The use of stone tools for grinding may have maximized the nutritional value of these foods, potentially leading to overexploited local cultivable land (Wright 1993; Düring 2010). However, wear rates during the Neolithic were lower than those observed in Mesolithic populations. Although no Late Neolithic sites were included in this study, an increase in wear rates compared to the Middle Neolithic samples would be expected due to the increasing reliance on plant-grinding tools, shown to be responsible for microwear formation (Mahoney, 2006).

The diet of the Early Medieval Casserres population was highly variable, consisting of a significant proportion of meat, abrasive plant foods like cereals and dried fruits, minimally processed complex carbohydrates, and low intake of simple sugars (Carrascal 2021). We observed similar dentin exposure rates in the Natufian and PPNB Neolithic samples, indicating a highly varied and highly processed but low-abrasive diet, though dietary practices may not have been uniform across medieval populations. In contrast, the recent Portuguese collection from Coimbra exhibited the lowest wear rates among all the samples studied, suggesting a diet with much less abrasive potential. Most individuals documented at Coimbra cemetery were from lower socioeconomic classes, whose diet primarily consisted of low-quality foods such as cornbread, dried vegetables, potatoes, some fish (usually sardines or salted cod), and bacon (Correia 1951; Cuesta-Torralvo et al., 2021). These foods, combined with their methods of processing and chewing, had low abrasive potential, leading to minimal dentin exposure rates.

In conclusion, the dentin exposure results derived from the regression model proxy provide a robust indicator of dietary shifts from the Mesolithic to the Neolithic, closely aligning with the expected patterns associated with the transition to agriculture and sedentary life. The molar dentin exposure rates clearly illustrate the dietary changes, particularly the increased consumption of carbohydrates, including ground grains and cereals, which led to a decrease in dentin exposure rates in Neolithic samples compared to the more abrasive diets of Mesolithic hunter-gatherers, who relied heavily on hunting, gathering, and shellfish. Importantly, we made these comparisons despite the absence of known age distributions within the samples, yet the computed wear rates remained consistent with the expected dietary patterns and food preparation techniques of each period. This approach underscores the utility of the wear rate indicators derived from regression models of molar dentin exposure, offering a valuable tool for understanding the dietary and lifestyle changes in ancient populations.

Credit authorship contribution statement

Susana Carrascal: Writing – original draft, Resources, Investigation, Formal analysis. **Ferran Estebaranz-Sánchez:** Resources, Investigation. **Albert E. Dyowe-Roig:** Investigation. **Shiyu Yang:** Resources, Investigation. **Claudia Umbelino:** Writing – review & editing, Resources, Investigation, Funding acquisition. **Bérénice Chamel:** Resources. **Miquel Molist:** Resources. **María Eulàlia Subirà:** Resources, Investigation. **Alejandro Pérez-Pérez:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Laura M. Martínez:** Resouces, Investigation, Writing, Project administration.

Funding

The Spanish *Ministerio de Ciencia e Innovación* (MNCIN) and the Europe Union Next Generation EU MICIN/AEI/https://doi.org/10.13039/5011001100011033, Ref. no. PID2020-112963 GB-I00 funded to APP, and PID2023-148818NB-I00 funded to LMM & APP, by ERDF *A way of Making Europe*, and the *Margarita Salas* postdoctoral contract to SC, by the EU.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank Prof. Quanchao Zhang, from Jilin University, Bioarchaeology Laboratory, Changchun, China, for his collaboration in the study of the Chinese Neolithic to Bronze Age populations cited here (Yang et al., 2024).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2024.104936.

Data availability

Data will be made available on request.

References

Akkermans PMMG, Schwartz GM (2003) The archaeology of Syria: from complex hunter-gatherers to early urban societies (c. 16,000-300 BC). Cambridge University Press. https://books.google.es/books?id=_4oqvpAHDEoC&printsec=frontcover&hl=es&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.

Akkermans PMMG (2004) Hunter-gatherer continuity: The transition from the Epipaleolithic to the Neolithic in Syria. *British Archaeological Reports* **286**, 281–293. Leiden University, Oxford, https://hdl.handle.net/1887/9832.

Alday Ruiz, A., 2012. The Neolithic in the Iberian Peninsula: an explanation from the perspective of the participation of Mesolithic communities. Zephyrus LXIX, 75–94. https://www.researchgate.net/publication/286463795_The_Neolithic_in_the_Iberian_Peninsula_An_explanation_from_the_perspective_of_the_participation_of_Mesolithic_communities.

Almenberg, J., Gerdes, C., 2012. Exponential growth bias and financial literacy. Appl. Econ. Lett. 19 (17), 1693–1696. https://doi.org/10.1080/13504851.2011.652772.

Alrousan, M., Al-Shorman, A., Galbany, J., Pérez-Pérez, A., 2013. Buccal dental microwear and stable isotopes of El Collado: a Mesolithic site from Spain. Bulletin

International Association for Paleodontology 7 (1), 4–11. https://hrcak.srce.hr/en/file/154093.
Araus JL, Gascón m, Ros-Sabéc E, Piqué R, Rezzouka FZ, Aguilera M, Voltasd J, Peña-Chocarro L, Pérez-Jordà G, Terradas X, Palomo A, Ferrio JP, Antolíni F (2024) Isotope and morphometrical evidence reveals the technological package associated with agriculture adoption in western Europe. Proceedins of the National Academy of Sciences PNAS **121**(32), e2401065121. https://doi-org.sire.ub.edu/10.1073/pnas.2401065121.
Arensburg, B., Belfer-Cohen, A., 1998. Skeletal Remains from Kebara Cave, Israel. In: Akazawa, T., Aoki, K., Bar-Yosef, O. (Eds.), Neanderthals and Modern Humans in Western Asia. Springer, pp. 129–148. https://doi.org/10.1007/0-306-47153-1_9.
Arias P, Diniz M, Araújo A, Armendariz A, Teira L (2021) New perspectives on the Mesolithic of the Sado Valley (southern Portugal): Preliminary results of the SADO MESO project. In: D Borić, D Antonović, B Mihailović (Eds.) Foraging Assemblages Vol.1. Serbian Archaeological Society. pp. 274 - 280. ISBN 978-86-80094-14-4 https://repositorio.ul.pt/bitstream/10451/47589/1/MESO%202015-Chapter%2041_Arias_etal_Sado.pdf.
Ash M & Nelson S (2003) Wheele's dental anatomy, physiology and occlusion. Sounders (Ed.), Philadelphia. ISBN 9780323638791.
Aurenche O (2005) Tell Halula (Syria) and the Pre-Pottery Neolithic B. In: The Origins of Pottery and Agriculture, WK Barnett and JW Hoopes (Eds.), pp. 41–70. Philadelphia: University of Pennsylvania, Museum of Archaeology and Anthropology, 2005.
Bar Yosef, O., 1998. The Natufian Culture in the Levant, threshold to the origins of agriculture. Evol. Anthropol. 6 (5), 159–177. https://onlinelibrary.wiley.com/doi/10.1002/(SICI)1520-6505(1998)6:5%3C159::AID-EVAN4%3E3.0.CO;2-7.
Benfer, R.A., Edwards, D.S., 1991. The principal axis method for measuring rate and amount of dental attrition. In: Kelley, M.A., Larsen, C.S. (Eds.), Advances in Dental Anthropology. Wiley Liss, New York, pp. 325–340.
Bernabeu Aubán, J., Orozco Köhler, T., 1991. La secuencia neolítica antigua en la Cuenca del Serpis (Valencia). El Collado. Saguntum-PLAV 24, 9–32.
Bicho, N., Umbelino, U., Detry, C., Pereira, T., 2010. The emergence of the Muge Mesolithic shellmiddens (central Portugal) and the 8200 cal yr BP cold event. Journal of Island and Coastal Archaeology 5, 86–104. https://doi.org/10.1080/15564891003638184.
Bicho, N., Cascalheira, J., Marreiros, J., Gonçalves, C., Pereira, T., et al., 2013. Chronology of the Mesolithic occupation of the Muge valley, central Portugal: The case of Cabeço da Amoreira. Quat. Int. 308–309, 130–139. https://doi.org/10.1016/j.quaint.2012.10.049.
Bicho, N., Cascalheira, J., Gonçalves, C., Umbelino, C., García Rivero, D., André, L., 2017. Resilience, replacement and acculturation in the Mesolithic/Neolithic transition: the case of Muge, central Portugal. Quat. Int. 446, 31–42. https://doi.org/10.1016/j.quaint.2016.09.049.
Bordas A, Borrell F, Bosch J (2009) Introducció. 10 anys de recerques arqueològiques a la serra de les Ferreres (Mines de Gavà, Baix Llobregat). In: Intervencions arqueològiques a les mines de Gavà (sector serra de les Ferreres), Anys 1998–2009. Museu de Gavà. Rubricatum **4**, 9–14. https://raco.cat/index.php/Rubricatum/article/view/203954/272486.
Carrascal, S., 2021. Catalunya a l'Alta Edat Mitjana a través de la necròpolis d'"Accés Est de Casserres. Universitat Autònoma de Barcelona. PhD Thesis.
Cebrià, A., Fullola, J.M., López Onaindia, D., Mangado, X., Nadal, J., Ollé, A., Oms, X., Pedro, M., Ruiz, J., Subirà, M.E., Torrente, A., Vergès, J.M., 2013. La cova sepulchral del pantà de Foix (Castellet i la Gornal). In: De Jaciment Arraconat a Jaciment Modèlic. III Monografies De Foix. Diputació de Barcelona, pp. 184–194.
Coll, J.M., Roig, J., 2005. Un assentament del neolític i un vilatge de l'antiguitat tardana als horts de can torras (Castellar del Vallès, Vallès Occidental). Castellar Del Vallès: Recerca 4, 45–58. https://dialnet.unirioja.es/servlet/articulo?codigo=5180776.
Connolly, J., Wayne, P., Bazzaz, F., 2001. Interspecific competition in plants: How well do current methods answer fundamental questions? Am. Nat. 157 (2), 107–125. https://doi.org/10.1086/318631.
Coqueugniot, É., 2000. Dja'dé (Syrie), un village néolithique du 9e millénaire avant J. C. Paléorient 26 (2), 89–103. https://doi.org/10.3406/paleo.2000.4691.
Coqueugniot, É., 2011. Dja'dé el-Mughara: a neolithic village on the Middle Euphrates. In: The Neolithic Revolution: New Perspectives on Southwest Asia in Light of Recent Discoveries on Cyprus. British Museum, pp. 53–66.
Correia, A.M., 1951. A alimentaçao do povo português. Lisboa: Instituto Nacional de povo português. Instituto Nacional de Estatística, Lisboa.
Cubas, M., Altuna, J., Álvarez-Fernández, E., Armendariz, A., Fano, M.A., López-Dóriga, I.L., Mariezkurrena, K., Tapia, J., Teira, L.C., Arias, P., 2016. Re-evaluating the Neolithic: the impact and the consolidation of farming practices in the Cantabrian region (Northern Spain). J. World Prehist. 29 (1), 79–116. https://doi.org/10.1007/s10963-016-909-2.
Cuesta Torralvo, E., Pacheco, D., Martínez, L.M., Romero, A., Umbelino, C., Avià, Y., Pérez-Pérez, A., 2021. Three-dimensional proxies to dental wear characterization in a known age-at-death skeletal collection. J. Archaeol. Method Theory 28 (4), 1261–1275. https://doi.org/10.1007/s10816-020-09496-1.
Cunha, E., Wasterlain, S., 2007. The_Coimbra_identified_osteological_collections. In: Grupe, G., Peters, J. (Eds.), Skeletal Series and Their Socio Economic Context. Verlag Marie Leidorf GmbH, Rahden/Westf, Germany, pp. 23–33 https://www.researchgate.net/publication/280992308_The_Coimbra_identified_osteological_collections.
Deter, A., 2009. Gradients of occlusal wear in hunter-gatherers and agriculturalists. Am. J. Phys. Anthropol. 138 (3), 247–254. https://doi.org/10.1002/ajpa.20922.
Düring, B., 2010. Early Farmers of the Southern Plateau (8500–6500 BC). In: The Prehistory of Asia Minor: from Complex Hunter-Gatherers to Early Urban Societies. Cambridge University Press, Cambridge, pp. 47–121. https://doi.org/10.1017/CBO9780511778926.005.
Elgart, A.A., 2010. Dental wear, wear rate, and dental disease in the African Apes. Am. J. Primatol. 72 (6), 481–491. https://doi.org/10.1002/ajp.20797.
Eshed, V., Gopher, A., Hershkovitz, I., 2006. Tooth wear and dental pathology at the advent of agriculture: New evidence from the Levant. Am. J. Phys. Anthropol. 130 (2), 145–159. https://doi.org/10.1002/ajpa.20362.
Estebaranz Sánchez, F., Martínez, L.M., Anfruns, J., Pérez-Pérez, A., 2007. Tell Halula (Syria), seasons 1992–2005. Bioarchaeology of the near East 1, 65–67. http://www.anthropology.uw.edu.pl/01/bne-01-04.pdf.
Ferembach, D., 1969. Étude anthropologique des ossements humains néolithiques Tell Ramad (Syrie). Annales Archéologiques Arabes Syriennes 19, 49–70.
Fontanals-Coll, M., Subirà, M.E., Diaz Zorita Bonilla, M., Gibaja, J.F., 2015. Human diet and the chronology of Neolithic societies in the north-east Iberian Peninsula: the necropolises of Puig d'en Roca and Can Gelats (Girona, Spain). J. Archaeol. Sci. Reports 3, 160–170. https://doi.org/10.1016/j.jasrep.2015.06.013.
Galbany, J., Estebaranz, F., Martínez, L.M., Romero, A., De Juan, J., Turbón, D., Pérez-Pérez, A., 2006. Comparative analysis of dental enamel polyvinysiloxane impression and polyurethane casting methods for SEM research. Microscopy Research Techniques 69 (4), 246–252. https://doi.org/10.1001/jemt.20296.
Galili, E., Weinstein-Evron, M., Hershkovitz, I., Kislev, M., Lernau, O., Kolska-Horwitz, L., Lernau, H., 1993. Atlit-Yam: a prehistoric site off the Israel coast. J. Field Archaeol. 20, 133–156. https://doi.org/10.1179/jfa.1993.20.2.133.
Garcia-Guixé, E., Richards, M., Subirà, M.E., 2006. Palaeodiets of humans and fauna at the Spanish Mesolithic site of El Collado. Curr. Anthropol. 47, 549–556. https://doi.org/10.1086/504170.
Garfinkel, Y., 1987. Yiftahel: a Neolithic village from the seventh millennium B.C. in lower Galilee. Israel. Journal of Field Archaeology 14, 199–212. https://doi.org/10.1179/009346987792208420.
Gibaja JF, Subirà ME, Terradas X, Santos JF, Agulló L, Gómez Martínez I, Allièse F, Fernández-López de Pablo J (2015). The emergence of Mesolithic cemeteries in SW Europe: Insights from the El Collado (Oliva, Valencia, Spain) radiocarbon record: PLoS ONE **10**(1), e0115505. pp. 1–18. doi: 10.1371/journal.pone.0115505.
Gibaja JF, Terradas X, Morell B, Allièse F, Subirà ME (2017a). El yacimiento prehistórico de El Collado (Oliva, Valencia): una necrópolis de los últimos cazadores de la Península Ibérica. Cabdells **XV**, 5–24.
Gibaja JF, Morell B, Barceló Álvarez JA, Dubosq S, Masclans A, Remolins G, Roig J, Martín A, González P, Plasencia J, Coll JM, Subirà ME (2017b) The chronology of the Neolithic necropolis Bòbila Maduell-Can Gambús in the Northeast Iberian Peninsula: Dating the pit burials cultural horizon and long range raw material exchange networks, Radiocarbon **59**(6), 1713–1736. Special Issue 8[th] International Symposium, Edinburgh, 27 June – 1 July 2016, Part 2 of 2, December 2017. doi: 10.1017/RDC.2017.131.
Gilmore, C.C., Grote, M.N., 2012. Estimating age from adult occlusal wear: a modification of the Miles method. Am. J. Phys. Anthropol. 149 (2), 181–192. https://doi.org/10.1002/ajpa.22106.
Godinho, R.M., Umbelino, C., Garcia, S., Gonçalves, C., 2023. Changes in dental wear magnitude in the last ~8000 years in southwestern Iberia. Arch. Oral Biol. 147, 105626. https://doi.org/10.1016/j.archoralbio.2023.105626.
Górka, K., Romero, A., Pérez-Pérez, A., 2015. First molar size and wear within and among modern hunter-gatherers and agricultural populations. Journal of Comparative Human Biology 65 (4), 299–315. https://doi.org/10.1016/j.jchb.2015.02.007.
Guitart I (1987) La necròpolis neolítica del Pla del Riu de les Marcetes (Manresa, Bages). Generalitat de Catalunya. Departament de Cultura. Tribuna d'Arqueologia 1986-1987, 1987, pàg. 41-47. https://calaix.gencat.cat/handle/10687/91439#page=1.
Han Z, Liu T, Sun Q, Li R, Xie J, Li B (2014) Application of compound interest laws in biology: Reunification of existing models to develop seed bank dynamics model of annual plants. Ecological Modelling. Vol. **278**, 67–73. ISSN 0304-3800. doi: 10.1016/j.ecolmodel.2014.01.024.
Hember, R.A., Kurz, W.A., Metsaranta, J.M., Black, T.A., Guy, R.D., Coops, N.C., 2012. Accelerating regrowth of temperate maritime forests due to environmental change. Glob. Chang. Biol. 18 (6), 2026–2040. https://doi.org/10.1111/j.1365-2486.2012.02669.x.
Henry, D.O., 1989. From foraging to agriculture: the Levant at the end of the Ice Age. Philadelphia University Press.
Hernández Pérez, M.S., Soler Mayor, P., 1997. El Collado: un asentamiento Neolítico antiguo en la Cuenca del Serpis. Trabajos Varios Del SIP 86, 9–32.
Hillson, S., Fitzgerald, C., Flinn, H., 2005. Alternative dental measurements: proposals and relationships with other measurements. Am. J. Phys. Anthropol. 126 (4), 413–426. https://doi.org/10.1002/ajpa.10430.
Hillson S (1996) Dental Anthropology. Cambridge University Press. On line ISBN 9781139170697. 2012, doi: 10.1017/CBO9781139170697.
Kaidonis, J.A., Ranjitkar, S., Lekkas, D., Townsend, G.C., 2012. An anthropological perspective: another dimension to modern dental wear concepts. International Journal of Dentistry 2012, 741405–741406. https://doi.org/10.1155/2012/741405.
Kaidonis JA (2008) Tooth wear: the view of the anthropologist. Clinical Oral Investigations 12 (Suppl 1), S21-S26. doi: 10.1007/s00784-007-0154-8.
Kaifu, Y., Kasai, K., Townsed, G.C., Richards, L.C., 2003. Tooth wear and the "design" of the human dentition: a perspective from evolutionary medicine. Am. J. Phys. Anthropol. 37, 47–61. https://doi.org/10.1002/ajpa.10329.
Lentacker, A., 1986. Preliminary results of the fauna of Cabeço de Amoreira and Arruda (Muge, Portugal). Trabalhos De Antropologia e Etnologia 26 (1–2), 9–26. https://scholar.google.com/scholar?hl=ca&as sdt=0%2C5&q=lentacker+1986+plreliminary+results+of+the+fauna+of+cabe%C3%A7o+de+amoreira&btnG=.
Lukacs, J.R., Pastor, R.F., 1988. Activity-induced patterns of dental abrasion in prehistoric Pakistan: evidence from Mehrgarh and Harappa. Am. J. Phys. Anthropol. 76 (3), 377–398. https://doi.org/10.1002/ajpa.1330760310.

Maat, G.J.R., 2001. Diet and age-at-death determinations from molar attrition a review related to the Low Countries. The Journal of Forensic Odonto-Stomatology 19 (1), 18–21.
Mahoney, P., 2006. Dental microwear from Natufian hunter-gatherers and early Neolithic farmers: comparisons within and between samples. Am. J. Phys. Anthropol. 130 (3), 308–319. https://doi.org/10.1002/ajpa.20311.
Maroto J, Soler N (2000). Els primers pobladors. In: Història de Girona. L Costa Fernández, J Maroto (Eds.). Ateneu d'Acció Comercial (ADAC). ISBN 84 404 7571 3. https://www.portalgironi.cat/index.php/fonts/fonts-bibliografia/2872-bibliografia-llibres/716-llibres-historia-girona-adac.
Masclans A (2017) Aproximació a les comunitats pertanyents a l'Horitzó c. 4.000–3.400 cal ANE al NE de la Península Ibèrica a partir dels estudis tecno-funcionals dels artefactes polits i bisellats situats en contextos funeraris i d'hàbitat [unpublished PhD dissertation] University of Girona.
McClatchie, M., McCormick, F., Kerr, T.R., O'Sullivan, A., 2015. Early medieval farming and food production: a review of the archaeobotanical evidence from archaeological excavations in Ireland. Veg. Hist. Archaeobotany 24, 179–186. https://doi.org/10.1007/s00334 014 0478 7.
Meiklejohn, C., Roksandic, M., Jackes, M., Lubell, D., 2009. Radiocarbon dating of the Mesolithic human remains in Portugal. Mesolithic Miscellany 20 (1), 4–16. https://drive.google.com/file/d/0Bytata4MEsThbG90bkhiM0xJTU0/view?resourcekey=0-XNIDsuZ_k_OymaA5dZdk0w.
Molist, M., Bofill, M., Borrell, F., Bosch, J., Buxó, R., Chambon, P., Clop, X., Gibaja, J., Gómez, A., Nadal, J., Oliva, M., Ortiz, A., Saña, M., Vicente, O., 2012. La caserna de Sant Pau del camp (Barcelona): una aproximación a los modelos de circulación de productos e ideas en un contexto funerario postcardial. Rubricatum (revista Del Museu De Gavà) 5, 449–458.
Molnar, S., 1971. Human tooth wear, tooth function and cultural variability. Am. J. Phys. Anthropol. 34 (2), 175–189. https://doi.org/10.1002/ajpa.1330340204.
Molnar, S., McKee, J.K., Molnar, I., 1983. Measurements of tooth wear among Australian Aborigines: I. serial loss of the enamel crown. Am. J. Phys. Anthropol. 61 (1), 51–65. https://doi.org/10.1002/ajpa.1330610106.
Nesbitt M (2002) When and where did domesticated cereals first occur in southwest Asia. The dawn of farming in the Near East. 113-32. https://www.researchgate.net/publication/234002845_When_and_where_did_domesticated_cereals_first_occur_in_southwest_Asia.
Oliva M, Palomo A, Terrats N, Carlús X, López X, Rodríguez A (2008) Las estructuras neolíticas de Can Roqueta (Sabadell, Barcelona). In: MS Hernández, JA Soler, JA López (Eds.) Actas del IV congreso del neolítico peninsular. Alicante, 2006. Museo Arqueolóogico de Alicante. Diputación de Alicante. I, 157–167. http://www.marqalicante.com/contenido/publicaciones/pub_58.pdf.
Oxilia, G., Bortolini, E., Martini, S., Papini, A., Boggioni, M., Buti, L., Figus, C., Sorrentino, R., Townsend, G., Kaidonis, J., Fiorenza, L., Cristiani, E., Kullmer, O., Moggi-Cecchi, J., Benazzi, S., 2018. The physiological linkage between molar inclination and dental macrowear pattern. Am. J. Phys. Anthropol. 166, 941–951. https://doi.org/10.1002/ajpa.23476.
Pandey R, Vijay P, Madurima D, Mahesh M, Ramesh CM (2017) Plant growth analysis. In: Manual of ICAR Sponsored Training Programme on Physiological Techniques to Analyze the Impact of Climate Change on Crop Plants 16-25 January, pp. 103–107. Division of Plant Physiology, IARI, New Delhi, Division of Plant Physiology, ICAR Indian Agricultural Research Institute (IARI), New Delhi-110 012. doi: 10.13140/RG.2.2.21657.72808.
Pérez, J.J., Arribas, A., 2013. Archaeobotany and Archaeology of the Early Medieval Period in the Iberian Peninsula. In: McGovern, P., Carleton, D.M.A.L., Renfrew, J.A. (Eds.), Archaeobotany and Ancient Foodways. Springer, pp. 145–160.
Petraru, O.-M., Bejenaru, L., Popovici, M., 2022. Diet-related dental wear in archaeological human populations of Chalcolithic and Bronze Age from North-Eastern Romania. Homo 73 (1), 77–92. https://doi.org/10.1127/homo/2022/1534.
Pou, R., Martí, M., Carlús, X., 1995. La necròpolis del camí de Can Grau, un conjunt funerari del Neolític Mitjà. Lauro: Revista Del Museu De Granollers 9, 3–8. https://raco.cat/index.php/Lauro/article/view/48204/53180.
Price, T.D., 2000. Europe's first farmers. Cambridge University Press, New York.
Richter, T., 2017. The Epipalaeolithic and Early Neolithic in the Jordanian Badia: recent fieldwork around the Qa' Shubayqa. Near East. Archaeol. 80, 30–37.
Richter, T., Arranz-Otaegui, A., Yeomans, L., Boaretto, E., 2017. High resolution AMS dates from Shubayqa 1, northeast Jordan reveal complex origins of Late Epipalaeolithic Natufian in the Levant. Sci. Rep. 7, 17025. https://doi.org/10.1038/s41598-017-17096-5.
Roche, A.J., 1972. Le gisement Mésolithique de Moita do Sebastião. Muge, Portugal. Lisbon, Instituto de Alta Cultura. ASIN B004Y728AK.
Romero, A., Galbany, J., De Juan, J., Pérez-Pérez, A., 2012. Brief communication: Short- and long-term in vivo human buccal dental microwear turnover. Am. J. Phys. Anthropol. 148 (3), 467–472. https://doi.org/10.1002/ajpa.22054.
Romero, A., Ramírez-Rozzi, F.V., Cuesta-TorralvoE, P.-Pérez A., 2019. Age-related tooth wear in African rainforest hunter-gatherers. Am. J. Phys. Anthropol. 170 (4), 622–628. https://doi.org/10.1002/ajpa.23934.
Rose, J.C., Ungar, P.S., 1998. Gross dental wear and dental microwear in historical perspective. In: Alt, K.W., Rosing, F.W., Teschler-Nicola, M. (Eds.), Dental Anthropology: Fundamentals, Limits and Prospects. Springer, Weinheim, pp. 349–356.
Scott, E.C., 1979. Principal axis analysis of dental attrition data. Am. J. Phys. Anthropol. 51 (2), 203–211. https://doi.org/10.1002/ajpa.1330510207.
Scott GR, Turner CG (1988) Dental anthropology. Annual Review of Anthropology **17**, 99-126. Link.
Shavit, A., Sharon, G., 2023. Can models of evolutionary transition clarify the debates over the Neolithic Revolution? Philosophical Transition Royal Society B 378, 20210413. https://doi.org/10.1098/rstb.2021.0413.
Shimojo M, Nakano Y, Ishimatsu S, Kakihara H, Shao T, Tobisa M (2010) Introducing viewpoints of mechanics into basic growth analysis: (XV) relationships between Richards growth function and basic growth function. Journal of the Faculty of Agriculture **55**(2), 259–260, Kyushu University. doi: 10.5109/18839.
Smith, P., 1972. Diet and attrition in the Natufians. Am. J. Phys. Anthropol. 37 (2), 233–238. https://doi.org/10.1002/ajpa.1330370207.
Smith, B.H., 1984. Patterns of molar wear in hunter-gatherers and agriculturalists. Am. J. Phys. Anthropol. 63 (1), 39–56. https://doi.org/10.1002/ajpa.1330630107.
Smith, P., Bar-Yosef, O., Sillen, A., 1984. Archaeological and skeletal evidence for dietary change during the late Pleistocene/early Holocene in the Levant. In: Cohen, M.N., Armelagos, G.J. (Eds.), Paleopathology at the Origins of Agriculture. University Press, Florida, pp. 101–136.
Smith A, Oechsner A, Rowley Conwy P, Moore AMT (2022) Epipalaeolithic animal tending to Neolithic herding at Abu Hureyra, Syria (12,800–7,800 cal BP): Deciphering dung spherulites. PLoS One **17**(9), e0272947: doi: 10.1371/journal.pone.0272947.
Smith, B.G.N., Knight, J.K., 1984. An index for measuring the wear of teeth. Br. Dent. J. 156 (12), 435–438. https://doi.org/10.1038/sj.bdj.4805394.
Stordeur, D., 2003. Tell Aswad: résultats préliminaires des campagnes 2001 et 2002. Neolithics 1 (3), 7–15.
Stordeur, D., Abbès, F., 2002. Du PPNA au PPNB: mise en lumière d'une phase de transition à Jerf el Ahmar (Syrie). Bulletin De La Société Préhistorique Française 99 (3), 563–595.
Subirà, M.E., Martínez, P., Fortó, A., Muñoz, V., Ortega, D., Gibaja, J.F., 2015. Las inhumaciones del Neolítico antiguo de Ca lEstrada (Canovelles, Barcelona). The ancient Neolithic burials of Ca l'Estrada (Canovelles. Barcelona) Munibe Antropologia-Arkeologia 66, 135–145. https://www.aranzadi.eus/fileadmin/docs/Munibe/2015135145AA.pdf.
Vidal Encinas JM, Prada Marcos ME, Fuertes Prieto MN, Fernandez Rodriguez C (2010) Los hombres mesolíticos de La Braña Arintero (Valdelugueros, León): el hallazgo, situación, aspectos arqueo-antropológicos, cronología y contexto cultural. In: M Vidal Encinas, ME Prada Marcos (Eds.), Los Hombres Mesolíticos de la Cueva de La Braña-Arintero (Valdelugueros, León). Junta de Castilla y León, León, pp. 16-61.
Vieira EP, Barbosa MS, Quintão CCA, Normando D (2015) Relationship of tooth wear to chronological age among indigenous Amazon Populations. PLoS ONE **10**(1), e0116138. doi: doi:10.1371/journal.pone.0116138.
Villalba MJ, Bañolas L, Arenas J, Alonso M (1986) Les mines neolítiques de Can Tintorer (Gavà). Excavacions 1978–1980. Excavacions arqueològiques a Catalunya, Barcelona. Generalitat de Catalunya Press.
Walker, P.L., Erlandson, J.M., 1986. Dental evidence for prehistoric dietary change on the Northern Channel Islands. California. American Antiquity 51 (2), 375–383.
Walsh, S., 2022. Early evidence of extra-masticatory dental wear in a Neolithic community at Bestansur, Iraqi Kurdistan. Int. J. Osteoarchaeol. 32 (6), 1264–1274. https://doi.org/10.1002/oa.3162.
Wang L (2018) Studies on the remains of the Neolithic Age in Houtaomuga site and relevant issues. Acta Archaeologica Sinica **2**, 141–164. https://kns.cnki.net/kcms/detail/detail.aspx?FileName= KGXB201802001&DbName=CJFQ2018.
Weide A, Riehl S, Zeidi M, Conard NJ (2018) A systematic review of wild grass exploitation in relation to emerging cereal cultivation throughout the Epipalaeolithic and aceramic Neolithic of the Fertile Crescent. Proceedings of the National Accademy of Science PNAS USA **13**(1), e0189811. doi: 10.1371/journal.pone.0189811.
Weinstein-Evron, M., 1991. New radiocarbon dates for the Early Natufian of el-Wad Cave, Mt. Carmel. Israel. Paleorient 17, 95–98. https://www.persee.fr/doc/paleo_0153 9345 1991 num 17 1 4542.
Weinstein-Evron, M., 2003. In B or not in B: a reappraisal of the Natufian burials at Shukbah Cave, Judea, Palestine. Antiquity 77, 96–101. https://doi.org/10.1017/S0003598X00061427.
Weinstein-Evron M (2009) Archaeology in the archives: Unveiling the Natufian Culture of Mount Carmel. ASPR, American School of Prehistoric Research Monograph Series. Brill (Ed.). ISBN 9789004167940.
Weis, A.E., Simms, E.L., Hochberg, M.E., 2000. Will plant vigor and tolerance be genetically correlated? Effects of intrinsic growth rate and self-limitation on regrowth. Evol. Ecol. 14, 331–352. https://doi.org/10.1023/A:1010950932468.
Wright, K., 1993. Early Holocene ground stone assemblages in the Levant. Levant 25 (1), 93–111. https://www.academia.edu/5851903/Wright_K_I_1993_Early_Holocene ground stone assemblages in the Levant Levant 25 1 93 111.
Yáñez de Aldecoa C (2003) La tomba de Segudet (Ordino): una nova aportació per al Neolític a Andorra. Papers de Recerca Història **1**, 10–23. Societat Andorrana de Ciències, Andorra. doi: 10.2436/20.0110.03.24.
Yang, S., Martínez, L.M., Romero, A., Carrascal, S., Guo, J., Dyowe, A.E., Zhang, Q., Pérez Pérez, A., 2024. Rethinking wear rate analysis: a new dentin exposure proxy and its applications to ancient Chinese populations. J. Archaeol. Method Theory 31, 2053–2081. https://doi.org/10.1007/s10816-024-09664-7.
Zilhão, J., 2001. Radiocarbon evidence for maritime pioneer colonization at the origins of Farming in West Mediterranean Europe. Proc. Natl. Acad. Sci. 98 (24), 14180–14185. https://doi.org/10.1073/pnas.241522898.

6.3. THE MAIN CASE OF SOUTHWEST ASIA

6.3.1. INTRODUCTION

Hypotheses of dietary and food-processing method heterogeneity among Southwest Asian groups were tested using a recently established dentine-exposure rate proxy (Yang et al. 2024). Carrascal et al., (2025) examined dental archaeological materials from the Pre-Pottery Neolithic B (PPNB) sites of Tell Aswad (8700–7500 cal. BC, N=5), Tell Halula (7800–6300 cal. BC, N=4), Tell Ramad (7230–6800 cal. BC, N=16), and Dja'de el Mughara (8800–8000 cal. BC, N=6). The PPNB sample was combined taken into consideration because the sample sizes by location for this 3D dentin exposure study were noticeably small. Sample sizes by molar type were particularly low for the posterior molars, even after integrating specimens from the PPNB era and using every molar quadrant in each specimen (N_{M1}= 31, N_{M2}=13, N_{M3}=3). The parameters (*ln a*, the intercept, and *b*, the slope) of the linear regression models (i.e. $\ln S = \ln a + b \ln D$) are found to be highly affected by the sample sizes of the molar teeth considered. The models derived from the natural-logarithmic transformed variables Di (i.e. the 3D surface area of dentin exposure for each molar) and S (i.e. the sum of the exposed areas of all three molars in a quadrant) are therefore of particular relevance.

The sites associated with the Euphrates irrigation areas (Dja'de and Tell Halula), which also include Tell Abu Hureyra (Syria, 11500–10500 cal. BC, N=3), despite being more closely related to the Natufian culture, and sites associated with more arid, desert areas (Tell Aswad and Tell Ramad) could be further divided into two groups from different geographic areas. Testing theories of nutritional adaptation to arid vs humid conditions may benefit from this distinction.

The sites associated with the Euphrates irrigation area (Dja'de el Mughara, Tell Halula, and Abu Hureyra), and sites associated with more arid, desert areas (Tell Aswad and Tell Ramad) could be further divided into two groups from different geographic areas. Testing theories of nutritional adaptation to arid *vs* humid conditions that may benefit the testing hypothesis. Furthermore, Carrascal et al. (2025) did not have access to a sample from the Pottery

Neolithic period, despite which they developed the hypothesis that "*an increase in wear rates compared to the Middle Neolithic samples would be expected due to the increasing reliance on plant-grinding tools, shown to be responsible for microwear formation*" (Mahoney, 2006).

The aim of this part of the study is to analyse in more depth the exposure rates of dentine in the dentition of Southwest Asian individuals during the transition from last societies with a subsistence hunting and gathering to those sedentary societies with an agricultural and livestock economy. In the present analysis, we include a new sample from Türkiye's Tepecik-Çiftlik in Central Anatolia. The site exhibits evidence of interaction with Neolithic groups in the Levant and is associated with an early habitation phase that corresponds to the PPNB (approximately 7000 BC). The Pottery Neolithic period (c. 7000–6500 BC) is linked to the main period of habitation, during which sophisticated village structures were constructed, and pottery was used.

In relation to resource, cultural, and environmental adaptations, the dietary patterns of the population at Tepecik-Çiftlik are believed to have differed from those observed at PPNB sites in the Levant. The availability and yield of water-intensive crops, such as barley and emmer wheat, which are staples in the Levant's wetter Mediterranean climate, were restricted by Tepecik-Çiftlik's semi-arid, continental environment. Despite the availability of these grains, the Anatolian diet was predominantly composed of wild plant species and drought-resistant crops such as pulses (peas and lentils) (Özdemir et al., 2025; Santiago-Marero et al., 2025).

The establishment of more reliable water supplies and larger agricultural surpluses enabled the Levant's more diverse and abundant agriculture to sustain a wider variety of crops, including figs, olives, and other fruits. The foundation of animal husbandry in Tepecik-Çiftlik was made up of sheep and goats, which thrived in semi-arid conditions and provided meat, milk, and wool (Özdemir et al., 2025; Santiago-Marero et al., 2025). The diet was further augmented by hunting and gathering of deer, hares, and wild vegetation. In contrast, the Levant experienced a significant impact from pigs, cattle, and a broader selection of wild and domesticated animals, although goats and sheep retained their importance. Furthermore, Tepecik-Çiftlik experienced a more limited resources of fat, while the Levant benefited from a diverse range of animal husbandry practices and olive production. Consequently, the combination of resource limitations, cultural preferences, and inventions that enabled survival in a harsher environment than the Levant led to the modification of agricultural and culinary practices by communities at Tepecik-Çiftlik to suit their surroundings.

6.3.2. MATERIALS AND METHODS

Samples from two collections were used in this study. Firstly, the University of Barcelona's Dental collections, specifically those under the Anthropology Unit, curated by Dra. Laura M. Martínez and Dr. Alejandro Pérez-Pérez, encompass samples from six sites in Southwest Asia, namely Abu Hureyra, Dja'de El Mughara, El Wad, Kebara, Shukba, Tell Aswad, Tell Halula, and Tell Ramad (Estebaranz et al., 2009, 2012; Martínez et al., 2016). A second new set of samples from Tepecik-Çiftlik archaeological site (in the present-day Turkiye) curated by Dr. Ali Metin Büyükkarakaya at Hacettepe University's - Human Behavioural Ecology and Archaeometry Laboratory (Idea Lab) (Büyükkarakaya, 2008, 2019) were also used in this study.

The sample studied included 92 molar teeth. The examination was conducted irrespective of the jaw type (maxilla or mandible) or the side (left or right). Molar quadrants exhibiting signs of diseases, including carious lesions and damage to dental crowns, were excluded from the study. For molars that were not exposed to dentin or exposure zones were not found, and molars that were lost as a result of an antemortem or postmortem consequence were also not included in accordance with the selection criteria established by Yang et al. (2024) and Carrascal et al. (2024).

In accordance with the established procedures made in Chapter 3.1 and 3.2, the teeth had been moulded using Colténe™ Affinis regular body materials (Galbany et al. 2006). Feropur PR55, a polyurethane, was utilised to create high-resolution castings of the entire dental crowns in each molar quadrant (Feroca™, Spain). A 3D EinScan SP scanner (Shinning™) was used to digitise the dental castings from occlusal, buccal, and lingual perspectives.

The measures were taken using the Shinning software measuerement tool. The dentine exposure was calculated following Yang et al. (2024) and Carrascal (2024) procedure calculating the areas of dentin exposure (D, in mm^2) directly from the 3D models. The programme automatically computed the entire dentin-exposed area after having manually selected the areas.

6.3.3. RESULTS

Table 10 displays the fundamental statistics (sample size, mean, and standard deviation) for the 3D exposure area (*D*, in mm^2) per location. Furthermore, the uncertain age distribution within each sample has a significant impact on the average *D* values per location. Average values are not useful since *D* rises in older age distributions. This pertains to theeight groups' average *D* values that were taken into consideration (table 10).

D did not follow a normal distribution in any of these groups (Natufian, PPNB and, PN) (K-S test, $P < 0.001$), despite the fact that several of these groups had large sample sizes. This is typical when the variable is age dependent, the sample size is small, or the age distribution is very diverse.

	M1			**M2**			**M3**		
Site	**N**	**mean**	**SD**	**N**	**mean**	**SD**	**N**	**mean**	**SD**
Kebara	7	8.623	4.462	5	1.886	1.882	2	1.425	0.448
El Wad	16	39.125	15.926	16	17.164	15.095	8	10.954	8.552
Abu Hureyra	3	28.807	22.211	3	4.946	3.957	-	-	-
Dja’de el M.	6	74.590	7.345	6	54.237	15.889	2	12.175	9.907
Tell Halula	4	9.910	6.448	1	3.150	-	-	-	-
Tell Aswad	5	26.088	22.788	3	12.067	9.001	1	4.420	-
Tell Ramad	16	10.821	10.676	3	1.200	0.641	-	-	-
Tepecik-Çif.	23	20.628	16.809	10	18.592	11.718	4	6.251	6.463

Table 10 Basic statistic of 3D dentine exposure by site. Toth type: M1, M2, M3; N: Sample size; mean: average 3D dentin exposure in mm^2; SD: standard deviation

Sample size ranged from 29 natufians to 31 PPNB on M1, 13 PPNB to 27 natufians on M2 and, 3 PPNB to 10 natufians on M3. As expected, given that later erupting molars are less common, the sample size decreased from M1 to M3. In addition, due to methodological limitations in molar selection, not all molar quadrants showed dentin exposure on M2 and similarly on M3. This further reduced the sample size. In all groups and teeth examined, with the exception of the PPNB group M2, the mean on the three-dimensional dentine exposure area of M1 was found to be greater than that of M2, and M2 was found to be greater than M3 (table 10 and 11). Expected due to the 6-year eruption delay between the different molars.

	M1			M2			M3		
Sample group	**N**	**mean**	**SD**	**N**	**mean**	**SD**	**N**	**mean**	**SD**
Natufian	29	33.139	23.170	27	15,208	16.889	10	9.048	8.547
PPNB	31	25.508	27.726	13	28.336	27.519	3	9.590	8.314
PN	23	20.628	16.809	10	18.592	11.718	4	6.251	6.463

Table 11 Basic statistics of 3D dentine exposure by periods. Toth type: M1, M2, M3; N: Sample size; mean average 3D dentin exposure in mm^2; SD: standard deviation.

Linear regression models were derived for the natural-logarithmic transformed *ln* D and *ln* S variables, as described in Carrascal et al. (2025). These models were classified by molar type, with *ln* S defined as *ln a* + *b ln* D. Tepecik-Çiftlik was then compared to the samples from the Levant (see Table 13). Additionally, the PPNB sample from the Levant was divided into Desert and Euphrates groups to test the hypothesis of climatic constraints affecting dentin exposure rates.

ID	Quadrant	D M1	D M2	D M3	SD
TP 016L_SK72	LR	39.158			39.158
TP 10_3_40	LL	15.957	6.108	1.230	23.294
	LR	20.808	14.012	3.504	38.325
TP 10_4_23	LR	6.163			6.163
TP 10_SK2010_3	UL	2.439			2.439
	UR	2.422			2.422
	LR	2.778			2.778
	LL	3.560			3.560
TP 10 17_2_28	LL	3.205			3.205
TP 10 17_K3_35	UR	11.099	4.105		15.204
TP 1017K3_4_23	LL	16.090	3.729		19.819
	UL	9.135			9.135
TP 1018J_SK41	LL	3.662			3.662
TP 102_23_17	LR	2.637			2.637
	LL	3.051			3.051
TP 11 17L_314	UR	11.135			11.135
TP 11 17L_4	LL	1.609			1.609
TP 12_SK58	LR	53.867	32.191	22.528	108.586
	UR	40.557	20.133	11.945	72.635
TP 12_SK70	LR	23.002	5.499		28.501
	LL	14.267	7.432		21.699
	UL	23.626	9.045		32.671
	UR	21.096	6.002		27.098

Table 12 Available dental sample from Tepecik-Çiftlik, including 14 specimens with 23 molar quadrants and 37 teeth. Reflecting area in mm².

In the context of analyses pertaining to dentin exposure wear rate, the consideration of small sample sizes assumes particular relevance. It is imperative that only molar teeth exhibiting exposed dentin are considered in the calculation of dentin exposure rates. It is acknowledged that the eruption gap present in the molar region can result in M3 teeth not displaying dentin exposure upon eruption and in full occlusion. A total of four M3 teeth exhibited dentin exposure in the Tepecik-Çiftlik sample (ANA), distributed across only two specimens (Table 11). A similar observation was made in the PPN sample from the Levant, where only three M3 teeth exhibited dentin exposure (Table 12). This precluded the division of this sample into the Euphrates (EUPH, NM3=2) and Desert (DES, N_{M3}=1) regions (Table 12).

The regression model for the M3 molar is pertinent to the calculation of dentin-exposure wear rates for the subadult age range (wSA). However, it should be noted that the calculation of wear rates for this interval is rendered impossible, or highly unreliable, due to the small sample sizes, as showed in Table 12 for the EUPHrates and DESert samples. The outcomes of this analysis may prove to be both unexpected and uninformative.

PER		**N**	**R**	**F**	**Sig.**	**ln(a)**	**a**	**e**	**t**	**P**	**b**	**e**	**t**	**P**
ANA	M1	23	0,985	1345,646	**<,001**	-0,177	0,838	0,076	-2,329	**0,030**	1,161	0,032	36,683	**<,001**
	M2	10	0,917	87,892	**<,001**	1,689	5,414	0,198	8,524	**<,001**	0,831	0,089	9,375	**<,001**
	M3	4	0,997	734,520	**0,001**	3,014	20,369	0,041	74,355	**<,001**	0,526	0,019	27,102	**0,001**
NAT	M1	29	0,959	625,061	**<,001**	-0,086	0,918	0,148	-0,579	0,568	1,125	0,045	25,001	**<,001**
	M2	27	0,811	107,418	**<,001**	2,513	12,342	0,135	18,673	**<,001**	0,580	0,056	10,364	**<,001**
	M3	10	0,679	16,893	**0,003**	3,182	24,095	0,260	12,193	**<,001**	0,537	0,131	4,110	**<,001**
PPN	M1	31	0,952	2101,169	**<,001**	-0,086	0,918	0,073	-1,176	0,249	1,103	0,026	43,126	**<,001**
	M2	13	0,970	56,642	**<,001**	2,335	10,329	0,256	9,124	<,001	0,626	0,087	7,210	**<,001**
	M3	3	0,559	0,998	0,500	3,443	31,281	1,317	2,614	0,233	0,618	0,618	0,999	0,500
EUPH	M1	10	0,982	443,385	**<,001**	-0,205	0,815	0,201	-1,020	0,337	1,171	0,056	21,057	**<,001**
	M2	7	0,997	1501,845	**<,001**	1,114	3,047	0,090	12,312	**<,001**	0,948	0,024	38,754	**<,001**
	M3	2				4,694	109,289				0,175			
DES	M1	21	0,989	1765,540	**<,001**	0,005	1,005	0,059	0,085	0,933	1,031	0,025	42,018	**<,001**
	M2	6	0,567	5,236	0,084	2,536	12,629	0,389	6,525	**0,003**	0,528	0,231	2,288	0,084
	M3	1												

Table 13 Linear models of the Power regression equations by group and tooth type for the combined jaw sample. ln(a): intercept of the linear model for ln(a)=0; $a=e^{lna}$; e: standard error of the intercept; t: Student statistic for ln a=0; P: significance probability for the intercept; b: slope of the linear regression model; e: standard error of the slope; t: Student t statistic for b=0; P: significance probability for the slope.

Anatolia demonstrated the lowest wJ wear rate (see Table 13) in comparison to the Levant PPNB and Natufian samples. Contrariwise, the Desert subsample exhibited the highest wJ rate, which may be indicative of a significantly elevated level of abrasiveness in the diet within this geographical area. However, the rate for the subadult age range (wJ) of the Desert sample could not be calculated due to its reduced sample (NM3=1). Despite the similar issue encountered in the Euphrates region (NM3=w), the wSA wear rate obtained (15.178

mm^2/year) was considerably higher than the values observed for the other samples, ranging from 1.679 to 2.993 mm^2/year. A higher value would be expected for the Desert area, but this could not be computed, and that observed for the Euphrates is likely unreliable.

	J		SA		J+SA	
	r	w	r	w	r	w
ANA	2.59%	0.763	1.58%	2.136	2.05%	1.502
NAT	3.61%	1.904	0.80%	1.679	2.09%	1.783
PPNB	3.36%	1.569	1.32%	2.993	2.26%	2.336
Euphrates	1.83%	0.372	4.26%	**15.178**	2.92%	**8.344**
Desert	3.52%	1.937				

Table 14 Wear rates computed for the juvenile (J), subadult (SA) and combines (J+SA) samples; r: % dentin exposure per month; w: dentin exposure area per year (mm2/year). ANA: Anatolia; NAT: Natufian; NEO: PPNB: Prepottery Neolithic; Euphrates: PPNB from Euphrates region; Desert: PPNB from desertic region.

The dentin exposure rates observed for the Anatolian sample are consistent with those observed in the Neat East Natufian and Neolithic samples (figure 38). The Tepecik-Çiftlik sample, inhabiting an inland, semi-arid environment, exhibited unexpected low levels of molar wear, despite being a Pottery Neolithic population with limited access to water sources or the water-intensive crops characteristic of the Levant's wetter Mediterranean climate.

Regarding the subsamples of the PPNB sample (Euphrates and Desert), the juvenile wear rate appears to suggest that the Desert sample may exhibit higher wear rates than the Euphrates ample. However, this cannot be verified for the subadult age interval, and the data currently available is not entirely reliable.

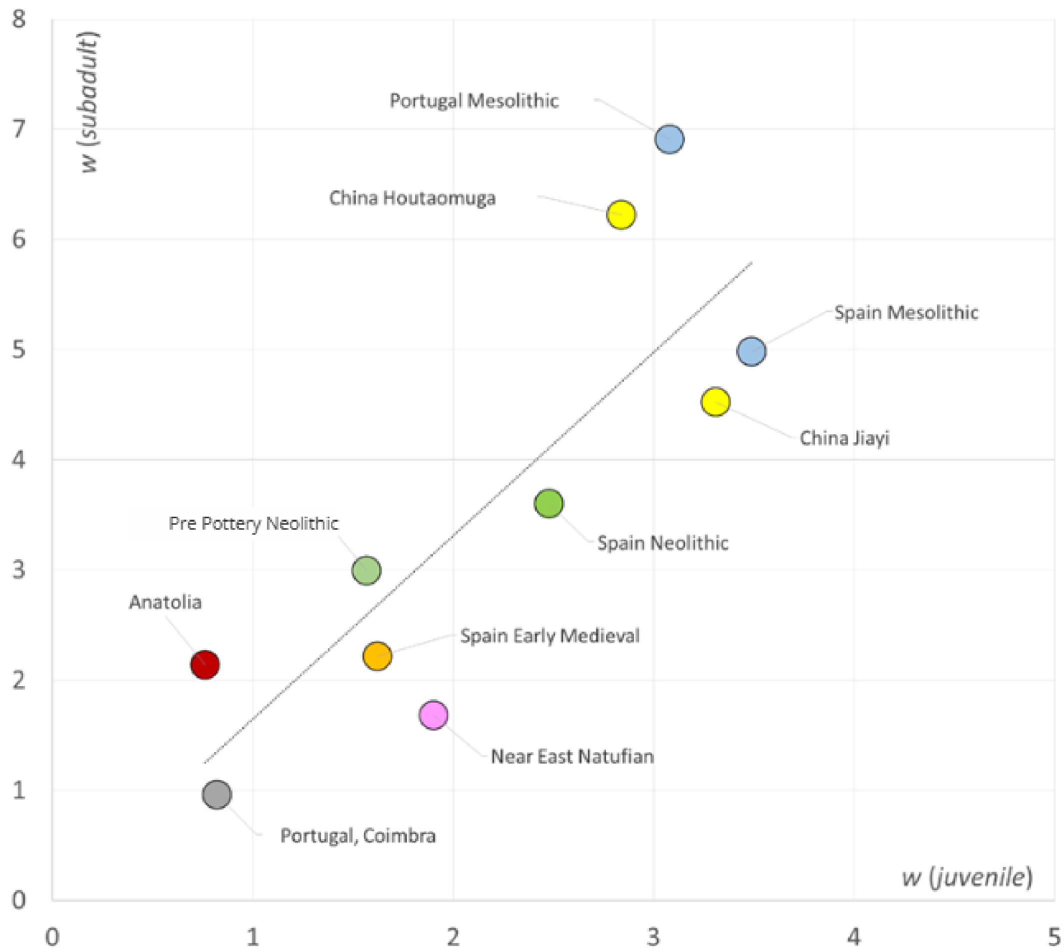


Figure 38 Bivaried plot of the wear rates (mm^2/year) for the juvenile (w1, X-axis) and the subadult (w2, Y-axis) age-intervals of all the groups studied (names shown in the plot)

6.3.4. CONCLUSION AND DISCUSSION

This study provides an unparalleled insight into the eating practices and environmental adaptations of early agricultural societies by examining dentine exposure rates across a range of Neolithic sites in Southwest Asia. This study proposes a novel methodological technique that promises to broaden our understanding of prehistoric feeding practices and the factors influencing them. This technique involves the use of a 3D dentine exposure proxy proposed by Yang et al. (2024).

The disparity in dentine wear patterns observed between Tepecik-Çiftlik and the Levant underscores the impact of local environmental factors on dietary adaptations. Specifically, the less pronounced dentin wear observed in the Anatolian population suggests a dietary composition that may have been less abrasive, potentially as a consequence of a reduced reliance on wheat and other hard plant components. The naked eye might suggest a change in diet compared to the PPNB populations, towards a less abrasive diet. An isotope study shows that the Tepecik-Çiftlik populations have a high consumption of C3 plants and C3 plant-consuming animals like the main source of plant input in the dietary habits of Anatolian populations throughout the Holocene, especially in prehistoric periods (Richards et al., 2003; Rao et al., 2012; Pickard et al., 2016; Özdemir et al., 2025). Therefore, it can be hypothesised that there has not been a complete change in diet. Instead, it is more plausible to hypothesise that there has been a specialisation in the treatment and processing of products for human consumption. This hypothesis is supported by the findings of Mahoney (2006), who demonstrated that variations in microwear, indicative of the lithic industry involved in food processing, are responsible for the observed variations.

In contrast, the prevalence of dentin wear has been observed to be higher in Levantine locations connected to the Euphrates irrigation systems. This finding suggests that the diets in these areas are characterised by a greater consumption of water-intensive cereals, such as wheat and barley, as well as a wider variety of fruits and vegetables. This observation proposes that the presence of diversified agricultural practices and a more varied diet, characterised by higher consumption of abrasive foods, is facilitated by the presence of nutrient-rich soils (Mahoney, 2006). This variation underscores the practical decisions humans make in response to their local environment, emphasising the potential influence of climatic and geographic factors on dietary adjustments.

The study effectively demonstrates the significance of sample size in the context of research investigating dental wear. The analysis underscores the challenges posed by limited sample sizes, particularly in the context of later erupting molars (M3), thereby underscoring the necessity for meticulous interpretation of the data. The methodological approach, which employs linear regression models with natural-logarithmic transformations, provides a robust framework for analysing dental wear across molars. However, the reliability of these findings is limited for third molars due to their small sample sizes, especially when stratified by environmental or geographic contexts (Carrascal et al., 2025).

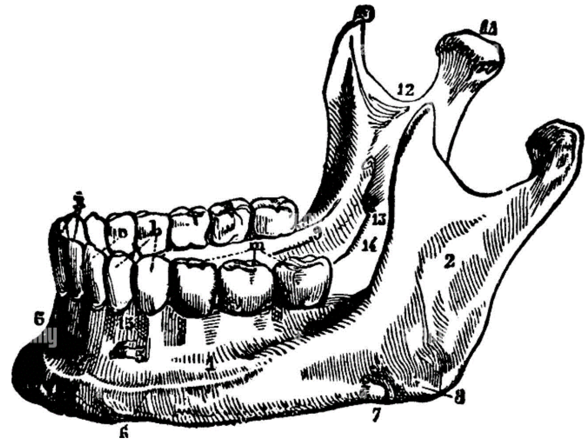
The utilisation of larger datasets and advanced techniques, such as high-resolution dental microwear analysis, which has the potential to complement macroscopic observations and enhance our understanding of intra-population variability in dietary habits, is recommended for future research. These efforts should aim to avoid the limitations currently encountered.

The transition from foraging to farming during the Neolithic era constitutes a major socioeconomic shift that this study places these dietary trends within. The transition to more stable subsistence patterns, particularly in the Fertile Crescent, is believed to have enabled the development of permanent settlements, social complexity, and higher population densities.

Tepecik-Çiftlik's nutritional adjustments underscore the significance of comprehending local adaptations within the broader context of Neolithic shifts. These adjustments demonstrate remarkable tenacity and resourcefulness in utilising available resources in a more arid climate. These results provide important new information on how early agricultural cultures dealt with environmental stresses and resource shortages, which in turn affected socioeconomic advancements including the formation of trade networks and technical advancement.

This study highlights the capacity of early human societies to adapt to diverse environmental conditions. The results obtained demonstrate how environmental influences shaped subsistence tactics and suggest that Neolithic civilisations' food patterns were an intricate web of innovation and continuity. The information from Anatolia offers a interesting case study of human adaptability, demonstrating that through the study of tooth wear, we can see how societies modified their agricultural and food habits to accommodate a range of environmental circumstances. It is hypothesised that these modifications promoted wider advancements in human communities throughout the Neolithic era by facilitating cross-regional cultural interactions and technology dissemination.

In conclusion, the dentine exposure study provides substantial evidence for the diversity of Neolithic dietary practices across Southwest Asia in response to environmental factors. In addition to providing a foundation for further research on human adaptability and resilience in prehistoric eras, this study deepens our understanding of how early agricultural communities modified their subsistence tactics. A more comprehensive knowledge of human development throughout the Neolithic era might result from further study integrating genetic, isotopic, and palaeobotanical data to better comprehend these intricate adaptive tactics.



CHAPTER 7. GENERAL DISCUSSION

CHAPTER 7
7. GENERAL DISCUSSION

This dissertation comprises a thorough investigation of the variations in dental morphology and wear throughout Southwest Asia during the transition from hunter-gatherer societies to early agricultural communities.

In the first introductory chapter, we explained how a climate transition and several significant ecological and socio-ecological changes occurred during the Pleistocene to Holocene era transition. The Bølling-Allerød interstadial (14,700-12,700 years BP) was characterised by an abrupt onset at the end of the Late Pleistocene Heinrich stadial 1 (HS1) in the Southern Levant (Alley et al., 2003; Bar-Yosef, 2011; Maher et al., 2011; Thiagarajan et al., 2014; Ibáñez et al., 2017; Naughton et al., 2023). The transition from open to wooded areas, as well as sea-level rise, have been attributed to rising global temperatures (Naughton et al., 2023). This transition subsequently led to the emergence of the Early Natufian civilisation, a more sophisticated and semi-sedentary society (Bar-Yosef & Belfer-Cohen, 1989; Belfer-Cohen & Bar-Yosef, 2000; Goring-Morris & Belfer-Cohen, 2011). Consequently, this Late Natufian populations transitioned from a hunter-gatherer to a farmer lifestyle during this climatic and ecological shift (Bar-Yosef & Belfer-Cohen, 1992, Miller, 1996; Hillman, 1996, Belfer-Cohen & Bar-Yosef, 2000, Isaar & Zohar, 2009). Then the PPNA (Pre-Pottery Neolithic A, 11,600-10,500 cal BP) was a period of regional demographic growth that was linked to an increase in precipitation following the YD, which resulted in an increase in the number and size of sites (Goring-Morris & Belfer-Cohen, 1998; Issar, 1998; Maher et al., 2011; Issar et al., 2012). The practice of hunting and gathering wild fruits and seeds persists concurrently with the emergence of cultivated cereals and legumes in several locations across Southwest Asia (Kuijt, 1994; Weninger et al., 2009; Zeder, 2011). The advent of the PPNB (PrePottery Neolithic B, 10,500–8,750 cal BP) period marked the onset of a period lasting several millennia during which these advantageous environmental circumstances persisted. The transition from a hunter-gatherer society to an agricultural one was accompanied by a shift in dietary habits in several regions across Southwest Asia (Kuijt, 1994; Weninger et al., 2009; Zeder, 2011).

All these climate and cultural changes led us to a series of questions, which this thesis aims to answer. Was it a widespread and preconceived idea (farming and agriculture) of these societies in which it expanded from a primary area? Alternatively, were new populations moved with this idea to a primary area? Or perhaps the local populations of hunters and gatherers changed their way of life without having any external influence? Have there been morphological changes in these societies due to changes in diet? Given the absence of DNA remains, is it possible to see similarities in these populations through morphology? A new proxy can be used to understand the development of dental wear in different periods and/or regions?

All these questions can be addressed by studying the dentition. Knowing how nutritional and climatic changes affect tooth morphology may help us better understand how these traits evolved under natural selection and how human populations have adapted over time.

In the field of biological anthropology, the study of tooth size is of particular significance, particularly in the context of adaptation and evolution. The decline in tooth size over the course of evolution has been the subject of extensive research and is now a well-established fact (Estebaranz et al., 2004).

In Southwest Asia (Smith, 1986, Brace et al., 1987; Kaifu, 1997; Erdal, 1999, Pinhasi et al., 2008; Alrousan, 2009; Le Luyer & Bayle, 2017; May et al., 2018; Menéndez & Buck, 2022) as well as other regions (Smith, 1972; Carlson & van Cerven, 1977; y'Edynak & Fleisch, 1983; Formicola, 1987; Jacobs, 1994; Le Luyer & Bayle, 2017; Pokhojaev et al., 2019; Nava et al., 2021; Godinho et al., 2023; Martin et al., 2023), a reduction and/or morphological changes in the craniofacial and dentition are observed probably as a result of the economic shift from hunting and gathering to a food production economy based on agriculture and husbandry and/or new processing techniques (Eshed et al., 2006).

For the first time, this study offers a comprehensive understanding of dental size and non-metric dental characteristics throughout Southwest Asia, spanning from the Levantine region through the Euphrates Valley, Sinai Peninsula, Zagros Mountains, and Anatolian Peninsula.

The present study's results indicate that dental reduction is more pronounced in the transitional societies of Southwest Asia, specifically in the transition from hunter-gatherer to the initial farming and agriculturalist populations. This phenomenon is not exclusive to Levantine populations but is observed across the entire region under study (Levant, Euphrates, Sinai, Zagros, and Anatolia). The general linear model analysis indicates that this tooth loss is more significant in the buccolingual dimensions. Determining whether this novel feature of reduced tooth size, particularly in de buccolingual measurements, represents any benefit or adaptation is challenging. The alterations to the human masticatory apparatus have occurred in a comparatively brief period when it is viewed in the context of the extensive time span encompassing human evolution (Hillson, 2005).

To elucidate the observed decrease in these areas, several evolutionary hypotheses have been advanced. In accordance with the probable mutation effect (Brace, 1963; Brace & Mahler, 1971; Pinhasi et al., 2008), spontaneous mutations occur in the absence of selection pressure, resulting in a reduction of dental morphology due to the loss of complexity. All dental metrics are expected to have homogenous variation or to decrease overall. It has been hypothesised that the introduction of pottery and the changes in food production that followed, made possible by pottery, may have caused the masticatory system's selection forces to relax. The probable mutation effect might have resulted from this, which would have caused the size of the teeth to decrease (Brace, 1963, 1971). If the start of pottery manufacture in the 7th millennium was the stimulus for changes in the dentition of agricultural civilisations, then this argument would be valid. However, as there is already a decline in the PPNA and PPNB periods about the 10th millennium compared to the Natufian, the results of this study suggest that this trend began earlier (Brace, 1963, 1971). Then as posited by Macchiarelli and Bondioli (1986), postulate the theory of the population density effect which indicates that a sedentary lifestyle resulted in a substantial deterioration in health and nutrition. Consequently, the overall size of the body and, by extension, the size of the teeth, would have diminished. It is predicted that all dental metrics and body size will generally decline in this scenario. Utilising a comparable methodological approach, Pinhasi (2015) has examined the mandibles of numerous individuals within the same research locale, asserting that the mandibles of farmers exhibit allometric scaling rather than being mere miniature replicas of older groups. A mosaic pattern of change is suggested by the MANOVA analysis, which shows that some mandibular dimensions shrink while others grow. In order to evaluate the veracity of this idea, it would be advantageous for future research to incorporate postcranial measures from various locations and time periods.

The selective compromise effect, which exerts pressure on smaller teeth, suggests that populations with larger teeth are more susceptible to dental crowding and caries (Y'Edynak & Fleisch, 1983; Calcagno & Gibson, 1991). However, it is hypothesised that the necessity to withstand severe wear – often resulting from the ingestion of abrasive foods, a consequence of novel Neolithic cooking techniques – has led to the selection of larger teeth with thicker enamel. This is discussed in two separate studies, Eshed et al. (2006) discovered that the Natufian and Neolithic populations had comparable rates of caries, periodontal lesions, and antemortem tooth loss. On the other hand, Pinhasi (2008) found that, in comparison to the PPN era, the Natufians had a noticeably greater prevalence of periodontal disease.

The evidence of variations in the two groups' (Natufian and PPN) wear patterns lends more credence to the thesis. In contrast, the PPN populations show a more inclined wear pattern and cupped wear on occlusal surfaces (Eshed et al., 2006; Pinhasi, 2008). Conversely, the Natufians have uniformly distributed flat wear. We can also state about the differences in wear patterns in chapter 6 of this dissertation where there are differences in the attrition of these societies which it will be discussed later.

It is reasonable to assume that changes in mastication demands lead to changes in the wear patterns that are seen. This might be related to certain mandibular measures and the noted decrease in the buccolingual dimensions of most of the dentition. It supports the "Masticatory-Functional Hypothesis" of Carlson and Van Gerven (1977), according to which the early agriculturalists' craniofacial complex changed simultaneously as the functional demands on the masticatory complex decreased.

In the same chapter, the topic of non-metrical characters is also studied. The systematic study of genetically determined anatomical traits is another method of identifying biological affinities, kinship and inbreeding among groups. According to Ullinger et al. (2005), Hanihara (2008), López-Onaindia & Subirà (2017), López-Onaindia et al. (2017), Maaranen et al. (2022), and others, the degree of phenetic similarity between people can be used as an indicator of their genetic relatedness. Due to their high genetic determination (Scott & Turner, 1997; Higgins et al., 2011; Hughes et al., 2013; Hlusko, 2016), lack of sexual dimorphism, and general perception as being neutral to selection (Turner, 1984; Hanihara, 1992; Irish, 1997; Scott & Turner, 1997), non-metric dental traits (NMDT) are frequently employed. In the present study we assessed 23 non-metric dental traits in the permanent dentition (13 for upper and 9 for lower teeth) according to the Arizona State University Dental Anthropology System (ASUDAS) (Turner et al., 1991).

This chapter focuses on a few characteristics that demonstrate clear variations over time, such as the upper M2's Cusp 5 (Metaconule) and the upper premolars' Mesial/Distal Accessory Cusps. Evidence is provided for the hypothesis that there is a potential evolutionary difference in tooth morphology specific to this time and location, based on the observation that Cusp 5 was present in 7% of the Tepecik-Çiftlik population throughout the Pottery Neolithic era of Anatolia. Significant regional differences in traits like the lower M2's Mid-Trigonid Crest and the lower premolars' Cusp Number 1 are shown by geographical analysis. In addition to the Mid-Trigonid Crest, which is more common among Kebara individuals from the Natufian era in the Levantine region, the variations in Cusp Number 1 between geographical regions and chronological periods suggest that these traits may have been locally influenced by evolutionary or genetic drift.

The ASUDAS trait analysis results demonstrate that different ancient populations exhibit variations in some aspects of dental morphology. The historical and geographic contexts of the respective populations have an impact on these disparities. Notable indicators of evolutionary or cultural distinction include features such as the cusp 5 in the upper M2 and the mid-trigonid crest in the lower M2. The limited number of traits that demonstrate significant variation underscores the intricacy of human evolutionary dynamics and underscores the necessity for further research to enhance our understanding of the factors influencing dental morphology. Despite the small percentage of significance, the results are in agreement with those obtained in chapter 5 dedicated to the study of dental topography. This suggests that there are morphological differences between different periods and/or geographical areas.

In order to quantitatively analyse 3D tooth structure and correlate shape with diet, we have used dental topography (Zuccotti et al., 1998; Ungar and Williamson, 2000; Ungar, 2004; Godfrey et al., 2012; Ledogar et al., 2013; Winchester et al., 2014; Berthaume, 2016a; Berthaume and Schroer, 2017). In addition to determining dietary ecology (Berthaume, 2018), dental topography has also been used to describe and assign new species (Boyer et al., 2012), analyse niche partitioning and other evolutionary forces (Boyer et al., 2012; Godfrey et al., 2012; Berthaume and Schroer, 2017), and predict enamel surface morphology based on the form of the enamel-dentin junction (Skinner et al., 2010; Guy et al., 2015).

In this study we used four dental topographic metrics. Relief Index (RFI) (Boyer 2008), which is calculated as the ratio of the its three-dimensional (3D) surface area to tooth's two-dimensional (2D) projection area on the occlusal plane (Teaford and Ungar, 2000; Allen et al., 2015; Pampush et al., 2018); The computation of the crown's curvature is achieved through the utilisation of Dirichlet normal energy (DNE), as proposed by Bunn et al. (2011); Tooth occlusal complexity (OPCR) (Evans et al. 2007), defined as the average number of dental elements, is potentially correlated with the selective compromise effect mentioned above (Calcagno & Gibson, 1991; Y'Edynak & Fleisch, 1983); And finally, PCV; Portion de Ciel Visible, which quantify the degree of exposure of a surface to ambient illumination when observed from the occlusal direction.

According to our findings, we found significant differences on dental topography metrics across different time periods and geographical locations. The results imply that the dental variables associated with tooth curvature and crown complexity (DNE and OPCR, respectively) did not result in significant differences. Accordingly, neither the cusp heights nor the depth of the foveas nor the crown complexity as measured by the number of places (patches) where food is likely to fracture changed in the lower molars under study (Berthaume et al., 2020). However, certain modifications from the Natufian to the later Neolithic settings (PPNB and ceramic Neolithic) were noted by the RFI and PCV indices. In comparison to PPNB samples, neolithic samples showed a greater RFI and tooth morphology with higher cusps (3D area) in relation to the tooth surface (2D area). Both the first and second lower molars had this pattern. In addition, the cusps of the PPNB samples were rounder and lower than those of the Anatolian Neolithic samples. This points to a shift from the PPNB period's lower, rounder cusps to the Neolithic period's higher, sharper cusps. These alterations might be the result of various dietary adjustments and behaviours that are most likely linked to adaptive responses, highlighting the significant influence that organism domestication and the development of agricultural systems have had on human subsistence patterns (Zeder, 2005; Peters et al., 2005).

Beyond just reflecting dietary trends, dental topography might reveal information about genetic adaptations. Phenotypic traits, such tooth development and morphology, are affected by genetic factors and can be impacted by both evolutionary responses and environmental stresses (Ungar et al., 2011). The interaction between genetics and dental morphology supports the idea that dental traits are not just nutritional responses but also function as indicators of population history and migration patterns. By using genetic research to clarify the connections between differences in tooth topography and the genetic ancestry of various cultures, we may better understand how environmental influences and genetic makeup have combined to create human adaptations across time.

With an 80% accurate classification rate, linear discriminant analysis (LDA) showed that the PPNB and Natufian populations were misclassified suggesting that there were minor morphological dental alterations throughout this transitional time. This emphasises the need of taking sample size and regional variability into account when assessing dental adaptations and ecological strategies (Godfrey et al., 2012; Berthaume & Schroer, 2017). The LDA (by geographical area) findings show that the geographical regions of the Levant and Anatolia are substantially further apart than the Euphrates, Zagros, and Desert. Notably, the geographic region of the Levant roughly correlates to the Natufian chronological period, and the geographic region of Anatolia includes the whole sample from the Neolithic Ceramic period. This might help to explain why most misclassifications (38.98% on M1L and 50% on M2L) correspond to geographic regions of the same historical period, indicating that dentition changes may have happened throughout time rather than being impacted by regional variations.

One possible explanation for the apparent separation between the Neolithic pottery people and the others is that they all come from the Tepecik-Çiftlik site on the Anatolian peninsula. The issue of the Anatolian Early Neolithic sites has previously been addressed by Yaka (2020), who points out that each site is represented in a distinct genetic cluster even if they are close to one another. However, the genetic gap between the Anatolian Neolithic and the Levantine Neolithic and the earliest farmers in Iran, as well as between the Anatolian Neolithic and the Neolithic of Europe and the Caucasian hunter-gatherers, is substantial (Kiliç, 2016, 2017; Feldman et al., 2019). Tepecik-Çiftlik has no genetic kinship with Çatalhoyuk, which is around 160 km apart, because of the extreme variety. This fully correlates with the ASUDAS results mentioned above in which the Anatolian region had significant differences in Metaconule and Cusp number 1 compared to the other geographical areas under study (Özbaşaran, 2011; Baird, 2012).

Additionally, Feldman et al. (2019) found that the genomic data of Late Pleistocene people from central Anatolia show a unique genetic profile that is strongly linked to both modern Anatolian groups and early Neolithic farmers in the area. The researchers found that these early farmers shared more genetic traits with local foragers than with Near Easterners, suggesting that the adoption of agricultural practices in Anatolia may have been the consequence of local evolution and adaptation rather than a widespread external migration. Furthermore, genetic continuity is essential to understanding the cultural shift towards agriculture, according to Feldman et al. (2019). Their reasoning is predicated on the idea that a slow transition made possible by technical and cultural exchanges is more likely to occur than a sudden change in the population. By proving that the early farmers had a sizable amount of ancestry in common with these older hunter-gatherer societies, they bolster this claim.

The dental topography and non-metric dental traits ASUDAS analysis conducted in this study provide additional evidence for this concept. They show that Tepecik-Çiftlik's dental topography differs significantly from that of other Neolithic Aceramic people in various sub-regions.

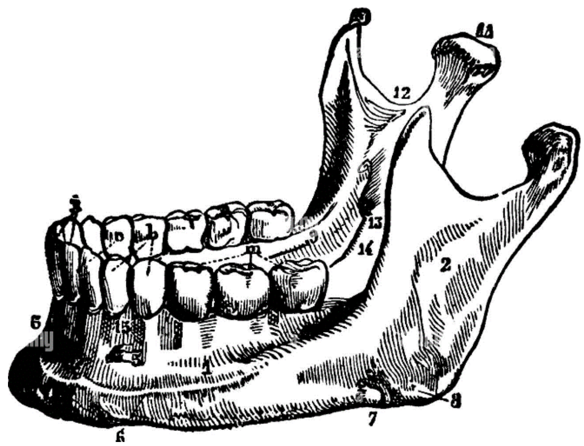
Lastly, it is necessary to emphasize the significance of tooth deterioration, a critical aspect that has been addressed in this dissertation, with a focus on macro-wear. Macro-wear is the term given to the macroscopic and obvious physiological wear of the teeth. To preserve the underlying tooth structure, this process usually starts with the loss of occlusal enamel and continues with the deposition of secondary dentine. The pulp chamber is shielded by subsequent dentin deposition (Larsen, 2002). In severe cases, the enamel may entirely vanish due to its cumulative nature (Larsen, 2002; Fiorenza et al., 2018). Furthermore, the study of dental wear has been applied in different aspects, including the determination of individual age (Holly-Smith, 1984; Mays et al., 1995; Yang et al., 2024) and the analysis of the use of the mouth as a tool (Lukacs and Pastor, 1988; Bermúdez de Castro et al., 2003; Molnar, 2008; Clement and Hillson, 2012;) or to ascertain status and general health (Elzay et al., 1977; Dawson and Brown, 2013). By analysing dentine exposure rates at many Neolithic sites in Southwest Asia, this work offers a unique perspective on the dietary habits and environmental adaptations of early agricultural cultures. The new analytical approach this study suggests could help us better understand prehistoric dietary habits and the variables that shaped them. Yang et al. (2024) suggested a 3D dentine exposure proxy, which is used in this method.

The findings demonstrated a difference in dentine wear patterns between the Levant and Tepecik-Çiftlik, highlighting the influence of regional environmental conditions on dietary adaptations. In particular, the Anatolian population's less noticeable dentin wear points to a potentially less abrasive dietary composition, which may have resulted from a decreased dependence on wheat and other hard plant components. This issue has already been discussed in the tooth size section. A shift towards a less abrasive diet in comparison to the PPNB populations may be apparent to the unaided eye. According to an isotope study, the Tepecik-Çiftlik populations consume a lot of C3 plants, and animals that eat C3 plants are similar to the primary source of plant input in Anatolian populations' diets throughout the Holocene, particularly during prehistoric times (Richards et al., 2003; Rao et al., 2012; Pickard et al., 2016; Özdemir et al., 2025). As a result, it is possible to speculate that the diet has not completely changed. The idea that there has been specialisation in the handling and processing of goods for human use is more tenable. The results of Mahoney (2006), who showed that the observed variances are caused by changes in microwear, a sign of the lithic industry involved in food preparation, lend credence to this theory.

However, it has been shown that dentin wear is more common in Levantine areas that are related to the Euphrates irrigation systems. This result implies that a larger intake of water-intensive grains, such wheat and barley, as well as a bigger range of fruits and vegetables, are characteristics of the diets in these regions. According to this discovery, nutrient-rich soils promote the existence of diverse agricultural techniques and a more varied diet, which is typified by a higher intake of abrasive foods (Mahoney, 2006). This variance highlights the pragmatic choices people make in response to their local environment, highlighting the possible impact of geographic and climatic conditions on dietary modifications.

The new methodological approach offers a strong foundation for analysing dental wear across molars by using linear regression models with natural-logarithmic transformations. However, the small sample sizes of third molars restrict the trustworthiness of these findings, particularly when stratified by geographic or environmental settings (Carrascal et al., 2025).

To sum up, the dentine exposure study offers strong proof of the variety in Neolithic eating habits in Southwest Asia because of environmental influences. This study advances our knowledge of how early agricultural cultures altered their subsistence strategies and lays the groundwork for future investigations into human adaptation and resilience in prehistoric times. To better understand these complex adaptive strategies, greater research combining genetic, isotopic, and palaeobotanical data may lead to a more thorough understanding of human evolution during the Neolithic era.



CHAPTER 8. CONCLUSIONS

CHAPTER 8
8. CONCLUSIONS

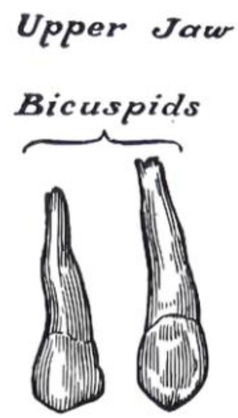
The conclusions of the present study are:

1. Our results show a consistent pattern of dental evolution that is probably associated with dietary and social-ecological shifts, thereby supporting a **significant reduction in tooth size**, particularly in the buccolingual dimensions, among diverse population groups in the region. This study provides significant insight into the dental morphological change when hunter-gatherer societies transitioned to agricultural cultures in Southwest Asia
2. The most significant differences in tooth size reduction are observed in the lower dentition compared to the upper premolars and molars. Furthermore, while the reduction in the upper dentition primarily occurs from the Natufian to the PPNB/Neolithic periods, in the lower dentition, changes in the buccolingual diameter are evident between the Natufian and PPNA periods. This suggests an earlier decrease in tooth dimensions in the lower dentition.
3. The study of non-metric dental traits (ASUDAS). Although the final sample size was small, the results obtained suggest that some populations such Natufians and Pottery Neolithic from Anatolia showed a higher percentage of some traits compared to the rest of the same period and area, suggesting some cases of probable genetic drift. However, the results presented here also showed that there were only few differences between populations of the same period, and these results suggest a genetic continuity in some of these populations.

4. In relation to dental topography. There are no significant differences regarding crown complexity (OPCR) and curvature (DNE) between sites and periods. In contrast to what

other authors suggest (Calcagno & Gibson, 1991; Y'Edynak & Fleisch, 1983; Calcagno & Gibson, 1991; Y'Edynak & Fleisch, 1983; Pinhasi et al., 2008) the complexity of the crown did not show a reduction from the Natufian to Pottery Neolithic in our sample. However, there are significant changes in occlusal relief and PCV, suggesting an increase of occlusal relief from the Natufian to Pottery Neolithic. On the other hand, PCV metrics show a decrease trend from Natufian to PN. The molars of PN have a higher surface area and sharp cusps than Natufian molars.

5. Applying a distinctive three-dimensional dentine exposure methodology, this study provides substantial insights into the dietary shift of early agricultural communities across Southwest Asia. The results demonstrate significant variations in dentine wear patterns, indicating that inhabitants of Tepecik-Çiftlik adapted to fewer abrasive diets comprising C3 plants, whereas those of Levantine groups exhibited more pronounced wear probably due to a diet consisting of water-intensive grains. This study emphasizes the impact of local environmental factors on subsistence strategies and the adaptability of these communities in managing agricultural operations under diverse conditions. It demonstrates the diversity and adaptability of Neolithic communities, thereby establishing a foundation for further research into human resilience and adaptability during this pivotal era, using a combination of genetic, isotopic, and palaeobotanical data.



RESUM

9. RESUM

9.1. INTRODUCCIÓ

9.1.1. CONTEXT ARQUEOLÒGIC: GEOGRAFIA, CRONOLOGIA, CLIMA

1.1.9.1. CONTEXT GEOGRÀFIC

El Sud-oest Asiàtic (SWA) o el terme "Pròxim Orient" (NE) s'utilitza per descriure una regió que engloba diverses àrees situades en diverses parts de l'Àsia Occidental. Aquestes àrees estan situades a l'est del Mar Mediterrani, al sud del Mar Roig i la Península del Sinaí, al sud-est del Golf Pèrsic, i al nord i est de les muntanyes Taurus i Zagros. Els països que actualment ocupen aquesta regió inclouen Palestina, Síria, Israel, Jordània, Líban, Iraq, Iran i una part d'Aràbia Saudita i Turquia.

En aquest estudi, s'utilitzarà el terme "Sud-oest Asiàtic" per referir-se a aquesta regió, ja que és un terme estrictament geogràfic per a totes les regions del món. És important reconèixer que el terme 'Pròxim Orient' o 'Orient Mitjà' és una designació geogràfica que es va originar a Europa i no és universalment acceptada (Figura 1).

El Sud-oest Asiàtic és una regió extensa que engloba una àmplia gamma de recursos naturals i entorns, caracteritzada per quatre zones bioclimàtiques diferents:

El clima mediterrani s'observa al Llevant del Sud-oest Asiàtic que envolta les planes costaneres i els vessants de les muntanyes que miren cap a la costa mediterrània. Aquesta zona es distingeix per un sistema de depressions que són el resultat de l'extensió de la Vall del Rift Africà on flueixen els rius Jordà i Orontes amb una precipitació mitjana anual d'aproximadament 500 mm/any la vegetació es caracteritza per oliveres vinyes alzines i pins (Aurenche & Kozlowski, 2003).

La zona desèrtica central està circumscrita per una zona d'estepa amb nivells de precipitació per sota dels 250 mm anuals creant un entorn especialment desafiant per a l'hàbitat humà excepte als voltants dels oasis. La vegetació és pràcticament inexistent tret d'algunes plantes herbàcies i palmeres en àrees amb nivells d'humitat lleugerament més elevats (Fisher, 2013).

La zona d'estepa, situada entre el desert central i les regions muntanyoses, presenta importants fluctuacions estacionals de temperatura i rep entre 500-250 mm de precipitació anual (Palmisano et al., 2021). Els roures i els pistatxers són predominants als pendents pronunciats, mentre que les plantes herbàcies adaptades a les condicions àrides dominen a les planes. Aquesta regió també va ser l'hàbitat de les principals espècies animals salvatges que van jugar un paper important en el procés de domesticació del Sud-oest Asiàtic, així com de cereals i llegums silvestres (Cauvin, 1997). L'Altiplà Anatòlic, el nord i centre de Síria, i la plana nord d'Iraq, s'inclouen dins la definició geogràfica de la zona d'estepa. La regió està delimitada a l'oest pels valls dels rius Jordà i Orontes, al nord per la serralada del Taure, i a l'est per la serralada del Zagros. Els rius Tigris i Eufrates, juntament amb els seus nombrosos afluents (incloent el Gran Zab, Petit Zab, i Diyala del Tigris; i el Khabur i Balikh de l'Eufrates), travessen l'estepa.

La serralada muntanyosa es forma a l'oest per una doble serralada costanera que corre paral·lela a la costa mediterrània. Cap a l'oest i l'est, les formacions muntanyoses del Taure i el Zagros, respectivament, constitueixen el terreny muntanyós que envolta la regió. La regió es distingeix per nivells de precipitació elevats, que arriben aproximadament als 500 mm anuals, els quals fomenten el creixement d'una flora diversa, incloent roures, alzines, pins i avets, especialment a les zones elevades (Hemming et al., 2010; Lelieveld et al., 2012).

La diversa topografia del Sud-oest Asiàtic té una influència considerable sobre el clima (Vegeu Figura 1). El centre del Llevant exhibeix un clima més continental, mentre que les seccions costaneres mostren un clima mediterrani, caracteritzat per estius calorosos i secs i hiverns freds i plujosos. Contràriament, el règim pluviomètric típic de la regió, que presenta una temporada seca durant els mesos d'estiu, reflecteix la influència del clima mediterrani. La resta de l'any es caracteritza per patrons de pluja erràtics, amb algunes regions, com la costa de la Palestina actual, experimentant el 80% de la precipitació anual total entre octubre i febrer.

El concepte de neolitització ha estat tradicionalment associat amb el "Creixent Fèrtil", en gran part a causa de les característiques ambientals distintives de la regió i l'emergència de les primeres espècies de plantes silvestres domesticades (Braidwood, 1960; Mellart, 1975; Cauvin, 1994). Les serralades del Taure i del Zagros funcionen com a límits naturals per al Creixent Fèrtil, que s'estén des de la Vall del Jordà fins a la desembocadura del Tigris i l'Eufrates (Simmons et al., 2007).

S'han desenvolupat models alternatius per classificar les ubicacions amb major similitud ambiental respecte a les dades arqueològiques, donada la naturalesa heterogènia i diversa dels règims meteorològics i geogràfics que cobreixen el Creixent Fèrtil. El "triangle daurat" proporciona un exemple il·lustratiu de l'adopció de les pràctiques de domesticació de plantes i animals, que és útil per entendre aquest fenomen (Kozlowski & Aurenche, 2005). No obstant això, el suggeriment del model més utilitzat és el d'Aurenche i Kozlowski (2003), que combina els models anteriors proposats per Mellart (1975), Redman (1978) i Cauvin (1994).

El corredor mediterrani del Llevant es defineix per una sèrie de relleus pre-costaners i costaners que creen depressions que inicien l'enorme Rift Africà. Aquesta àrea té una importància primordial en aquest context. Aquest corredor s'ha subdividit en la literatura arqueològica.

1.1.9.2. CANVI CLIMATIC I CRONOLOGIA

Segons Aurenche et al. (2001) i Kozlowski i Aurenche (2005), es creu que el procés de neolitització va començar al mateix temps que la transició del Pleistocè a l'Holocè (13.000-11.000 BP). Els primers indicis del procés de neolitització coincideixen amb variacions climàtiques. Basant-se en les característiques físiques i tècniques dels components que componen el registre material, així com dels habitatges, aquest període s'ha dividit en una sèrie de sistematitzacions cronoculturals. Garrod (1928) va començar a utilitzar el terme Natufià a la zona llevantina, el primer període que es va atribuir al procés neolític. Aquest terme es refereix a societats de caçadors-recol·lectors complexos amb un alt grau de sedentarització al final de l'Epipal·leolític (13.000 - 9.800 cal BP) (Goring-Morris & Belfer-Cohen, 2008). Kenyon (1956, 1960) va denominar i classificar els períodes del Neolític Primerenc després del Natufià com a Neolític Pre-Ceràmic A (PPNA) (9.700 - 8.500 cal BP), Neolític Pre-Ceràmic B (PPNB) (8.700 - 6.250) i Neolític Ceràmic (PN). Tingueu en compte que el Neolític Pre-Ceràmic B Antic (EPPNB), el Neolític Pre-Ceràmic B Mitjà (MPPNB), el Neolític Pre-Ceràmic B Tardà/Recent (LPPNB) són els tres períodes en què sovint es divideix el PPNB. Malgrat que aquesta classificació de períodes s'ha utilitzat en molts estudis, també ha estat controvertida. Alguns investigadors consideren que l'EPPNB és una fase de transició del PPNA al PPNB (Bar-Yosef, 1981; Gopher, 1996; Goring-Morris & Belfer-Cohen, 1998), però altres, com Kujit (1998), consideren que no hi ha prou base empírica per a això. D'altra banda, només a la zona sud-llevantina hi ha una altra subdivisió anomenada PPNB Final o PPNC.

9.1.2. LA DENTICIÓ

Les dents tenen una gran importància en contextos arqueològics i forenses, i a més de ser una font d'informació valuosa, són l'os millor conservat en contextos arqueològics i paleontològics. La raó per la qual les dents solen conservar-se millor que altres ossos es deu a dos factors principals: 1) La superfície de l'esmalt és el teixit més dur del cos humà perquè la major part (95-96%) prové de fonts inorgàniques, principalment hidroxiapatita de calci [Ca10(PO4)6(OH)2]. 2) Totes les persones en tots els llocs i moments han tingut, tenen o tindran dents, amb l'excepció d'un petit nombre d'individus anodonts.

La dentició humana té dos conjunts de dents, fent-la difiodonta. Aquests conjunts són la dentició permanent, que substitueix gradualment la dentició primària, i la dentició decidual, també coneguda com a dentició de llet. L'esmalt i el ciment cobreixen, respectivament, la corona i l'arrel de cada dent. La unió ciment-esmalt, també coneguda com a línia cervical, és on es troben les dues estructures. Mentre que la corona emergeix a la cavitat oral, l'arrel es posiciona en la cavitat alveolar de la mandíbula (maxil·lar i mandíbula inferior), que està suportada pel procés alveolar. El teixit dentinari, que envolta la cavitat pulpar - l'únic material dental tou - es troba sota les capes de ciment i esmalt. A més d'aquestes semblances generals en l'estructura dental, la morfologia de les dents varia segons el tipus de dent i el maxil·lar superior o inferior on es troba la dent, especialment perceptible en els incisius i queixals (que tenen patrons diferents de cúspides).

Normalment, per a una millor comprensió o identificació, cada maxil·lar i mandíbula es divideix en quadrants esquerre i dret. Així, la dentició es divideix en quatre quadrants: superior dret, superior esquerre, inferior esquerre i inferior dret. Els quadrants esquerre i dret del crani són imatges en mirall l'un de l'altre perquè estan separats per la línia mitjana sagital.

Com tots els mamífers, humans inclosos, som heterodonts, cada quadrant conté dents amb morfologies diferents. Hi ha quatre tipus diferents de dents en humans: incisius, canins, premolars i molars. La dentició permanent està formada per dos incisius, un caní, dos premolars i tres molars.

9.1.3. NOMENCLATURA

En aquesta tesi, cada dent es refereix mitjançant la primera lletra del seu nom (I per incisius, C per canins, Pm per premolars i M per molars). Les dents permanents s'indiquen amb lletres majúscules, mentre que les temporals (deciduals) s'especifiquen amb minúscules precedides per "deci". Cada lletra va seguida d'un nombre i dues altres lletres: la primera indica si la dent és inferior (L) o superior (U) i la segona si és esquerra (L) o dreta (R). Per exemple, el primer bicuspid inferior dret s'identifica com 'M1LR' i el quart premolar superior esquerre com 'Pm4UL'.

La part de la corona que fa front a la dent oposada s'anomena superfície oclusal en premolars i molars. Les superfícies de la corona es nomenen segons la seva posició en el maxil·lar o mandíbula. A cada arc del maxil·lar o mandíbula, les dents estan disposades en fila, amb la superfície que mira cap a l'exterior de la boca o el pla sagital medial anomenada mesial, mentre que la que mira cap a l'oposat s'anomena distal. La superfície que mira cap a la llengua s'anomena superfície lingual, i la que mira cap a l'exterior de l'arc, cap als llavis i galtes, es diu bucal, labial o vestibular; "labial" s'utilitza habitualment per a incisius, mentre que "bucal" és per a canins, premolars i molars.

9.1.4. PATRÓ DE LA HISTÒRIA DE VIDA

Un subcamp de la biologia conegut com a "patró de història de vida" estudia com els organismes distribueixen l'energia durant funcions vitals com el desenvolupament, el manteniment, la reproducció i l'adquisició d'independència dels seus descendents. També abasta les estratègies que utilitzen els organismes per evitar la mortalitat. Els elements clau d'aquests patrons en primats inclouen el moment del naixement, l'edat de desmamat, la durada dels diferents estats abans de la reproducció, el nombre de descendents, el nombre de fills per naixement i la esperança de vida. Aquest patró de l'estratègia de vida ajuda a entendre com els organismes són modelats per la selecció natural i altres processos evolutius per millorar les seves possibilitats de supervivència i reproducció en condicions ecològiques canviants.

En el camp de l'estratègia de vida, es poden identificar dues categories d'informació. La primera categoria inclou variables com el període de gestació, l'edat de desmamat, la longevitat, l'interval entre naixements i l'edat de la primera i última reproducció, anomenades Variables de Història de Vida (LHV). La segona categoria comprèn variables empíricament correlacionades amb les LHV en primats, conegudes com a variables relacionades amb la història de vida (LHRV), que inclouen la massa corporal, la mida del cervell i el desenvolupament dental. Des d'un punt de vista paleontològic, aquestes últimes són importants, ja que poden ser investigades en fòssils d'homínids per inferir les variables de història de vida (LHV).

9.1.5. DESENVOLUPAMENT HUMÀ

En comparació amb altres espècies de primats, els humans moderns presenten tendències de creixement diferents. Aquestes inclouen una fase de creixement prolongada, que s'estén fins als aproximadament 20 anys, un interval significatiu entre el desmamat i la pubertat, i l'inici de la pubertat a l'adolescència.

Per entendre l'evolució del patró de desenvolupament somàtic de l'Homo sapiens, és necessari identificar les etapes que caracteritzen el seu desenvolupament ontogenètic. Hi ha quatre grans etapes en el model de desenvolupament humà: infància, infantesa, joventut i adolescència..

Després del part, hi ha un període postnatal de poc més d'un mes anomenat infància, que dura fins que emergeixen els segons molars decidus, entre els dos i dos anys i mig. Durant aquesta etapa, els nadons experimenten un ràpid creixement cerebral i desenvolupen els sistemes motor i sensorial.

Seguidament, la infantesa comprèn el període entre l'erupció del segon molar decidu i l'aparició del primer molar permanent, que es produeix al voltant dels 6-7 anys. Els nens són desmamats però continuen depenent dels pares i comencen a tenir una dieta variada essencial per al creixement cerebral.

La següent etapa és la joventut, que es caracteritza per la maduració del sistema nerviós central i l'erupció de la dentició permanent. Aquesta fase dura entre set i dotze anys per als nens i entre set i deu per a les nenes. La maduració del sistema immunitari i digestiu ocorre durant aquesta etapa, que finalitza amb l'inici de la pubertat.

L'adolescència, l'última etapa abans de l'edat adulta, dura uns 5 a 10 anys després de la pubertat, i es marca per l'aparició del tercer molar permanent. A partir d'aquí, es desenvolupen característiques sexuals secundàries, canvis en la veu i un accelerament del creixement físic.

Els humans solen arribar a l'edat adulta als 20 anys, moment en què es conclou el creixement somàtic i s'assoleix la maduresa esquelètica. No obstant això, el neocortex no madura completament fins als 30 anys. L'edat adulta es divideix en dues fases: l'estabilització de processos homeostàtics seguit de la senescència i l'envelliment, que impliquen una disminució de la funcionalitat corporal.

A la majoria de mamífers, el creixement és constant fins a la pubertat, quan la taxa de creixement disminueix. En primats, s'inclou una etapa juvenil que retarda la maduresa sexual i allarga el desenvolupament somàtic. En comparació, els ximpanzés i goril·les tenen un període de desenvolupament més breu que els humans. El creixement humà es pot descriure mitjançant tres funcions matemàtiques distintes, que mostren diversos patrons de creixement fins a l'edat adulta.

9.1.6. ODONTOGÈNESI

El terme 'odontogènesi' es fa servir en el camp mèdic per descriure la formació i erupció de les dents. Com amb qualsevol òrgan, l'odontogènesi requereix tres processos fonamentals: 1) **iniciació**, que determina on començarà a formar-se la dents; 2) **morfogènesi**, on les cèl·lules comencen a formar l'òrgan rudimentari; i 3) **diferenciació**, on es formen les estructures específiques de la dent. Les dents s'originen de l'epidermis i el derma embrionaris (ectoderm i mesoderm).

La formació de la làmina dental és la primera indicació morfològica del desenvolupament dental, resultant d'un notable engrosament de l'epiteli oral. Posteriorment, es forma el gemm dental quan la làmina dental creix al teixit connectiu del primer arc branquial. La invaginació de l'epiteli dins del mesènquima es produeix a través d'un procés de senyalització entre ambdós. Això condueix a la creació d'una estructura en forma de tapa al voltant de la papil·la dental.

La diferenciació de la làmina dental marca l'inici de l'odontogènesi. Aproximadament al dia 28 del desenvolupament embrionari, l'epiteli oral comença a engrosar-se, formant les placodes dentals. La interacció entre els gens Fgf i Bmp de l'ectoderm i el gen Pax9 del mesènquima és crucial per determinar la ubicació d'aquestes placodes.

La morfogènesi del gemm dental implica la divisió de cèl·lules mesenquimals i epitelials. La fase de tapa comença amb l'ampliació dels vorals del gemm per divisió cel·lular, i es generen diversos òrgans d'esmalt. Durant la seva evolució, emergeixen nusos d'esmalt que regulen el creixement i els patrons dentals.

L'expressió de gens com Bmp4 i Fgf en els nusos d'esmalt és fonamental per les etapes de morfogènesi del gemm dental. La diferència i mineralització comencen quan el gemm arriba a l'estat de campana tardana, amb les cèl·lules que es diferencien en odontoblasts i ameloblasts. L'odontoblasts produeixen la matriu de dentina, mentre que l'ameloblasts sintetitzen la matriu d'esmalt.

La formació de les arrels de les dents comença després de la formació de la dentina coronària i la matriu d'esmalt. Les cèl·lules mesenquimals del fol·licle dental es diferencien en cèl·lules per al periodonti i la polpa radicular, amb la influència de les làmines epitelials radiculars de Hertwig. El Bmp4 és un dels reguladors més importants en aquest procés.

9.1.7. CICLE DE MASTEGAT

L'ús de les dents per alimentació implica un procés de preparació dels aliments de dues etapes amb la dentició anterior i una etapa de reducció dels aliments amb la dentició posterior. Aquesta activitat, coneguda com el cicle de mastegat, provoca desgast a les superfícies oclusals quan les dents superiors i inferiors entren en contacte entre si o amb els aliments.

El cicle de mastegat es divideix en tres etapes distinctes: l'etapa d'obertura, l'etapa de força i l'etapa de tancament. El cicle comença amb l'etapa d'obertura, durant la qual l'aliment es introdueix a la cavitat oral, seguida de l'etapa de tancament, en què la cavitat oral es tanca per facilitar el contacte entre les cúspides. L'etapa de força es divideix en dues fases: l'esclafament i el triturat dels aliments.

La Fase I implica un moviment de fregament entre les cúspides dels molars, el que resulta en una oclusió al punt central. Durant aquesta fase, les superfícies linguals de les cúspides linguals dels molars superiors contacten amb les cúspides bucals dels molars inferiors. En la Fase II, es produeix un moviment a partir del punt central, on les superfícies linguals de les cúspides bucals dels molars inferiors es poleixen contra les superfícies bucals de les cúspides linguals dels molars superiors. La darrera part del cicle de mastegat torna a ser una etapa d'obertura, on la mandíbula s'obre de nou.

Durant el cicle de mastegat, les superfícies de la Fase I realitzen un moviment de tall, mentre que les superfícies de la Fase II executen un moviment de trituració. Això provoca que les facetes d'esguit que s'originen de cada fase estiguin subjectes a diferents mecanismes de desgast.

9.1.8. MIDA DENTAL

L'estudi de la mida de les dents, com a indicador de canvi evolutiu i processos d'adaptació, és una part essencial de l'antropologia física. S'ha identificat una gran multitud de variables genètiques i ambientals que contribueixen a la variació observada en la mida dental dins i entre poblacions humanes i al llarg de l'evolució homínida. Es demostra que els grups humans dedicats a la caça i la recol·lecció presenten una mida dental superior en comparació amb aquells que practiquen l'agricultura i altres activitats de processament d'aliments. A més, s'ha documentat una notable reducció en les dimensions dentals dels Homo sapiens durant els darrers 100,000 anys, així com canvis en els paràmetres craniofacials.

En les últimes dècades, s'han proposat tres models d'adaptació morfo-funcional per caracteritzar i explicar la variància dental:

Efecte de mutació probable: Postula que, davant l'absència de pressió selectiva, es produiran mutacions espontànies que resultaran en una reducció i simplificació de la morfologia dental. L'adopció d'un estil de vida neolític ha alterat significativament les pràctiques alimentàries, relaxant la pressió selectiva que afavoria dents més grans i complexes.

Efecte de densitat poblacional en augment: Argumenta que l'augment de la densitat poblacional i el estil de vida sedentari van provocar una disminució dràstica de la ingesta nutricional i la salut general. Aquesta reducció en les necessitats nutricionals i metabòliques hauria d'haver contribuït a la disminució de la mida corporal i de les dents.

Efecte de compromís selectiu: Suggereix que les poblacions amb dents més grans són més susceptibles a la congestió dental i les càries, cosa que exerceix pressió sobre les dents més petites. Per suportar el desgast provocat per l'alimentació abrasiva, es creu que es van seleccionar dents més grans amb un esmalt més fort.

El mètode més utilitzat per investigar la variabilitat de la mida dental és l'ús de mesures lineals simples, com distàncies i angles, juntament amb índexs associats. Les mesures més comunes per caracteritzar la mida dental són mesio-distal (MD) i bucco-lingual (BL), i el diàmetre cervical-incisal, també conegut com a altura de la corona, que s'ha utilitzat àmpliament.

9.1.9. CARACTERISTIQUES DENTALS NO MÈTRIQUES

Totes les variàncies anatòmiques observades a les dents es consideren característiques dentals no mètriques. Aquestes característiques poden estar presents o absents i sovint es troben en diferents graus d'expressió. Poden ser trets negatius, com ara estructures positives com cúspides auxiliars, tubercles o crestes. Altres propietats, com variacions en la quantitat, la ubicació i la mida de cúspides i arrels, també es consideren característiques o trets no mètrics.

En conseqüència, les característiques es poden classificar en tres categories principals:

Característiques dicotòmiques: Són aquelles que es poden classificar com a presents o absents.

Característiques ordenades i graduades: Aquestes es relacionen amb l'estadi de desenvolupament i poden estar presents o absents amb diferents graus d'expressió.

Característiques amb una expressió variable però desorganitzada: Inclouen patrons de valls en molars mandibulars o característiques de les incisives, que no representen etapes de desenvolupament distintes.

Tant la dentició decídua com la permanent presenten característiques similars, però la recerca sobre la morfologia dental es concentra en la dentició permanent ja que les sepultures en infants són menys comuns i els ossos es conserven poc. Només un 30-40% de les més de 100 característiques documentades de la dentició humana han estat suficientment caracteritzades i investigades. El sistema de puntuació desenvolupat per la Universitat Estatal d'Arizona (ASUDAS) és el més complet i utilitzat globalment.

L'aplicació d'aquest mètode a una dentició completa permet obtenir 121 variables, que expliquen i mostren 35 trets dentals. L'avantatge d'aquesta tècnica de puntuació és la seva amplitud d'ús, que permet dades comparatives de diverses poblacions. No obstant això, no totes les variables proporcionaran informació rellevant. Per tant, és fonamental seleccionar les característiques més adequades amb cura.

En general, hi ha poc dimorfisme sexual discernible pel que fa a les característiques de corones i arrels. Quan es detecten diferències, aquestes solen ser menors i varien entre mostres. La majoria dels estudis han identificat diferències en les característiques de les dents canines, els incisius en forma de pala i el tubercle de Carabelli.

Així, la capacitat d'integrar dades de tots dos sexes per determinar les freqüències poblacionals és un avantatge que les característiques morfològiques orals comparteixen amb les característiques genètiques autosòmiques. Les petites col·leccions esquelètiques es beneficien d'això, ja que permeten utilitzar la mostra com una entitat unificada.

En examinar els principals grups demogràfics, com africans, asiàtics, nadius americans, aborígens australians i caucàsics, es fa evident que certes característiques són més discriminables que altres. Les incisives en forma de pala, el setè cúspide en molars mandibulars i el tubercle de Carabelli exemplifiquen aquesta variabilitat. Es coneix que els incisius en forma de pala són més comuns en grups asiàtics i nadius americans, mentre que les cúspides de Carabelli són més freqüents en poblacions caucàsiques i africanes. Scott i Turner proporcionen una categoria general dels principals grups humans moderns en funció de les poblacions i les freqüències de diverses característiques dentals. Aquesta classificació és útil, especialment en investigacions forenses o materials arqueològics, per formular hipòtesis sobre l'origen dels individus. Per distingir els europeus occidentals del grup caucàsic, s'ha descrit el Complex Dental Eurodont.

9.1.10. TOPOGRAFIA DENTAL

Entre finals dels anys 90 i principis dels anys 00, van aparèixer noves eines digitals i tècniques d'imatge que van permetre desenvolupar mètodes d'anàlisi innovadors. La topografia dental és una eina que s'utilitza per estudiar les superfícies de les dents, emprant mesures quantitatives que reflecteixen un o més aspectes de la seva forma. El concepte de topografia dental prové de la metodologia dels sistemes d'informació geogràfica (SIG), que es fa servir per mapar territoris. De manera similar, la topografia dental permet quantificar diversos aspectes de la morfologia dental mitjançant una comparació amb paisatges naturals, abordant aspectes com relleus, incisions, inclinacions, crestes, depressions i pics.

A principis d'aquest segle, els estudis han començat a utilitzar metodologies no basades en SIG. La topografia dental ha emergit com a mètode de quantificació i anàlisi de la forma general de la dent, que no requereix diversos punts de referència, sinó que es basa en una sola mesura. Això permet comparar dents amb variacions morfològiques significatives, especialment respecte al nombre de cúspides o crestes.

En les seves primeres etapes, els anàlisis topogràfics es basaven en superfícies en dues dimensions, associant cada punt amb una elevació específica per formar una topografia en 2.5D. Amb el temps, aquesta metodologia ha evolucionat cap a una representació tridimensional basada en superfícies o malles, cosa que permet l'examen de característiques complexes com l'angle i el relleu dental i la descripció d'estructures invisibles en vista oclusal.

La topografia dental s'ha utilitzat principalment per caracteritzar formes dentals i establir enllaços entre forma i funció en una àmplia gamma de mamífers. Aquesta aplicació ha contribuït a avançar el nostre coneixement sobre adaptacions dentals relacionades amb la fragmentació dels aliments. S'ha aplicat a dents sense desgast de grans primats, així com en primats en general, incloent-hi especialment els cercocecoids i els homínids fòssils, així com en poblacions humanes modernes.

A més, aquesta metodologia ha permès derivar informació sobre l'ecologia i la dieta de diverses espècies, així com una comprensió més profunda de l'evolució dels patrons oclusals dentals al llarg del temps. Les anàlisis poden centrar-se tant en la superfície oclusal de les dents com en la unió entre l'esmalt i la dentina.

Les mètriques de topografia dental comprenen diversos paràmetres clau, incloent-hi la curvatura (DNE, Dirichlet Normal Energy), el relleu oclusal (OR), l'Índex de Relleu de la Corona (RFI), la complexitat (OPCR, Orientation Patch Count Rotated), i l'oclusió ambiental (PCV, Portion De Ciel Visible):

DNE (Dirichlet Normal Energy): És una mesura de la curvatura de la superfície dental. Aquesta mètrica s'utilitza per quantificar el relleu de la superfície de l'objecte, ajudant a analitzar com es distingeixen les diverses característiques de la dent.

RFI (Crown Relief Index): Aquest índex avalua la complexitat i el relleu de la corona dental. El RFI ajuda a caracteritzar les variacions en les formes de les dents, tenint en compte factors com les cúspides i les depressions.

OPCR (Orientation Patch Count Rotated): Mesura la complexitat de la superfície dental obtinguda a partir de la quantificació de trossos de superfície en diferentes orientacions. Aquesta mètrica és útil per a comparar la diversitat entre les formes dentals i les adaptacions funcionals.

PCV (Portion De Ciel Visible): Fa referència a la quantitat d'espai visible o accessible d'una superfície dental específica. Aquesta mètrica permet avaluar l'impacte de les estructures dentals en la funció i l'ús dels aliments.

9.1.11. MACRO-DESGAST

El terme 'macro-desgast' es fa servir per descriure el desgast macroscòpic observable de la dentició. Esmentar que el desgast dental no és una malaltia, sinó un procés fisiològic normal. Aquest procés comença amb la pèrdua de l'esmalt oclusal, que és substituït per dentina secundària per protegir l'estructura dental subjacent. A causa de la seva naturalesa acumulativa, en casos extrems l'esmalt pot desaparèixer completament.

El procés de mastegat comprèn dues fases distintes. En la primera fase, les dents no entren en contacte directe entre si, sinó que poden entrar en contacte amb els aliments mateixos, creant un patró de desgast uniforme a la superfície oclusal. En la segona fase, les dents fan contacte amb els aliments mentre són mastegats, provocant un desgast oblic.

S'han identificat dues formes principals de macro-desgast: l’atrició, que resulta del contacte entre dents, i l'abrasió, que prové del contacte entre dents i aliments. La duresa i preparació dels aliments influencien significativament la gravetat del desgast dental.

S'han proposat diverses escales analítiques per avaluar el patró de desgast en diferents poblacions. L'escala més coneguda és la de Murphy, que classifica els valors de desgast de l'1 al 8 segons el patró de dentina exposada. Molnar va desenvolupar una escala similar per a dentició anterior i posterior, i Scott va adaptar aquesta metodologia per als molars. En els darrers anys, els models 3D d'alta resolució s'han introduït en l'estudi del macro-desgast dental, permetent la inclusió de mesures espacials detallades que ajuden a inferir hàbits dietètics en poblacions arqueològiques i espècies extingides.

El desgast dental també documenta fases significatives en l'evolució biològica i cultural, com l'accés a recursos alimentaris, l'aparició del foc i la cuina i la invenció d'eines de processament d'aliments. A més, l'estudi del desgast dental s'aplica en la determinació de l'edat, l'ús de la boca com a eina i l'estat de salut general.

9.2. MATERIAL I MÈTODES

El anàlisis realitzats en aquest estudi s'han dut a terme a partir de les mostres òssies obtingudes dels següents jaciments arqueològics:

Abu Hureyra: És un important jaciment prehistòric situat en l'actual Síria, pertanyent al PPNB. Aquest assentament és considerat un dels primers exemples d'agricultura sedentària, amb evidències de la transició de la caça i la recol·lecció cap a pràctiques agrícoles més estables. Durant les excavacions, es van trobar restes de cereals com el blat i l'ordi, així com eines i artefactes que demostren un coneixement avançat de la cultiu.

Dja'de el-Mughara: Situat en l'actual Síria, és reconegut per les seves restes d'habitacions i artefactes relacionats amb les primeres societats agrícoles presenta cronologies tant del PPNA com del PPNB.

El Wad: Actual Israel. Amb restes d'assentaments que mostren la vida quotidiana de les societats primerenques, El Wad destaca per la seva importància en la comprensió de la transició a l'agricultura i la vida sedentària amb cronologies del Natufià.

Jerf el Ahmar: Un lloc arqueològic a Síria. Presenta cronologies del PPNA. Està marcat per la seva arquitectura de pedra i proves d'assentaments permanents que representen la població que feia la transició cap a la vida agrícola.

Kebara: Situat a la regió de Galilea, Israel. Reflecteix les ultimes societats de caçadors-recol·lectors que van cap a una vida més sedentària durant el període Natufià.

Shukba: Aquest lloc a Cisjordània, presenta cronologies del període Natufià. Les coves van ser habitades i s'han trobat restes animals i eines que il·lustren la vida quotidiana de les societats prehistòriques i la seva subsistència.

Tell Aswad: Un important tell a Síria que presenta un període cronològic situat en el PPNB, amb restes que indiquen una economia agrícola, com ara la domesticació d'animals i el cultiu de cereals, que demostren una vida sedentària intensa.

Tell Halula: Aquest lloc, també a Síria, mostra evidències d'assentaments amb una base agrícola, incloent restes de cereals que indiquen la transició de les societats nòmades a les sedentàries en contextos del PPNB i Neolític Ceràmic.

Tell Ramad: Un altre jaciment arqueològic a Síria amb cronologies del PPNB amb restes que reflecteixen l'activitat humana i la vida sedentària.

Nemrik 9: Situat a l'actual Iraq, és datat en el PPNB i proporciona una visió valuosa de les primeres comunitats agrícoles, amb evidències arquitectòniques i artefactes que demostren una vida sedentària establerta.

Ali Kosh: Un lloc en l'actual Iran que data del PPNB, i és conegut per les seves restes d'assentaments i artefactes que indiquen pràctiques agrícoles i domesticació d'animals, reflectint el canvi cap a societats més complexes.

Tepecik-Çiftlik: Situat a l'actual Turquia, data de la transició del PPNB al Neolític Ceràmic. Les troballes d'aquest lloc ofereixen evidències de les transicions culturals i agrícoles en les primeres societats sedentàries, amb un fort enfocament en la domesticar animals i cultius.

Un dels principals objectius d'aquest estudi és obtenir una comprensió més completa dels orígens d'aquestes primeres societats sedentàries del Sud-oest d'Àsia. A tal fi, la mostra es va extreure d'excavacions realitzades en campanyes anteriors, així com de països amb una situació política contemporània complexa, amb condicions ambientals adverses i emmagatzemades per distintes institucions. Per abordar aquesta problemàtica, inicialment es van fer motlles dentals pel Dr. Alejandro Pérez-Pérez, el Dr. Ferran Estebaranz i la Dra. Laura M. Martínez, que corresponen ara a la col·lecció dental de la Unitat d'Antropologia de la Universitat de Barcelona (coordinada i dirigida per la Dra. Laura M. Martínez i el Dr. Alejandro Pérez-Pérez) que inclou mostres de 7 llocs al Sud-oest d'Àsia: Abu Hureyra, Dja'de El Mughara, El Wad, Jerf el Ahmar, Kebara, Shukba, Tell Aswad, Tell Halula, Tell Ramad. En els darrers anys, s'han obtingut nous motlles dentals d'altres llocs i altres regions dins de l'àrea d'estudi, d'una banda Nemrik 9 (actual Iraq) i Ali Kosh (actual Iran). I d'altra banda, aquí hi ha un segon conjunt de mostres de Tepecik-Çiftlik (actual Turquia).

L'ús de motlles dentals elimina complicacions potencials que sorgeixen del transport de restes arqueològiques i humanes. A més, permet la conservació de rèpliques d'aquests materials que, d'altra manera, podrien haver estat destruïts durant els nombrosos conflictes a la regió. La consolidació de totes les mostres en una única ubicació simplifica el procés d'estudi, facilitant així una comprensió completa del tema. Al mateix temps, el mètode permet realitzar una varietat de proves sense el potencial de produir danys irreparables a la mostra original.

SELECCIÓ DE DENTS

En l'etapa inicial de l'estudi, es van seleccionar totes les dents per a la creació de repliques dentals. Els motlles es van obtenir de tot l'arc dental inferior i superior, incloent dents des d'I1 fins a M3. Això abastava individus de tots els grups d'edat, des d'infants fins a adults, sempre que la dent estigués ben conservada i no en risc de ser malmesa durant el procés de emmotllatge. Aquesta metodologia es va adoptar per assegurar que no es perdi l'oportunitat de realitzar diverses proves dietètiques i morfològiques. A més, es poden dur a terme estudis addicionals en el futur si es fan disponibles noves tècniques analítiques.

NETEJA DE DENTS

Les dents de cada individu es van netejar per eliminar qualsevol resta que pogués haver-se adherit a la superfície de l'esmalt com a resultat del procés tafonòmic. La morfologia es distorsiona a causa de les partícules que danyen les característiques de desgast micro i macroscòpic. Les superfícies d'esmalt es van netejar amb acetona pura, i qualsevol material exterior que hagués pogut adherir-se a les dents es va retirar amb un cotó isotòpic. Després d'aplicar acetona, s'assegura la evaporació abans de repetir el procés amb etanol al 70% per evitar residus que podrien afectar l'adhesió del material de emmotllatge.

EMMOTLLATGE I POSITIVATGE DE DENTS

Es va aplicar silicona dental a les dents seguint els processos estàndards de Galbany et al. (2004, 2006). Es va utilitzar el material d'impressió AFFINIS Perfect Impressions (Coltene®), que proporciona una bona reproducció de la superfície sense danyar l'estructura de la dent. Aquest material es barreja i s'aplica a la superfície dental.

Després de fer els motlles, cal esperar almenys trenta minuts abans de començar el procés de replicat perquè el polièter aconsegueixi una consistència òptima. Per produir els positius, es va utilitzar FEROPUR PR-55 WHITE (Feroca®), un poliuretà de dos components que s'endureix a temperatura ambient. Els components es barregen en proporcions iguals i es col·loquen en els motlles d'impressió. Abans de la poli-meorització, els motlles amb la barreja s'han de centrifugar durant un minut per eliminar possibles bombolles d'aire. Després d'un període de cinc minuts, els positius es poden retirar fàcilment dels motlles negatius.

ESCANEJAT DENTAL

Les rèpliques dentals es van digitalitzar d'una banda amb un escàner 3D de superfície de llum estructurada DAVID SLS-2, utilitzant la configuració de màxima resolució. Per digitalitzar tota la superfície, es van realitzar vuit escanejos amb un angle de rotació de 30°, utilitzant la plataforma giratòria per obtenir una imatge completa de 360°. Les imatges es van alinear automàticament superposant les regions comunes. La longitud de l'escala de calibratge es va establir en 30 mm, que és el valor recomanat per escanejar objectes petits. Els escanejos es van unificar per formar una malla tancada, que es va exportar a un fitxer .ply, el format més utilitzat en treballs de digitalització 3D. D'altra banda, també es va utilitzar un escàner 3D de superfície de llum estructurada Shining EinScan-SP utilitzant la configuració de màxima resolució. Per digitalitzar tota la superfície, es van realitzar vuit escanejos utilitzant la plataforma giratòria per obtenir una imatge completa de 360°. Els escanejos es van unificar per formar una malla tancada, que es va exportar a fitxers .ply i .obj.

9.3. CANVIS EN LA MIDA DENTAL

9.3.1. INTRODUCCIÓ

L'estudi de les distàncies morfològiques (biodistàncies) continua sent rellevant en l'arqueologia moderna, complementant amb tècniques com l'ADN antic i l'anàlisi d'isòtops. Les biodistàncies són una tècnica no invasiva que s'utilitza com a indicador fenotípic per entendre les relacions filogenètiques entre grups de població.

Un dels esdeveniments més importants en la història humana és el canvi en les estratègies de subsistència, passant de la caça i recol·lecció a l'agricultura i ramaderia. Aquest procés, conegut com a neolitització, va començar a l'Àsia Sud-occidental durant l'Holocè, fa uns 12.000 anys.

La transició a una economia basada en l'agricultura i la ramaderia va provocar canvis en la dieta, que al seu torn van afectar la morfologia cranial i dental. S'ha observat una reducció i canvis morfològics en el crani i les dents tant al Pròxim Orient com en altres regions.

Aquests canvis podrien ser conseqüència de:

- Una pressió selectiva direccional deguda a la reducció de les forces masticatòries.

- Una simplificació morfològica de la corona dental per reduir la incidència de patologies com la càries.
- Algun nivell de discontinuïtat poblacional entre el Mesolític i el Neolític.

Aquest estudi examina la mida de les dents des d'una perspectiva àmplia de les poblacions del Sud-oest asiàtic, incloent la península del Sinaí, el Llevant, la vall de l'Èufrates, les muntanyes Zagros i la península d'Anatòlia, per fer comparacions a gran escala entre grups esquelètics antics de la mateixa àrea geogràfica.

9.3.2. MATERIAL I MÈTODES

L'estudi analitza restes dentals de 32 jaciments arqueològics del Sud-oest asiàtic, seleccionats segons un marc temporal que coincideix amb el canvi climàtic i ecològic. Inclou: 8 jaciments Natufians, 4 jaciments PPNA, 16 jaciments PPNB, 4 jaciments del Neolític ceràmic.

Els jaciments es van agrupar per regions geogràfiques: Llevant/Mediterrani (n=20); Eufrates Mitjà/Anti-Taurus (n=4); Regió desèrtica Sàhara-Aràbiga (n=4); Muntanyes Zagros (n=2); Sud/Centre d'Anatòlia/Taurus (n=2)

Les mostres analitzades provenen de diverses fonts:

- Motlles d'alta resolució de la Unitat d'Antropologia de la Universitat de Barcelona, incloent 7 jaciments.
- Dents originals de Tepecik-Çiftlik i Gre Filla, conservades a la Universitat de Hacettepe.
- Mostra de Kharaysin, conservada a l'Institut Milà i Fontanals d'Investigació en Humanitats.
- Nemrik 9 i Ali Kosh, motllejats a la Universitat de Varsòvia i replicats a la Universitat de Barcelona.

Mesures obtingudes d'articles científics i recursos en línia publicats anteriorment, incloent 19 jaciments addicionals.

Aquest enfocament divers en la recollida de dades permet una anàlisi àmplia i representativa de les poblacions del Sud-oest asiàtic durant el període de transició al Neolític.

Els mètodes utilitzats en aquest estudi es van centrar en dues àrees principals: les mesures dentals i els trets dentals no mètrics. Per a les mesures dentals, es van registrar els diàmetres bucolingual (BL) i mesiodistal (MD) màxims utilitzant un peu de rei digital amb una sensibilitat de 0,01 mm. Es van excloure de l'anàlisi les dents perdudes, danyades o en mal estat, així com aquelles afectades per desgast interproximal o oclusal significatiu.

Pel que fa als trets dentals no mètrics (TDNM), es van avaluar 23 característiques en la dentició permanent seguint el sistema ASUDAS (Arizona State University Dental Anthropology System). Es van excloure les característiques obtruides per deteriorament de l'esmalt, desgast o caries. Per garantir la consistència, un únic investigador va documentar totes les observacions. L'anàlisi es va limitar als jaciments amb dents originals o motlles d'alta resolució disponibles. Es va utilitzar l'enfocament de recompte individual per determinar les freqüències dels trets, i l'expressió d'aquests es va classificar en termes de presència o absència.

L'anàlisi estadístic es va realitzar utilitzant IBM SPSS Statistics 23 i Microsoft Excel 2016. Es va dur a terme un anàlisi de normalitat per a cada tipus de dent, seguit del càlcul de models lineals generals per avaluar els canvis dimensionals al llarg del temps. També es van realitzar proves post hoc i comparacions múltiples per parells per identificar diferències específiques entre mitjanes. A més, es va analitzar la taxa de creixement del canvi per quantificar la disminució percentual en diferents poblacions al llarg del temps.

Per als trets no mètrics, es va realitzar una anàlisi de freqüència, seguida d'un estudi de taula creuada per examinar la relació entre diferents períodes i àrees geogràfiques. Finalment, es va aplicar una prova de Chi-quadrat per avaluar la relació entre jaciments i períodes de temps.

Aquesta metodologia integral, que combina anàlisis mètriques i no mètriques, proporciona una visió detallada dels canvis dentals durant la transició al Neolític al Sud-oest asiàtic, contribuint així a la comprensió de les dinàmiques poblacionals durant aquest període crucial.

9.3.3. RESULTATS

MIDA DENTAL

El test de normalitat de Kolmogorov-Smirnov no va ser significatiu per a cap tipus de dent (p>0,05) en les mesures bucolinguals, excepte per al Pm3 inferior (p=0,006) i el M3 inferior (p=0,005). Pel que fa als resultats mesiodistals, es va trobar significació en diferents dents com el Pm3 inferior (p=0,000), el Pm4 inferior (p=0,000) i el M1 superior (p=0,003).

El model lineal general suggereix que hi ha diferències significatives entre les mesures bucolinguals tant entre diferents períodes com en diferents regions geogràfiques, independentment les unes de les altres.

En el test post hoc, es van trobar diferències significatives en el valor de *p* entre els diferents períodes només en les mesures bucolinguals. En la majoria d'ells, tendeix a ser el període Natufià el que es diferencia de la resta. Es van observar diferències significatives en el Pm3 inferior entre Natufià i PPNA (p=0,014), PPNB (p=0,000) i Neolític ceràmic (p=0,000); en el Pm4 inferior entre Natufià i PPNB (p=0,040), PN (p=0,037); en el M1 inferior entre Natufià i PPNA (p=0,033), PPNB (p=0,000) i Neolític ceràmic (p=0,000); en el M2 inferior entre Natufià i PPNB (p=0,000) i Neolític ceràmic (p=0,009); en el Pm3 superior entre Natufià i PPNB (p=0,006); en el Pm4 superior entre Natufià i PPNB (p=0,002); en el M1 superior entre Natufià i PPNB (p=0,000), Neolític (p=0,001); i en el M2 superior entre Natufià i PPNB (p=0,007) i Neolític ceràmic (p=0,005).

TRETS DENTALS NO MÈTRICS

Pel que fa als resultats dels caràcters no mètrics analitzats, observem que només dos caràcters ASUDAS, el Cusp 5 (Metacònul) (P=0,012) del M2 superior i els Mesial/Distal Accessory Cusps (P=0,014) dels premolars superiors, mostren resultats significatius en les freqüències d'aquests caràcters entre els diferents períodes. De manera similar, els resultats de les freqüències ASUDAS entre diferents regions (fitò)ecològiques i/o geogràficament diferenciades mostren que només hi ha resultats significatius en el Mid-Trigonid Crest

(P=0,028) del M2 inferior, el Cusp Number 1 (P=0,038) dels premolars inferiors i el Cusp 5 (Metacònul) (P=0,012) del M2 superior. Per tant, només el 5,88% dels trets ASUDAS mostren significació per període i només el 8,82% dels trets ASUDAS mostren significació per zona geogràfica.

9.3.4. CONCLUSIÓ I DISCUSSIÓ

Durant la transició entre el Pleistocè i l'Holocè, es van donar una sèrie de canvis simultanis en els entorns natural i socioecològic a la regió del sud-oest d'Àsia. Aquests incloïen un canvi climàtic, una transformació ecològica, un canvi socioecològic en la producció d'aliments (de caçadors-recol·lectors a agricultors i pastors) i un canvi biològic marcat per la reducció de les estructures anatòmiques, especialment la disminució de la mida de les dents.

Tradicionalment, aquesta seqüència d'esdeveniments s'ha interpretat com a prova d'una relació causal on el canvi climàtic hauria desencadenat un canvi ecològic que hauria obligat les poblacions del sud-oest d'Àsia a adoptar un nou sistema de producció d'aliments, provocant al seu torn un canvi dietètic que hauria tingut un impacte significatiu en la reducció de la mida de les dents d'aquestes poblacions (Larsen 1997; Erdal 1999; Estebaranz 2004; Pinhasi 2008, 2015). Aquest model reduccionista suggereix que el canvi climàtic hauria estat el principal factor desencadenant de tot aquest procés de transformació.

No obstant això, la realitat és que l'explicació d'aquests esdeveniments és actualment més complexa del que aquest model simplista suggereix (Maher et al., 2011). De fet, no hi va haver un canvi climàtic unidireccional i gradual, sinó més aviat oscil·lacions climàtiques amb períodes de màxims climàtics seguits de ràpids períodes de deteriorament ambiental (Maher et al., 2011). Aquesta variabilitat climàtica hauria tingut un impacte complex sobre els ecosistemes i les estratègies de subsistència de les poblacions humanes, les quals haurien hagut d'adaptar-se mitjançant diferents respostes socioecològiques.

La mida de les dents té una gran rellevància en l'antropologia biològica, especialment en relació amb l'adaptació i l'evolució. S'ha estudiat àmpliament i és un fet ben establert que hi ha hagut una reducció de la mida dental al llarg de l'evolució dels homínids (Estebaranz et al., 2004). La mida i el gruix de l'esmalt dental s'utilitzen sovint com a indicadors de la disponibilitat d'aliments i es consideren dades clau per rastrejar les adaptacions dietètiques i ecològiques del llinatge dels Hominini (Estebaranz et al., 2004; Alrousan, 2009).

En aquest context, s'han realitzat diversos estudis a la regió del Mediterrani oriental en els darrers anys, que proporcionen una visió de tota l'àrea del sud-oest d'Àsia, des del Llevant fins a Anatòlia, pel que fa a la mida dental i els trets dentals no mètrics. Els resultats d'aquests estudis han demostrat i confirmat l'accentuació de la reducció dental en les societats de transició des dels caçadors-recol·lectors fins a les primeres poblacions d'agricultors, no només al Llevant, sinó a tot el sud-oest d'Àsia. No obstant això, l'anàlisi del model lineal general suggereix que aquesta reducció dental és efectiva només en les dimensions bucolinguals.

Aquestes dades dentals proporcionen una imatge més complexa i matisada del procés de transició entre el Pleistocè i l'Holocè a la regió, posant en qüestió la narrativa tradicional d'una relació causal lineal entre el canvi climàtic, l'ecologia i els canvis biològics. Cal, per tant, aprofundir més en l'estudi d'aquests processos d'adaptació.

9.4. CANVIS EN LA TOPOGRAFIA DENTAL

9.4.1. INTRODUCCIÓ

Durant el Younger Dryas, l'entorn va canviar, reduint la capacitat de càrrega dels ecosistemes a causa de la imprevisibilitat climàtica, la qual va disminuir les fonts d'aliment per a la població de caçadors-recol·lectors. L'activitat humana també va afectar la distribució i productivitat dels cereals silvestres i la quantitat de fruits com pistatxos i glans, influenciant les adaptacions humanes. Per fer front a la manca de recursos, les poblacions tardanes natufianes van fer la transició d'un estil de vida de caça-recollida a un de basat en l'agricultura durant aquesta transició climàtica, afavorida per un augment ràpid de temperatura i precipitació que va marcar el Holocè.

El període Pre-Pottery Neolithic A (PPNA) (11,600–10,500 anys BP) es caracteritzà per un augment de la població i la quantitat d'assentaments, al costat de pràctiques de recol·lecció de fruits i llavors silvestres juntament amb l'aparició de cereals i llegums domesticats. Aquestes condicions favorables van perdurar fins a l'arribada del Pre-Pottery Neolithic B (PPNB) (10,500–8,750 anys BP), on els aliments es van basar cada vegada més en cultius i animals domesticats.

Les variacions dentals entre diferents tàxons, com variants de homínids, són utilitzades per indicar canvis a les pautes nutricionals, que també poden reflectir canvis ambientals. Per analitzar quantitativament les dents humanes i d'altres tàxons, s'utilitzen tècniques com l'estudi de la mida i forma de les dents, així com l'anàlisi de la topografia dental, que fa uso de sistemes d'informació geogràfica (GIS) per correlacionar la forma dental amb la dieta.

A l'estudi de poblacions antigues de l'Àsia Occidental, s'han utilitzat quatre mètriques topogràfiques dentals. Encara que les espècies puguin consumir aliments similars, poden presentar variacions en el seu comportament dental degudes a diferents moviments masticatoris. Per exemple, les dents amb corones cúspides baixes presenten un menor índex de relleu, que es calcula com la ràtio entre l'àrea del projecte bidimensional i l'àrea de superfície tridimensional de la dent. Les tècniques per calcular la curvatura de les corones, així com la seva complexitat o exposició a la llum, són rellevants per a la comprensió de com els factors nutricionals influeixen en la morfologia dental.

9.4.2. MATERIAL I MÈTODES

L'estudi ha analitzat 105 restes dentals (primers i segons molars inferiors) de 10 jaciments arqueològics al sud-oest d'Àsia (El Wad, Kebara, Dja'de el Mughara, Abu Hureyra, Tell Aswad, Tell Ramad, Tell Halula, Ali Kosh, Nemrik 9 i Tepecik-Çiftlik). Els llocs estan limitats a diferents períodes cronològics: Natufià, Neolític Preceràmic B i Neolític Ceràmic. A més, aquests jaciments arqueològics s'han dividit en regions (fitoc)ecològiques i/o geogràficament diferenciades per comparar patrons regionalitzats (Horwitz & Tchernov, 2000; Ibáñez et al., 2017; Palmisano et al., 2021): Llevant/Mediterrani, Mig Eufrates/Anti Taurus, Regió desèrtica Saharo-aràbiga, Muntanyes Zagros i Anatòlia Sud/Central/Taurus.

Les col·leccions dentals que van ser analitzades es troben en diversos laboratoris i institucions. Les mostres van ser obtingudes de set jaciments al sud-oest d'Àsia. Abu Hureyra, Dja'de El Mughara, El Wad, Jerf el Ahmar, Kebara, Shukba, Tell Aswad, Tell Halula, Tell Ramad (Estebaranz et al., 2007). Les col·leccions han estat analitzades (Martínez et al., 2016), corresponent a la col·lecció dental de la Unitat d'Antropologia de la Universitat de Barcelona (coordinada i dirigida per Dra. Laura M. Martínez i Dr. Alejandro Pérez-Pérez). A més, un segon conjunt de mostres va ser realitzat per Dr. Arkadiuz Sołtysiak a la Universitat de Varsòvia i posteriorment analitzat a la Universitat de Barcelona. El tercer conjunt de mostres va ser realitzat per Dr. Ali Metin Büyükkarakaya del Laboratori d'Ecologia del Comportament Humà i Arqueometria (IDEA Lab), Departament d'Antropologia, Universitat de Hacettepe, específicament el Tepecik-Çiftlik de la península Anatòlica.

Pel que fa a la metodologia utilitzada, les mostres es van netejar per eliminar qualsevol imperfecció causada per processos tafonòmics amb isòtops de cotó i etanol pur. Es van fabricar motlles de silicona utilitzant Affinis® Regular Body (Coltène-Whaledent) polivinilsiloxà. Aquests motlles van ser replicats utilitzant poliuretà Ferropur PR-55 (Ferroca® Composites, Espanya) segons els procediments descrits per Galbany (2016). Es van obtenir escanejos tridimensionals amb tecnologia d'escaneig 3D de llum blanca estructurada, concretament Shining Einscan SP, amb una resolució de 0,05 mm. Els arxius es van exportar en format poligonal (.ply). Les mostres escanejades es van processar amb Geomagic Studio/Wrap 2014 tallant-les per aïllar la vista oclusal de les dents (Berthaume, 2019) i simplificant la malla a 10.000 polígons (Winchester, 2016). Posteriorment, els models es van importar a Meshlab (ISTI-CNR, Universitat de Pisa) per orientar-los, amb la cara oclusal de la dent situada perpendicularment a l'eix Z (Pampush et al., 2016).

Per obtenir les dades mètriques de la topografia de les malles poligonals 3D, es va utilitzar el programari Morphotester per calcular l'índex de relleu (RFI) (Boyer, 2008), l'energia normal de Dirichlet (DNE) (Bunn et al., 2011) i el recompte de pegats d'orientació rotats (OPCR)

(Evans et al., 2007). Per calcular l'oclusió ambiental (PCV; Percentatge de Cel Visible), es va utilitzar el programari 3D Cloud Compare (Berthaume, 2019a).

L'anàlisi estadística es va dur a terme utilitzant el programari estadístic SPSS estadístiques 23.0 (IBM, Armonk, NY, USA). Segons el test de Shapiro-Wilk, els factors topogràfics dentals no seguien una distribució normal per període cronològic i àrea geogràfica ($p < 0{,}05$). Es va utilitzar l'ANOVA d'un factor per cada variable (DNE, RFI, OPCR, PCV) segons període cronològic i àrea geogràfica, utilitzant el test de significació honest de Tukey (HSD) per determinar la variació significativa durant la transició dels últims caçadors-recol·lectors a les primeres poblacions agrícoles per període cronològic i àrees geogràfiques. Es van realitzar dues anàlisis discriminants amb l'objectiu d'identificar el mètode òptim per diferenciar entre els grups; d'una banda, es van utilitzar els grups de períodes cronològics, i de l'altra, els grups d'àrees regionalitzades. Es va dur a terme una anàlisi discriminant lineal (LDA) sobre la matriu de correlació per determinar els patrons de variació topogràfica que explicaven la variació observada en diferents grups. Es va realitzar una anàlisi discriminant de funció lineal pas a pas utilitzant Addinsoft XLSTAT 2020.5.

9.4.3. CONCLUSIÓ I DISCUSSIÓ

Aquest estudi examina les adaptacions dietètiques significatives que els humans van fer en resposta a les fluctuacions climàtiques del període Younger-Dryas Recent i l'època posterior, l'Holocè. Les troballes demostren que els reptes ambientals associats amb la impredictibilitat climàtica dels estadis climàtics van reduir significativament la capacitat dels ecosistemes, cosa que va impactar immediatament les poblacions humanes que depenien d’aquests recursos (Molleson, 1994; Cappers, 2002). La transició de la caça i la recol·lecció a estils de vida agrícoles primerencs entre les societats del Natufià tardà es pot atribuir a les limitacions de recursos, que representen una resposta evolutiva cabdal a les pressions ecològiques (Bar-Yosef & Belfer-Cohen, 1992; Miller, 1996; Hillman, 1996).

L'anàlisi discriminant aplicada per explorar la morfologia dental va mostrar diferències notables en les mesures mètriques de la topografia dental a través de diverses èpoques i àrees geogràfiques. Els resultats suggereixen que alguns dels índexs dentals (DNE i OPCR) no van produir diferències significatives, mentre que els índexs RFI i PCV van indicar alguns canvis del Natufià als contextos posteriorment neolítics (PPNB i Neolític ceràmic). Aquests canvis poden reflectir desplaçaments en la dieta i respostes adaptatives associades, ressaltant així l'impacte profund en els patrons de subsistència de la gent a través de la domesticació d'organismes i el desenvolupament del sistema agrícola (Zeder, 2005; Peters et al., 2005).

Un punt de gir important va venir amb la transició a l'Holocè, caracteritzada clarament per una millora climàtica relativa que va facilitar els augments de població i l'expansió dels assentaments humans (Alley, 2000; Robinson et al., 2006; Weninger et al., 2009). Encara que la caça i la recol·lecció continuaven en ús, l'emergència de cultius domesticats va permetre l'inici de societats agrícoles més complexes. Les característiques dentals destacades associades amb certes formes d'explotació de recursos ofereixen pistes sobre com aquests canvis es manifesten en la forma de les estructures dentals (Lucas et al., 2008; Ungar & Sponheimer, 2011). La presència de diferents mètriques topogràfiques entre les mostres no només indica la distribució de les dietes de les poblacions més recents, sinó també possibilitats eco-crítiques més àmplies a la regió del sud-oest d'Àsia (Berthaume, 2018).

Els resultats de l'anàlisi discriminant lineal (LDA), amb una taxa d'encert superior al 80%, proporcionen més informació sobre la relació entre la variació morfològica i la categorització cronològica. La classificació errònia entre les poblacions PPNB i Natufià indica l'existència de pautes socials o nutricionals subtils durant aquest període de transició. En avaluar les adaptacions dentals i les estratègies ecològiques, es subratlla la importància de considerar la mida de la mostra i l'heterogeneïtat geogràfica (Godfrey et al., 2012; Berthaume & Schroer, 2017).

D’altra banda, també es va realitzar un LDA a nivell d'àrea geogràfica per avaluar si els canvis morfològics observats en la dentició estan associats amb les diferents zones geogràfiques i climàtiques existents. Els resultats demostren que les àrees geogràfiques d'Anatòlia i el Llevant estan significativament més distants que el Desert, Eufrates i Zagros. És remarcable que l'àrea geogràfica d'Anatòlia abasta tota la mostra del període Neolític Ceràmic i que l'àrea geogràfica del Llevant correspon en gran mesura al període cronològic del Natufià. Això pot explicar per què la major part de les classificacions errònies (38,98% en M1L i 50% en M2L) s'alineen amb àrees geogràfiques del mateix període, suggerint que els canvis en dentició podrien haver ocorregut al llarg del temps més que no pas per influències de diferències regionals.

La topografia dental pot proporcionar informació sobre adaptacions genètiques, més enllà de la mera reflectància dels patrons alimentaris. Tant els factors d'estrès ambiental com les reaccions evolutives poden afectar característiques fenotípiques, com el creixement i la forma dels dents, que estan influenciades per variables genètiques (Ungar et al., 2011). La noció que les característiques dentals no són simplement respostes dietètiques, sinó que també serveixen com a marques de la història poblacional i dels patrons migratoris, s'ha de sustentar amb la interacció entre la genètica i la morfologia dental. La nostra comprensió de com els factors ambientals i la composició genètica han interactuat per produir adaptacions humanes al llarg del temps pot ser millorada mitjançant l'ús de l'anàlisi genètica per aclarir les relacions entre les variacions en la topografia dental i els orígens genètics de les diverses poblacions.

La distància observada entre els individus del neolític cràmic i els altres pot atribuir-se al fet que tots ells provenen del jaciment de Tepecik-Çiftlik, que està situat a la península de l'Anatòlia. Yaka (2020) ja aborda la qüestió dels jaciments neolítics temprans d'Anatòlia, assenyalant que, malgrat la seva proximitat, cadascun d'ells està representat en un grup genètic diferent. No obstant això, la distància genètica entre el Neolític anatòlic i el Neolític europeu i els caçadors-recol·lectors del Caucas és significativa, així com la distància entre el Neolític anatòlic i el Neolític llevantí i els primers agricultors iranians (Kiliç, 2016, 2017; Feldman, 2019). La diversitat és tan gran que Tepecik-Çiftlik no té aquesta afinitat genètica ni amb Çatalhoyuk, que es troba a uns 160 quilòmetres de distància.

Un flux genètic regional és evident entre el 7500 i el 6500 aC (Yaka, 2020). Es pot postular que l'efecte d'aquest flux genètic podria explicar l'augment observat en la diversitat genètica en poblacions neolítiques durant la transició del Neolític aceràmic al Neolític Ceràmic a

Anatòlia. Aquesta transició, o més aviat aquest canvi, és contemporàni amb l'emergència de societats més complexes amb una organització social diferent (Özbaşaran, 2011; Baird, 2012). En contrast, Tepecik-Çiftlik representa un aïllament genètic en comparació amb altres jaciments contemporanis. La discrepància pot atribuir-se a la inferior qualitat de les dades genòmiques o la presència d'una estructura genètica distinta, corroborada pel registre material del mateix jaciment, que difereix dels d'altres jaciments de cronologia comparable (Bıçakçı, 2012). Aquesta hipòtesi es recolza encara més en l'anàlisi topogràfica dental realitzada en aquest estudi, que revela que la topografia dental de Tepecik-Çiftlik és notablement distinta de la d'altres poblacions neolítiques aceràmiques en diferents subregions.

9.5. CANVIS EN ELS NIVELLS DE DESGAST

9.5.1. RETHINKING WEAR RATE ANALYSIS: A NEW DENTIN EXPOSURE PROXY AND ITS APPLICATIONS TO ANCIENT CHINESE POPULATIONS

"REPENSANT L'ANÀLISI DE LA TAXA DE DESGAST: UN NOU PROXY D'EXPOSICIÓ DE DENTINA I LES SEVES APLICACIONS A LES POBLACIONS XINESES ANTIGUES"

1.5.9.1. INTRODUCCIÓ

Aquest és un article (publicat, Yang et al., 2024) que introdueix una nova metodologia per a l'anàlisi de l'exposició de la dentina en molars, millorant així l'estudi del desgast dental en poblacions xineses prehistòriques. Es proposa que el desgast dental es pot definir com un procés fisiològic dependent de l'edat, influenciat per la duresa i l'abrasivitat dels aliments consumits. Aquesta afirmació és recolzada per estudis anteriors (Kaifu et al., 2003; Romero et al., 2019). Les tècniques convencionals per a l'anàlisi del desgast subestimen sovint l'edat real dels individus, ja que es basen en puntuacions discretes que no reflecteixen adequadament les variacions en les taxes de desgast segons l'estil de vida i la dieta de cada població (Gilmore & Grote, 2012).

Aquest estudi es centra en restes humanes de jaciments arqueològics xinesos, incloent Houtaomuga, Banlashan, Dunping i Jiayi, i analitza 275 individus. La metodologia emprada incorpora escaneig tridimensional (3D) i la mesura de les superfícies de dentina exposades, superant així les limitacions dels mètodes anteriors. Aquest model de mesura contínua permet l'avaluació de les taxes de desgast a través de múltiples molars, facilitant així una comprensió més precisa i exhaustiva dels patrons de desgast dental al llarg del temps.

Les troballes indiquen que les taxes més altes de desgast succeeixen durant la infància, amb un augment gradual de l'exposició de la dentina a mesura que els molars es tornen funcionalment actius. A més, les taxes de desgast observades varien considerablement entre les poblacions estudiades, reflectint les diferències en els hàbits dietètics i les condicions ambientals. Les poblacions amb dietes més abrasives, que s'associen típicament amb entorns àrids, van exhibir un desgast dental més pronunciat. En contrast, la població de Dunping, situada en una regió amb una major diversitat ecològica, va demostrar taxes de desgast considerablement més baixes.

Aquesta nova metodologia no només facilita una caracterització més precisa de les taxes de desgast dental, sinó que també proporciona informació sobre les condicions ecològiques i les pràctiques dietètiques de les poblacions antigues. Es pot concloure que l'anàlisi de l'exposició de la dentina a través de la modelització 3D proporciona un mètode fiable per a l'estimació de l'edat en el moment de la mort en contextos arqueològics i paleontològics. Això enriqueix per tant el camp de la bioarqueologia i el seu focus en les pràctiques culturals i dietètiques de les societats passades.

9.5.2. EVALUATING A DENTIN EXPOSURE PROXY FOR WEAR RATES ESTIMATIONS ON MESOLITHIC AND NEOLITHIC POPULATIONS FROM THE NEAR EAST AND THE IBERIAN PENINSULA: A COMPARATIVE ANALYSIS.

"AVALUACIÓ D'UN PROXY D'EXPOSICIÓ A DENTINA PER A ESTIMACIONS DE TAXES DE DESGAST DE POBLACIONS MESOLÍTIQUES I NEOLÍTICES DEL PRÒXIM ORIENT I DE LA PENÍNSULA IBÈRICA: UNA ANÀLISI COMPARATIVA"

2.5.9.1. INTRODUCCIÓ

El desenvolupament d'un nou indicador estadístic per mesurar les taxes d'exposició de dentina en molars va ser avaluat com un recurs potencialment fiable per a comparacions interpoblacionals segons Yang et al. (2024). L'anàlisi fet en l'article següent es centra en les pràctiques dietètiques i socioeconòmiques de les poblacions humanes antigues dels períodes Mesolític i Neolític al sud-oest d'Àsia i la península Ibèrica (Portugal i Espanya), regions que van mostrar patrons diferents en la producció d'aliments i restriccions ecològiques.

Comparant les taxes de desgast dental entre els grups estudiats, es van obtenir models de regressió clars, que estaven alineats amb les hipòtesis dietètiques anteriors, independentment de la distribució d'edat dels espècimens en les mostres. Els resultats van revelar tendències significatives en les taxes de desgast al llarg de diferents períodes i pràctiques socioeconòmiques. Es va trobar que les taxes d'exposició de dentina, comparant les edats d'erupció en els molars, eren més altes en les poblacions del Mesolític, principalment poblacions caçadores-recol·lectores, en comparació amb les poblacions del Neolític que estaven orientades cap a l'agricultura. Les mostres modernes i contemporànies van mostrar les taxes d'atrició més baixes, mentre que els espècimens Natufians van demostrar taxes d'exposició de dentina més semblants a les de períodes més tardans del Neolític que a les mostres "contemporànies" del Mesolític de la mateixa àrea geogràfica. En conclusió, el proxy 3D per a les taxes d'exposició de dentina va permetre la comparació de mostres arqueològiques poc representades, oferint així una perspectiva clara per provar hipòtesis en relació amb els hàbits dietètics, els canvis d'estil de vida al llarg del temps o les restriccions ecològiques durant la transició d'un estil de vida predominantment basat en la caça i la recol·lecció a una societat neolititzada basada en l'agricultura.

9.5.3. EL CAS ESPECÍFIC DEL SUD-OEST D'ÀSIA

3.5.9.1. INTRODUCCIÓ

En aquesta secció, es posen a prova hipòtesis sobre la heterogeneïtat dietètica i dels mètodes de processament d'aliments entre grups del sud-oest d'Àsia utilitzant un nou indicador per mesurar les taxes d'exposició de dentina (Yang et al., 2024). Carrascal et al. (2025) van analitzar materials arqueològics dentals del PPNB, incloent Tell Aswad, Tell Halula, Tell Ramad i Dja'de el Mughara. En vista de l'escassedat de materials, es va combinar el mostreig de PPNB. Això resulta especialment significatiu, tenint en compte que les mostres de molars posteriors eren particularment baixes, amb un total de 31 per a M1, 13 per a M2 i només 3 per a M3. L'anàlisi de la regressió lineal dels paràmetres indica que la mida de la mostra afecta significativament els resultats.

Els llocs relacionats amb les àrees d'irrigació de l'Èufrates i el d'àrees desèrtiques, es poden classificar en dos grups geogràfics diferents, permetent així examinar teories d'adaptació nutricional a condicions àrides i humides. Tot i no tenir accés a mostres del període Neolític ceràmic, Carrascal et al. (2025) van formular la hipòtesi que es podria esperar un augment en les taxes de desgast degut a la major dependència d'eines per a la molta de plantes, que s'han relacionat amb la formació de microestries (Mahoney, 2006).

L'objectiu principal d'aquesta anàlisi és aprofundir en les taxes d'exposició de dentina dels individus del sud-oest d'Àsia durant la transició de societats de caça i recol·lecció a societats sedentàries amb economies agrícoles i ramaderes. Aquest estudi inclou una nova mostra del jaciment arqueològic de Tepecik-Çiftlik a la regió d'Anatòlia Central, que presenta proves d'interacció amb grups neolítics del Llevant.

Els patrons dietètics a Tepecik-Çiftlik es preveu que fossin diferents dels observats als llocs PPNB i del Natufià, a causa de la disponibilitat limitada de cultius d'intensiu d'aigua degut a la seva semi-aridesa continental. Mentre que les poblacions del Llevant i Èufrates podien cultivar cereals com l'ordi i el blat, mentres que a Tepecik-Çiftlik prevalien les espècies de plantes silvestres i cultius resistents a la sequera com els llegums.

La diversificació de l'agricultura al Llevant i la disponibilitat de fruites com figues i olives reflecteixen una infraestructura d'irrigació més eficaç i una major abundància de recursos. Tot i que la base de la ramaderia a Tepecik-Çiftlik incloïa ovelles i cabres adaptades a les condicions semi-àrides, la diversitat de fauna domesticada al Llevant, incloent porcs i bestiar, va proporcionar una dieta més rica en grasses. Això va portar a un ajustament dels mètodes agrícoles i culinaris a Tepecik-Çiftlik, adequant-se a les limitacions de recursos locals i preferències culturals, demostrant com les comunitats s’adapten a les seves condicions ambientals.

3.5.9.2. MATERIAL I MÈTODES

Es van utilitzar mostres de dues col·leccions en aquest estudi. En primer lloc, les col·leccions dentals de la Universitat de Barcelona, específicament les que pertanyen a la Unitat d'Antropologia, curades per la Dra. Laura M. Martínez i el Dr. Alejandro Pérez-Pérez, inclouen mostres de sis llocs al sud-oest d'Àsia, a saber, Abu Hureyra, Dja'de El Mughara, El Wad, Kebara, Shukba, Tell Aswad, Tell Halula, Tell Ramad, Nemrik9 i Ali Kosh (Estebaranz et al., 2009, 2012; Martínez et al., 2016). També es va utilitzar un segon nou conjunt de mostres del lloc arqueològic de Tepecik-Çiftlik (a l'actual Turquia) curat pel Dr. Ali Metin Büyükkarakaya al Laboratori d'Ecologia Comportamental Humana i Arqueometria de la Universitat Hacettepe (Idea Lab) (Büyükkarakaya, 2008, 2019).

La mostra estudiada incloïa 92 dents molars. L'examen es va realitzar sense tenir en compte el tipus de mandíbula (maxil·la o mandíbula) ni el costat (esquerra o dreta). Els quadrants molars que presentaven signes de malalties, incloent lesions i danys a les corones dentals, van ser exclosos de l'estudi. No es van incloure aquells molars que no tenien exposició de dentina o que no presentaven zones d'exposició, així com els molars perduts com a resultat d'una conseqüència *antemortem* o *postmortem*, d'acord amb els criteris de selecció establerts per Yang et al. (2024) i Carrascal et al. (2024).

Seguint els procediments establerts en els Capítols 3.1 i 3.2, les dents havien estat negativitzades utilitzant materials de cos regular ColténeTM Affinis (Galbany et al., 2006). Es va utilitzar Feropur PR55, un poliuretà, per crear reproduccions d'alta resolució de les coronetes dentals de cada quadrant molar (FerocaTM, Espanya). Un escàner 3D EinScan SP (ShinningTM) es va fer servir per digitalitzar les còpies dentals des de perspectives oclusals, bucals i linguals.

Les mesures es van realitzar utilitzant l'eina de mesura del programari *Shinning*. L'exposició de dentina es va calcular seguint el procediment de Yang et al. (2024) i Carrascal (2024), calculant les àrees d'exposició de dentina (D, en mm^2) directament dels models 3D. El programa va calcular automàticament l'àrea total exposada de dentina després de seleccionar manualment les àrees.

3.5.9.3. RESULTATS

La Taula 8 presenta les estadístiques fonamentals (mida de mostra, mitjana i desviació estàndard) de l'àrea d'exposició en 3D (D, en mm^2) per a cada ubicació. A més, la distribució d'edats incerta dins de cada mostra impacta significativament en els valors mitjans de D per ubicació, ja que els valors mitjans no són útils quan D augmenta en distribucions d'edats més antigues. Això fa referència als valors mitjans de D de set grups diferents (taula 9).

No es va observar una distribució normal en cap d'aquests grups (Natufians, PPNB i PN) (test K-S, $P < 0.001$), a pesar que diversos d'aquests grups tenien mides de mostra grans. Això és habitual quan la variable depèn de l'edat, la mida de la mostra és petita o la distribució d'edats és molt diversa.

Les mides de mostra variaven des de 29 natufians a 31 PPNB per al M1, 13 PPNB a 27 natufians per al M2 i 3 PPNB a 10 natufians per al M3. Com era d'esperar, donat que els molars d'erupció tardana són menys comuns, la mida de la mostra disminuïa de M1 a M3. A més, a conseqüència de limitacions metodològiques en la selecció de molars, no tots els quadrants molars mostraven exposició de dentina en M2 i M3, cosa que restringia encara més la mida de la mostra. En tots els grups i dents examinades, llevat del grup PPNB M2, la mitjana de l'àrea d'exposició de dentina 3D del M1 era superior a la del M2, i aquesta a la del M3 (taula 9), esperat per un retard d'erupció de 6 anys entre els diferents molars.

Els models de regressió lineal es van derivar per les variables transformades de ln D i ln S, tal com es descriu en Carrascal et al. (2025). Aquests models es van classificar per tipus de molar. La mostra de Tepecik-Çiftlik es va comparar amb les mostres del Llevant, i la mostra PPNB del Llevant es va dividir en grups del Desert i Euphrates per provar la hipòtesi de les restriccions climàtiques que afecten les taxes d'exposició de dentina.

Les taxes d'exposició de dentina observades per a la mostra anatòlica coincideixen amb les observades en les mostres Natufians i neolítiques d'Orient Mitjà. La mostra de Tepecik-Çiftlik, situada en un entorn semi-àrid interior, va mostrar nivells de desgast dental inesperadament baixos, malgrat ser una població del Neolític de ceràmica amb accés limitat a fonts d'aigua o cultius que requereixen molta aigua, característics del clima mediterrani més humit del Llevant.

En relació amb les subconjunts de la mostra PPNB (Èufrates i Desert), la taxa de desgast juvenil sembla indicar que la mostra del Desert pot mostrar taxes de desgast més altes que la mostra de l'Èufrates. No obstant això, això no es pot verificar per al període d'edat subadult i les dades actualment disponibles no són completament fiables.

3.5.9.4. CONCLUSIÓ I DISCUSSIÓ

Aquest estudi proporciona una comprensió sobre les pràctiques alimentàries i les adaptacions ambientals de les primeres societats agrícoles mitjançant l'examen de les taxes d'exposició de dentina a través de diversos llocs neolítics al sud-oest d'Àsia. Proposa una nova tècnica metodològica que promet ampliar la nostra comprensió de les pràctiques d'alimentació prehistòriques i dels factors que les influencien, utilitzant un proxy d'exposició de dentina en 3D proposat per Yang et al. (2024).

La disparitat en els patrons de desgast de dentina entre Tepecik-Çiftlik i el Llevant subratlla la influència dels factors ambientals locals en les adaptacions dietètiques. El menor desgast observat en la població anatòlica indica una dieta menys abrasiva, possiblement a causa de la menor dependència del blat i altres components vegetals durs. Un estudi isotòpic mostra que les poblacions de Tepecik-Çiftlik consumien principalment plantes C3, suggerint que no hi ha hagut un canvi complet en la dieta, sinó una especialització en el tractament i processament dels productes per al consum humà. Aquesta hipòtesi està recolzada pels descobriments de Mahoney (2006), que demostren que les variacions en la microdesgast evidencien la influència de la indústria lítica en el processament d'aliments.

En contrast, s'ha observat que el desgast de dentina és més prevalent en els llocs del Llevant relacionats amb els sistemes d'irrigació de l'Eufrates, la qual cosa suggereix que les dietes d'aquestes àrees estan caracteritzades per un major consum de cereals d'aigua, com el blat i l'ordi. Aquesta observació indica la presència de pràctiques agrícoles diversificades facilitades per sòls rics en nutrients, la qual cosa influïa en les decisions pràctiques dels humans en resposta al seu entorn local.

L'estudi ressalta la importància de la mida de la mostra en la investigació del desgast dental, subratllant els reptes pels quals s'enfronten les mostres petites, especialment en els molars d'erupció tardana (M3), que limiten la fiabilitat dels resultats. Es recomana l'ús de conjunts de dades més grans i tècniques avançades com l'anàlisi de microdesgast dental d'alta resolució per evitar les limitacions actuals.

La transició de la recol·lecció a l'agricultura durant l'era neolítica representa un canvi socioeconòmic important que contextualitza aquestes tendències dietètiques. Aquesta transició cap a patrons de subsistència més estables, especialment al Creixent Fèrtil, va facilitar el desenvolupament de assentaments permanents i una major complexitat social.

Les adaptacions nutricionals de Tepecik-Çiftlik demostren la importància de comprendre les adaptacions locals dins del context més ampli dels canvis neolítics. Els resultats proveeixen nova informació sobre com les primeres cultures agrícoles van afrontar les tensions ambientals i la manca de recursos, que alhora van afectar els avenços socioeconòmics com ara la formació de xarxes comercials i millores tècniques.

Aquest estudi destaca la capacitat de les societats humanes primerenques per adaptar-se a diverses condicions ambientals. Els resultats mostren com les influències ambientals modelaven les tàctiques de subsistència, suggerint que els patrons alimentaris de les civilitzacions neolítiques eren una xarxa complexa d'innovació i continuïtat.

En conclusió, l'estudi de l'exposició de dentina proporciona proves substancials en la diversitat de les pràctiques dietètiques neolítiques al sud-oest d'Àsia en resposta als factors ambientals. Així mateix, estableix una base per a futures investigacions sobre l'adaptabilitat humana i la resiliència en èpoques prehistòriques, aprofundint en la nostra comprensió de com les comunitats agrícoles primerenques van modificar les seves tàctiques de subsistència. Una coneixença més completa sobre el desenvolupament humà durant l'època neolítica podria resultar d'un estudi addicional que integri dades genètiques, isotòpiques i paleobotàniques per comprendre millor aquestes tàctiques adaptatives complexes.

9.6. DISCUSSIÓ GENERAL

Aquesta tesi presenta una investigació exhaustiva sobre les variacions en la morfologia dental i el desgast en el del Sud-oest asiàtic durant la transició de les societats caçadores-recol·lectores a les primeres comunitats agrícoles. La tesi comença contextualitzant les transicions climàtiques i els canvis ecològics significatius que es van produir del Pleistocè al Holocè. L'interstadial Bølling-Allerød (aproximadament 14,700 a 12,700 anys BP) és especialment destacat, reconegut per la seva aparició abrupta després de l'Heinrich stadial 1 (HS1) del Pleistocè tardà al Llevant meridional (Alley et al., 2003; Bar-Yosef, 2011; Maher et al., 2011; Thiagarajan et al., 2014; Ibáñez et al., 2017; Naughton et al., 2023). Aquest període va presentar canvis ambientals significatius, incloent una transició ecològica d'àrees obertes a zones boscoses i l'augment del nivell del mar, atribuïts a l'increment de les temperatures globals (Naughton et al., 2023).

Aquests canvis climàtics van facilitar l'emergència de societats en l'anomenat període *Early Natufian*, caracteritzat per estructures socials més sofisticades i estils de vida semi-sedentaris (Bar-Yosef & Belfer-Cohen, 1989; Belfer-Cohen & Bar-Yosef, 2000; Goring-Morris & Belfer-Cohen, 2011). Com a resultat, les poblacions del *Late Natufian* van passar d'una vida de caça i recol·lecció a pràctiques agrícoles enmig d'aquestes transformacions ecològiques (Bar-Yosef & Belfer-Cohen, 1992; Miller, 1996; Hillman, 1996; Belfer-Cohen & Bar-Yosef, 2000; Isaar & Zohar, 2009).

La investigació explora també el període Pre-Pottery Neolithic A (PPNA) (aproximadament 11,600–10,500 cal BP), que marca un creixement demogràfic regional associat a l'augment de les precipitacions després del Younger Dryas (YD) (Goring-Morris & Belfer-Cohen, 1998; Issar, 1998; Maher et al., 2011; Issar et al., 2012). Conjuntament, mentre la pràctica de la caça i la recol·lecció persistia, també va emergir el cultiu de cereals i llegums en diverses ubicacions del Sud-oest asiàtic (Kuijt, 1994; Weninger et al., 2009; Zeder, 2011).

A l'arribar el període Pre-Pottery Neolithic B (PPNB) (aproximadament 10,500–8,750 cal BP), les condicions favorables per al desenvolupament agrícola es van mantenir estables, impactant en els hàbits dietètics a través de diferents regions (Kuijt, 1994; Weninger et al., 2009; Zeder, 2011). Aquest context històric condueix a un seguit de qüestions: Era el concepte de l'agricultura una idea preconcebuda entre aquestes societats, que es van expandir des d'una àrea primària, o va emergir a través de la migració de noves poblacions? Alternativament, podien les societats locals de caçadors-recol·lectors haver canviat les seves maneres de vida sense influències externes? Els canvis en la dieta podien portar a adaptacions morfològiques en aquestes poblacions?

Per abordar aquestes preguntes, la tesi emfatitza l'anàlisi de la dentició, ja que entendre com la nutrició i el clima influeixen en la morfologia dental és fonamental per comprendre com aquests trets han evolucionat sota la selecció natural (Estebaranz et al., 2004). L'estudi discuteix la importància de la mida dental, particularment en el context de l'adaptació antropològica i l'evolució, i s'observa que hi ha un descens ben documentat en la mida dels dents al llarg de la història evolutiva (Smith, 1986; Brace et al., 1987; Kaifu, 1997; Erdal, 1999; Le Luyer & Bayle, 2017; Pinhasi et al., 200 8; Alrousan, 2009; May et al., 2018; Menéndez & Buck, 2022). Els canvis morfològics en les estructures craniofacials es connecten també amb el canvi econòmic de la caça i la recol·lecció en l'agricultura (Eshed et al., 2006).

Els resultats apunten a una pronunciada reducció dental en les societats de transició del Sud-oest asiàtic, marcada especialment durant la transició de les poblacions caçadores-recol·lectores a les primeres poblacions agrícoles. Aquest patró no és exclusiu de les poblacions del Llevant, sinó que s'observa en tota la regió estudiada en aquesta tesi. Els anàlisis estadístics indiquen que aquesta pèrdua dental és notablement significativa en les dimensions buccolinguals. Comprendre si aquesta tendència dental representa algun avantatge o adaptació és complex, ja que els canvis en l'aparell masticatori semblen haver-se produït en un període relativament breu en comparació amb la vasta línia de temps dedicada a l'evolució humana (Hillson, 2005).

S'han avaluat múltiples hipòtesis evolutives per explicar les tendències morfològiques observades, incloent l'efecte de mutació probable, on les mutacions espontànies, que ocorren en absència de pressions selectives, donen lloc a una reducció en la complexitat dental (Brace, 1963; Brace & Mahler, 1971; Pinhasi et al., 2008). La introducció de la ceràmica i els canvis culturals associats podrien haver relaxat les pressions selectives sobre el sistema masticatori (Brace, 1963; 1971). La teoria de l'efecte de densitat poblacional postula que un estil de vida sedentari podria haver ocasionat un deteriorament substancial en la salut i la nutrició, resultant en una disminució de la mida del cos i, per extensió, de la mida dental (Macchiarelli & Bondioli, 1986).

La investigació dels trets dentals no mètrics també és clau, a través de l'estudi d'aquests trets es pot arribar a determinar afinitats biològiques i connexions genètiques entre grups. Mitjançant l'anàlisi de 23 trets dentals no mètrics en la dentició permanent, es va establir una correlació entre la variació de trets en el temps i les característiques morfològiques específiques d'aquestes poblacions. Els resultats de l'anàlisi ASUDAS (Arizona State University Dental Anthropology System) indiquen que les poblacions antigues mostren variacions significatives en alguns aspectes de la morfologia dental, que reflecteixen les diferents influències històriques i geogràfiques que han modelat les diversitats dentals en aquestes comunitats (Turner et al., 1991).

A més, l'estudi de l'anàlisi de la topografia dental permet determinar la correlació entre la forma dental i la dieta, destacant una relació entre la complexitat dental i els hàbits alimentaris. La topografia dental es va examinar amb mètodes d'anàlisi de sistemes d'informació geogràfica (GIS), la qual cosa implica que les variacions en les mides i estructures dentals poden reflectir afinitats genètiques, adaptacions dietètiques i respostes evolutives a les condicions ambientals (Zuccotti et al., 1998; Ungar i Williamson, 2000; Godfrey et al., 2012; Berthaume et al., 2016a).

Els resultats revelen que l'anàlisi discriminant utilitzat per investigar la morfologia dental va mostrar variacions significatives en la topografia dental a través de diferents períodes i ubicacions geogràfiques. La taxa d'error de classificació entre les poblacions del PPNB i del Natufià suggereix que hi havia alteracions morfològiques dentals menors durant aquest període de transició, presentant la necessitat d'entendre sobre les variacions regionals i les seves implicacions en les adaptacions dentals (Godfrey et al., 2012).

Per concloure, l'estudi de l'exposició de la dentina proporciona proves contundents sobre la varietat dels hàbits dietètics de les primeres societats neolítiques en el Sud-oest asiàtic a causa d'influències ambientals. Els resultats obtinguts d'aquesta investigació avancen en la nostra comprensió de com les cultures agrícoles primerenques van modificar les seves estratègies de subsistència i estableixen les bases per a futures investigacions sobre l'adaptació i la resiliència humana en temps prehistòrics.

Particularment, l'estudi subratlla la importància del deteriorament dental, un aspecte clau tractat en aquesta tesi, amb un enfocament en l'erosió macroscòpica. El macro-desgast es refereix a l'erosió fisiològica macroscòpica evident de les dents, que generalment comença amb la pèrdua de l'esmalt oclusal i continua amb la deposició de dentina secundària. Aquesta deposició protegeix la càmera pulpar en els casos més severs (Larsen, 2002). En casos extrems, l'esmalt pot desaparèixer completament. (Larsen, 2002; Fiorenza et al., 2018).

La recerca sobre l'erosió dental s'ha aplicat en diversos àmbits, incloent la determinació de l'edat individual (Holly-Smith, 1984; Mays et al., 1995; Yang et al., 2024) i l'anàlisi de l'ús de la boca com a eina (Lukacs i Pastor, 1988; Bermúdez de Castro et al., 2003; Molnar, 2008; Clement i Hillson, 2012), així com per determinar l'estatus i la salut general (Elzay et al., 1977; Dawson i Brown, 2013). Aquesta investigació proporciona una nova perspectiva sobre els hàbits alimentaris i les adaptacions ambientals de les cultures agrícoles primerenques a través de l'anàlisi de les taxes d'exposició de la dentina en múltiples llocs neolítics al Sud-oest asiàtic.

Els resultats demostren diferències en els patrons de desgast de dentina entre el Llevant i el Neolític ceràmic de Tepecik-Çiftlik, destacant la influència de les condicions ambientals regionals sobre les adaptacions dietètiques. En particular, la disminució del desgast de la dentina en la població anatòlica apunta a una composició dietètica potencialment menys abrasiva, possiblement resultant d'una menor dependència del blat i altres components vegetals durs. És raonable suposar que s'ha produït un canvi cap a una dieta menys abrasiva en comparació amb les poblacions del Neolític aceramic.

Un estudi isotòpic indicaria que les poblacions de Tepecik-Çiftlik consumien una gran quantitat de plantes C3, i els animals que consumeixen són consumidors també de plantes C3. Semblants a la principal font vegetal en les dietes de les poblacions anatòliques al llarg del Holocè. (Richards et al., 2003; Rao et al., 2012; Pickard et al., 2016; Özdemir et al., 2025). Per tant, es pot especular que la dieta no ha canviat radicalment. La idea que hi ha hagut una especialització en la manipulació i processament dels aliments per a l'ús humà seria el més plausible. Els resultats de Mahoney (2006), mostren que les variàncies observades en els canvis de l'erosió microscòpica, indiquen que la tecnologia lítica està fortament involucrada en la preparació d'aliments. Fet que reforça aquesta teoria.

No obstant això, s'ha demostrat que el desgast en la dentina és més comú en les zones del Llevant i les relacionades amb els sistemes d'irrigació del riu Èufrates. Aquest resultat implica que una major ingesta de grans que requereixen molta aigua, com el blat i l'ordi, així com una major varietat de fruits i verdures, són característiques de les dietes d'aquestes regions. Aquesta troballa suggereix que els sòls rics en nutrients afavoreixen l'existència de diverses tècniques agrícoles i una dieta més variada, que es caracteritza per una major ingestió d'aliments abrasius (Mahoney, 2006). Aquesta variància ressalta les eleccions pragmàtiques que fan els humans en resposta al seu entorn local, destacant l'impacte potencial de les condicions geogràfiques i climàtiques sobre les modificacions dietètiques.

El nou enfocament metodològic proporciona una base sòlida per a l'anàlisi del desgast dental a través dels molars mitjançant l'ús de models de regressió lineal amb transformacions logarítmiques naturals. No obstant això, la baixa mostra dels tercers molars limiten la fiabilitat d'aquests resultats, especialment quan es classifiquen per ambients geogràfics o ambientals (Carrascal et al., 2025).

Per concloure, l'estudi de l'exposició de la dentina aporta proves contundents sobre la diversitat dels hàbits alimentaris neolítics al Sud-oest asiàtic a causa d'influències ambientals i adaptatives. Aquesta investigació no només amplia la nostra comprensió de les estratègies de subsistència de les cultures agrícoles primerenques, sinó que també assenyala la necessitat de futures investigacions que integrin dades genètiques, isòtopiques i paleo-botàniques per obtenir una imatge més completa de l'evolució humana durant l'era neolítica.

A més, la recerca posa de manifest com les adaptacions culturals i dietètiques, juntament amb les condicions ambientals, han influït en l'evolució de les característiques dentals a través del temps. Això revela una complexa interacció entre els factors biològics, ambientals i culturals en l'evolució humana, el que ens permet comprendre millor l'adaptació a les diverses condicions de vida al llarg de la prehistòria.

Finalment, aquest treball contribueix a una millor comprensió de com les experiències locals i regionals van modelar la trajectòria de les societats humanes en un moment de canvi, posant de relleu la importància de l'estudi interdisciplinari en la interpretació de les dades arqueològiques i biològiques.

9.7. CONCLUSIONS

Les conclusions del present estudi són:

1. Els nostres resultats mostren un patró coherent d'evolució dental que probablement s'associa amb canvis dietètics i socioecològics, donant suport a una reducció significativa de la mida de les dents, particularment en les dimensions bucolingües, entre els diversos grups de població de la regió. Aquest estudi proporciona una visió significativa del canvi morfològic dental quan les societats caçadores-recol·lectores van passar a les cultures agrícoles al sud-oest d'Àsia

2. Les diferències més significatives en la reducció de la mida de les dents s'observen en la dentadura inferior en comparació amb les premolars i molars superiors. A més, mentre que la reducció de la dentadura superior es produeix principalment des del natufià fins al període PPNB/Neolític, en la dentadura inferior, els canvis en el diàmetre bucolingüístic són evidents entre el natufià i el període PPNA. Això suggereix una disminució anterior de les dimensions de les dents en la dentadura inferior.

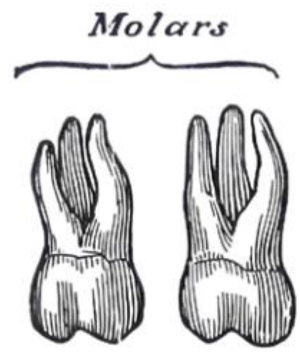
3. L'estudi dels trets dentals no mètrics (ASUDAS). Tot i que la mida final de la mostra era petita, els resultats obtinguts suggereixen que algunes poblacions com els natufians i el Neolític Ceràmic d'Anatòlia van mostrar un percentatge més alt d'alguns trets en comparació amb la resta del mateix període i àrea, suggerint alguns casos de deriva genètica. No obstant això, els resultats presentats aquí també van mostrar que només hi havia poques diferències entre poblacions del mateix període, i aquests resultats suggereixen una continuïtat genètica en algunes d'aquestes poblacions.

4. En relació amb la topografia dental. No hi ha diferències significatives pel que fa a la complexitat de la corona (OPCR) i la curvatura (DNE) entre llocs i períodes. En contrast amb el que altres autors suggereixen (Calcagno & Gibson, 1991; Y'Edynak & Fleisch, 1983; Calcagno & Gibson, 1991; Y'Edynak & Fleisch, 1983; Pinhasi et al., 2008) la complexitat de la corona no va mostrar una reducció del natufià al neolític a ceràmic en la nostra mostra.

No obstant això, hi ha canvis significatius en el relleu oclusal i el PCV, el que suggereix un augment del relleu oclusal des del naufià fins al neolític ceràmic. D'altra banda, les mètriques de PCV mostren una tendència de disminució de Natufià a Neolític ceràmic. Els molars del Neolític ceràmic tenen una superfície més alta i cúspides afilades que les molars natufianes.

5. Aplicant una metodologia d'exposició a dentina tridimensional distintiva, aquest estudi proporciona informació substancial sobre el canvi dietètic de les primeres comunitats agrícoles al sud-oest d'Àsia. Els resultats mostren variacions significatives en els patrons de desgast de la dentina, indicant que els habitants de Tepecik-Çiftlik s'adaptaven a dietes abrasives que comprenien plantes C3, mentre que els dels grups llevantins mostraven un desgast més pronunciat probablement a causa d'una dieta que consistia en conreus intensius en aigua. Aquest estudi posa l'accent en l'impacte dels factors ambientals locals en les estratègies de subsistència i l'adaptabilitat d'aquestes comunitats en la gestió de les operacions agrícoles en condicions diverses. Demostra la diversitat i adaptabilitat de les comunitats neolítiques, establint així les bases per a una major investigació sobre la resiliència

i adaptabilitat humanes durant aquesta era crucial, utilitzant una combinació de dades genètiques, isotòpiques i paleobotàniques.



REFERENCES

10. REFERENCES

A

Akkermans, P. M. M. G. (2014). Late Neolithic Tell Sabi Abyad in perspective. En P. M. M. G. Akkermans, M. L. Brüning, H. O. Huigens, & O. P. Nieuwenhuyse (Eds.), *Excavations at Late Neolithic Tell Sabi Abyad, Syria: The 1994-1999 Field Seasons* (pp. 247–256). Brepols.

Akkermans, P. M. M. G., Brüning, M. I., Huigens, H. O., & Nieuwenhuyse, O. P. (2014). Tell Sabi Abyad 1994-1999 campaigns: Late Neolithic stratigraphy and architecture. En P. M. M. G. Akkermans, M. L. Brüning, H. O. Huigens, & O. P. Nieuwenhuyse (Eds.), *Excavations at Late Neolithic Tell Sabi Abyad, Syria: The 1994-1999 Field Seasons* (pp. 29–86). Brepols.

Akkermans, P. M. M. G., Fokkens, H., & Waterbolk, H. T. (1981). Stratigraphy, architecture and lay-out of Bouqras. En J. Cauvin & P. Sanlaville (Eds.), *Préhistoire du Levant: Chronologie et organisation de l'espace depuis les origines jusqu'au VIe millénaire* (pp. 485–501). CNRS Éditions.

Akkermans, P. M. M. G., & Schwartz, G. M. (2003). *The archaeology of Syria: From complex hunter-gatherers to early urban societies (ca. 16,000–300 BC)*. Cambridge University Press.

Aksu, A., & Kizildag, S. (2019). Morphometric analysis of dental traits in southeastern Anatolian populations: ASUDAS application. *Anthropological Science*, 127(1), 23-32. https://doi.org/10.1537/ase.180804.

Aiello, L. C., Montgomery, C., & Dean, C. (1991). The natural history of deciduous tooth attrition in hominoids. *Journal of Human Evolution, 21*, 397–412. https://doi.org/10.1016/0047-2484(91)90046-V

Alley, R. B. (2000). The Younger Dryas cold interval as viewed from central Greenland. *Quaternary Science Reviews, 19*, 213–226. https://doi.org/10.1016/S0277-3791(99)00063-4

Alley, R. B., Marotzke, J., Nordhaus, W. D., et al. (2003). Abrupt climate change. *Science, 299*, 2005–2010. https://doi.org/10.1126/science.1081056

Alrousan, M. F. (2009). The Mesolithic-Neolithic transition in the Near East: Biological implications of the shift in subsistence strategies through the analysis of dental morphology and dietary habits of human populations in the Mediterranean area 12,000–5,000 BP (Tesis doctoral). Universidad de Barcelona.

Andres, M. S., Bernasconi, S. M., McKenzie, J. A., & Röhl, U. (2003). Southern Ocean deglacial record supports global Younger Dryas. *Earth and Planetary Science Letters, 216*(4), 515–524. https://doi.org/10.1016/S0012-821X(03)00596-0

Anthony, M. R. L., & Kay, R. F. (1993). Tooth form and diet in ateline and alouattine primates: Reflections on the comparative method. *Journal of Vertebrate Paleontology, 11*, 356–382. https://doi.org/10.1080/02724634.1991.10011363

Araus, J. L., Ariel, G., Romagosa, I., & Molist, M. (2001). Estimated wheat yields during the emergence of agriculture based on the carbon discrimination of grains: Evidence from a 10th Millennium BP site on the Euphrates. *Journal of Archaeological Science, 28*, 341–350. https://doi.org/10.1006/jasc.2000.0574

Arnold, W. H., Naumova, E. A., Koloda, V. V., & Gaengler, P. (2007). Tooth wear in two ancient populations of the Khazar Kaganat region in the Ukraine. *International Journal of Osteoarchaeology, 17*, 52–62. https://doi.org/10.1002/oa.875

Aurenche, O. (1977). *Dictionnaire illustré multilingue de l'architecture du Proche-Orient ancien*. Publication hors série de l'Institut français d'archéologie de Beyrouth.

Aurenche, O. (1981). *La Maison Orientale: L'architecture du Proche-Orient ancien des origines au milieu du quatrième millénaire*. P. Geuthner.

Aurenche, O., Cauvin, J., Cauvin, M. C., Copeland, L., Hours, F., & Sanlaville, P. (1981). Chronologie et organisation de l'espace dans le Proche-Orient de 12000 à 5600 avant J.C. En J. Cauvin & P. Sanlaville (Eds.), *Préhistoire du Levant* (pp. 571–601). CNRS Editions.

Aurenche, O., & Desfargues, P. (1983). Travaux d'ethnoarchéologie en Syrie et en Jordanie. Rapports préliminaires. *Syria, 60*(1/2), 147–185.

Aurenche, O., & Kozlowski, S. K. (1999). *La naissance du Néolithique au Proche-Orient ou le paradis perdu*. Errance.

Aurenche, O., Galet, P., Régagnon-Caroline, E., & Évin, J. (2001). Les cultures proto-néolithiques et néolithiques au Moyen-Orient: Naissance de l'agriculture, de l'élevage et de la céramique: Une chronologie calibrée du 14C 12,500–5,500 cal BC. *Radiocarbon, 43*(3), 1191–1202. https://doi.org/10.1017/S0033822200035388

Aurenche, O., & Kozlowski, S. K. (2003). *El origen del Neolítico en el Próximo Oriente: El paraíso perdido*. Ariel.

Avià, Y., Romero, A., Estebaranz-Sánchez, F., Pérez-Pérez, A., Cuesta-Torralvo, E., & Martínez, L. M. (2022). Dental topography and dietary specialization in Papionini primates. *Frontiers in Ecology and Evolution, 10*, 969007. https://doi.org/10.3389/fevo.2022.969007

B

Baby, T. K., Sunil, S., & Babu, S. S. (2017). Nonmetric traits of permanent posterior teeth in Kerala population: A forensic overview. *Journal of Oral and Maxillofacial Pathology, 21*, 301-308.

Baeza, A. N. (2023). *Nutritional stress & early development in the Neolithic Near East: A comparison of adult and subadult tooth size* (Doctoral dissertation, University of Nevada, Reno).

Bailey, S. E. (2004). A morphometric analysis of maxillary molar crowns of Middle-Late Pleistocene hominins. *Journal of Human Evolution, 47*, 183-198.

Bailey, S. E., & Lynch, J. M. (2005). Diagnostic differences in mandibular P4 shape between Neandertals and anatomically modern humans. *American Journal of Physical Anthropology, 126*, 268-277.

Bailit, H. L. (1975). Dental variation among populations: An anthropological view. *Dental Clinics of North America, 19*(1), 125-139.

Bailit, H. L., & Friedlaender, J. S. (1966). Tooth size reduction: A hominid trend. *American Anthropologist, 68*, 665-672.

Balkan-Atlı, N., & Binder, D. (2011). Neolithic obsidian workshop at Kömürcü-Kaletepe (Central Anatolia). In M. Özdoğan, N. Başgelen, & P. Kuniholm (Eds.), *The Neolithic in Turkey* (Vol. 3): New excavations & new research, Central Turkey (pp. 71–88). Archaeology and Art Publications.

Banning, E. B. (1998). The Neolithic period: Triumphs of architecture, agriculture, and art. *Near Eastern Archaeology, 61*(4), 188-237.

Banning, E. B. (2002a). Ceramic Neolithic, Late or Pottery Neolithic. In P. Peregrine & M. Ember (Eds.), *Encyclopedia of prehistory: 8. South and Southwest Asia* (pp. 40-55). Kluwer Academic/Plenum.

Banning, E. B. (2002b). Consensus and debate on the Late Neolithic and Chalcolithic of the Southern Levant. *Paléorient, 28*(2), 143-156.

Banning, E. B. (2011). So fair a house: Göbekli Tepe and the identification of temples in the Pre-Pottery Neolithic of the Near East. *Current Anthropology, 52*(5), 619-660.

Barker, G. (2006). *The agricultural revolution in prehistory: Why did foragers become farmers?* Oxford University Press.

Bar-Matthews, M., & Ayalon, A. (2003). Climatic conditions in the eastern Mediterranean during the Last Glacial (60–10 ky BP) and their relations to the Upper Palaeolithic in the Levant: Oxygen and carbon isotope systematics of cave deposits. In A. N. Goring-Morris & A. Belfer-Cohen (Eds.), *More than meets the eye: Studies on Upper Palaeolithic diversity in the Near East* (pp. 13–18). Oxbow Books.

Bar-Matthews, M., Ayalon, A., & Kaufman, A. (1997). Late Quaternary paleoclimate in the eastern Mediterranean region from stable isotope analysis of speleothems at Soreq Cave, Israel. *Quaternary Research, 47*(2), 155-168.

Bar-Matthews, M., Ayalon, A., Kaufman, A., & Wasserburg, G. J. (1999). The eastern Mediterranean paleoclimate as a reflection of regional events: Soreq Cave, Israel. *Earth and Planetary Science Letters, 166*(1-2), 85-95.

Bar-Yosef, O. (1981). The "Pre-Pottery Neolithic" period in the southern Levant. In J. Cauvin & P. Sanlaville (Eds.), *Préhistoire du Levant* (pp. 551-570). CNRS Éditions.

Bar-Yosef, O. (1983). The Natufian in the southern Levant. In P. E. L. Young & P. Mortensen (Eds.), *The Hilly Flanks and Beyond: Studies in Ancient Oriental Civilization* (pp. 11-42). University of Chicago Press.

Bar-Yosef, O. (1986). The walls of Jericho: An alternative interpretation. *Current Anthropology, 27*(2), 157-162.

Bar-Yosef, O. (1998). The Natufian culture in the Levant, threshold to the origins of agriculture. *Evolutionary Anthropology: Issues, News, and Reviews, 6*(5), 159-177.

Bar-Yosef, O. (2001). From sedentary foragers to village hierarchies: The emergence of social institutions. In W. G. Runciman (Ed.), *The origin of human social institutions*. *Proceedings of the British Academy, 110*, 1-38. Oxford University Press.

Bar-Yosef, O. (2002). The Upper Paleolithic revolution. *Annual Review of Anthropology, 31*, 363-393.

Bar-Yosef, O. (2014). The origins of sedentism and agriculture in Western Asia. In C. Renfrew & P. Bahn (Eds.), *The Cambridge world prehistory* (pp. 1408-1438). Cambridge University Press.

Bar-Yosef, O., & Belfer-Cohen, A. (1989). The origins of sedentism and farming communities in the Levant. *Journal of World Prehistory, 3*(4), 447-498.

Bar-Yosef, O., & Belfer-Cohen, A. (1992). From foraging to farming in the Mediterranean Levant. In A. B. Gebauer & T. D. Price (Eds.), *Transitions to agriculture in prehistory* (pp. 21-48). Prehistory Press.

Bar-Yosef, O., & Meadow, R. H. (1995). The origins of agriculture in the Near East. In T. D. Price & A. B. Gebauer (Eds.), *Last hunters, first farmers: New perspectives on the prehistoric transition to agriculture* (pp. 39-94). School of American Research Press.

Bar-Yosef, O., & Valla, F. (1979). L'évolution du Natoufien. Nouvelles suggestions. *Paléorient, 5*, 145-152.

Bar-Yosef, O., & Valla, F. (1991). *The Natufian culture in the Levant.* International Monographs in Prehistory.

Bartov, Y., Stein, M., Enzel, Y., Agnon, A., & Reches, Z. (2002). Lake levels and sequence stratigraphy of Lake Lisan, the Late Pleistocene precursor of the Dead Sea. *Quaternary Research, 57*, 9–21.

Bartov, Y., Goldstein, S. L., Stein, M., & Enzel, Y. (2003). Catastrophic arid episodes in the eastern Mediterranean linked with the North Atlantic Heinrich events. *Geology, 31*(5), 439-442.

Bartov, Y., Enzel, Y., Porat, N., & Stein, M. (2007). Evolution of the Late Pleistocene–Holocene Dead Sea basin from sequence stratigraphy of fan deltas and lake-level reconstruction. *Journal of Sedimentary Research, 77*(9), 680-692.

Belfer-Cohen, A. (1988). The Natufian graveyard in Hayonim cave. *Paléorient, 4*(2), 297-308.

Belfer-Cohen, A. (1991). The Natufian in the Levant. *Annual Review of Anthropology, 20*, 167-186.

Belfer-Cohen, A. (1995). Rethinking social stratification in the Natufian culture: The evidence from burials. In S. Campbell & A. Green (Eds.), *The Archaeology of Death in the Ancient Near East* (pp. 9-16). Oxbow Books.

Belfer-Cohen, A., & Arensburg, B. (1997). The human remains from Netiv Hagdud. In O. Bar-Yosef & A. Gopher (Eds.), *An early Neolithic village in the Jordan Valley. Part 1: The archaeology of Netiv Hagdud* (pp. 201-208). Cambridge: American School of Prehistoric Research.

Belfer-Cohen, A., & Bar-Yosef, O. (2002). Early sedentism in the Near East: A bumpy ride to village life. In I. Kuijt (Ed.), *Life in Neolithic farming communities: Social organization, identity, and differentiation* (pp. 19-38). Boston: Springer.

Belfer-Cohen, A., & Hovers, E. (1992). In the eye of the beholder: Mousterian and Natufian burials in the Levant. *Current Anthropology, 33*(4), 463-471.

Belfer-Cohen, A., & Bar-Yosef, O. (2000). Early sedentism in the Near East: A bumpy road to village life. In I. Kuijt (Ed.), *Life in Neolithic farming communities: Social organization, identity and differentiation* (pp. 19-37). New York: Plenum Publishers.

Benazzi, S., Fornai, C., Buti, L., Toussaint, M., Mallegni, F., Ricci, S., Gruppioni, G., Weber, G. W., Condemi, S., & Ronchitelli, A. (2012). Cervical and crown outline analysis of worn Neanderthal and modern human lower second deciduous molars. *American Journal of Physical Anthropology, 149*, 537–546.

Berger, J. F., & Guilaine, J. (2009). The 8200 cal BP abrupt environmental change and the Neolithic transition: A Mediterranean perspective. *Quaternary International, 200*, 31-49.

Berger, J. F., Guilaine, J., & Ozdogan, M. (2016). Interactions between climate change and human activities during the early to mid-Holocene in the eastern Mediterranean basins. *Climate of the Past, 12*, 1847–1877.

Bermúdez de Castro, J. M., Bromage, T. G., & Jalvo, Y. F. (1988). Buccal striations on fossil human anterior teeth: Evidence of handedness in the Middle and early Upper Pleistocene. *Journal of Human Evolution, 17*, 403–412.

Bermúdez de Castro, J. M., Martínez, I., Gracia-Téllez, A., Martinón-Torres, M., & Arsuaga, J. L. (2020). The Sima de los Huesos Middle Pleistocene hominin site (Burgos, Spain). Estimation of the number of individuals. *The Anatomical Record*.

Bermúdez de Castro, J. M. (2002). *El chico de la Gran Dolina: En los orígenes de lo humano* (4th ed.). Barcelona: Crítica.

Bermúdez de Castro, J. M., Martinón-Torres, M., Sarmiento, S., Lozano, M., Arsuaga, J. L., & Carbonell, E. (2003). Rates of anterior tooth wear in Middle Pleistocene hominins from Sima de los Huesos (Sierra de Atapuerca, Spain). *Proceedings of the National Academy of Sciences, 100*, 11992–11996.

Berthaume, M. A. (2014). Tooth cusp sharpness as a dietary correlate in great apes. *American Journal of Physical Anthropology*, 153(2), 226-235.

Berthaume, M. A. (2016). On the relationship between tooth shape and masticatory efficiency: A finite element study. *The Anatomical Record, 299*(5), 679–687. https://doi.org/10.1002/ar.23328.

Berthaume, M. A., Winchester, J. M., & Kupczik, K. (2019a). Ambient occlusion and PCV (portion de ciel visible): A new dental topographic metric and proxy of morphological wear resistance. *PLoS ONE, 14*(5), e0215436.

Berthaume, M. A., Winchester, J., & Kupczik, K. (2019b). Effects of cropping, smoothing, triangle count, and mesh resolution on six dental topographic metrics. *PLoS ONE, 14*(5), e0216229.

Berthaume, M. A., Delezene, L. K., & Kupczik, K. (2018). Dental topography and the diet of Homo naledi. *Journal of Human Evolution, 118*, 14-26.

Berthaume, M., & Schroer, K. (2017). Extant ape dental topography and its implications for reconstructing the emergence of early Homo. *Journal of Human Evolution, 112*, 15-29.

Berthaume, M. A., Lazzari, V., & Guy, F. (2020). The landscape of tooth shape: Over 20 years of dental topography in primates. *Evolutionary Anthropology, 29*(5), 1-18.

Bıçakçı, E. (2001). Tepecik-Çiftlik Höyüğü (Niğde) ışığında Orta Anadolu Tarihöncesi kültürleri ile ilgili yeni bir değerlendirme. *Tüba-Ar, 4*, 25–41.

Bıçakçı, E. (2012). Tepecik-Çiftlik Kazısı 2010 Yılı Çalışmaları. *33. Kazı Sonuçları Toplantısı (1. Cilt)*, ss. 69–89.

Bıçakçı, E., Godon, M., & Çakan, Y. G. (2012). Tepecik-Çiftlik. In P. Özdoğan, M. Başgelen, & N. Kuniholm (Eds.), *The Neolithic in Turkey* (pp. 89–134). Istanbul: Archeology and Art Publications.

Bıçakçı, E., Altınbilek Algül, Ç., Balcı, S., & Godon, M. (2007). Tepecik-Çiftlik. In M. Özdoğan & N. Başgelen (Eds.), *Türkiye'de Neolitik Dönem* (pp. 237–253). Arkeoloji ve Sanat Yayınları.

Bıçakçı, E., Godon, M., & Çakan, Y. G. (2011). Tepecik-Çiftlik. In M. Özdoğan, N. Başgelen, & P. Kuniholm (Eds.), *The Neolithic in Turkey 3* (pp. 89–134). Archaeology and Art Publications.

Bıçakçı, E., Godon, M., Büyükkarakaya, A. M., Erturaç, K., Kuzucuoğlu, C., Çakan, Y. G., & Vinet, A. (2017). Les fouilles de Tepecik-Çiftlik et les activités du programme Melendiz préhistorique, campagne 2016. *Anatolia Antiqua, 25*, 71–94.

Binder, D. (2002). Stone making sense: What obsidian could tell about the origins of the Central Anatolian Neolithic. In F. Gerard & L. Thissen (Eds.), *The Neolithic of Central Anatolia, Internal Developments and External Relations During the 9th-6th Millennia cal BC* (pp. 79–90). Ege Yayınları.

Binford, L. (1971). Mortuary practices: Their study and their potential. In *Approaches to the Social Dimensions of Mortuary Practices* (pp. 6–29). Society for American Archaeology.

Bock, W. J., & von Wahlert, G. (1965). Adaptation and the form-function complex. *Evolution, 19*, 269-299.

Bogin, B. (1997). Evolutionary hypotheses for human childhood. *Yearbook of Physical Anthropology, 40*, 63-89.

Bogin, B. (1999a). *Patterns of Human Growth* (2nd ed.). Cambridge University Press.

Bogin, B. (1999b). Evolutionary perspective on human growth. *Annual Review of Anthropology, 28*, 109-153.

Bogin, B. (2001). *The Growth of Humanity* (1st ed.). Wiley-Liss.

Bogin, B. (2003). The human pattern of growth and development in paleontological perspective. *Cambridge Studies in Biological and Evolutionary Anthropology*, 15-44.

Bogin, B. (2009). Childhood, adolescence, and longevity: A multilevel model of the evolution of reserve capacity in human life history. *American Journal of Human Biology, 21*, 567-577.

Bogin, B., & Smith, B. H. (1996). Evolution of the human life cycle. *American Journal of Human Biology, 8*, 703-716.

Bond, G., Heinrich, H., Broecker, W., & others. (1992). Evidence for massive discharges of icebergs into the North-Atlantic Ocean during the last glacial period. *Nature, 360*, 245–249.

Bond, G. C., & Lotti, R. (1995). Iceberg discharges into the North-Atlantic on millennial time scales during the last glaciation. *Science, 267*, 1005–1010.

Bouchud, J. (1987). *La faune du gisement Natoufien de Mallaha (Eynan) Israël*. Association Paléorient - Mémoires et travaux du centre de recherche français de Jérusalem.

Brook, A. H. (1984). A unifying aetiological explanation for anomalies of human tooth number and size. *Archives of Oral Biology, 29*, 373-378.

Brook, A. H. (2009). Multilevel complex interactions between genetic, epigenetic, and environmental factors in the aetiology of anomalies of dental development. *Archives of Oral Biology, 54(s)*, s3-s17.

Bookman, R., Bartov, Y., Enzel, Y., & Stein, M. (2006). Quaternary lake levels in the Dead Sea basin: Two centuries of research. In Y. Enzel, A. Agnon, & M. Stein (Eds.), *New Frontiers in Dead Sea Palaeoenvironmental Research* (Special Papers 401, pp. 155–170). Boulder, CO: Geological Society of America.

Bocquentin, F. (2003). *Pratiques funéraires, paramètres biologiques et identités culturelles au Natoufien: Une analyse archéo-anthropologique* [Tesis doctoral, Université de Bordeaux].

Boughner, J. C., & Dean, M. C. (2008). Mandibular shape, ontogeny, and dental development in bonobos (*Pan paniscus*) and chimpanzees (*Pan troglodytes*). *Evolutionary Biology, 35*, 296–308.

Boyer, D. M. (2008). Relief index of second mandibular molars is a correlate of diet among prosimian primates and other euarchontan mammals. *Journal of Human Evolution, 55*, 1118–1137.

Boyer, D. M., Costeur, L., & Lipman, Y. (2012). Earliest record of *Platychoerops* (Primates, Plesiadapidae), a new species from Mouras Quarry, Mont de Berru, France. *American Journal of Physical Anthropology, 149*, 329–346.

Boyer, D. M., Evans, A. R., & Jernvall, J. (2010). Evidence of dietary differentiation among late Paleocene-early Eocene plesiadapids (Mammalia, Primates). *American Journal of Physical Anthropology, 142*, 194–210.

Boyer, D. M., Puente, J., Gladman, J. T., Glynn, C., Mukherjee, S., Yapuncich, G. S., & Daubechies, I. (2015). A new fully automated approach for aligning and comparing shapes. *The Anatomical Record, 298*, 249–276.

Boz, B., & Hager, L. D. (2013). Making sense of social behavior from disturbed and commingled skeletons: A case study from Çatalhöyük, Turkey. In *Springer* (pp. 17–33).

Brace, C. L. (1962). Cultural factors in the evolution of the human dentition. In M. F. A. Montagu (Ed.), *Culture and the Evolution of Man* (pp. 343–354). New York: Oxford University Press.

Brace, C. L. (1963). Structural reduction in evolution. *The American Naturalist, 97*(892), 39–49. https://doi.org/10.1086/282252

Brace, C. L. (1967). Environment, tooth form, and size in the Pleistocene. *Journal of Dental Research, 48*, 809–816.

Brace, C. L., & Mahler, P. E. (1971). Post-Pleistocene changes in the human dentition. *American Journal of Physical Anthropology, 34*(2), 191–203. https://doi.org/10.1002/ajpa.1330340205

Brace, C. L., & Ryan, A. S. (1980). Sexual dimorphism and human tooth size differences. *Journal of Human Evolution, 9*, 417–435.

Braidwood, R. J. (1960). The agricultural revolution. *Scientific American, 203*(3), 130–152.

Bunn, J. M., & Ungar, P. S. (2009). Dental topography and diets of four Old World monkey species. *American Journal of Primatology, 71*(6), 466–477.

Bunn, J. M., Boyer, D. M., Lipman, Y., St. Clair, E. M., Jernvall, J., & Daubechies, I. (2011). Comparing Dirichlet normal surface energy of tooth crowns, a new technique of molar shape quantification for dietary inference, with previous methods in isolation and in combination. *American Journal of Physical Anthropology, 145*(2), 247–261.

Buikstra, J. E., & Ubelaker, D. H. (1994). *Standards for Data Collection from Human Skeletal Remains*. Arkansas Archeological Survey Research Series.

Büyükkarakaya, A. M., Erdal, Y. S., & Metin, Ö. (2008). Tepecik-Çiftlik İnsanlarının Antropolojik Açıdan Değerlendirilmesi. *24. Arkeometri Sonuçları Toplantısı*.

Büyükkarakaya, A. M. (2017a). Tepecik-Çiftlik Neolitik Topluluğunun Demografik Özellikleri. *Folklor ve Edebiyat, 23*(92), 79–98. https://doi.org/10.22559/folkloredebiyat.2017.58

Büyükkarakaya, A. M. (2017). On the formation process of the BB collective burial from Tepecik-Çiftlik, Central Anatolia (Turkey). In *19th Annual Conference of the British Association for Biological Anthropology and Osteoarchaeology*, Abstract Book (p. 25). Liverpool John Moores University.

Büyükkarakaya, A. M., Erdal, Y. S., & Özbek, M. (2009). Tepecik-Çiftlik İnsanlarının Antropolojik Açıdan Değerlendirilmesi. *Arkeometri Sonuçları Toplantısı, 24*, 119–138.

Büyükkarakaya, A. M., Erdal, Y. S., & Özbek, M. (2012). Tepecik-Çiftlik Höyük'te Bulunan Neolitik Dönem Kolektif Gömünün Paleoantropolojik Analizi. *34th International Symposium of Excavations, Surveys and Archaeometry*, Çorum, 28 May – 1 June.

Büyükkarakaya, A. M., Erdal, Y. S. (2014). New data on mortuary practices from the early Pottery Neolithic site of Tepecik-Çiftlik, Central Anatolia. In *20th Annual Meeting of European Association of Archaeologists* (pp. 525). Archaeology and Art Publications.

Büyükkarakaya, A. M., Akyol, A. A., & Özdemir, K. (2017). Investigation of weaning process in the Neolithic period Tepecik-Çiftlik population. *Hitit University Journal of Social Science Institute, 10*, 169–196.

Büyükkarakaya, A. M., Çakan, Y. G., Godon, M., Erdal, T. S., & Bıçakçı, E. (2019). Handling dead bodies: Investigating the formation process of a collective burial from Neolithic Tepecik-Çiftlik, Central Anatolia (Turkey). *Journal of Anthropological Archaeology, 5*, 101118.

C

Calcagno, J. M. (1986). Dental reduction in early Holocene Nubia. *American Journal of Physical Anthropology, 70*, 349–363.

Calcagno, J. M., & Gibson, K. R. (1988). Human dental reduction: Natural selection or the probable mutation effect. *American Journal of Physical Anthropology, 77*, 505–517.

Calcagno, J. M. (1989). *Mechanisms of human dental reduction: A case study from post-Pleistocene Nubia* (Publication No. 18). Lawrence: University of Kansas Publications in Anthropology.

Campana, D. V., & Crabtree, P. J. (2017). Bone implements from Chalcolithic Tepecik-Çiftlik: Traces of manufacture and wear on two classes of bone objects recovered from the 2013 excavation season. *Quaternary International*. https://doi.org/10.1016/j.quaint.2017.11.042

Cappers, R. T. J., Bottema, S., Bar-Yosef, O., & Belfer-Cohen, A. (2002). Facing environmental crisis: Societal and cultural changes at the transition from the Younger Dryas to the Holocene in the Levant. In R. T. J. Cappers & S. Bottema (Eds.), *The Dawn of Farming in the Near East* (Studies in Early Near Eastern Production, Subsistence, and Environment, vol. 6, pp. 55–66). Berlin: Ex Oriente.

Carlson, D. S., & Van Gerven, D. P. (1977). Masticatory function and post-Pleistocene evolution in Nubia. *American Journal of Physical Anthropology, 46*, 495–506.

Cauvin, J. (1972). Nouvelles fouilles à Tell Mureybet (Syrie) 1971-1972: Rapport préliminaire. *AAAS, 22*, 105–115.

Cauvin, J. (1974). Troisième campagne de fouilles à Tell Mureybet (Syrie) en 1973: Rapport préliminaire. *AAAS, 24*, 47–51.

Cauvin, J. (1977). Les fouilles de Mureybet (1971-1974) et leur signification pour les origines de la sédentarisation au Proche-Orient. *AASOR, 44*, 19–48.

Cauvin, J. (1978). *Les premiers villages de Syrie–Palestine du IXe au VIIe millénaire av. JC.* Lyon: Maison de l'Orient - TMO.

Cauvin, J. (1980). Le Moyen Euphrate au VIIIème millénaire d'après Mureybet et Cheikh Hassan. In J.-C. Margueron (Ed.), *Le Moyen Euphrate, Zone de contacts et d'échanges: Actes du colloque de Strasbourg* (pp. 21–34).

Cauvin, J. (1989a). La néolithisation au Levant et sa première diffusion. In O. Aurenche & J. Cauvin (Eds.), *Néolithisations: Proche et Moyen Orient, Méditerranée orientale, Nord de l'Afrique, Europe méridionale, Chine, Amérique du Sud* (BAR International Series 516, pp. 3–36). Oxford - Lyon: BAR.

Cauvin, J. (1989b). La néolithisation du Levant, huit ans après… *Paléorient, 15*(1), 174–179.

Cauvin, J. (1994). *Naissances des divinités, naissance de l'agriculture: La révolution des symboles au Néolithique*. Paris: CNRS éditions.

Cauvin, J. (Dir.). (1973a). Mureybet 1972-1973, carrés R31-R32, cahier 1. *Cahiers de fouilles de Mureybet*, archivés à l'antenne de Jalès.

Cauvin, J. (Dir.). (1973b). Mureybet 1973, carré S32. *Cahiers de fouilles de Mureybet*, archivés à l'antenne de Jalès.

Cauvin, J., Cauvin, M.-C., Helmer, D., & Willcox, G. (1997). L'homme et son environnement au Levant nord entre 30 000 et 7 500 BP. *Paléorient, 23*(2), 51–69.

Cauvin, M.-C. (1974a). Outillage lithique et chronologie à Tell Aswad (Damascène, Syrie). *Paléorient, 2*(2), 429–436.

Cauvin, M.-C. (1974b). Note préliminaire sur l'outillage lithique de la phase IV de Tell Mureybet. *AAAS, 24*, 59–63.

Cauvin, M.-C. (1976). Cheikh Hassan 1976, secteurs MC1-MC2. In J. Cauvin (Dir.), *Cahiers de fouilles de Cheikh Hassan 1976*, Antenne de Jalès.

Cauvin, M.-C. (1995). L'industrie lithique de Tell Aswad. In H. de Contenson (Ed.), *Aswad et Ghoraifé, sites néolithiques en Damascène (Syrie) au IXe et VIIe millénaire avant l'ère chrétienne* (pp. 81–122). Beyrouth: IFAPO.

Cauvin, M.-C. (2006). L'Aswadien: Réévaluation de sa mise en évidence. *Syria, 83*, 31–38.

Cauvin, M.-C. (2008). Historique. In J. J. Ibáñez (Ed.), *Le site néolithique de Tell Mureybet (Syrie du Nord)* (Vol. I, pp. 17–20). Oxford - Lyon: BAR.

Cauvin, M.-C., & Cauvin, J. (1993). La séquence Néolithique PPNB au Levant nord. *Paléorient, 19*(1), 23–28.

Cauvin, M.-C., & Chataignier, C. (1998). Distribution de l'obsidienne dans les sites archéologiques du Proche et du Moyen-Orient (par phase chronologique). In M.-C. Cauvin, A. Gourgaud, B. Gratuze, M. Arnaud, G. Poupeau, J.-L. Poidevin, & C. Chataignier (Eds.), *L'obsidienne au Proche et Moyen Orient: Du volcan à l'outil* (BAR International Series 738, pp. 325–350). Oxford - Lyon: BAR.

Chambrade, M. L. (2012). *Dynamique spatio-temporelle et environnement des sites néolithiques précéramiques de Syrie intérieure* [Thèse de doctorat]. Université de Franche-Comté.

Chamel, B. (2014). *Bioanthropologie et pratiques funéraires des populations néolithiques du Proche Orient : l'impact de la Néolithisation (étude de sept sites syriens : 9820-6000 cal. BC)* [PhD thesis]. Université Lumière Lyon 2.

Chamel, B., & Le Mort, F. (2014). The impact of the Neolithisation process on the funerary practices and health status of the Levant populations: From North to South. *North-South Connections and Disconnections in the Prehistory and Proto-history of the Levant*, Session du XVIIème Congrès de l'Union Internationale des Sciences Préhistoriques et Protohistoriques, Burgos, Spain. ⟨hal-01819288⟩.

Chattah, N. L.-T., & Smith, P. (2006). Variation in occlusal dental wear of two Chalcolithic populations in the southern Levant. *American Journal of Physical Anthropology*, 130, 471–479.

Chowdhry, A., Popli, D. B., Sircar, K., & Kapoor, P. (2023). Study of twenty non-metric dental crown traits using ASUDAS system in NCR (India) population. *Egyptian Journal of Forensic Sciences, 13*(1), 8.

Clarke, J., Brooks, N., Banning, E. B., Bar-Matthews, M., Campbell, S., Clare, L., & Zerboni, A. (2016). Climatic changes and social transformations in the Near East and North Africa during the "long" 4th millennium BC: A comparative study of environmental and archaeological evidence. *Quaternary Science Reviews, 136*, 96–121. https://doi.org/10.1016/j.quascirev.2015.10.003

Clement, A. F., & Hillson, S. W. (2012). Intrapopulation variation in macro tooth wear patterns—a case study from Igloolik, Canada. *American Journal of Physical Anthropology, 149*, 517–524.

Contenson, H. de, & Van Liere, W. J. (1964). Sondages a Tell Ramad en 1963. Rapport preliminaire. *Annales Archéologiques de Syrie*, 14, 109-124.

Contenson, H. de, & Van Liere, W. J. (1966). Seconde Campagne á Tell Ramad, 1965. *Annales Archéologique Arabe Syriennes*, 16(2), 165-174.

Contenson, H. de (1967). Troisième Campagne á Tell Ramad, 1966, *Rapport Préliminaire. Annales Archéologique Arabe Syriennes,* 17, 17-24.

Contenson, H. de. (1971). Tell Ramad, a village of Syria of the 7th and 6th millennia B.C. Archaeology, 24, 278-285.

Contenson, H. de (1972). Tell Aswad. Fouilles de 1971. *AAAS, 22*, 75–84.

Contenson, H. de (1973). Chronologie absolue de Tell Aswad (Damascène, Syrie). *BSPF, 70*(8), 253–256.

Contenson, H. de (1974). Tell Aswad, site néolithique précéramique près de Damas (Syrie). *BSPF, 71*(1), 5–6.

Contenson, H. de (1978). Tell Aswad. Fouilles de 1972. *AAAS, 27-28*, 207–215.

Contenson, H. de (1992). Les coutumes funéraires dans le néolithique syrien. *BSPF, 89*, 184–191.

Contenson, H. de (1995). *Aswad et Ghoraifé, sites néolithiques en Damascène (Syrie) au IXe et VIIe Millénaire avant l'ère chrétienne.* Beyrouth: IFAPO.

Contenson, H. (2000). *Ramad Site Néolithique en Damascène (Syrie) aux VIII Millénaires avant l'ère chrétienne.* Beiruth: IFAPO.

Contenson, H. de, & Van Liere, W. J. (1966). Premier sondage à Bouqras en 1965. Rapport préliminaire. *AAAS, 16*(2), 181–192.

Contenson, H. de, Cauvin, M.-C., Van Zeist, W., Bakker-Heeres, J. A. H., & Leroi-Gourhan, A. (1979). Tell Aswad (Damascène). *Paléorient, 5*, 153–176.

Cordova, C. (2000). Geomorphological evidence of intense prehistoric soil erosion in the Highlands of Central Jordan. *Physical Geography, 21*(6), 538–567.

Coqueugniot, E. (1981). *Les grattoirs et herminettes de Mureybet (Syrie), IX au VII Mill. av. J.C. Analyse typologique et fonctionnelle* [Thèse de doctorat]. Université de Lyon 2.

Coqueugniot, E. (1992). Fouilles de sauvetage à Dja'det el-Mughara en 1991 et 1992. *Chronique Archéologique en Syrie, 1*, 19–22.

Coqueugniot, E. (1998a). Dja'de el-Mughara (Moyen Euphrate), un village néolithique dans son environnement naturel à la veille de la domestication. In M. Fortin & O. Aurenche (Eds.), *Espace naturel, espace habité en Syrie du Nord (10-2º millénaires av. J-C.)* (pp. 109–114). Lyon: Maison de l'Orient - TMO n°28.

Coqueugniot, E. (1998b). Dja'de el-Mughara 1997. *Chronique Archéologique en Syrie, 2*, 125–132.

Coqueugniot, E. (1999). Tell Dja'de el-Mughara. In G. Del Olmo Lete & J.-L Montero Fenollos (Eds.), *Archéologie du haut Euphrate syrien - la zone du barrage de Tishrin* (pp. 41–55). Barcelone : Éditorial Ausa.

Coqueugniot, E. (2000). Dja'de (Syrie), un village à la veille de la domestication (Seconde moitié du IXeme millénaire av. J. C.). In J. Guilaine (Ed.), *Premiers paysans du monde, naissances des agricultures* (pp. 63–79). Paris: Errance.

Coqueugniot, E., Jamieson, A. S., Montero Fenollos, J. L., & Anfruns, J. (1998). Une tombe en bronze ancien à Dja'de el-Mughara (Moyen Euphrate, Syrie). *Cahiers de l'Euphrate, 8*, 85–112.

Coqueugniot, E. (Dir.) (1999). *Dja'de el-Mughara. Rapport Scientifique 1999, Campagne de fouilles 1999 (6 mai-1 juillet)*. np.

Coqueugniot, E. (Dir.) (2002). *Dja'de el-Mughara. Rapport Scientifique 2002, Campagne de fouilles 2002 (12 septembre-26 octobre)*. np.

Coqueugniot, E. (2004). *Fouille Neolitique de Dja'de El Mughara. Rapport Scientifique de la campagne de 2004.* Lyon: Maison de l'Orient Mediterranéen.

Coqueugniot, E. (Dir.) (2006). *Dja'de el-Mughara. Rapport Scientifique 2006, Campagne de fouilles 2006 (26 aout-6 octobre)*. np.

Coqueugniot, E. (Dir.) (2007). *Dja'de el-Mughara. Rapport Scientifique 2007, Campagne de fouilles 2007 (28 aout-11 octobre)*. np.

Coqueugniot, E. (Dir.) (2008). *Dja'de el-Mughara. Rapport Scientifique 2008, Campagne de fouilles 2008 (27 aout-20 octobre)*. np.

Cruells, W. (2005). *Orígens, emergència i desenvolupament de la ceràmica Halaf a Siria* [PhD thesis]. Universitat Autònoma de Barcelona.

Cruells, W., & Gómez-Bach, A. (2016). Chagar Bazar (Hassake). In Y. Kanjou & A. Tsuneki (Eds.), *A History of Siria in One Hundred Sites* (pp. 84–87). Oxford: Archaeopress Archaeology.

Cruells, W., & Molist, M. (2021). Akarçay Tepe in Southeastern Turkey: A key site on the origins of the first pottery productions in the Near East. In R. Özbal, M. Erdalkiran, & Y. Tonoiko (Eds.), *Neolithic Pottery from the Near East: Production, Distribution and Use* (pp. 25–44). Istanbul: Koç University Press.

Cruells, W., & Nieuwenhuyse, O. (2004). The Proto-Halaf Period in Syria: New sites, new data. *Paléorient, 30*(1), 47–68.

Croix, S., Frei, K. M., Sindbæk, S. M., & Søvsø, M. (2020). Individual geographic mobility in a Viking-Age emporium—Burial practices and strontium isotope analyses of Ribe's earliest inhabitants. *PLOS ONE, 15*(8), e0237850.

Croucher, K. (2012). *Death and dying in the Near East*. Oxford University Press.

Cuesta, E (2020). Geometric Morphometrics and topographic analyses of dental wear in modern human populations. Universitat de Barcelona (Phd Tesis)

D

Darabi, H. (2017). *A report on the stratigraphy and chronology of Tapeh Ali Kosh*. Tehran: Iranian Center for Archaeological Research.

Dawson, H., & Brown, K. R. (2013). Exploring the relationship between dental wear and status in late medieval subadults from England. *American Journal of Physical Anthropology, 150*, 433–441.

Dayan, T. (1994). Early domesticated dogs of the Near East. *Journal of Archaeological Science*, 21(5), 633-640.

Dean, M. C., & Vesey, P. (2008). Preliminary observations on increasing root length during the eruptive phase of tooth development in modern humans and great apes. *Journal of Human Evolution, 54*, 258–271.

Delgado, M., Ramírez, L. M., Adhikari, K., Fuentes-Guajardo, M., Zanolli, C., Gonzalez José, R., Canizales, S., Bortolini, M.-C., Poletti, G., Gallo, C., Rothhammer, F., Bedoya, G., & Ruiz-Linares, A. (2019). Variation in dental morphology and inference of continental ancestry in admixed Latin Americans. *American Journal of Physical Anthropology, 168*(3), 438–447.

Dennis, J. C., Hunger, P. S., Teaford, M. F., & Glander, K. E. (2004). Dental topography and molar wear in *Alouatta palliata* from Costa Rica. *American Journal of Physical Anthropology, 125*, 152–161.

Denton, G. H., Alley, R. B., Comer, G. C., & Broecker, W. S. (2005). The role of seasonality in abrupt climate change. *Quaternary Science Reviews, 24*, 1159–1182.

Desideri, J. (2007). *L'Europe du 3e millénaire avant notre ère et la question du Campaniforme: histoire des peuplements par l'étude des traits non métriques dentaires* (Unpublished PhD Dissertation). Université de Genève.

Deter, C. A. (2009). Gradients of occlusal wear in hunter-gatherers and agriculturalists. *American Journal of Physical Anthropology, 138*, 247–254.

E

Echegaray, J. G. (1964). *Excavaciones en la terraza de Khiam (Jordania). Estudio de los yacimientos y los niveles paleolíticos*. Biblioteca Prehistórica Hispana, Vol. V. Madrid.

Echegaray, J. G. (1966). *Excavaciones en la Terraza de El-Khiam (Jordania)*. Madrid: Consejo Superior de Investigaciones Científicas.

Edwards, P. C. (1988). Natufian settlement in Wadi Al-Hammeh. *Paléorient*, 14(2), 309-315.

Edwards, P. C. (1989a). Problems of recognizing earliest sedentism: The Natufian example. *Journal of Mediterranean Archaeology*, 2(1), 5-48.

Edwards, P. C. (1989b). Revisting the Broad Spectrum Revolution and its role in the origins of Southwest Asian food production. *Antiquity*, 63, 225-246.

Edwards, P. C. (1991). Wadi Hammeh 27: An early Natufian site at Pella, Jordan. In O. Bar-Yosef & F. R. Valla (Eds.), *The Natufian culture in the Levant* (pp. 123-148). International Monographs in Prehistory, Archaeological Series 1.

Edwards, P. C., Bourke, S. J., Colledge, S. M., Head, J., & Macumber, P. G. (1988). Late Pleistocene prehistory in the Wadi al-Hammeh, Jordan Valley. In A. N. Garrard & H. G. Gebel (Eds.), *The prehistory of Jordan. The state of research in 1986* (pp. 525-563). BAR International Series, 396.

Elzay, R. P., Allison, M. J., & Pezzia, A. (1977). A comparative study on the dental health status of five Precolumbian Peruvian cultures. *American Journal of Physical Anthropology, 46*, 135–139.

Esin, U., & Harmankaya, S. (1999). Aşıklı. In M. Özdogan & N. Basgelen (Eds.), *Neolithic in Turkey: The cradle of civilization; new discovery* (pp. 115-132). Istanbul: Arkeoloji ve Sanat Yayınları.

Erdal, Y. S. (1999). Neolitikten günümüze Anadolu insan topluluklarının dişlerinde boyut küçülmesi. *Hacettepe Diş Hekimliği Fakültesi Dergisi, 23*(1), 12–19.

Erdal, Y. S. (2013). Life and death at Hakemi Use. In O. P. Nieuwenhuyse, R. Bernbeck, P. M. M. G. Akkermans, & J. Rogasch (Eds.), *Interpreting the Late Neolithic of Upper Mesopotamia*. Brepols Publishers, Turnhout.

Erdal, Y. S. (2015). Bone or flesh: Defleshing and post-depositional treatments at Körtik Tepe (Southeastern Anatolia, PPNA Period). *European Journal of Archaeology, 18*(1), 4–32.

Eshed, V., Gopher, A., & Hershkovitz, I. (2006). Tooth wear and dental pathology at the advent of agriculture: New evidence from the Levant. *American Journal of Physical Anthropology, 130*, 145-159.

Estebaranz, F., Martínez, L., Hiraldo, O., Bonnin, V. E., Farrés, M., & Pérez-Pérez, A. (2004). Tooth crown size and dentine exposure in Australopithecus and early Homo: Testing hypotheses of dietary related selective pressures. *Anthropologie, XLII*(1), 59-63.

Estebaranz, F., Martínez, L. M., Anfruns, J., & Pérez-Pérez, A. (2007). Tell Halula (Syria), seasons 1992–2005. *Bioarchaeology of the Near East, 1*, 65-67.

Estebaranz, F., Martínez, L. M., Galbany, J., Turbon, D., & Pérez-Pérez, A. (2009). Testing hypotheses of dietary reconstruction from buccal dental microwear in *Australopithecus afarensis*. *Journal of Human Evolution, 57*(6), 739-750.

Estebaranz, F., Galbany, J., Martínez, L. M., Turbon, D., & Pérez-Pérez, A. (2012). Buccal dental microwear analyses support greater specialization in consumption of hard foodstuffs for *Australopithecus anamensis*. *Journal of Anthropological Sciences, 90*, 163-185.

Evans, A. R., Wilson, G. P., Fortelius, M., & Jernvall, J. (2007). High-level similarity of dentitions in carnivorans and rodents. *Nature, 445*(7123), 78-81.

Evans, A. R., & Jernvall, J. (2009). Patterns and constraints in carnivoran and rodent dental complexity and tooth size. *Journal of Vertebrate Paleontology, 29*, 24A.

Evans, A. R. (2013). Shape descriptors as ecometrics in dental ecology. *Hystrix, 24*(1), 133-140.

Evans, A. R., & Janis, C. M. (2014). The evolution of high dental complexity in the horse lineage. *Annales Zoologici Fennici, 51*, 73-79.

Evans, A. R., Daly, E. S., Catlett, K. K., Paul, K. S., King, S. J., Skinner, M. M., & Jernvall, J. (2016). A simple rule governs the evolution and development of hominin tooth size. *Nature, 530*(7591), 477-480.

Evershed, R. P., Payne, S., Sherratt, A. G., Copley, M. S., Coolidge, J., Urem-Kotsu, D., Kotsakis, K., Özdoğan, M., Özdoğan, A. E., Nieuwenhuyse, O., Akkermans, P. M. M. G., Bailey, D., Andeescu, R. R., Campbell, S., Farid, S., Hodder, I., Yalman, N., Özbaşaran, M., Bıçakcı, E., Garfinkel, Y., Levy, T., & Burton, M. M. (2008). Earliest date for milk use in the Near East and southeastern Europe linked to cattle herding. *Nature, 455*(7212), 528-531.

F

Feldman, M., Fernández-Domínguez, E., Reynolds, L., Baird, D., Pearson, J., Hershkovitz, I., May, H., Goring-Morris, N., Benz, M., Gresky, J., et al. (2019). Late Pleistocene human genome suggests a local origin for the first farmers of central Anatolia. Nature Communications, 10, 1–10.

Fenollós, J., Vidal Palomino, J., & Masó Ferrer, F. (Eds.). (n.d.). *De la estepa del Mediterráneo. Congreso de Arqueología e Historia Antigua del Oriente Próximo, Barcelona* (Vol. 7, p. 22).

Ferembach, D. (1970). Etude anthropologique des ossements humains néolithiques de Tell Ramad (Syrie campagnes 1963-66). L'Anthropologie, 74, 247-254.

Ferembach, D., Schwidetzky, I., & Stloukal, M. (1980). Recommendations for age and sex diagnosis of skeletons. *Journal of Human Evolution, 9*, 517-549.

Fernández, E., Pérez-Pérez, A., Gamba, C., Prats, E., Cuesta, P., et al. (2014). Ancient DNA analysis of 8000 B.C. Near Eastern farmers supports an early Neolithic pioneer maritime colonization of mainland Europe through Cyprus and the Aegean Islands. *PLOS Genetics, 10*(6), e1004401. https://doi.org/10.1371/journal.pgen.1004401

Ferrio, J., Araus, J., & Slafer, G. (2011). Global change and the origins of agriculture. In J. Araus & G. Slafer (Eds.), *Crop stress management and global climate change*. CABI Publishing, Wallingford, United Kingdom.

Ferrio, J., et al. (2012). Agricultural expansion and settlement economy in Tell Halula (Mid Euphrates Valley): A diachronic study from early Neolithic to present. *Journal of Arid Environments, 86*, 104-112.

Fiorenza, L., Benazzi, S., Oxilia, G., & Kullmer, O. (2018). Functional relationship between dental macrowear and diet in Late Pleistocene and recent modern human populations. *International Journal of Osteoarchaeology, 28*, 153–161.

Fisher, W. B. (2013). *The Middle East (Routledge Revivals): A Physical, Social and Regional Geography*. Routledge, London.

Fitzgerald, C., & Hillson, S. W. (2008). Alternative methods of assessing tooth size in Late Pleistocene and Early Holocene hominids. In J. D. Irish & G. Nelson (Eds.), *Technique and Application in Dental Anthropology* (pp. 364-388). Cambridge: Cambridge University Press.

Formicola, V. (1987). Neolithic transition and dental changes: The case of an Italian site. *Journal of Human Evolution, 16*, 131-239.

Frangipane, M. (1996). *La nascita dello Stato nel Vicino Oriente: Dai lignaggi allá burocrazia nella grande Mesopotamia* (Vol. 85). Roma: Laterza.

Frayer, D. (1977). Metric dental change in the European Upper Palaeolithic and Mesolithic. *American Journal of Physical Anthropology, 46*, 109–120.

Frayer, D. (1978). *The evolution of the dentition in Upper Paleolithic and Mesolithic Europe*. Lawrence: University of Kansas Publications in Anthropology, 10.

Frayer, D. (1981). Body size, weapon use, and natural selection in the European Upper Palaeolithic and Mesolithic. *American Anthropologist, 83*, 57-73.

Frayer, D. (1988). Sex differences in tooth wear at Skateholm. *Mesolithic Miscellany, 9*, 11-12.

Frieß, M., & Baylac, M. (2003). Exploring artificial cranial deformation using elliptic Fourier analysis of Procrustes aligned outlines. *American Journal of Physical Anthropology, 122*(1), 11–22.

Frumkin, A., Ford, D. C., & Schwartz, H. P. (1999). Continental oxygen isotopic record of the last 170,000 years in Jerusalem. *Quaternary Research, 51*(3), 317–327.

Fuhrer, K., Neftel, A., Anklin, M., & Maggi, V. (1993). Continuous measurement of hydrogen-peroxide, formaldehyde, calcium and ammonium concentrations along the new GRIP ice core from Summit, Central Greenland. *Atmospheric Environment Section A, 27*, 1873–1880.

G

Galbany, J., & Pérez-Pérez, A. (2004). Buccal enamel microwear variability in Cercopithecoidea primates as a reflection of dietary habits in forested and open savanna environments. *Anthropologie, 42*(1), 13-19.

Galbany, J., Martínez, L. M., & Pérez-Pérez, A. (2004). Tooth replication techniques, SEM imaging and microwear analysis in primates: Methodological obstacles. *Anthropologie, 42*(1), 5-12.

Galbany, J., Estebaranz, F., Martínez, L. M., Romero, A., De Juan, J., Turbón, D., et al. (2006). Comparative analysis of dental enamel polyvinylsiloxane impression and polyurethane casting methods for SEM research. *Microscopy Research and Technique, 69*, 246–252. https://doi.org/10.1002/jemt.20296

Galbany, J., Estebaranz, F., Martínez, L. M., & Pérez-Pérez, A. (2009). Buccal dental microwear variability in extant African Hominoidea: Taxonomy versus ecology. *Primates, 50*(3), 221-230.

Galland, M., Van Gerven, D. P., Von Cramon-Taubadel, N., & Pinhasi, R. (2016). 11,000 years of craniofacial and mandibular variation in Lower Nubia. *Scientific Reports, 6*, 31040.

Garfinkel, Y. (1996). Critical observations on the so-called Khiamian flint industry. In S. K. Kozlowski & H. G. Gebel (Eds.), *Neolithic chipped stone industries of the fertile crescent, and their contemporaries in adjacent regions* (pp. 15-21). Berlin: Ex Oriente - Studies in Early Near Eastern Production, Subsistence and Environment 3.

Garfinkel, Y. (1987). Burnt lime products and social implications in the Pre-Pottery Neolithic B villages of the Near East. *Paléorient, 13*(1), 69-76.

Garrod, D. A. E. (1928). Excavation of a Palaeolithic cave in Western Judaea. *Palestine Exploration Fund, Quarterly Statement for 1928, 60*, 182-185.

Garrod, D. A. E. (1932). A new Mesolithic industry: The Natufian of Palestine. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland, 62*, 257-269.

Garrod, D. A. E. (1931). Excavations at the Mugharet el-Wad, 1930. *Palestine Exploration Quarterly, 63*, 99-103.

Garrod, D. A. E., & Bate, D. M. A. (1937). The Stone Age of Mount Carmel: Excavations at the Wady El-Mughara (Vol. 1). *Clarendon Press*.

Garrod, D. A. E. (1942). Excavations at the cave of Shukbah, Palestine. *Proceedings of the Prehistoric Society, 8*, 1-20.

Garrod, D. A. E. (1951). A transitional industry from the base of the Upper Palaeolithic in Palestine and Syria. *Journal of the Royal Anthropological Institute, 81*, 121-130.

Garrod, D. A. E. (1957). The Natufian culture: The life and economy of a Mesolithic people in the Near East. *Proceedings of the British Academy, 43*, 211-227.

Garrod, D. A. E., & Bate, D. M. A. (1937). *The Stone Age of Mount Carmel, Vol. I.* Oxford: Clarendon Press.

Geyh, M. A. (1994). The paleohydrology of the eastern Mediterranean. En O. Bar-Yosef & R. S. Kra (Eds.), *Late Quaternary Chronology and Paleoclimates of the Eastern Mediterranean* (pp. 131–145). Tucson, AZ: Radiocarbon.

Gilmore, C. C., & Grote, M. N. (2012). Estimating age from adult occlusal wear: A modification of the miles method. *American Journal of Physical Anthropology*, 149(2), 181–192. https://doi.org/10.1002/ajpa.22106

Gkantidis, N., Dritsas, K., Ren, Y., Halazonetis, D., & Katsaros, C. (2020). An accurate and efficient method for occlusal tooth wear assessment using 3D digital dental models. *Scientific Reports*, 10(1), 10103.

Godfrey, L. R., Winchester, J. M., King, S. J., Boyer, D. M., & Jernvall, J. (2012). Dental topography indicates ecological contraction of lemur communities. *American Journal of Physical Anthropology*, 148(2), 215–227.

Godinho, R. M., Carretero, J. M., Paredes, R., Cascalheira, J., Marreiros, J. M., & Bicho, N. F. (2023). Mandibular morphology and the Mesolithic–Neolithic transition in Westernmost Iberia. *Scientific Reports*, 13, 16648.

Gómez-Bach, A. (2011). *Caracterización del producto cerámico en las comunidades neolíticas de mediados del VI milenio cal BC: El valle del Eufrates y el valle del Khabur en el Halaf final* (Tesis doctoral). Universitat Autònoma de Barcelona.

Gómez-Robles, A., Martinón-Torres, M., Bermúdez de Castro, J. M., Margvelashvili, A., Bastir, M., Arsuaga, J. L., Pérez-Pérez, A., Estebaranz, F., & Martínez, L. M. (2007). A geometric morphometric analysis of hominin upper first molar shape. *Journal of Human Evolution*, 53, 272–285.

Gómez-Robles, A., Martinón-Torres, M., Bermúdez de Castro, J. M., Prado, L., Sarmiento, S., & Arsuaga, J. L. (2008). Geometric morphometric analysis of the crown morphology of the lower first premolar of hominins, with special attention to Pleistocene Homo. *Journal of Human Evolution*, 55, 627–638.

Gómez-Robles, A., Martinón-Torres, M., Bermúdez de Castro, J. M., Prado-Simón, L., & Arsuaga, J. L. (2011). A geometric morphometric analysis of hominin upper premolars: Shape variation and morphological integration. *Journal of Human Evolution*, 61, 688–702.

Godfrey, S. J., et al. (2012). Applications of dental topography in understanding diet. *American Journal of Physical Anthropology*, 149(3), 391-403.

Godon, M. (2012). Cappadocia’s first pottery production: Tepecik-Çiftlik earliest levels. *Arkeometri Sonuçları Toplantısı*, 29(3), 317–340.

Goose, D. H., & Lee, G. T. R. (1971). The mode of inheritance of Carabelli's trait. *Human Biology*, 43, 64–69.

Gopher, A., & Goring-Morris, A. N. (1998). Abu Salem: A Pre-Pottery Neolithic B camp in the Central Negev Highlands, Israel. *Bulletin of the American Schools of Oriental Research*, 312(1), 1–20.

Goring-Morris, A. N. (1991). The Harifian of the southern Levant. En O. Bar-Yosef & F. R. Valla (Eds.), *The Natufian Culture in the Levant* (pp. 173–216). Ann Arbor, MI: International Monographs in Prehistory Archaeological Series 1.

Goring-Morris, A. N., & Belfer-Cohen, A. (1998). The articulation of cultural processes and Late Quaternary environmental changes in Cisjordan. *Paléorient*, 23(2), 80–82.

Goring-Morris, A. N., & Kolska Horwitz, L. (2007). Funerals and feasts during the Pre-Pottery Neolithic B of the Near East. *Antiquity*, 81, 902–919.

Goring-Morris, A. N., & Belfer-Cohen, A. (2008). A roof over one's head: Developments in Near Eastern residential architecture across the Epipalaeolithic-Neolithic transition. En *The Neolithic Demographic Transition and Its Consequences* (pp. 239–286). Dordrecht: Springer.

Goring-Morris, A. N., Hovers, E., & Belfer-Cohen, A. (2009). The dynamics of Pleistocene and Early Holocene settlement patterns and human adaptations in the Levant: An overview. En J. J. Shea & D. E. Lieberman (Eds.), *Transitions in Prehistory, Essays in Honor of O. Bar-Yosef* (pp. 185–252). Oxford: American School of Prehistoric Research Monograph Series, Oxbow Books.

Goring-Morris, A. N., & Belfer-Cohen, A. (2011). Neolithization processes in the Levant: The outer envelope. *Current Anthropology*, 52(S4), S195–S208.

Goring-Morris, A. N., & Belfer-Cohen, A. (2013). Houses and households: A Near Eastern perspective. En *Tracking the Neolithic House in Europe* (pp. 19–44). New York: Springer.

Gourichon, L., & Helmer, D. (2004). Exploitation du gibier dans le Moyen Euphrate syrien du XII au IX millénaires av. J.-C. En J.-P. Brugal & J. Desse (Dirs.), *Petits Animaux et Sociétés Humaines: Du Complément Alimentaire aux Ressources Utilitaires, Actes des XXIV Rencontres Internationales d'Archéologie et d'Histoire d'Antibes* (pp. 431–449).

Gourichon, L., & Helmer, D. (2008). Étude archéozoologique de Mureybet. En J. J. Ibañez (Ed.), *Le Site Néolithique de Tell Mureybet (Syrie du Nord)* (Vol. I, pp. 115–228). Oxford/Lyon: BAR International Series 1843.

Grimoud, A.-M., & Gibbon, V. E. (2017). Dental wear quantity and direction in Chalcolithic and Medieval populations from southwest France. *HOMO*, 68, 1–9.

Gvirtzman, G., & Wieder, M. (2001). Climate of the last 53,000 years in the eastern Mediterranean, based on soil-sequence stratigraphy in the coastal plain of Israel. *Quaternary Science Reviews*, 20(18), 1827–1849.

Guerrero, E., Molist, M., Kuijt, I., & Anfruns, J. (2009). Seated memory: New insights into Near Eastern Neolithic mortuary variability from Tell Halula, Syria. *Current Anthropology*, 50(3), 379–391.

Gutiérrez-Obeid, A. I., & Vera, M. (2021). Dental morphology analysis in pre-Columbian populations of the Andes: A case study using ASUDAS. American Journal of Physical Anthropology, 174(2), 295-308. https://doi.org/10.1002/ajpa.24105.

Guy, F., Gouvard, F., Boistel, R., Euriat, A., & Lazzari, V. (2013). Prospective in (primate) dental analysis through tooth 3D topographical quantification. *PLOS ONE*, 8, e66142.

Guy, F., Lazzari, V., Gilissen, E., & Thiery, G. (2015). To what extent is primate second molar enamel occlusal morphology shaped by the enamel-dentine junction? *PLOS ONE*, 10, e0138802.

H

Hald, M., & Hagen, S. (1998). Early Preboreal cooling in the Nordic seas region triggered by meltwater. *Geology*, 26(7), 615–618.

Hanihara, T. (1992). Dental and cranial affinities among populations of East Asia and the Pacific: The basic populations in East Asia, IV. *American Journal of Physical Anthropology*, 88, 163–182.

Hanihara, T. (2008). Morphological variation of major human populations based on nonmetric dental traits. *American Journal of Physical Anthropology*, 136(2), 169–182.

Harris, E. F. (1977). *Anthropologic and genetic aspects of the dental morphology of Solomon Islanders, Melanesia* (Tesis doctoral no publicada). Department of Anthropology, Arizona State University, Tempe.

Harris, E. F., & Buck, A. L. (2002). Tooth mineralization: A technical note on the Moorrees-Fanning-Hunt standards. *Dental Anthropology*, 16, 15–21.

Harris, E. F., & Sjøvold, T. (2004). Calculation of Smith's mean measure of divergence for intergroup comparisons using nonmetric data. *Dental Anthropology*, 17, 83–93.

Heinrich, H. (1988). Origin and consequences of cyclic ice rafting in the northeast Atlantic Ocean during the past 130,000 years. *Quaternary Research*, 29(2), 142–152.

Helmer, D. (1992). *La domestication des animaux par les hommes préhistoriques*. Paris: Masson.

Helmer, D. (1994). La domestication des animaux d'embouche dans le Levant nord (Syrie du nord et Sinjar) du milieu du IXe millénaire BP à la fin du VIIIe millénaire BP. Nouvelles données d'après les fouilles récentes. *Anthropozoologica*, 20, 41–54.

Helmer, D. (1998). Les lièvres de Mureybet (fouilles Cauvin). Essai d’interprétation climatique du site. *Cahiers de l’Euphrate*, 8, 55–61.

Helmer, D. (2000). Discrimination des genres Ovis et Capra à l’aide des prémolaires inférieures 3 et 4. L’exemple de Dikili Tash (Macédoine – Grèce). En B. Bassano, G. Giacobini & V. Peracino (Eds.), *Animal Management and Demography Through the Ages*. *Ibex Journal of Mountain Ecology* 5 – *Anthropozoologica*, 31, 29–38.

Helmer, D., Roitel, V., Sana, M., & Willcox, G. (1998). Interprétations environnementales des données archéozoologiques et archéobotaniques en Syrie du nord de 16000 BP à 7000 BP, et les débuts de la domestication des plantes et des animaux. En M. Fortin & O. Aurenche (Eds.), *Espace naturel, espace habité en Syrie du nord (10e-2e millénaires av. J-C.)* (pp. 9–33). Lyon: Maison de l’Orient TMO n°28.

Helmer, D., Gourichon, L., Monchot, H., Peters, J., & Saña Seguí, M. (2005). Identifying early domestic cattle from the Pre-Pottery Neolithic sites on the Middle Euphrates using sexual dimorphism. En J.-D. Vigne, J. Peters & D. Helmer (Eds.), *The First Steps of Animal Domestication: New Archaeozoological Approaches* (pp. 86–94). Oxford: Oxbow Books.

Helmer, D., & Gourichon, L. (2008). Premières données sur les modalités de subsistance à Tell Aswad (Syrie, PPNB moyen et récent, Néolithique céramique ancien) - Fouilles 2001-2005. *MOM Editions*, 49(1), 119–151.

Hemming, D., Buontempo, C., Burke, E., Collins, M., & Kaye, N. (2010). How uncertain are climate model projections of water availability indicators across the Middle East? *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 368(1931), 5117–5135.

Henry, D. O. (1989). *From Foraging to Agriculture: The Levant at the End of the Ice Age*. Philadelphia: University of Pennsylvania Press.

Henson, K., Harding, T., Starcher, K., Smith, A., & Seccurro, D. (2020). Intraobserver and interobserver error in osteological analysis as an indicator for non-expert skeletal analysis. *Journal of Forensic Science & Criminology*, 8, 1–7.

Hershkovitz, I., & Gopher, A. (2008). Demographic, biological and cultural aspects of the Neolithic revolution: A view from the southern Levant. En J.-P. Bocquet-Appel & O. Bar-Yosef (Eds.), *The Neolithic demographic transition and its consequences* (pp. 441–479). Springer.

Hillman, G. (1996). Late Pleistocene changes in wild plant foods available to hunter-gatherers of the northern Fertile Crescent: Possible preludes to cereal cultivation. En D. R. Harris (Ed.), *The Origins of Agriculture and Pastoralism in Eurasia* (pp. 159–203). London: UCL Press.

Hillson, S. (2001). Dental disease. En *Dental Anthropology* (pp. 260–301). Cambridge: Cambridge University Press.

Hillson, S. (2005). *Teeth*. Cambridge: Cambridge University Press.

Hillson, S. (2001). Recording dental caries in archaeological human remains. *International Journal of Osteoarchaeology*, 11, 249–289.

Hillson, S., Fitzgerald, C., & Flinn, H. (2005). Alternative dental measurements: Proposals and relationships with other measurements. *American Journal of Physical Anthropology*, 126(4), 413–426. https://doi.org/10.1002/ajpa.10430

Hillson, S. (1996). *Dental anthropology*. Cambridge: Cambridge University Press.

Hillson, S., & Bond, S. (1997). Relationship of enamel hypoplasia to the pattern of tooth crown growth: A discussion. *American Journal of Physical Anthropology*, 104, 89–103.

Hillson, S., Grigson, C., & Bond, S. (1998). Dental defects of congenital syphilis. *American Journal of Physical Anthropology*, 107, 25–40.

Hillson, S. W. (1979). Diet and dental disease. *World Archaeology*, 11, 147–162.

Higgins, D., Hughes, T. E., James, H., & Townsend, G. C. (2009). Strong genetic influence on hypocone expression of permanent maxillary molars in South Australian twins. *Dental Anthropology*, 22, 1–7. https://doi.org/10.26575/daj.v22i1.83

Hlusko, L. J. (2016). Elucidating the evolution of hominid dentition in the age of phenomics, modularity, and quantitative genetics. *Annals of Anatomy*, 203, 3–11. https://doi.org/10.1016/j.aanat.2015.05.001

Hlusko, L. J., Lease, L. R., & Mahaney, M. C. (2006). Evolution of genetically correlated traits: Tooth size and body size in baboons. *American Journal of Physical Anthropology*, 131(3), 420–427. https://doi.org/10.1002/ajpa.20435

Hole, F., Flannery, K. V., & Neely, J. A. (1969). *Prehistory and human ecology of the Deh Luran plain: An early village sequence from Khuzistan, Iran*. Ann Arbor: University of Michigan.

Holly-Smith, B. (1984). Patterns of molar wear in hunter-gatherers and agriculturalists. *American Journal of Physical Anthropology*, 63, 39–56.

Horwarth, L., Hillson, S., & Boaventura, R. (2014). Assessing change in diet and biological affinity between the 4th and 3rd millennia cal BC in the Portuguese Estremadura: A preliminary dental comparison of Feteira II and Bolores. *Homo*, 65, 87–100.

Horwitz, L. K., & Tchernov, E. (2000). Climatic change and faunal diversity in Epipaleolithic and early Neolithic sites from the lower Jordan Valley. En M. Mashkour & H. Buitenhuis (Eds.), *Archaeozoology of the Near East IVA: Proceedings of the Fourth International Symposium on the Archaeozoology of Southwestern Asian and Adjacent Areas* (pp. 49–66). ARC Publications.

Hours, F., Aurenche, O., Cauvin, M. C., Copeland, L., & Sanlaville, P. (1994). *Atlas des sites du Proche-Orient (14000-5700)*. Paris: De Boccard.

Hughes, T. E., & Townsend, G. C. (2013). Twin and family studies of human dental crown morphology: Genetic, epigenetic, and environmental determinants of the modern human dentition. En G. R. Scott & J. D. Irish (Eds.), *Anthropological perspectives on tooth morphology: Genetics, evolution, variation* (pp. 31–68). Cambridge: Cambridge University Press.

Hughes, P. D., & Gibbard, P. L. (2015). A stratigraphical basis for the Last Glacial Maximum (LGM). *Quaternary International*, 383, 174–185. https://doi.org/10.1016/j.quaint.2014.06.006

I

Ibáñez, J. J., González-Urquijo, J., Teira-Mayolini, L. C., & Lazuén, T. (2017). The emergence of the Neolithic in the Near East: A protracted and multi-regional model. *Quaternary International*, 1–27.

Irish, J. D., Hemphill, B. E., de Ruiter, D. J., & Berger, L. R. (2016). The apportionment of tooth size and its implications in *Australopithecus sediba* versus other Plio-Pleistocene and recent African hominins. *American Journal of Physical Anthropology*, 161(3), 398–413.

Issar, A. S. (1998). Climate change and history during the Holocene in the eastern Mediterranean region. En A. S. Issar & N. Brown (Eds.), *Water, Environment and Society in Times of Climatic Change: Contributions from an International Workshop within the framework of International Hydrological Program (IHP) UNESCO, held at Ben-Gurion University, Sede Boker, Israel from 7–12 July 1996* (pp. 113–128). Dordrecht: Springer Netherlands.

Issar, A. S., & Zohar, M. (2009). Climate change impacts on the environment and civilization in the Near East. En H. G. Brauch et al. (Eds.), *Facing Global Environmental Change: Environmental, Human, Energy, Food, Health and Water Security Concepts* (pp. 119–130). Berlin, Heidelberg: Springer Berlin Heidelberg.

Izdebski, A., Holmgren, K., Weiberg, E., Stocker, S. R., & Büntgen, U. (2015). The environmental, archaeological and historical evidence for regional climatic changes and their societal impacts in the Eastern Mediterranean in Late Antiquity. *Quaternary Science Reviews*, 136, 189–208.

J

Jacobs, K. (1994). Human dento-gnathic metric variation in Mesolithic/Neolithic Ukraine: Possible evidence of demic diffusion in the Dnieper Rapids region. *American Journal of Physical Anthropology*, 95, 1–26.

Jernvall, J., Åberg, P., Kettunen, P., Keränen, S., & Thesleff, I. (1998). The life history of an embryonic signalling center: BMP-4 induces p21 and is associated with apoptosis in the mouse tooth enamel knot. *Development*, 125, 161–169.

Jernvall, J., & Thesleff, I. (2000). Reiterative signalling and patterning during mammalian tooth morphogenesis. *Mechanisms of Development*, 92, 19–29.

Jernvall, J., & Jung, H.-S. (2000). Genotype, phenotype, and developmental biology of molar tooth characters. *Yearbook of Physical Anthropology*, 43, 171–190.

Johnsen, S. J., Dahl-Jensen, D., Gundestrup, N., et al. (2001). Oxygen isotope and palaeotemperature records from six Greenland ice-core stations: Camp Century, Dye3, GRIP, GISP2, Renland, and NorthGRIP. *Journal of Quaternary Science*, 16(4), 299–307.

K

Kaifu, Y. (1997). Changes in mandibular morphology from the Jomon to modern periods in Eastern Japan. *American Journal of Physical Anthropology, 104*(2), 227–243.

Kaifu, Y., Kasai, K., Townsed, G. C., & Richards, L. C. (2003). Tooth wear and the "design" of the human dentition: A perspective from evolutionary medicine. *American Journal of Physical Anthropology*, 37, 47–61. https://doi.org/10.1002/ajpa.10329

Kassai, Y., Munne, P., Hotta, Y., Penttilä, E., Kavanagh, K., Ohbayashi, N., Takada, S., Thesleff, I., Jernvall, J., & Itoh, N. (2005). Regulation of mammalian tooth cusp patterning by ectodin. *Science, 309*, 2067–2070.

Katz, D. C., Grote, M. N., & Weaver, T. D. (2017). Changes in human skull morphology across the agricultural transition are consistent with softer diets in preindustrial farming groups. *Proceedings of the National Academy of Sciences, 114*, 9050–9055.

Kaul, V., & Prakash, S. (1981). Morphological features of the Jat dentition. *American Journal of Physical Anthropology, 54*, 123–127.

Kay, R. F. (1975). The functional adaptations of primate molar teeth. *American Journal of Physical Anthropology*, 43(2), 195-216.

Kay, R. F., & Covert, H. H. (1984). Anatomy and behavior of extinct primates. In D. J. Chivers, B. A. Wood, & A. Bilsborough (Eds.), *Food acquisition and processing in primates* (pp. 467–508). New York: Plenum Press.

Kay, R. F., & Hiiemae, K. M. (1974a). Jaw movement and tooth use in recent and fossil primates. *American Journal of Physical Anthropology, 40*, 227–256.

Kay, R. F., & Hylander, W. L. (1978). The dental structure of mammalian folivores with special reference to primates and Phalangeroidea (Marsupialia). In G. G. Montgomery (Ed.), *The Ecology of Arboreal Folivores* (pp. 173–191). Washington, D.C.: Smithsonian Institution Press.

Kay, R. F., & Sheine, W. S. (1979). On the relationship between chitin particle size and digestibility in the primate *Galago senegalensis*. *American Journal of Physical Anthropology, 50*(3), 301–308.

Keith, A. (1931). *New discoveries relating to the antiquity of man*. Williams & Norgate.

Keith, A. (1932). The late Paleolithic inhabitants of Palestine. In *Proceedings of the first International Congress of Prehistoric and Protohistoric Sciences* (pp. 46-47).

Kenyon, K. M. (1956). Jericho and its setting in Near Eastern history. *Antiquity, 30*(120), 184–197.

Kenyon, K. (1957). *Digging up Jericho*. London: Ernest Benn.

Kenyon, K. M. (1960). Excavations at Jericho, 1957–58. *Palestine Exploration Quarterly, 92*(2), 88–113.

Kenyon, K. M., & Holland, T. A. (1983). *Excavations at Jericho. Vol. 5. The pottery phases of the tell and other finds*. London: British School of Archaeology in Jerusalem.

Kieser, J. A., & Preston, C. B. (1981). The dentition of the Lengua Indians of Paraguay. *American Journal of Physical Anthropology, 55*, 485–490.

Kılınç, G. M., Omrak, A., Özer, F., Günther, T., Büyükkarakaya, A. M., Bıçakçı, E., et al. (2016). The demographic development of the first farmers in Anatolia. *Current Biology,* 26(19), 2659–2666.

Kılınç, G., et al. (2017). Archaeogenomic analysis of the first steps of neolithisation in Anatolia and the Aegean. *Proceedings of the Royal Society B*, 284, 20172064.

Kılınç, G. M., Kashuba, N., Yaka, R., Sümer, A. P., Yüncü, E., Shergin, D., Ivanov, G. L., Kichigin, D., Pestereva, K., Volkov, D., et al. (2018). Investigating Holocene human population history in North Asia using ancient mitogenomes. *Scientific Reports*, 8, 1–10.

King, S. J., Arrigo-Nelson, S. J., Pochron, S. T., Semprebon, G. M., Godfrey, L. R., Wright, P. C., & Jernvall, J. (2005). Dental senescence in a long-lived primate links infant survival to rainfall. *Proceedings of the National Academy of Sciences USA, 102*, 16579–16583.

Kingery, W. D., Vandiver, P. B., & Prickett, M. (1988). The beginnings of pyrotechnology, part II: Production and use of lime and gypsum plaster in the pre-pottery Neolithic Near East. *Journal of Field Archaeology, 15*(2), 219–244.

Kinzey, W. G. (1978). Feeding behaviour and molar features in two species of titi monkey. In D. J. Chivers & J. Herbert (Eds.), *Recent Advances in Primatology, Vol. 1, Behaviour*. London: Academic Press.

Kinzey, W. G. (1992). Dietary and dental adaptations in the Pitheciinae. *American Journal of Physical Anthropology, 88*, 499–514.

Kinzey, W. G., & Norconk, M. A. (1993). Physical and chemical properties of fruit and seeds eaten by *Pithecia* and *Chiropotes* in Surinam and Venezuela. *International Journal of Primatology, 14*, 207–227.

Khalaily, H., Bar-Yosef, O., Barzilai, O., Boaretto, E., Bocquentin, F., Eirikh-Rose, A., Greenhut, Z., Goring-Morris, A. N., Le Dosseur, G., Marder, O., Sapir-Hen, L., & Yizhaq, M. (2007). Excavations at Motza in the Judean Hills and the Early Pre-Pottery Neolithic B in the Southern Levant. *Paléorient, 33*(2), 5–37. https://doi.org/10.3406/paleo.2007.5218

Kuijt, I. (1994). Pre-Pottery Neolithic A settlement variability: Evidence for sociopolitical developments in the Southern Levant. *Journal of Mediterranean Archaeology, 7*, 41–68.

Kuijt, I., & Gorring-Morris, N. (2002). Foraging, farming, and social complexity in the Pre-Pottery Neolithic of the Southern Levant: A review and synthesis. *Journal of World Prehistory, 16*(4), 361–440.

Kuzucuoğlu, C. (2013). Geomorphological mapping as an illustration of geomorphological evolution reconstruction: The example of the Çiftlik Plain in Cappadocia (Niğde). In *Profesör Doktor İlhan Kayan'a Armağan* (pp. 133–146). Bornova.

Kozlowski S. K. (1989) Nemrik 9, a PPN Neolithic site in Northern Iraq. *Paléorient*, 15(1). pp. 25-31

Kozlowski, S. K., & Aurenche, O. (2005). *Territories, boundaries and cultures in the Neolithic Near East*. Oxford: BAR International Series, Archaeopress.

Kozlowski, S., & Aurenche, O. (2005). *Territories, Boundaries and Cultures in the Neolithic Near East*. Archaeopress-Maison de l'Orient et de la Méditerranée.

Landmann, G., Reimer, A., Lemcke, G., & Kempe, S. (1996). Dating Late Glacial abrupt climate changes in the 14,570 yr long continuous varve record of Lake Van, Turkey. *Palaeogeography, Palaeoclimatology, Palaeoecology, 122*, 107–118.

Larsen, C. S. (1995). Biological changes in human populations with agriculture. *Annual Review of Anthropology, 24*(1), 185–213.

Larsen, C. S. (1997). *Bioarcheology: Interpretation behavior from human skeleton*. Cambridge University Press, Cambridge.

Larsen, C. S. (2002). Bioarchaeology: The lives and lifestyles of past people. *Journal of Archaeological Research, 10*, 119–166.

Larsen, C. S. (2015). *Bioarchaeology: Interpreting behavior from the human skeleton* (Vol. 69). Cambridge University Press.

Lazaridis, I., Alpaslan-Roodenberg, S., Acar, A., Açıkkol, A., Agelarakis, A., Aghikyan, L., ... & Ruka, R. (2022). The genetic history of the Southern Arc: A bridge between West Asia and Europe. *Science, 377*(6609), eabm4247.

Le Luyer, C., & Bayle, P. (2017). Microevolution of outer and inner structure of upper molars in late Pleistocene and Early Holocene humans. *Comptes Rendus Palevol.*

Le Mort, F. (1994). Les sépultures. In M. Lechevallier & A. Ronen (Eds.), *Le gisement de Hatoula en Judée occidentale, Israël* (pp. 39-57). Paris: Mémoires et travaux du centre de recherche français de Jérusalem.

Le Mort, F. (2011). Le regroupement des morts dans le Néolithique précéramique du Proche-Orient : Diversité et évolution des pratiques. In D. Castex, P. Courtaud, H. Duday, F. Le Mort & A.-M. Tillier (Eds.), *Le regroupement des morts. Genèse et diversité archéologique* (pp. 181-188). Bordeaux: Ausonius Editions – Maison des Sciences de l'Homme d'Aquitaine.

Le Mort, F., Erim-Özdogan, A., Özbek, M., & Yilmaz, Y. (2000). Feu et archéoanthropologie au Proche-Orient (Epipaléolithique et Néolithique): Le lien avec les pratiques funéraires. Données nouvelles de Çayönü. *Paléorient, 26*(2), 37-50.

Ledogar, J. A., Winchester, J. M., St. Clair, E. M., & Boyer, D. M. (2013). Diet and dental topography in pitheciine seed predators. *American Journal of Physical Anthropology, 150*(1), 107-121.

Legge, A. J. (1975). The fauna of Tell Abu Hureyra: Preliminary analysis. In A. M. Moore (Ed.), *The excavation of Tell Abu Hureyra in Syria: A preliminary report*, *Proceedings of the Prehistoric Society, 41*, 74-77.

Legge, A. J. (1996). The beginning of caprine domestication in Southwest Asia. In D. R. Harris (Ed.), *The origins and spread of agriculture and pastoralism in Eurasia* (pp. 238-262). London: UCL Press.

Legge, A. J., & Rowley-Conwy, P. A. (2000). The exploitation of animals. In A. M. T. Moore, G. C. Hillman, & A. J. Legge (Eds.), *Village on the Euphrates, from foraging to farming at Abu Hureyra* (pp. 423-474). New York: Oxford University Press.

Lelieveld, J., Hadjinicolaou, P., Kostopoulou, E., Chenoweth, J., El Maayar, M., Giannakopoulos, C., Hannides, C., Lange, M. A., Tanarhte, M., Tyrlis, E., & Xoplaki, E. (2012). Climate change and impacts in the eastern Mediterranean and the Middle East. *Climatic Change, 114*(3–4), 667–687.

Leigh, R. W. (1925). Dental pathology of Indian tribes of varied environmental and food conditions. *American Journal of Physical Anthropology, 8*, 179-199.

Leroy, S. A. G., et al. (2019). Human responses to environmental change on the southern coastal plains of the Caspian Sea during the Mesolithic and Neolithic periods. *Quaternary Science Reviews, 218*, 343-364.

Lezot, F., Thomas, B., Greene, S. R., Hotton, D., Yuan, Z.-A., Castaneda, B., Bolaños, A., Depew, M., Sharpe, P., Gibson, C. W., & Berdal, A. (2008). Physiological implications of DLX homeoproteins in enamel formation. *Journal of Cell Physiology, 216*, 688-697.

Littleton, J., & Frohlich, B. (1989). An analysis of dental pathology and diet on historic Bahrain. *Paléorient*, 59-75.

Littleton, J., & Frohlich, B. (1993). Fish-eaters and farmers: Dental pathology in the Arabian Gulf. *American Journal of Physical Anthropology, 92*, 427–447.

Littleton, J., Scott, R., McFarlane, G., & Walshe, K. (2013). Hunter-gatherer variability: Dental wear in South Australia. *American Journal of Physical Anthropology, 152*, 273–286.

López-Onaindia, D., Lozano, M., Gómez-Robles, A., Arrizabalaga, A., & Subirà, M. E. (2023). Neanderthal teeth from Lezetxiki (Arrasate, Iberian Peninsula): New insights and reassessment. *American Journal of Biological Anthropology, 180*(4), 745-760.

López-Onaindia, D., Schmitt, A., Gibaja, J. F., & Subirà, M. E. (2022). Non-metric dental analysis of human interactions around the Pyrenees during the Neolithic and their biological impact. *Annals of Anatomy-Anatomischer Anzeiger, 242*, 151895.

López-Onaindia, D., Gibaja, J. F., & Subirà, M. E. (2019). Heirs of the glacial maximum: Dental morphology suggests Mesolithic human groups along the Iberian Peninsula shared the same biological origins. *Archaeology and Anthropology Sciences, 11*, 5499-5512.

López-Onaindia, D., & Subirà, M. E. (2017). Prehistoric funerary complexity in northern Iberia studied by using dental morphology. *Homo J. Comp. Hum Biol, 68*, 122-133.

López-Onaindia, D., Coca, M., Gibaja, J. F., & Subirà, M. E. (2017). Biological differences related to cultural variability during the Neolithic in a micro-geographical area of the Iberian Peninsula. *Archaeology and Anthropology Sciences, 10*, 1957–1969.

Lowe, J. J., Rasmussen, S. O., Björck, S., et al. (2008). Synchronisation of palaeoenvironmental events in the North Atlantic region during the Last Termination: A revised protocol recommended by the INTIMATE group. *Quaternary Science Reviews, 27*(1–2), 6–17.

Louail, M., & Prat, S. (2018). Readjustment of the Standard ASUDAS to encompass dental morphological variations in Plio-Pleistocene hominins. *Bulletins et Mémoires de la Société d'anthropologie de Paris, 30*, 32-48.

Lucas, L. (2012). Variation in dental morphology and bite force along the tooth row in anthropoids. PhD Dissertation, Arizona State University.

Lucas, P. (2004). *Dental Functional Morphology: How Teeth Work.* Cambridge: Cambridge University Press.

Lucas, P. W., Corlett, R. T., & Luke, D. A. (1986). Postcanine tooth size and diet in anthropoid primates. *Z. Morphol. Anthropol., 76*, 253-276.

Lucas, P. W., Constantino, P. J., & Wood, B. A. (2008). Inferences regarding the diet of extinct hominins: Structural and functional trends in dental and mandibular morphology within the hominin clade. *Journal of Anatomy, 212*, 486-500.

Lucas, P. W., & Luke, D. A. (1983). Methods for analyzing the breakdown of food in human mastication. *Archives of Oral Biology, 28*, 813-819.

Lucas, P. W., & Luke, D. A. (1984). Chewing it over: Basic principles of food breakdown. In D. Chivers, B. A. Wood, & A. Bilsborough (Eds.), *Food acquisition and processing in primates*. New York: Plenum.

Lucas, P. W., Omar, R., Al-Fadhalah, K., Almusallam, A., Henry, A., Michael, S., Thai, L. A., Watzke, J., Strait, D., & Atkins, A. (2013). Mechanisms and causes of wear in tooth enamel: Implications for hominin diets. *Journal of the Royal Society Interface*, 1-9.

Lucas, P. W., & Teaford, M. F. (1994). Functional morphology of colobine teeth. In A. G. Davies & J. F. Oates (Eds.), *Colobine Monkeys: Their Ecology, Behaviour and Evolution.* Cambridge: Cambridge University Press.

Lucas, P. W., & Teaford, M. F. (1995). Significance of silica in leaves to long-tailed macaques (*Macaca fascicularis*). *Folia Primatol., 64*, 30-36.

Lucas, P. W., Turner, I. M., Dominy, N. J., & Yamashita, N. (2000). Mechanical defences to herbivory. *Annals of Botany, 86*, 913-920.

Lukacs, J. R., & Pastor, R. F. (1988). Activity-induced patterns of dental abrasion in prehistoric Pakistan: Evidence from Mehrgarh and Harappa. *American Journal of Physical Anthropology, 76*, 377–398.

Lukacs, J. R. (2022). Sexual dimorphism in deciduous tooth crown size: Variability within and between groups. *American Journal of Human Biology, 34*(10), e23793.

M

M'Kirera, F., & Ungar, P.S. (2003). Occlusal relief changes with molar wear in *Pan troglodytes troglodytes* and *Gorilla gorilla gorilla*. *American Journal of Primatology, 60*(2), 31-41.

Maaranen, N., Walker, J., & Sołtysiak, A. (2022). Societal segmentation and early urbanism in Mesopotamia: Biological distance analysis from Tell Brak using dental morphology. *Journal of Anthropological Archaeology, 67*, 101421.

Macchiarelli, R., & Bondioli, L. (1986). Post-pleistocene reductions in human dental structure: A reappraisal in terms of increasing population density. *Human Evolution, 1*(5), 405–417. https://doi.org/10.1007/BF02436617

Maher, L.A., Richter, T., & Stock, J.T. (2012). The Pre-Natufian Epipaleolithic: Long-term behavioral trends in the Levant. *Evolutionary Anthropology, 21*, 69-81.

Maher, L.A., et al. (2011). Oasis or Mirage? Assessing the Role of Abrupt Climate Change in the Prehistory of the Southern Levant. *Cambridge Archaeological Journal, 21*(1), 1–29.

Malarova, E., Dubska, L., Fleischmannova, J., Chlastakova, I., Janeckova, E., & Tucker, A.S. (2010). Cell proliferation and apoptosis in the primary enamel knot measured by flow cytometry of laser microdissected samples. *Archives of Oral Biology, 55*, 570-575.

Malarova, E., Svandova, E., & Tucker, A.S. (2012). Apoptotic signaling in mouse odontogenesis. *O.M.I.C.S.: A Journal of Integrative Biology, 16*, 60-70.

Malarova, E., Tucker, A.S., & Sharpe, P.T. (2004). Death in the life of a tooth. *Journal of Dental Research, 83*(11), 11-16.

May, H., Sella-Tunis, T., Pokhojaev, A., Peled, N., & Sarig, R. (2018). Changes in mandible characteristics during the terminal Pleistocene to Holocene Levant and their association with dietary habits. *Journal of Archaeological Science: Reports, 22*, 413-419.

Mayewski, P., Meeker, L. D., Twickler, M. S., Whitlow, S., Yang, Q., & Prentice, M. (1997). Major features and forcing of high latitude northern hemisphere circulation using a 110,000-year-long glaciochemical series. *Journal of Geophysical Research, 102*, 26345–26366.

Mays, S., de la Rua, C., & Molleson, T. (1995). Molar crown height as a means of evaluating existing dental wear scales for estimating age at death in human skeletal remains. *Journal of Archaeological Science, 22*, 659–670.

Mazar, A. (1990). *Archaeology of the land of the Bible 10,000–586 BC*. New York: Doubleday.

Mellaart, J. (1975). *The Neolithic of the Near East*. Londres: Thames and Hudson.

Menéndez, L. P., & Buck, L. T. (2022). Evaluating potential proximate and ultimate causes of phenotypic change in the human skeleton over the agricultural transition.

Martín, N., Thibeault, A., Varadzinová, L., Ambrose, S. H., Antoine, D., Havelková, P. B., Honegger, M., Irish, J. D., Osypiński, P., Usai, D., Vanderesse, N., Varadzin, L., Whiting, R. J., Velemínský, P., & Crevecoeur, I. (2024). From hunter-gatherers to food producers: New dental insights into the Nile Valley population history (Late Paleolithic–Neolithic). *American Journal of Biological Anthropology*, e24948. https://doi.org/10.1002/ajpa.24948.

Martrat, B., Grimalt, J.O., & Lopez-Martinez, C. (2004). Abrupt temperature changes in the western Mediterranean.

Miller, N.F. (1996). Seed eaters of the ancient Near East: human or herbivore? *Current Anthropology, 37*, 521–528.

Molist, M. (ed.). (1996). *Tell Halula (Siria). Un yacimiento neolítico del valle medio del Eufrates. Campañas de 1991 y 1992*. Madrid: Instituto del Patrimonio Histórico Español.

Molist, M. (1998a). Des représentations humaines peintes au IXe millénaire BP sur le site de Tell Halula (Vallée de l'Euphrate, Syrie). *Paléorient, 24*(1), 81-87.

Molist, M. (1998b). Espace collectif et espace domestique dans le Néolithique des IXème et VIIIème millénaires BP au nord de la Syrie: Apports du site de Tell Halula (vallée de l'Euphrate). *MOM Éditions, 28*(1), 115-130.

Molist, M. (2008). Foyers et fours du site de Mureybet. In J. J. Ibañez (ed.), *Le site néolithique de Tell Mureybet (Syrie du Nord). En hommage à Jacques Cauvin* (pp. 1-??). Oxford: BAR International Series 1843, Archaeopress.

Molist, M., & Vicente, O. (2013a). Tell Halula 1995-2005. Análisis estratigráfico y arquitectónico de los diferentes horizontes históricos. In M. Molist (ed.), *Tell Halula: Un poblado de los primeros agricultores en el valle del Eufrates, Siria* (pp. 31-96). Madrid: Ministerio de Educación, Cultura y Deporte.

Molist, M., & Vicente, O. (2013b). Los restos pictóricos de las casas de Tell Halula (Periodo PPNB medio-reciente). In M. Molist (ed.), *Tell Halula: Un poblado de los primeros agricultores en el valle del Eufrates, Siria* (pp. 111-126). Madrid: Ministerio de Educación, Cultura y Deporte.

Molist, M., Vicente, O., & Barceló, J.A. (2013). La serie de dataciones C14 del yacimiento de Tell Halula (Valle del Eufrates, Siria). In M. Molist (ed.), *Tell Halula: Un poblado de los primeros agricultores en el valle del Eufrates, Siria* (pp. 87-94). Madrid: Ministerio de Educación, Cultura y Deporte.

Molist, M., Gómez, A., Bofill, M., Cruells, W., Faura, J.M., Marchiori, C., & Martín, J. (2014). Maisons et structures d'habitation au Néolithique. Une approche de l'évolution des habitations familiales à partir des documents de Tell Halula (vallée de l'Euphrate, Syrie). In J.L. Montero-Fenollós (éd.), *Redonner la vie aux Mésopotamiens. Mélanges offerts à Jean-Claude Margueronn à l'occasion de ses 80 ans* (pp. 107-126). Ferrol: Société luso-galicienne d'études mésopotamiennes.

Molist, M., Sisa-López de Pablo, J., Wattez, J., & Gómez-Bach, A. (2020). Architectural phases, episodes of life and taphonomic processes in tell's formation: An approach to Tell Halula archaeological site. In A. Blanco & T. L. Kienlin (Eds.), *Current Approaches to Tells in the Prehistoric Old World* (pp. 11-23). Oxford: Oxbow Books.

Molleson, T., Andrews, P., & Boz, B. (2005). Reconstruction of the Neolithic people of Çatalhöyük. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995-99 seasons* (pp. 279-300). Exeter: British Institute of Archaeology at Ankara.

Molleson, T., Arnold-Foster, T. (2014). A question of identity: is 72.501 from Tell Abu Hureyra, Syria, an early Neolithic foundation burial? *British Association for Near Eastern Archaeology* (9th-11th January 2014) University of Reading (résumé).

Molleson, T., Comerford, G., & Moore, A. (1992). A Neolithic painted skull from Tell Abu Hureyra, Northern Syria. *Cambridge Archaeological Journal, 2*(2), 230-235.

Molleson, T., Cruse, K., & Mays, S. (1998). Some sexually dimorphic features of the human juvenile skull and their value in sex determination in immature skeletal remains. *JAS, 25*(8), 719-728.

Molleson, T., Jones, K., & Jones, S. (1993). Dietary changes and the effects of food preparation on microwear patterns in the Late Neolithic of Abu Hureyra, Northern Syria. *Journal of Human Evolution, 24*, 455-468.

Molleson, T. (1994). The eloquent bones of Abu-Hureyra. *Scientific American, 271*, 70-75.
Molleson, T. (1995). The importance of porridge. In M. Otte (Ed.), *Nature et Culture* (E.R.A.U.L. 68, pp. 479-486). Liège.

Molleson, T. (2000). The human remains. In A. M. T. Moore, G. C. Hillman, & A. J. Legge (Eds.), *Village on the Euphrates: From foraging to farming at Abu Hureyra* (pp. 533-543). New York: Oxford University Press.

Molleson, T. (2006). The third hand: Neolithic basket markers of Abu Hureyra. In E. Żądzińska (Ed.), *Current trends in dental morphology research: Papers from the 13th International Symposium on Dental Morphology (24-27 August 2005, Łódź, Pologne)* (pp. 115-126).

Molleson, T., & Jones, K. (1991). Dental evidence for dietary change at Abu Hureyra. *JAS, 18*, 525-539.
Molnar, P. (2008). Dental wear and oral pathology: Possible evidence and consequences of habitual use of teeth in a Swedish Neolithic sample. *American Journal of Physical Anthropology, 136*, 423–431.

Molnar, P. (2011). Extramasticatory dental wear reflecting habitual behavior and health in past populations. *Clinical Oral Investigations, 15*, 681–689. https://doi.org/10.1007/s00784-010-0447-1

Molnar, S. (1971). Human tooth wear, tooth function and cultural variability. *American Journal of Physical Anthropology, 34*, 175–189.

Molnar, S., Barrett, M. J., Brian, L., Brace, C. L., Brose, D. S., Dewey, J. R., ... & Greene, D. L. (1972). Tooth wear and culture: A survey of tooth functions among some prehistoric populations. *Current Anthropology, 13*, 511–526.

Molnar, S., McKee, J. K., & Molnar, I. (1983). Measurements of tooth wear among Australian Aborigines: I. Serial loss of the enamel crown. *American Journal of Physical Anthropology, 61*, 51–65.

Molnar, S., Richards, L., McKee, J., & Molnar, I. (1989). Tooth wear in Australian Aboriginal populations from the River Murray Valley. *American Journal of Physical Anthropology, 79*, 185–196.

Moore, A. M. T. (1975). The excavation of Tell Abu Hureyra in Syria: A preliminary report. *Proceedings of the Prehistoric Society, 41*, 50–77.

Moore, A. M. T. (1998). The interaction between people and environment at the early village of Abu Hureyra on the Euphrates. In M. Fortin & O. Aurenche (Eds.), *Espace naturel, espace habité en Syrie du Nord (10-2 millennia BC)* (pp. 131-137). Lyon: Maison de l'Orient TMO n°28.

Moore, A. M. T. (2003). The Abu Hureyra project: Investigating the beginning of farming in Western Asia. In A. J. Ammerman & P. Biagi (Eds.), *The widening harvest: The Neolithic transition in Europe: Looking back, looking forward* (pp. 59-74). Boston, MA: Colloquia and conference papers.

Moore, A. M. T., & Molleson, T. I. (2000). Disposal of the dead. In A. M. T. Moore, G. C. Hillman, & A. J. Legge (Eds.), *Village on the Euphrates, from foraging to farming at Abu Hureyra* (pp. 277-299). New York: Oxford University Press.

Moore, A. M. T., Hillman, G. C., & Legge, A. J. (2000). *Village on the Euphrates, from foraging to farming at Abu Hureyra*. New York: Oxford University Press.

Moorrees, C. F. A. (1957). Mesiodistal crown diameters of the deciduous and permanent teeth in individuals. *Journal of Dental Research, 36*, 39–47.

Moorrees, C. F. A., Fanning, E. A., & Hunt, E. E. Jr. (1963). Age variation of formation stages of ten permanent teeth. *Journal of Dental Research, 42*, 1490–1501.

Moulins, D. de (1997). *Agricultural changes at Euphrates and steppe sites in the mid 8th to 6th millennium BC*. Oxford: BAR International Series 683.

Moulins, D. de (2000). The plant food economy of Abu Hureyra 2: Plant remains from the Neolithic. In A. M. T. Moore, G. C. Hillman, & A. J. Legge (Eds.), *Village on the Euphrates, from foraging to farming at Abu Hureyra* (pp. 399-415). New York: Oxford University Press.

Munro, N. D. (2003). Small game, the youngest dryas, and the transition to agriculture in the southeastern levant. *Mitteilungen der Gesellschaft für Urgeschichte, 12*, 47.

Munro, N. D. (2004). Zooarchaeological measures of hunting pressure and occupation intensity in the Natufian: Implications for agricultural origins. *Current Anthropology, 45*(S4), 5-34.

Murphy, T. (1959a). The changing pattern of dentine exposure in human tooth attrition. *American Journal of Physical Anthropology, 17*, 167–178.

Murphy, T. (1959b). Gradients of dentine exposure in human molar tooth attrition. *American Journal of Physical Anthropology, 17*, 179–186.

Mülinen, G. von (1908). Beitrage zür Kenntnis des Karmels. *Zeitschrift des Deutschen Palästina Vereins, 31*, 190ff.

N

Nadel, D. (1990). The Khiamian as a case of Sultanian intersite variability. *Journal of the Israel Prehistoric Society, 23*, 86-99.

Nadel, D. (2006). Residence ownership and continuity: From the Early Epipalaeolithic unto the Neolithic. In E. B. Banning & M. Chazan (Eds.), *Domesticating space: Construction, community, and cosmology in the late prehistoric Near East* (pp. 25-34). Berlín: Ex Oriente.

Nadel, D., Tsatskin, A., Belmaker, M., Boaretto, E., Kislev, M., Mienis, H., Rabinovich, R., Simchoni, O., Simmons, T., Weiss, E., & Zohar, I. (2004). On the shore of a fluctuating lake: Environmental evidence from Ohalo II (19,500 B.P.). *Israel Journal of Earth Sciences, 53*, 207-23.

Nanci, A. (2008). *Ten Cate's oral histology: Development, structure and function* (7th ed.). Elsevier: St. Louis Mosby.

Nanci, A. (2014). *Ten Cate's oral histology: Development, structure, and function* (8th ed.). Elsevier Health Sciences.

Naughton, F., Sánchez Goñi, M. F., Landais, A., Vázquez Riveiros, N., Rodrigues, T., & Toucanne, S. (2023). The Bølling-Allerød interstadial. In *European glacial landscapes*. Elsevier. https://doi.org/10.1016/B978-0-323-91899-2.00015-2

Nava, A., Fiorin, E., Zupancich, A., et al. (2021). Multipronged dental analyses reveal dietary differences in last foragers and first farmers at Grotta Continenza, central Italy (15,500–7000 BP). *Scientific Reports, 11*, 4261. https://doi.org/10.1038/s41598-021-82401-2

Nelson, S. J., & Ash, M. M. (2010). *Wheeler's dental anatomy, physiology and occlusion* (9th ed.). Saunders, Elsevier.

O

Olipant, N., (2006). Excavations on Carmel. *Palestine Exploration Quarterly, 5*, 7-15.

Onoda, Y., Westoby, M., Adler, P. B., Choong, A. M. F., Clissold, F. J., Cornelissen, J. H. C., ... & Wright, S. J. (2011). Global patterns of leaf mechanical properties. *Ecology Letters, 14*, 301-312.

Ortiz, A., Chambon, P., & Molist, M. (2013). "Funerary bundles" in the PPNB at the archaeological site of Tell Halula (middle Euphrates valley, Syria): Analysis of taphonomic dynamics of seated bodies. *Journal of Archaeological Science, 40*, 4150-4161.

Ortiz, A. (2018). 2012 Dahlberg Award Winner Dental morphological variation among six Pre-Hispanic South American populations with implications for the peopling of the New World. *Dental Anthropology Journal*.

Özbal, H., Thissen, L., Doğan, T., Gerritsen, F. A., Özbal, R. D., & Türkekul Bıyık, A. (2013). Neolitik Batı Anadolu ve Marmara Yerleşimleri Çanak Çömleklerinde Organik Kalıntı Analizleri. In H. Dönmez & Ö. Ötgün (Eds*.), Arkeometri Sonuçları Toplantısı* (pp. 105–114). Ankara: Antiquity and Archeology, Art and Culture, History, Antiquity, CLUE+.

Özbaşaran, M. (2011). The Neolithic on the Plateau. In S. Steadmann & G. McMahon (Eds.), *The Oxford Handbook of Ancient Anatolia: 10,000-323 B.C.E.* (pp. 99–124). Oxford University Press.

Özbaşaran, M. (2012). Aşıklı. In The Neolithic in Turkey (pp. 135–158*). Istanbul: Arkeoloji Sanat Yayınları*.

Özbaşaran, M., Duru, G., & Uzdurum, M. (2018). Architecture of the Early Settlement and Trends through the Cultural Sequence. In The Early Settlement at Aşıklı Höyük. *Istanbul: Ege Yayınları.*

Özbek, M. (1976a). Étude anthropologique d'ossements humains néolithiques du VIIIème millénaire A.C. provenant de Mureybet, Syrie. *AAAS, 26*, 161-180.

Özbek, M. (1976b). Hommes de Byblos: Étude comparative des squelettes des âges des métaux au Proche-Orient. (Thèse de doctorat, Université de Paris VII).

Özbek, M. (1995). Dental pathology of the prepottery Neolithic residents of Çayönü, Turkey. *Rivista di Antropologia, 73*, 99-122.

Özbek, M. (1998). Human skeletal remains from Aşıklı, a Neolithic village near Aksaray, Turkey. In G. Arsebük, M. J. Mellink, & W. Schirmer (Eds.), *Light on top of the black hill: Studies presented to Halet Çambel* (pp. 567-579). Istanbul: Ege Yayınları.

Özbek, M. (2009). Remodeled human skulls in Köşk Höyük (Neolithic age, Anatolia): A new appraisal in view of recent discoveries. *Journal of Archaeological Science, 26*, 279-286.

Özdemir, K., Irvine, B., Doğan, T., Büyükkarkaya, AM., Gökan, Y., Yümni, C., Kulak, F., Bıçakçı, E. (2025). Investigation of dietary habits in the Neolithic Tepecik-Çiftlik population. *Journal of Archaeological Science: Reports.* 61-104919. https://doi.org/10.1016/j.jasrep.2024.104919

Özdoğan, A. (1999). Çayönü. In M. Özdoğan & N. Başgelen (Eds.), *Neolithic in Turkey: The cradle of civilization; new discovery* (pp. 35-63). Istanbul: Archaeology and Art Publications.

Özdoğan, M., & Özdoğan, A. (1998). Buildings of cult and the cult of buildings. In G. Arsebük, M. J. Mellink, & W. Schirmer (Eds.), *Light on top of the black hill: Studies presented to Halet Çambel* (pp. 581-601). Istanbul: Ege Yayınları.

Özdoğan, M. (2002). Defining the Neolithic of central Anatolia. In F. Gerard & L. Thissen (Eds.), *The Neolithic of Central Anatolia: Internal developments and external relations during the 9th-6th millennia cal BC* (pp. 253–261). Ege Yayınları, İstanbul.

Özdoğan, M. (2011). Archaeological evidence on the westward expansion of farming communities from Eastern Anatolia to the Aegean and the Balkans. *Current Anthropology,* 52(S4), S415–S430.

Öztaş, A. (2010). Archaeological investigations at Köşk Höyük, Niğde. Geoarchaeological activities in Southern Cappadocia, Turkey. In *Studia Mediterranea, 22*, Proceedings of the meeting held at Pavia, 20.11.2008 (pp. 83–95). Italian University Press.

P

Palmisano, A., Lawrence, D., de Gruchy, M. W., Bevan, A., & Shennan, S. (2021). Holocene regional population dynamics and climatic trends in the Near East: A first comparison using archaeo-demographic proxies. *Quaternary Science Reviews, 252*, 106739. https://doi.org/10.1016/j.quascirev.2020.106739

Pampush, J. D., Spradley, J. P., Morse, P. E., Harrington, A. R., Allen, K. L., Boyer, D. M., & Kay, R. F. (2016a). Wear and its effects on dental topography measures in howling monkeys (*Alouatta palliata*). *American Journal of Physical Anthropology, 161*(4), 705-721.

Pampush, J. D., Winchester, J. M., Morse, P. E., Vining, A. Q., Boyer, D. M., & Kay, R. F. (2016b). Introducing molaR: A new R package for quantitative topographic analyses of teeth (and other topographic surfaces). *Journal of Mammalian Evolution, 23*(4), 397-412.

Pampush, J. D., Spradley, J. P., Morse, P. E., Griffith, D., Gladman, J. T., Gonzales, L. A., & Kay, R. F. (2018). Adaptive wear-based changes in dental topography associated with atelid (*Mammalia: Primates*) diets. *Biological Journal of the Linnean Society, 124*(4), 584–606.

Payne, J. C. (1976). The terminology of the Aceramic Neolithic period in the Levant. In UISPP, IXe Congrès, Nice, Colloque III: Terminology of Prehistory of the Near East (pp. 131-137).

Payne, S. (1985). Morphological distinctions between the mandibular teeth of young sheep, *Ovis*, and goats, *Capra*. *Journal of Archaeological Science, 12*, 139-147.

Perrot, J. (1978). *Syrie-Palestine I: Des origines à l'âge du Bronze*. Genève: Nagel.

Perrot, J., & Ladiray, D. (1988). Les sépultures. In J. Perrot, D. Ladiray, & O. Solivères Masséi (Eds.), *Les hommes de Mallaha (Eynan) Israël* (pp. 1-106). Paris: Association Paléorient - Mémoires et Travaux du Centre de Recherche Français de Jérusalem.

Petanjek, Z., Judaš, M., Šimić, G., Rašin, M. R., Uylings, H. B. M., Rakic, P., & Kostović, I. (2011). Extraordinary neoteny of synaptic spines in the human prefrontal cortex. *Proceedings of the National Academy of Sciences, 108*, 13281-13286.

Peters, H., & Balling, R. (1999). Teeth: Where and how to make them. *Trends in Genetics, 15*, 59-65.

Peters, J., Von den Driesch, A., & Helmer, D. (2005). The upper Euphrates-Tigris basin: Cradle of agro-pastoralism? In J.-D. Vigne, J. Peters, & D. Helmer (Eds.), *The first steps of animal domestication: New archaeological approaches* (pp. 125-146). Oxford: Oxbow Books.

Pickard, C., Schoop, U.D., Dalton, A., Sayle, K.L., Channell, I., Calvey, K., Thomas, J.L., Bartosiewicz, L., Bonsall, C., 2016. Diet at Late Chalcolithic Çamlıbel Tarlası, north-central Anatolia: An isotopic perspective. *J. Archaeol. Sci. Rep*. 5, 296–306.

Pilloud, M. A., & Welsh, S. (2017). The use of ASUDAS in the examination of dental traits among ancient populations from the American Southwest. International Journal of Paleopathology, 18, 73-81. https://doi.org/10.1016/j.ijpp.2017.04.003.

Pineda-Muñoz, S., Lazagabaster, I. A., Alroy, J., & Evans, A. R. (2017). Inferring diet from dental morphology in terrestrial mammals. *Methods in Ecology and Evolution, 8*, 481-491.

Pinhasi, R., & Eshed, V. (2015). Incongruity between affinity patterns based on mandibular and lower dental dimensions following the transition to agriculture in the Near East, Anatolia and Europe. *PLOS ONE, 10*(3), e0117301. https://doi.org/10.1371/journal.pone.0117301

Pinhasi, R., Eshed, V., & Shaw, P. (2008). Evolutionary changes in the masticatory complex following the transition to farming in the southern Levant. *American Journal of Physical Anthropology, 135*, 136–148.

Pinhasi, R., & Meiklejohn, C. (2011). Dental reduction and the transition to agriculture in Europe. In R. Pinhasi & J. T. Stock (Eds.), *Human bioarchaeology of the transition to agriculture* (pp. 451–474). New York: Wiley-Liss.

Pokhojaev, S., Karpov, Y., & Melikhov, D. (2016). Changes in human mandibular shape during the Terminal Pleistocene-Holocene Levant. *Scientific Reports*.

Pokhojaev, A., Avni, H., Sella-Tunis, T. et al. (2019). Changes in human mandibular shape during the Terminal Pleistocene-Holocene Levant. Sci Rep 9, 8799. https://doi.org/10.1038/s41598-019-45279-9

van der Plicht, J., van Geel, B., Bohncke, S. J. P., et al. (2004). The Preboreal climate reversal and a subsequent solar-forced climate shift. *Journal of Quaternary Science, 19*(3), 263–269.

R

Rao, Z.G., Chen, F.H., Zhang, X., Xu, Y.B., Xue, Q., Zhang, P.Y., 2012. Spatial and temporal variations of C3/C4 relative abundance in global terrestrial ecosystem since the last glacial and its possible driving mechanism. *Chin Sci Bull* 57, 4024–4035.

Rathmann, H., Francken, M., Lismann, S., & Spatzier, A. (2023). Estimating inter-individual Mahalanobis distances from mixed incomplete high-dimensional data: Application to human skeletal remains from 3rd to 1st millennia BC Southwest Germany. *Journal of Archaeological Science, 156*, 105802.

Rathmann, H., & Reyes-Centeno, H. (2021, March). The utility of dental nonmetric ASUDAS traits and trait combinations for inferring human population history. In *American Journal of Physical Anthropology* (Vol. 174, pp. 88-88). Wiley.

Rathmann, H., Perretti, S., Porcu, V., Hanihara, T., Scott, G. R., Irish, J. D., ... & Harvati, K. (2023). Inferring human neutral genetic variation from craniodental phenotypes. *PNAS Nexus, 2*(7), pgad217.

Redman, C. L. (1978). *The rise of civilization: From early farmers to urban society in the ancient Near East*. San Francisco: W.H. Freeman and Company.

Redman, C. L. (1983). Regularity and change in the architecture of an early village. In T. C. Young, P. E. L. Smith, & P. Mortensen (Eds.), *The Hilly Flanks and Beyond: Essays on the Prehistory of Southwestern Asia* (pp. 189-197). Chicago: University of Chicago, Oriental Institute.

Ricaut, FX., Auriol, V., von Cramon-Taubadel, N., Keyser, C., Murail, P., Ludes, B., & Crubézy, E. (2010). Comparison between morphological and genetic data to estimate biological relationship: The case of the Egyin Gol necropolis (Mongolia). *American Journal of Physical Anthropology, 143*(3), 355–364. https://doi.org/10.1002/ajpa.21322

Richards, M. P. (2002). A brief review of the archaeological evidence for Palaeolithic and Neolithic subsistence. *European Journal of Clinical Nutrition, 56*, S1-S5.

Richards, M.P., Pearson, J.A., Russell, N., Molleson, T.I., Martin, L., 2003. Stable isotope evidence of diet at Neolithic Çatalhoyük. ¨ Turkey. *J. Archaeol. Sci*. 30, 67–76. https://doi.org/10.1006/jasc.2001.082

Řídký, J. (2009). Fragmentation and secondary use of the manos and metates from the Tepecik – Çiftlik site in central Turkey. In P. Maříková-Vlčková, J. Mynářová, & M. Tomášek (Eds.), *My Things Changed Things: Social Development and Cultural Exchange in Prehistory, Antiquity and the Middle Ages* (pp. 140–149). Charles University in Prague, Faculty of Arts – Institute of Archaeology of the Academy of Sciences of the Czech Republic.

Riehl, S. (2008). Climate and agriculture in the ancient Near East: A synthesis of the archaeobotanical and stable carbon isotope evidence. *Vegetation History and Archaeobotany, 17*, 43–51. http://dx.doi.org/10.1007/s00334-008-0156-8

Riehl, S. (2009). Archaeobotanical evidence for the interrelationship of agricultural decision-making and climate change in the ancient Near East. *Quaternary International, 197*, 93–114. http://dx.doi.org/10.1016/j.quaint.2007.08.005

Robinson, S., Black, S., & Sellwood, B. (2006). A review of palaeoclimates and palaeoenvironments in the Levant and Eastern Mediterranean from 25,000 to 5,000 years BP: Setting the environmental background for the evolution of human civilisation. *Quaternary Science Reviews, 25*, 1517–1541.

Robson, S., & Wood, B. (2008). Hominin life history: Reconstruction and evolution. *Journal of Anatomy, 212*, 394–425.

Roche, D., Paillard, D., & Cortijo, E. (2004). Constraints on the duration and freshwater release of Heinrich event 4 through isotope modelling. *Nature, 432*, 379–382.

Rollefson, G. O. (1989). The Late Aceramic Neolithic of the Levant: A synthesis. *Paléorient, 15*(1), 168–173.

Rollefson, G. O., & Kohler-Rollefson, I. (1993). PPNC adaptations in the first half of the 6th millennium B.C. *Paléorient, 19*(1), 33–42.

Romero, A., Ramírez-Rozzi, F. V., Cuesta-Torralvo, E., & Pérez-Pérez, A. (2019). Age-related tooth wear in African rainforest hunter-gatherers. *American Journal of Physical Anthropology*, 170(4), 622–628. https://doi.org/10.1002/ajpa.23934

Rosen, A. M. (2007). *Civilizing climate: Social responses to climate change in the ancient Near East*. Lanham, MD: AltaMira Press.

Rosen, A. M., & Rivera-Collazo, I. (2012). Climate change, adaptive cycles, and the persistence of foraging economies during the late Pleistocene/Holocene transition in the Levant.

Rossignol-Strick, M. (1999). The Holocene climatic optimum and pollen records of sapropel 1 in the eastern Mediterranean, 9000–6000 BP. *Quaternary Science Reviews, 18*(4–5), 515–530.

S

Saña, M. (1999). Arqueología de la domesticación animal. La gestión de los recursos animales en Tell Halula (Valle del Eufrates-Siria) del 8800 al 7000 BP. *Treballs d'Arqueologia del Proxim Orient, 1*. Barcelona: Universitat Autònoma de Barcelona.

Saña, M., & Helmer, D. (1999). The process of animal domestication in the North of the Euphrates Valley (Syria): Socio-economic implications. In G. del Olmo Lete & J. L. Montero Fenollos (Eds.), *Archeology of the Upper Syrian Euphrates. The Tishrin Dam area* (pp. 257–278). Barcelona: Editorial Ausa.

Saña, M., & Tornero, C. (2008). Consumption of animal resources at the sites of Akarçay Tepe and Tell Halula (Middle Euphrates Valley, 8th-6th millennia cal BC). In E. Vila, L. Gourichon, H. Buitenhuis, & A. Choyke (Eds.), *Archaeozoology of Southwest Asia and Adjacent Areas VIII. Proceedings of the 8th ASWA Conference (Lyon, 28 June - 1 July 2006)* (pp. 153–167). Paris: Travaux de la Maison de l'Orient.

Saña, M., & Tornero, C. (2013). La gestión de los recursos animales en Tell Halula: Nuevas hipótesis y aproximaciones metodológicas para el estudio de la domesticación animal y producción ganadera. In M. Molist (Ed.), *Tell Halula: Un poblado de los primeros agricultores en el Valle del Eufrates, Siria* (pp. 277–332). Madrid: Ministerio de Educación, Cultura y Deporte.

Santana, S. E., Strait, S., & Dumont, E. R. (2011). The better to eat you with: Functional correlates of tooth structure in bats. *Functional Ecology, 25*(4), 839–847.

Santiago-Marero, CG., Büyükkarakaya, AM., Küçükel, E., Rídký, J. (2025). Microbotanical analyses of dental calculus and caries occurrence at Neolithic Tepecik-Çiftlik, Türkiye: insights into diet and oral health. *Archaeological and Anthropological Sciences,* 17:15 https://doi.org/10.1007/s12520-024-02140-z

Scarascia-Mugnozza, G., Oswald, H., Piussi, P., Radoglou, K., & Dahl-Jensen, D. (2000). Forests of the Mediterranean region: Gaps in knowledge and research needs. *Forest Ecology and Management, 132*, 97–109.

Scheuer, L., & Black, S. (2000). *Developmental juvenile osteology*. Academic Press, London.

Scheuer, L., & Black, S. (2004). *The juvenile skeleton*. Academic Press, London.

Schroeder, L., & Ackermann, R. R. (2023). Moving beyond the adaptationist paradigm for human evolution and why it matters. *Journal of Human Evolution, 174*, 103296.

Schoeninger, M. (1981). The agricultural "revolution": Its effect on human diet in prehistoric Israel and Iran. *Paléorient, 7*(1).

Schoeninger, M. (1982). Diet and the evolution of modern human form in the Near East. *American Journal of Physical Anthropology, 58*, 37–52.

Schultz, A. H. (1960). Age changes in primates and their modification in man. In J. M. Tanner (Ed.), *Human growth* (pp. 1–20). Oxford: Pergamon Press.

Scott, G. R., Turner, C. G. II. (1997). *The anthropology of modern human teeth: Dental morphology and its variations in recent human populations*. Cambridge: Cambridge University Press.

Scott, G. R., Potter, R. H. Y., Noss, J. F., Dahlberg, A. A., & Dahlberg, T. (1983). The dental morphology of Pima Indians. *American Journal of Physical Anthropology, 61*, 13–31.

Scott, R. G., & Turner, C. G. II. (1988). Dental anthropology. *Annual Review of Anthropology, 17*, 99–126.

Scott, R., Ungar, P. S., Bergström, T., Brown, C., Grine, F., Teaford, M., & Walker, A. (2005). Dental microwear texture analysis shows within-species diet variability in fossil hominins. *Nature, 463*, 693–695.

Scott, G. R., Anta, A., Schomberg, R., & de la Rúa, C. (2013). Basque dental morphology and the "Eurodont" dental pattern. In G. R. Scott & J. D. Irish (Eds.), *Anthropological perspectives on tooth morphology* (pp. 296–318). Cambridge University Press.

Scott, G. R., Turner II, C. G., Townsend, G. C., & Martinón-Torres, M. (2018). *The anthropology of modern human teeth: Dental morphology and its variation in recent and fossil Homo sapiens*. Cambridge University Press.

Severinghaus, J. P., & Brook, E. J. (1999). Abrupt climate change at the end of the Last Glacial period inferred from trapped air in polar ice. *Science, 286*, 930–934.

Severinghaus, J. P., Sowers, T., Brook, E. J., Alley, R. B., & Bender, M. L. (1998). Timing of abrupt climate change at the end of the Younger Dryas interval from thermally fractionated gases in polar ice. *Nature, 391*, 141–146.

Şevketoğlu, M. (2006). Cypro-Anatolian relations in the 9th millennium B.C.: Akanthou/Tatlısu Rescue Excavation. *Anatolia, 30*, 119–136.

Şevketoğlu, M. (2008). Early settlements and procurement of raw materials: New evidence based on research at Akanthou-Arkosykos (Tatlısu-Çiftlikdüzü), Northern Cyprus. *TÜBA-AR, XI*, 63–72.

Sheine, W. S., & Kay, R. F. (1977). An analysis of chewed food particle size and its relationship to molar structure in the primates *Cheirogaleus medius* and *Galago senegalensis* and the insectivoran *Tupaia glis*. *American Journal of Physical Anthropology, 47*(1), 15–20.

Sheine, W. S., & Kay, R. F. (1982). A model for comparison of masticatory effectiveness in primates. *Journal of Morphology, 172*(2), 139–149.

Sillen, A. (1984). Dietary change in the Epi-Paleolithic and Neolithic of the Levant: The Sr/Ca evidence. *Paléorient, 10*(1).

Silvana, M., Borgonini, M., & Repetto, B. (1985). Dietary patterns in the Mesolithic samples from Uzzo and Molara caves (Sicily): The evidence of teeth. *Journal of Human Evolution, 14*, 241–254.

Simmons, T., Goring-Morris, N., & Kolska Horwitz, L. (2007). "What ceremony else?" Taphonomy and the ritual treatment of the dead in the Pre-Pottery Neolithic B mortuary complex at Kfar Hahoresh, Israël. In M. Faerman, L. Kolska Horwitz, T. Kahana, & U. Zilberman (Eds.), *Faces from the past: Diachronic patterns in the biology of human populations from the eastern Mediterranean* (pp. 100–126). Oxford: BAR International Series 1603.

Skinner, M. (1996). Developmental stress in immature hominines from Late Pleistocene Eurasia: Evidence from enamel hypoplasia. *Journal of Archaeological Science, 23*, 833–852. https://doi.org/10.1006/jasc.1996.0078

Skinner, M. (1997). Dental wear in immature Late Pleistocene European hominines. *Journal of Archaeological Science, 24*, 677–700.

Skinner, M. M., Gunz, P., Wood, B. A., & Hublin, J. J. (2008). Enamel-dentine junction (EDJ) morphology distinguishes the lower molars of *Australopithecus africanus* and *Paranthropus robustus*. *Journal of Human Evolution, 55*(6), 979–988.

Skinner, M. M., Wood, B. A., & Hublin, J. J. (2009). Protostylid expression at the enamel-dentine junction and enamel surface of mandibular molars of *Paranthropus robustus* and *Australopithecus africanus*. *Journal of Human Evolution, 56*(1), 76–85.

Skinner, M. M., Evans, A., Smith, T., Jernvall, J., Tafforeau, P., Kupczik, K., Olejniczak, A. J., Rosas, A., Radovcić, J., Thackeray, J. F., Toussaint, M., & Hublin, J. J. (2010). Brief communication: Contributions of enamel-dentine junction shape and enamel deposition to primate molar crown complexity. *American Journal of Physical Anthropology, 142*(1), 157–163.

Smith, B. G., & Knight, J. K. (1984). An index for measuring the wear of teeth. *British Dental Journal, 156*(12), 435-438. https://doi.org/10.1038/sj.bdj.4805394

Smith, P. (1972). Diet and attrition in the Natufians. *American Journal of Physical Anthropology, 37*, 233–238.

Smith et al. (1986). Post-Pleistocene changes in tooth root and jaw relationships. *American Journal of Physical Anthropology, 70*, 339–348.

Soltysiak, A. (2007). Reduction of tooth size in the Khabur basin (Northern Mesopotamia).

Sołtysiak, A., & Darabi, H. (2017). Human remains from Ali Kosh, Iran, 2017. *Bioarchaeology of the Near East, 11*, 76–83.

Sołtysiak, A., Schutkowski, H. (2015). Continuity and change in subsistence at Tell Bari, NE Syria. *Journal of Archaeological Science: Reports, 2*, 176–185.

Sołtysiak, A., Wiercińska, A., & Kozłowski, S. K. (2015). Human remains from Nemrik, Iraq: An insight into living conditions and burial customs in a Pre-Pottery Neolithic village. *Paléorient, 41*(2), 101–114. https://doi.org/10.3406/paleo.2015.5678

Sołtysiak, A., & Darabi, H. (2017). Human remains from Ali Kosh, Iran: 2017. *Bioarchaeology of the Near East, 11*(1), 76–83.

Stordeur, D. (1976). Cheikh Hassan 1976, secteur DS. In J. Cauvin (Dir.), *Cahiers de fouilles de Cheikh Hassan 1976, archivés à l'antenne de Jalès* (n.p.).

Stordeur, D. (1989). Vannerie et tissage au Proche-Orient néolithique: IXe-Ve millénaire. In *Tissage, corderie, vannerie: Actes des IXe Rencontres Internationales d'Archéologie et d'Histoire* (Antibes, 20-22 octobre 1988) (Collectif) (pp. 19-39). Juan-les-Pins: Editions APDCA.

Stordeur, D. (1993). Sédentaires et nomades du PPNB final dans le désert de Palmyre (Syrie). *Paléorient, 19*(1), 187-204.

Stordeur, D. (1999). Reprise des fouilles préhistoriques à Cheikh Hassan: Une campagne de reconnaissance. *AAAS, 43*, 59-64.

Stordeur, D. (2000). Jerf El Ahmar et l'émergence du Néolithique au Proche Orient. In J. Guilaine (Ed.), *Premiers paysans du monde: Naissances des agricultures* (pp. 33-60). Paris: Errance.

Stordeur, D. (2003a). Tell Aswad. Résultats préliminaires des campagnes 2001 et 2002. *Neolithics, 1*(03), 7-15.

Stordeur, D. (2003b). Des crânes surmodelés à Tell Aswad de Damascène (PPNB – Syrie). *Paléorient, 29*(2), 109-115.

Stordeur, D., & Abbes, F. (2002). Du PPNA au PPNB: Mise en lumière d'une phase de transition à Jerf el Ahmar (Syrie). *BSPF, 99*(3), 563-595.

Stordeur, D., & Khawam, R. (2007). Les crânes surmodelés de Tell Aswad (PPNB, Syrie). Premier regard sur l'ensemble, premières réflexions. *Syria, 84*, 5-32.

Stordeur, D., & Khawam, R. (2008). Une place pour les morts dans les maisons de Tell Aswad (Syrie). (Horizon PPNB ancien et PPNB moyen). In N. Balken, M. Molist, & D. Stordeur (Eds.), *Workshop I. Houses for the living and a place for the dead: Proceedings of the 5th International Congress on the Archaeology of the Ancient Near East* (Vol. III) (pp. 561-589). Madrid: 3-5 April 2006.

Stordeur, D., & Ibanez, J. J. (2008). Stratigraphie et répartition des architectures de Mureybet. In J. J. Ibanez (Ed.), *Le site néolithique de Tell Mureybet (Syrie du Nord)* (Vol. I, pp. 33-94). Oxford - Lyon: BAR I.S. 1843.

Stordeur, D., & Lebreton, M. (2008). Figurines, pierres à rainures, « petits objets divers » et manches de Mureybet. In J. J. Ibanez (Ed.), *Le site néolithique de Tell Mureybet (Syrie du Nord)* (Vol. II, pp. 619–644). Oxford - Lyon: BAR I.S. 1843.

Stordeur, D., Brene, M., Der Aprahamian, G., & Roux, J.-C. (2001). Les bâtiments communautaires de Jerf El Ahmar et Mureybet horizon PPNA (Syrie). *Paléorient, 26*(1), 29–44.

Stordeur, D., Khawam, R., Jammous, B., & Morero, E. (2006). L'aire funéraire de Tell Aswad (PPNB). *Syria, 83*, 39–62.

Stordeur, D., Helmer, D., Jammous, B., Khawam, R., Molist, M., & Willcox, G. (2010). Le PPNB de Syrie du sud à travers les découvertes récentes à Tell Aswad. In M. Al-Maqdissi, F. Braemer, & J.-M. Dentzer (Eds.), *Hauran V: La Syrie du sud du Néolithique à l'Antiquité tardive: Actes du colloque de Damas (2007)* (pp. 41–68).

Stordeur, D., & Brenet, M. (2014). Les sépultures de Jerf el Ahmar (Syrie, 9500-8700 av. J.-C.). Archéologie des pratiques funéraires. In P. Bodu, L. Chehmana, L. Klaric, L. Mevel, S. Soriano, & N. Teyssandier (Eds.), *Le Paléolithique supérieur ancien de l'Europe du Nord-Ouest* (pp. 657-671). Mémoire de la Société Préhistorique Française.

T

Tanner, J. M. (1990). *Foetus into man: Physical growth from conception to maturity*. Harvard University Press.

Teaford, M. F., & Ungar, P. S. (2000). Diet and the evolution of the earliest human ancestors. *Proceedings of the National Academy of Sciences, 97*, 13506–13511. https://doi.org/10.1073/pnas.26036889

Thesleff, I. (2003). Epithelial-mesenchymal signalling regulating tooth morphogenesis. *Journal of Cell Science, 116*, 1647–1648.

Thiagarajan, N., Subhas, A. V., Southon, J. R., Eiler, J. M., & Adkins, J. (2014). Abrupt pre-Bølling–Allerød warming and circulation changes in the deep ocean. *Nature*. https://doi.org/10.1038/nature13472

Thiery, G., Gillet, G., Lazzari, V., Merceron, G., & Guy, F. (2017). Was *Mesopithecus* a seed-eating colobine? Assessment of cracking, grinding and shearing ability using dental topography. *Journal of Human Evolution, 112*, 79–92.

Thiery, G., Guy, F., & Lazzari, V. (2019). A comparison of relief estimates used in three-dimensional dental topography. *American Journal of Physical Anthropology, 170*, 260–274.

Thomas, H. F. (1995). Root formation. *International Journal of Developmental Biology, 39*, 231–237.

Timiras, P. S. (1972). *Developmental physiology and aging*. Macmillan, New York.

Townsend, G. C., Brown, T. (1981). The Carabelli trait in Australian aboriginal dentition. *Archives of Oral Biology, 26*, 809–814.

Townsend, G., Richards, L. C., Brown, R., & Burgess, V. B. (1988). Twin zygosity determination on the basis of dental morphology. *Journal of Forensic Odonto-Stomatology, 6*, 1–15.

Townsend, G. C., Harris, E. F., Lesot, H., Clauss, F., & Brook, A. (2009a). Morphogenetic fields within the human dentition: A new, clinically relevant synthesis of an old concept. *Archives of Oral Biology, 54*, s34–s44.

Townsend, G., Hughes, T., Luciano, M., Bockman, M., & Brook, A. (2009b). Genetic and environmental influences on human dental variation: A critical evaluation of studies involving twins. *Archives of Oral Biology, 54*(s), s45–s51.

Turner, C. G. II. (1984). Advances in the dental search for Native American origins. *Acta Anthropogenetica, 8*, 23–78.

Turner, C. G. II, Nichol, C. R., & Scout, G. R. (1991). Scoring procedures for key morphological traits of the permanent dentition. The Arizona State University Dental Anthropology System. In M. A. Kelley & C. S. Larsen (Eds.), *Advances in Dental Anthropology* (pp. 13–31). New York: Wiley-Liss.

Turner, C. G. II, & Scott, G. R. (1977). Dentition of the Easter Islanders. In A. A. Dahlberg & T. M. Graber (Eds.), *Orofacial growth and development* (pp. 229–249). The Hague: Mouton.

Turville-Petre, S. (1932). Excavations in the Mugharet el-Kebarah. *Journal of the Royal Anthropology Institute*, 32, 271-276.

U

Ulhaas, L., Kullmer, O., Schrenk, F., & Henke, W. (2004). A new 3-D approach to determine functional morphology of cercopithecoid molars. *Annals of Anatomy, 186*(5-6), 487–493.

Ullinger, J. M., Sheridan, S. G., Hawkey, D. E., Turner, C. G., & Cooley, R. (2005). Bioarchaeological analysis of cultural transition in the southern Levant using dental nonmetric traits. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropology*.

Ungar, P. S., & Williamson, M. D. (2000). Exploring the effects of tooth wear on functional morphology: A preliminary study using dental topographic analysis. *Palaeontologia Electronica, 3*(1), 1–18.

Ungar, P. S., & M'Kirera, F. (2003). A solution to the worn tooth conundrum in primate functional anatomy. *Proceedings of the National Academy of Sciences of the United States of America, 100*(7), 3874–3877.

Ungar, P. (2004). Dental topography and diets of *Australopithecus afarensis* and early *Homo*. *Journal of Human Evolution, 46*(5), 605–622.

Ungar, P. S. (2010). Mammal Teeth: Origin, Evolution, and Diversity. *Johns Hopkins University Press*.

Ungar, P. S., Healy, C., Karme, A., Teaford, M. F., & Fortelius, M. (2018). Dental topography and diets of platyrrhine primates. *Historical Biology, 30*(1-2), 64–75.

V

Valla, F. R. (1988). Aspects du sol de l'abri 131 de Mallaha (Eynan). *Paléorient, 14*(2), 283–296.

Valla, F. R. (2000). La sédentarisation au Proche-Orient: La culture natoufienne. In J. Guilaine (Ed.), *Premiers paysans du monde: Naissance des agricultures* (pp. 13–30). París: Errance.

Valla, F. R. (2003). La tradition natoufienne et les progrès de la Néolithisation au Levant. In B. Vandermeersch (Ed.), *Échanges et diffusion dans la Préhistoire méditerranéenne: Actes des Congrès Nationaux des Sociétés Historiques et Scientifiques, 121e Nice* (pp. 15–27). Paris: Comité des travaux historiques et scientifiques.

Valla, F. R. (2004). Natufian behavior in the Hula Basin: The question of territoriality. In N. Goren-Inbar & J. D. Speth (Eds.), *Human paleoecology in the Levantine corridor* (pp. 207–220). Oxford: Oxbow Books.

Valla, F. & Bocquentin, F. (2008). Les maisons, les vivants, les morts: Le cas de Mallaha (Eynan), Israël. In N. Balken, M. Molist, & D. Stordeur (Eds.), *Workshop I. Houses for the living and a place for the dead: Proceedings of the 5th International Congress on the Archaeology of the Ancient Near East* (Vol. III) (pp. 521–546). Madrid: 3-5 April 2006.

Vallois, H. V. (1936). Les ossements natoufiens de Erq-el-Ahmar (Palestine). *L'Anthropologie*, 46, 529-539.

Vallois, H. V. (1957). Le squelette de fœtus humain fossile d'Antelias. *Quaternaria*, 4, 1-12.

Van Loon, M. N. (1967). The Tabqa reservoir survey 1964. Ladies: DGAM.

Van Loon, M. N. (1968). The Oriental Institute excavations at Mureybit, Syria: Preliminary report on the 1965 campaign. *Journal of Near Eastern Studies, 27*(4), 265–290.

Van Zeist, W., & Bakker-Heeres, J. A. (1982). Archaeobotanical studies in the Levant: I. Neolithic sites in the Damascus basin: Aswad, Ghoraife, Ramad*. Palaeohistoria*, 165-256.

Vigne, J.D. (2000). Les débuts néolithiques de l'élevage des ongulés au Proche-Orient et en Méditerranée: Acquis récents et questions. In J. Guilaine (Ed.), *Premiers paysans du monde: Naissance des agricultures* (pp. 143–168). Paris: Errance.

Vigne, J.D. (2004). *Les origines de la culture: Les débuts de l'élevage*. Paris: Le Collège de la Cité.

Vigne, J.D. (2005). Maitrise et usages de l'élevage et des animaux domestiques au Néolithique: Quelques illustrations au Proche-Orient et en Europe. In J. Guilaine (Ed.), *Populations néolithiques et environnement* (pp. 87–115). Paris: Errance.

Vigne, J.D., & Helmer, D. (2007). Was milk a « secondary product » in the Old World Neolithisation process? Its role in the domestication of cattle, sheep, and goats. *Anthropozoologica, 42*(2), 9–40.

Vigne, J.D., Helmer, D., & Peters, J. (2005). New archaeozoological approaches to trace the first steps of animal domestication: General presentation, reflections, and proposals. In J. D. Vigne, J. Peters, & D. Helmer (Eds.), *The first steps of animal domestication, 9th ICAZ Conference, Durham (2002)* (pp. 1–16).

Von Cramon-Taubadel, N. (2011). Global human mandibular variation reflects differences in agricultural and hunter-gatherer subsistence strategies. *Proceedings of the National Academy of Sciences, 108*(49), 19546–19551.

W

Wang, Q., & Zhang, L. (2020). Analysis of dental morphological variation in contemporary Chinese populations using ASUDAS: Implications for anthropological research. Journal of Human Evolution, 143, 102749. https://doi.org/10.1016/j.jhevol.2020.102749.

Weaver, A. J., Saenko, O. A., Clark, P. U., & Mitrovica, J. X. (2003). Meltwater pulse 1A from Antarctica as a trigger of the Bølling-Allerød warm interval. *Science, 299*, 1709–1713.

Webb, S., & Eduards, P. C. (2002). The Natufian human skeletal remains from Wadi Hammeh 27 (Jordan). *Paléorient*, 28(1), 103-124.

Weinstein-Evron, M. (1991). New radiocarbon dates for the Early Natufian of el-Wad Cave, Mt. Carmel, Israel. *Paléorient, 17*, 95–98.

Weinstein-Evron, M. (1994). Biases in archaeological pollen assemblages: Case studies from Israel. *American Association of Stratigraphic Palynologists Contributions Series, 29*, 193–205.

Weinstein-Evron, M. (1997). The Natufian use of el-Wad Cave, Mount Carmel, Israel. In C. Bonsall & C. Tolan-Smith (Eds.), *The human use of caves* (pp. 155–166). BAR International Series 667. Oxford.

Weinstein-Evron, M. (1998). *Early Natufian el-Wad revisited*. Liège: ERAUL 77.

Weinstein-Evron, M. (2008). Archaeology in the archives: Unveiling the Natufian culture of Mount Carmel. *American School of Prehistoric Research, Monograph Series*. Boston: Brill Inc. (in press).

Weinstein-Evron, M., & Belfer-Cohen, A. (1993). Natufian figurines from the new excavations of the el Wad Cave, Mt Carmel, Israel. *Rock Art Research, 10*, 102–106.

Weinstein-Evron, M., Kaufman, D., & Bird-David, N. (2001). Rolling stones: Basalt implements as evidence for trade/exchange in the Levantine Epipaleolithic. *Journal of the Israel Prehistoric Society, 31*, 25–42.

Weinstein-Evron, M., Lang, B., & Ilani, S. (1999). Natufian trade/exchange in basalt implements: Evidence from northern Israel. *Archaeometry, 41*, 267–273.

Weinstein-Evron, M., & Lev-Yadun, S. (2000). Palaeoecology of *Pinus halepensis* in Israel in the light of palynological and archaeobotanical data. In G. Ne'eman & L. Trabaud (Eds.), *Ecology, biogeography and management of Pinus halepensis and P. brutia forest ecosystems in the Mediterranean Basin* (pp. 119–130). Leiden: Backhuys.

Weinstein-Evron, M., Kaufman, D., Bachrach, N., Bar-Oz, G., Bar-Yosef Mayer, D. E., Chaim, S., ... & Weissbrod, L. I. O. R. (2007). After 70 years: New excavations at the el-Wad Terrace, Mount Carmel, Israel. *Journal of the Israel Prehistoric Society, 37*, 37–134.

Weninger, B. et al. (2006). Climate forcing due to the 8200 cal yr BP event observed at Early Neolithic sites in the eastern Mediterranean. *Quaternary Research, 66*, 401–420.

Weninger, B. et al. (2009). The impact of rapid climate change on prehistoric societies during the Holocene in the Eastern Mediterranean. *Documenta Prehistorica, XXXVI*.

Weninger, B., Clare, L., Rohling, E. J., Bar-Yosef, O., Böhner, U., Budja, M., Bundschuh, M., Feurdean, A., Gebel, H. G., Jöris, O., Linstädter, J., Mayewski, P., Mühlenbruch, T., Reingruber, A., Rollefson, G., Schyle, D., Thissen, L., Todorova, H., & Zielhofer, C. (2009). The impact of rapid climate change on prehistoric societies during the Holocene in the eastern Mediterranean. In M. Budja (Ed.), *16th Neolithic Studies* (pp. 367–459). University of Ljubljana, Ljubljana.

White, D. J. (1997). Dental calculus: Recent insights into occurrence, formation, prevention, removal and oral health effects of supragingival and subgingival deposits. *European Journal of Oral Sciences*.

White, S. N., Paine, M. L., Ngan, A. Y., Miklus, V. G., Luo, W., Wang, H., & Snead, M. L. (2007). Ectopic expression of dentin sialoprotein during amelogenesis hardens bulk enamel. *Journal of Biological Chemistry, 282*, 5340–5345.

Willcox, G. (1996). Evidence for plant exploitation and vegetation history from three Early Neolithic pre-pottery sites on the Euphrates (Syria). *Vegetation History and Archaeobotany, 5*(1), 143–152.

Willcox, G. (2002). Charred plant remains from a 10th millennium BP kitchen at Jerf el Ahmar (Syria). *Vegetation History and Archaeobotany, 11*(1), 55–60.

Willcox, G., & Català, M. (1996). Análisis paleobotánico. In M. Molist (Ed.), *Tell Halula (Siria). Un yacimiento neolítico del valle medio del Eufrates: Campañas de 1991 y 1992* (pp. 135–142). Madrid: Ministerio de Educación y Cultura.

Willcox, G., & Fornite, S. (1999). Impressions of wild cereal chaff in pisé from the 10th millennium uncal BP at Jerf et Ahmar and Mureybet: Northern Syria. *Vegetation History and Archaeobotany, 8*(1), 21–24.

Willcox, G. (2000). Nouvelles données sur l'origine de la domestication des plantes au Proche-Orient. In J. Guilaine (Ed.), *Premiers paysans du monde: Naissances des agricultures* (pp. 123–139). Paris: Errance.

Willcox, G., Fornite, S., & Herveux, L. (2008). Early Holocene cultivation before domestication in northern Syria. *Vegetation History and Archaeobotany, 17*(3), 313–325.

Willcox, G., Buxo, R., & Herveux, L. (2009). Late Pleistocene and early Holocene climate and the beginnings of cultivation in northern Syria. *The Holocene, 19*(1), 151–158.

Willcox, G., & Savard, M. (2011). Botanical evidence for the adoption of cultivation in southeast Turkey. In M. Özdogan, N. Başgelen, & P. Kuniholm (Eds.), *The Neolithic in Turkey, new excavations and new research, 2: The Euphrates Basin* (pp. 267–280). Estambul: Archaeology and Art Publications.

Willcox, G., & Stordeur, D. (2012). Large-scale cereal processing before domestication during the tenth millennium cal BC in northern Syria. *Antiquity, 86*(331), 99–114.

Winchester, J. M. (2016). MorphoTester: An open source application for morphological topographic analysis. *PLOS ONE, 11*(2), e0147649.

Winchester, J. M., Boyer, D. M., St Clair, E. M., Gosselin-Ildari, A. D., Cooke, S. B., & Le-Dogar, J. A. (2014). Dental topography of platyrrhines and prosimians: Convergence and contrasts. *American Journal of Physical Anthropology, 153*, 29–44.

Woelfel, J. B. (1990). *Dental anatomy: Its relevance to dentistry*. Lea & Febiger, Philadelphia.

Wood, L. (1996). Frequency and chronological distribution of linear enamel hypoplasia in a North American colonial skeletal sample. *American Journal of Physical Anthropology, 100*, 247–259.

Wright, K. (1993). Early Holocene ground stone assemblages in the Levant. *Levant, 25*, 93–111.

Wright, K. I. (1994). Ground-stone tools and hunter-gatherer subsistence in Southwest Asia: Implications for the transition to farming. *American Antiquity, 59*, 238–263.

Y

Yaka, R. (2020). Archaeogenomic analysis of population genetic relationships and kinship patterns in the sedentary societies from Neolithic Anatolia (Doctoral dissertation). *Middle East Technical University, Graduate School of Natural and Applied Sciences.*

Yamashita, N. (1996). Seasonality and site specificity of mechanical dietary patterns in two Malagasy lemur families (*Lemuridae* and *Indriidae*). *International Journal of Primatology, 17*, 35–387.

Yamashita, N. (1998). Functional dental correlates of food properties in five Malagasy lemur species. *American Journal of Physical Anthropology, 106*, 169–188.

Yamashita, N. (2002). Diets of two lemur species in different microhabitats in Beza Mahafaly Special Reserve, Madagascar. *International Journal of Primatology, 23*, 1025–1051.

Yamashita, N., Igarashi, Y., & Ai, M. (2003). Tooth contacts at the mandibular retruded position: Influence of operator's skill on bite registration. *Journal of Oral Rehabilitation, 30*, 318–323.

Yamashita, N., Vinyard, C. J., & Tan, C. L. (2009). Food mechanical properties in three sympatric species of *Hapalemur* in Ranomafana National Park, Madagascar. *American Journal of Physical Anthropology, 139*, 368–381.

Yang, S., Martínez, L. M., Romero, A., Carrascal, S., Guo, J., Dyowe, AE,. Zhang, Q., Pérez-Pérez, A. (2024). Rethinking wear rate analysis: A new dentin exposure proxy and its applications to ancient Chinese populations. *Journal of Archaeological Method and Theory, 31*, 2053–2081. https://doi.org/10.1007/s10816-024-09664-7

Yilmaz, Y. (2010). Les pratiques funéraires des populations néolithiques d'Anatolie: Le cas de Çayönü. *Thèse de doctorat, Bordeaux et Istanbul*: Université de Bordeaux 1 et Université d'Istanbul.

y'Edynak, G. (1989). Yugoslav Mesolithic dental reduction. *American Journal of Physical Anthropology, 78*, 17–36.

y'Edynak, G., & Fleisch, S. (1983). Microevolution and biological adaptability in the transition from food-collecting to food-producing in the Iron Gates of Yugoslavia. *Journal of Human Evolution, 12*, 279–296.

Z

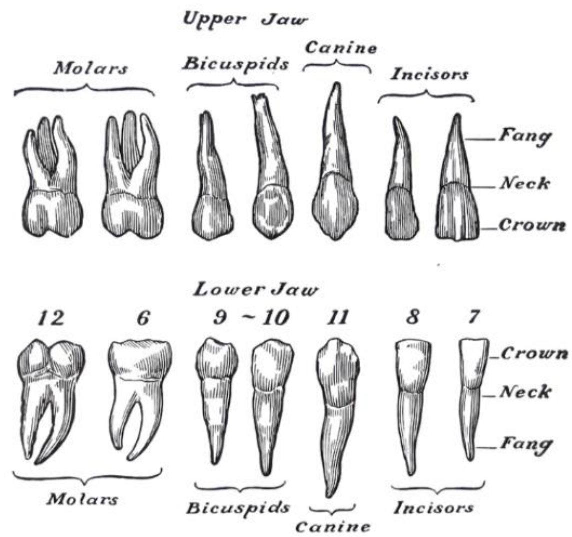
Zalloua, P. A., & Matisoo-Smith, E. (2017). Mapping post-glacial expansions: The peopling of Southwest Asia. *Scientific Reports, 7,* 40338. https://doi.org/10.1038/srep40338

Zeder, M. (2005). A view from the Zagros: New perspectives on livestock domestication in the Fertile Crescent. In J.-D. Vigne, J. Peters, & D. Helmer (Eds.), *The first steps of animal domestication: New archaeological approaches* (pp. 125–146). Oxford: Oxbow Books.

Zeder, M. A. (2011). The origins of agriculture in the Near East. *Current Anthropology, 52*(4), S221.

Zoubov, A. A. (1998). La antropología dental y la práctica forense. *Maguaré, 13*, 243–252.

Zuccotti, L. F., Williamson, M. D., Limp, W. F., & Ungar, P. S. (1998). Technical note: Modeling primate occlusal topography using geographic information systems technology. *American Journal of Physical Anthropology, 107*(1), 137–142.


Upper Jaw
Molars
Bicuspids
Canine
Incisors
Fang
Neck
Crown
Lower Jaw
12
6
9 ~ 10
11
8
7
Crown
Neck
Fang
Molars
Bicuspids
Canine
Incisors

ANNEXES

11. ANNEXES

ANNEX 1.

In the following pages you will find the principal database used in this study.

ID	SITE	PERIOD	TOOTH	JAW
AH Ph 9 Tr E	Abu Hureyra	PPNB	C	max
AH Ph 9 Tr E	Abu Hureyra	PPNB	P3	max
AH Ph 9 Tr E	Abu Hureyra	PPNB	P4	max
AH Ph 9 Tr E	Abu Hureyra	PPNB	M1	max
AH Ph 9 Tr E	Abu Hureyra	PPNB	M2	max
AH E PH 9	Abu Hureyra	PPNB	M1	man
AH PH 8 TR B	Abu Hureyra	PPNB	P3	man
AH PH 8 TR B	Abu Hureyra	PPNB	P4	man
AH PH 8 TR B	Abu Hureyra	PPNB	M1	man
AH PH 8 TR B	Abu Hureyra	PPNB	M2	man
AH PH 9 TE E	Abu Hureyra	PPNB	M1	man
AH TR E	Abu Hureyra	PPNB	P3	man
AH TR D	Abu Hureyra	PPNB	I1	max
AH TR D	Abu Hureyra	PPNB	M1	man
AH TR D	Abu Hureyra	PPNB	M1	max
AH TR D	Abu Hureyra	PPNB	M1	man
Ah Tr B	Abu Hureyra	PPNB	M1	man
AH PH8 TR B	Abu Hureyra	PPNB	P3	man
AH PH8 TR B	Abu Hureyra	PPNB	P4	man
AH PH8 TR B	Abu Hureyra	PPNB	M1	man
AH PH8 TR B	Abu Hureyra	PPNB	M2	man
AH PH8 TR B	Abu Hureyra	PPNB	M3	man
AH TR B	Abu Hureyra	PPNB	M2	man
AH TR B	Abu Hureyra	PPNB	M3	man
AH PH 7 TR E	Abu Hureyra	PPNB	M1	max
AH TR B	Abu Hureyra	PPNB	M2	man
AH TR E PH 9	Abu Hureyra	PPNB	P4	man
AH TR E PH 9	Abu Hureyra	PPNB	M1	man
AH PH5 TR E	Abu Hureyra	PPNB	M1	man
AH PH9 TR B	Abu Hureyra	PPNB	P3	man
AH PH9 TR B	Abu Hureyra	PPNB	P4	man
Ah ¿?	Abu Hureyra	PPNB	P3	man
AH PH TR E	Abu Hureyra	PPNB	P3	man
AH PH TR E	Abu Hureyra	PPNB	P4	man
AH PH TR E	Abu Hureyra	PPNB	M1	man
AH PH TR E	Abu Hureyra	PPNB	M2	man
AH PH TR E	Abu Hureyra	PPNB	M3	man
AH TR B	Abu Hureyra	PPNB	P3	man
AH Ph 9 Tr E	Abu Hureyra	PPNB	P3	man
Ah Tr B	Abu Hureyra	PPNB	M1	man
AH TR B	Abu Hureyra	PPNB	M3	max
Ah Tr B	Abu Hureyra	PPNB	I1	max
AH TR B	Abu Hureyra	PPNB	M1	max
AH TR B	Abu Hureyra	PPNB	P3	man
AH Tr B C UL	Abu Hureyra	PPNB	C	max
AH TR E PH 7	Abu Hureyra	PPNB	M1	man
AH TR E PH 10	Abu Hureyra	PPNB	M1	man
AH Tr D	Abu Hureyra	PPNB	M1	max
AH TR	Abu Hureyra	PPNB	P3	man
AH Tr C Ph 2A	Abu Hureyra	PPNB	C	max
AH TR C PH 2A	Abu Hureyra	PPNB	P4	man
AH Tr C Ph 2A	Abu Hureyra	PPNB	P4	max
AH TR C PH 2A	Abu Hureyra	PPNB	M3	max
AH TR E3 PH 8	Abu Hureyra	PPNB	M1	max
AH E PH 5	Abu Hureyra	PPNB	M1	max
AH TR D	Abu Hureyra	PPNB	M1	max
AH TR B PH 8	Abu Hureyra	PPNB	M2	man
AH TR E PH 6	Abu Hureyra	PPNB	M2	man
-	Abu Hureyra	PPNB	M1	man
AH WCG 65-6	Abu Hureyra	PPNB	M1	man
AH WCG 65-66	Abu Hureyra	PPNB	P4	man
AH TR E PH8	Abu Hureyra	PPNB	P4	max
AH TR E PH8	Abu Hureyra	PPNB	M1	max
AH Tr E Ph 9	Abu Hureyra	PPNB	M1	max
AH TR E PH8	Abu Hureyra	PPNB	I1	max
AH TR E PH8	Abu Hureyra	PPNB	M1	man
AH TR E PH8	Abu Hureyra	PPNB	P4	man
DJ 96 D SqM 14/10	D jade	PPNB	m1 dec	man
DJ 96 D SqM 14/10	D jade	PPNB	m2 dec	man
DJ 96 D SqM 14/10	D jade	PPNB	m1 dec	man
DJ 96 D SqM 14/10	D jade	PPNB	m2 dec	man
D.J S-180 Dj00 J C U	D jade	PPNB	C	max
DJS 180 DJ 00J	D jade	PPNB	P3	man
D.J S- 180 Dj00 J ¿??	D jade	PPNB	C/I?	man
DJ 01 A Structure 308	D jade	PPNB	M2	max
DJ 01 A Structure 308	D jade	PPNB	m1 dec	max
DJ 01 A Structure 308	D jade	PPNB	M1	max
DJ 03 BW 7-10 n 597	D jade	PPNB	m1 dec	max
-	D jade	PPNB	m1 dec	max
DJ 03 BW 7-10 n 597	D jade	PPNB	M2	max

DJ 03 BW 7-10 n 597	D jade	PPNB	M1	max
DJ 00 SQD CCLXXXIII	D jade	PPNB	M3	man
DJ 00 SQD CCLXXXIII	D jade	PPNB	M2	man
DJ 00 SQD CCLXXXIII	D jade	PPNB	M1	max
DJ 00 SQD CCLXXXIII	D jade	PPNB	M1	man
DJ 00 SqD CCLXXXIII Om3	D jade	PPNB	P4	man
D.J 00 SqD CCLXXXIII C	D jade	PPNB	C	man
DJ 00 SqD CCLXXXIII	D jade	PPNB	P3	man
DJ 00 SQD CCLXXXIII	D jade	PPNB	M1	max
DJ 07 Structure 550 sep 16	D jade	PPNB	M1	man
DJ 07 Structure 550 sep 16	D jade	PPNB	M2	man
DJ 07 Structure 550 sep 16	D jade	PPNB	M1	man
DJ 07 Structure 550 sep 16	D jade	PPNB	M2	man
DJ 07 Structure 550 sep 16	D jade	PPNB	P4	man
DJ F2d CXXVII Sp A Dj 95	D jade	PPNB	M1	man
DJ 00 A Fosse DC. W 2/4	D jade	PPNB	m1 dec	man
DJ 00 A Fosse DC. W 2/4	D jade	PPNB	m1 dec	max
DJ 97 D CLV (2209) 362 M2 LL	D jade	PPNB	M2	man
DJ S-180 crane G caja 4 2000	D jade	PPNB	M1	man
DJ S-180 crane G caja 4 2000	D jade	PPNB	P4	man
DJ S-180 crane G caja 4 2000	D jade	PPNB	M1	man
DJ SQN	D jade	PPNB	m1 dec	max
DJ SQN	D jade	PPNB	m1 dec	man
DJ SQN	D jade	PPNB	m2 dec	man
DJ SQN	D jade	PPNB	m1 dec	man
DJ SQN	D jade	PPNB	m2 dec	man

DJ 01 STRUCTURE 550 CRANE 8	D jade	PPNB	P3	max
DJ 01 STRUCTURE 550 CRANE 8	D jade	PPNB	P4	max
DJ 01 STRUCTURE 550 CRANE 8	D jade	PPNB	M1	max
DJ 01 structure 550 crane 8	D jade	PPNB	M2	max
DJ 01 structure 550 crane 8	D jade	PPNB	M3	max
DJ 01 STRUCTURE 550 CRANE 8	D jade	PPNB	M1	man
DJ 01 STRUCTURE 550 CRANE 8	D jade	PPNB	P4	man
D. J 01 structure 550 crane 8 inci	D jade	PPNB	I1	max
DJ 01 STRUCTURE 550 CRANE 8	D jade	PPNB	M1	man
DJ 01 STRUCTURE 550 CRANE 8	D jade	PPNB	M2	man
DJ 01 structure 550 crane 8	D jade	PPNB	P4	max
DJ 01 STRUCTURE 550 CRANE 8	D jade	PPNB	P4	man
D.J 01 structure 550 crane 8 Ca	D jade	PPNB	I1	max
DJ 01 structure 550 crane 8	D jade	PPNB	C	man
D.J 01 structure 550 crane 8 I-C	D jade	PPNB	I2	man
D.J 01 structure 550 crane 8 I-C	D jade	PPNB	C	man
DJ 99 crane D Sep CLXXX	D jade	PPNB	P3	man
DJ 99 crane D Sep CLXXX	D jade	PPNB	P4	man
DJ 07 A ST SEP 350	D jade	PPNB	M1	man
D.J 07 A ST sep 350 I1-I2 UR	D jade	PPNB	I1	max
D.J 07 A ST sep 350 I1-I2 UR	D jade	PPNB	I2	max
DJ 07 A ST SEP 350	D jade	PPNB	M1	max
-	D jade	PPNB	M1	max
D.J 350 Man n 242 inc dec	D jade	PPNB	I1	man

D.J 350 Man n 242 C	D jade	PPNB	C	man
DJ 350 Man n 242	D jade	PPNB	m1dec	man
-	D jade	PPNB	m1 dec	man
-	D jade	PPNB	m2 dec	man
DJ 350 Man n 242	D jade	PPNB	m1 dec	man
-	D jade	PPNB	m1 dec	man
DJ 350 Man n 242	D jade	PPNB	M1	man
-	D jade	PPNB	M1	man
D.J 350 Man n 242 C	D jade	PPNB	C	man
D.J 00-10 I1	D jade	PPNB	I1	max
D.J 00-10l lower	D jade	PPNB	I1	man
Dj 00-10	D jade	PPNB	P3	max
Dj 00-10	D jade	PPNB	P4	max
Dj 00-10	D jade	PPNB	P4	max
DJ 00-10	D jade	PPNB	P3	max
Dj 00-10	D jade	PPNB	M1	max
DJ 99 W1 CRANE D	D jade	PPNB	M2	man
DJ 99 W1 CRANE D	D jade	PPNB	M1	man
DJ 99 W1 CRANE D	D jade	PPNB	M1	man
DJ 99 W1 CRANE D	D jade	PPNB	M2	man
D.J 02 8/10 ST W01 ST 413 C	D jade	PPNB	C	max
D.J 02 8/10 ST W01 ST 413 I	D jade	PPNB	I2?	max?
D.J 02 8/10 ST W01 ST 413 I U1	D jade	PPNB	I1	max
D.J 02 8/10 ST W01 ST 413 I U1	D jade	PPNB	I1	max
DJ 97 CAJA MODEL	D jade	PPNB	M1	max
DJ 02 8/10 ST W01 ST 413	D jade	PPNB	P4	man
-	D jade	PPNB	P4	man
-	D jade	PPNB	M1	max
DJ 02 8/10 ST W01 ST 413	D jade	PPNB	M1	man
D. J 97 caja model incisors	D jade	PPNB	I1	man?
D. J 97 caja model incisors	D jade	PPNB	I2	man?
D. J 97 caja model incisors	D jade	PPNB	I1	man?
-	D jade	PPNB	M1	man
DJ 02 8/10 ST W01 ST 413	D jade	PPNB	M1	man
DJ 97 CAJA MODEL	D jade	PPNB	M1	man
DJ 97 CAJA MODEL	D jade	PPNB	M2	man
DJ 02 8/10 ST W01 ST 413	D jade	PPNB	M2	man
-	D jade	PPNB	M1	man
DJ 02 8/10 ST W01 ST 413 not the same ind	D jade	PPNB	m2 dec	man
DJ 97 CAJA MODEL	D jade	PPNB	P4	man
DJ 97 CAJA MODEL	D jade	PPNB	M1	man
-	D jade	PPNB	M1	man
DJ 97 CAJA MODEL	D jade	PPNB	P3	man
D. J 97 caja model P4	D jade	PPNB	P4	-
D. J 97 caja model incis	D jade	PPNB	I1	man
D. J 97 caja model incis	D jade	PPNB	I2	man
D. J 97 caja model incis	D jade	PPNB	C	man
D. J 97 caja model canian	D jade	PPNB	C	man?
DJ 01 ST 350 H4 (A) 443	D jade	PPNB	P4	man
DJ 01 ST 350 H4 (A) 443	D jade	PPNB	M1	man
DJ 01 ST 350 H4 (A) 443	D jade	PPNB	M2	man
DJ 01 ST 350 H4 (A) 443	D jade	PPNB	M3	man
DJ 01 ST 350 H4 (A) 443	D jade	PPNB	M1	man
DJ 01 ST 350 H4 (A) 443	D jade	PPNB	M2	man
DJ 01 ST 350 H4 (A) 443	D jade	PPNB	M3	man
DJ 01 ST 350 H4 (A) 443	D jade	PPNB	M1	max
DJ 01 ST 350 H4 (A) 443	D jade	PPNB	M3	max
DJ 01 ST 350 H4 (A) 443	D jade	PPNB	P3	man

E128.2ELWAD	El wad	Natufian	M1	man
E128.2ELWAD	El wad	Natufian	M2	man
E128.2ELWAD	El wad	Natufian	M3	man
E133ELWAD	El wad	Natufian	I2	man
E133ELWAD	El wad	Natufian	C	man
E133ELWAD	El wad	Natufian	P3	man
E133ELWAD	El wad	Natufian	P4	man
E134ELWAD	El wad	Natufian	P3	man
E134ELWAD	El wad	Natufian	P4	man
E134ELWAD	El wad	Natufian	M1	man
E134ELWAD	El wad	Natufian	M2	man
E135ELWAD	El wad	Natufian	P4	man
E135ELWAD	El wad	Natufian	M1	man
E135ELWAD	El wad	Natufian	M2	man
E135ELWAD	El wad	Natufian	M3	man
E136ELWAD	El wad	Natufian	M1	man
E136ELWAD	El wad	Natufian	M2	man
E137ELWAD	El wad	Natufian	P4	man
E137ELWAD	El wad	Natufian	M1	man
E137ELWAD	El wad	Natufian	M2	man
E138ELWAD	El wad	Natufian	P4	man
E138ELWAD	El wad	Natufian	M1	man
E138ELWAD	El wad	Natufian	M2	man
E138ELWAD	El wad	Natufian	M3	man
E139ELWAD	El wad	Natufian	M1	man
E139ELWAD	El wad	Natufian	M2	man
E140ELWAD	El wad	Natufian	I2	man
E140ELWAD	El wad	Natufian	C	man
E140ELWAD	El wad	Natufian	P3	man
E140ELWAD	El wad	Natufian	P4	man
E140ELWAD	El wad	Natufian	M1	man
E140ELWAD	El wad	Natufian	M2	man
E141.1ELWAD	El wad	Natufian	C	man
E141.1ELWAD	El wad	Natufian	P3	man
E141.1ELWAD	El wad	Natufian	P4	man
E141.1ELWAD	El wad	Natufian	M1	man
E141.1ELWAD	El wad	Natufian	M2	man
E141.1ELWAD	El wad	Natufian	M3	man
E141.2ELWAD	El wad	Natufian	I1	max
E141.2ELWAD	El wad	Natufian	I1	max
E141.2ELWAD	El wad	Natufian	I2	max
E141.2ELWAD	El wad	Natufian	C	max
E141.2ELWAD	El wad	Natufian	P3	max
E141.2ELWAD	El wad	Natufian	P4	max
E141.2ELWAD	El wad	Natufian	M1	max
E142ELWAD	El wad	Natufian	I2	man
E142ELWAD	El wad	Natufian	C	man
E142ELWAD	El wad	Natufian	P3	man
E142ELWAD	El wad	Natufian	P4	man
E142ELWAD	El wad	Natufian	M1	man
E142ELWAD	El wad	Natufian	M2	man
E142ELWAD	El wad	Natufian	M3	man
E143ELWAD	El wad	Natufian	M1	man
E143ELWAD	El wad	Natufian	M2	man
E143ELWAD	El wad	Natufian	M3	man
E144ELWAD	El wad	Natufian	C	max
E144ELWAD	El wad	Natufian	P3	max
E144ELWAD	El wad	Natufian	P4	max
E144ELWAD	El wad	Natufian	M1	max
E144ELWAD	El wad	Natufian	M2	max
E144ELWAD	El wad	Natufian	M3	max
E145ELWAD	El wad	Natufian	C	man
E145ELWAD	El wad	Natufian	P3	man
E145ELWAD	El wad	Natufian	P4	man
E145ELWAD	El wad	Natufian	M1	man
E145ELWAD	El wad	Natufian	M2	man
E145ELWAD	El wad	Natufian	M3	man
E146ELWAD	El wad	Natufian	P3	max
E146ELWAD	El wad	Natufian	P4	max
E146ELWAD	El wad	Natufian	M1	max
E147ELWAD	El wad	Natufian	I1	man
E147ELWAD	El wad	Natufian	I2	man
E147ELWAD	El wad	Natufian	C	man
E147ELWAD	El wad	Natufian	P3	man
E147ELWAD	El wad	Natufian	P4	man
E147ELWAD	El wad	Natufian	M1	man
E147ELWAD	El wad	Natufian	M1	man
E148ELWAD	El wad	Natufian	P4	man
E148ELWAD	El wad	Natufian	M1	man
E148ELWAD	El wad	Natufian	M2	man
E150ELWAD	El wad	Natufian	C	man
E150ELWAD	El wad	Natufian	P3	man
E150ELWAD	El wad	Natufian	P4	man
E150ELWAD	El wad	Natufian	M1	man
E150ELWAD	El wad	Natufian	M2	man
E150ELWAD	El wad	Natufian	M3	man
E151.1ELWAD	El wad	Natufian	I2	man
E151.1ELWAD	El wad	Natufian	C	man
E151.1ELWAD	El wad	Natufian	P3	man
E151.2ELWAD	El wad	Natufian	I1	man

E151.2ELWAD	El wad	Natufian	I2	man
E151.2ELWAD	El wad	Natufian	C	man
E151.2ELWAD	El wad	Natufian	P3	man
E151.3ELWAD	El wad	Natufian	M1	man
E151.3ELWAD	El wad	Natufian	M2	man
E151.4ELWAD	El wad	Natufian	M1	man
E151.4ELWAD	El wad	Natufian	M2	man
E152ELWAD	El wad	Natufian	I2	man
E152ELWAD	El wad	Natufian	C	man
E152ELWAD	El wad	Natufian	P3	man
E152ELWAD	El wad	Natufian	P4	man
E152ELWAD	El wad	Natufian	M1	man
E152ELWAD	El wad	Natufian	M2	man
E152ELWAD	El wad	Natufian	M3	man
E 153.1ELWAD	El wad	Natufian	P4	man
E 153.1ELWAD	El wad	Natufian	M1	man
E 153.1ELWAD	El wad	Natufian	M2	man
E 153.1ELWAD	El wad	Natufian	M3	man
E 153.2ELWAD	El wad	Natufian	P4	man
E 153.2ELWAD	El wad	Natufian	M1	man
E 153.2ELWAD	El wad	Natufian	M2	man
E 153.2ELWAD	El wad	Natufian	M3	man
E 149 EL WAD	El wad	Natufian	I1	man
E 149 EL WAD	El wad	Natufian	I2	man
E 149 EL WAD	El wad	Natufian	C	man
E 149 EL WAD	El wad	Natufian	P3	man
E 149 EL WAD	El wad	Natufian	P4	man
E 149 EL WAD	El wad	Natufian	M1	man
E 149 EL WAD	El wad	Natufian	M2	man
E 149 EL WAD	El wad	Natufian	M3	man
E 149 EL WAD	El wad	Natufian	I1	man
E 149 EL WAD	El wad	Natufian	I2	man
E 149 EL WAD	El wad	Natufian	C	man
E 149 EL WAD	El wad	Natufian	P3	man
E 149 EL WAD	El wad	Natufian	P4	man
E 149 EL WAD	El wad	Natufian	M1	man
E 149 EL WAD	El wad	Natufian	M2	man
E 149 EL WAD	El wad	Natufian	M3	man
JF 97 15 g	Jerf Ahmar	PPNA	M1	max
JF 97 15 g	Jerf Ahmar	PPNA	P3	max
JF 97 14/og	Jerf Ahmar	PPNA	M2	max
JF 97 A5	Jerf Ahmar	PPNA	M2	max
JF 13-9-97 carre 135	Jerf Ahmar	PPNA	M1	max
JF 97 11/9	Jerf Ahmar	PPNA	M2	max
JF 95	Jerf Ahmar	PPNA	P3	max
JF 95	Jerf Ahmar	PPNA	P4	max
JF 99 14/06 k 90	Jerf Ahmar	PPNA	P3	man
JF 99 14/06 k 90	Jerf Ahmar	PPNA	P4	man
JF 99 14/06 k 90	Jerf Ahmar	PPNA	M1	man
JF 99 14/06 k 90	Jerf Ahmar	PPNA	M2	man
JF 99 14/06 k 90	Jerf Ahmar	PPNA	M3	man
JF 98 K90 01/10	Jerf Ahmar	PPNA	P3	max
JF 98 K90 01/10	Jerf Ahmar	PPNA	P4	max
JF 98 K90 01/10	Jerf Ahmar	PPNA	M1	max
E 180 upper PB 053	Kebara	Natufian	I1	max
E 180 upper PB 053	Kebara	Natufian	I2	max
E 180 upper PB 053	Kebara	Natufian	C	max
E 180 upper PB 053	Kebara	Natufian	P3	max
E 180 upper PB 053	Kebara	Natufian	P4	max
E 180 upper PB 053	Kebara	Natufian	M1	max
E 180 upper PB 053	Kebara	Natufian	M2	max
E 180 upper PB 052	Kebara	Natufian	I1	max
E 180 upper PB 053	Kebara	Natufian	I2	max
E 180 upper PB 053	Kebara	Natufian	C	max
E 180 upper PB 053	Kebara	Natufian	P3	max
E 180 upper PB 053	Kebara	Natufian	P4	max
E 180 upper PB 053	Kebara	Natufian	M1	max
E 180 upper PB 053	Kebara	Natufian	M2	max
E 180 upper PB 053	Kebara	Natufian	M3	max
E 182 Kebara PB-055	Kebara	Natufian	I1	max
E 182 Kebara PB-055	Kebara	Natufian	C	max
E 182 Kebara PB-055	Kebara	Natufian	P3	max
E 182 Kebara PB-055	Kebara	Natufian	P4	max
E 182 Kebara PB-055	Kebara	Natufian	M1	max
E 182 Kebara PB-055	Kebara	Natufian	M2	max
E 182 Kebara PB-055	Kebara	Natufian	M3	max
E 121	Kebara	Natufian	C	max
E 121	Kebara	Natufian	P3	max
E 121	Kebara	Natufian	P4	max
E 120	Kebara	Natufian	I1	man
E 120	Kebara	Natufian	I1	man
E 120	Kebara	Natufian	I2	man
E 120	Kebara	Natufian	C	man
E 169	Kebara	Natufian	m1	man
E 169	Kebara	Natufian	m2	man
E 169	Kebara	Natufian	M1	man
E 169	Kebara	Natufian	m1	man
E 169	Kebara	Natufian	m2	man
E 169	Kebara	Natufian	M1	man
E 170 PB-043	Kebara	Natufian	M1	max

E 171	Kebara	Natufian	I1	man
E 171	Kebara	Natufian	I2	man
E 171	Kebara	Natufian	C	man
E 171	Kebara	Natufian	m1	man
E 171	Kebara	Natufian	m2	man
E 171	Kebara	Natufian	M1	man
E 171	Kebara	Natufian	I1	man
E 171	Kebara	Natufian	I2	man
E 171	Kebara	Natufian	m1	man
E 171	Kebara	Natufian	m2	man
E 171	Kebara	Natufian	M1	man
E 171	Kebara	Natufian	M2	man
E 177.1 Kebara PB-050	Kebara	Natufian	C	max
E 177.1 Kebara PB-050	Kebara	Natufian	P3	max
E 177.1 Kebara PB-050	Kebara	Natufian	P4	max
E 177.1 Kebara PB-050	Kebara	Natufian	M1	max
E 177.1 Kebara PB-050	Kebara	Natufian	M2	max
E 177.1 Kebara PB-050	Kebara	Natufian	M3	max
E 177.2 Kebara PB-050	Kebara	Natufian	I2	max
E 177.2 Kebara PB-050	Kebara	Natufian	C	max
E 177.2 Kebara PB-050	Kebara	Natufian	P3	max
E 177.2 Kebara PB-050	Kebara	Natufian	P4	max
E 177.2 Kebara PB-050	Kebara	Natufian	M1	max
E 177.2 Kebara PB-050	Kebara	Natufian	M2	max
E 177.2 Kebara PB-050	Kebara	Natufian	M3	max
E 177.3 Kebara PB-050	Kebara	Natufian	M1	man
E 177.3 Kebara PB-050	Kebara	Natufian	M2	man
E 177.3 Kebara PB-050	Kebara	Natufian	M3	man
E 177.4 Kebara PB-050	Kebara	Natufian	I2	man
E 177.4 Kebara PB-050	Kebara	Natufian	C	man
E 177.4 Kebara PB-050	Kebara	Natufian	P3	man
E 177.4 Kebara PB-050	Kebara	Natufian	P4	man
E 177.5 Kebara PB-050	Kebara	Natufian	P4	man
E 177.5 Kebara PB-050	Kebara	Natufian	M1	man
E 177.5 Kebara PB-050	Kebara	Natufian	M2	man
E 177.5 Kebara PB-050	Kebara	Natufian	M3	man
E 178.1 Kebara PB-051	Kebara	Natufian	C	max
E 178.1 Kebara PB-051	Kebara	Natufian	P3	max
E 178.1 Kebara PB-051	Kebara	Natufian	P4	max
E 178.1 Kebara PB-051	Kebara	Natufian	M1	max
E 178.1 Kebara PB-051	Kebara	Natufian	M2	max
E 178.1 Kebara PB-051	Kebara	Natufian	M3	max
E 178.2 Kebara PB-051	Kebara	Natufian	P3	man
E 178.2 Kebara PB-051	Kebara	Natufian	P4	man
E 178.2 Kebara PB-051	Kebara	Natufian	M1	man
E 178.2 Kebara PB-051	Kebara	Natufian	M2	man
E 178.2 Kebara PB-051	Kebara	Natufian	M3	man
E 179.1 Kebara PB-052	Kebara	Natufian	C	max
E 179.1 Kebara PB-052	Kebara	Natufian	P3	max
E 179.1 Kebara PB-052	Kebara	Natufian	P4	max

E 179.1 Kebara PB-052	Kebara	Natufian	M1	max
E 179.1 Kebara PB-052	Kebara	Natufian	M2	max
E 179.1 Kebara PB-052	Kebara	Natufian	M3	max
E 179.2 Kebara PB-052	Kebara	Natufian	I1	man
E 179.2 Kebara PB-052	Kebara	Natufian	I2	man
E 179.2 Kebara PB-052	Kebara	Natufian	C	man
E 179.2 Kebara PB-052	Kebara	Natufian	P3	man
E 179.2 Kebara PB-052	Kebara	Natufian	P4	man
E 179.2 Kebara PB-052	Kebara	Natufian	M1	man
E 179.2 Kebara PB-052	Kebara	Natufian	M2	man
E 179.2 Kebara PB-052	Kebara	Natufian	M3	man
E 179.3 Kebara	Kebara	Natufian	P4	man
E 179.3 Kebara	Kebara	Natufian	M1	man
E 179.3 Kebara	Kebara	Natufian	M2	man
E 179.3 Kebara	Kebara	Natufian	M3	man
E 181.1 Kebara PB 053	Kebara	Natufian	M1	man
E 181.2 Kebara PB 053	Kebara	Natufian	P3	man
E 183.1 PB-056	Shukba	Natufian	m1 dec	max
E 183.1 PB-056	Shukba	Natufian	m2 dec	max
E 183.1 PB-056	Shukba	Natufian	M1	max
E 183.2 PB-056	Shukba	Natufian	C	man
E 183.2 PB-056	Shukba	Natufian	m1 dec	man
E 183.2 PB-056	Shukba	Natufian	m2 dec	man
E 184.1 PB-057	Shukba	Natufian	C	max
E 184.1 PB-057	Shukba	Natufian	P3	max
E 184.1 PB-057	Shukba	Natufian	P4	max
E 184.1 PB-057	Shukba	Natufian	M1	max
E 184.1 PB-057	Shukba	Natufian	M2	max
E 184.1 PB-057	Shukba	Natufian	M3	max
E 184.2 PB-057	Shukba	Natufian	I2	max
E 184.2 PB-057	Shukba	Natufian	C	max
E 184.2 PB-057	Shukba	Natufian	P3	max
E 184.3 PB-057	Shukba	Natufian	P4	max
E 184.3 PB-057	Shukba	Natufian	M1	max
E 184.3 PB-057	Shukba	Natufian	M2	max
E 184.3 PB-057	Shukba	Natufian	M3	max
E 185.3 PB-058	Shukba	Natufian	I1	man
E 185.3 PB-058	Shukba	Natufian	I2	man
E 185.3 PB-058	Shukba	Natufian	C	man
E 185.3 PB-058	Shukba	Natufian	P3	man
E 185.3 PB-058	Shukba	Natufian	P4	man
E 185.3 PB-058	Shukba	Natufian	M1	man
E 185.3 PB-058	Shukba	Natufian	M2	man
E 185.3 PB-058	Shukba	Natufian	I1	man
E 185.3 PB-058	Shukba	Natufian	I2	man
E 185.3 PB-058	Shukba	Natufian	C	man
E 185.3 PB-058	Shukba	Natufian	P3	man
E 185.3 PB-058	Shukba	Natufian	P4	man
E 185.3 PB-058	Shukba	Natufian	M1	man
E 185.3 PB-058	Shukba	Natufian	M2	man
E 185.3 PB-058	Shukba	Natufian	M3	man
E 184 N10334P	Shukba	Natufian	C	max
E 184 N10334P	Shukba	Natufian	P3	max
E 184 N10334P	Shukba	Natufian	P4	max
E 184 N10334P	Shukba	Natufian	M1	max
E 184 N10334P	Shukba	Natufian	M2	max
E 184 N10334P	Shukba	Natufian	M3	max
E 184 N10334P	Shukba	Natufian	C	max
E 184 N10334P	Shukba	Natufian	P3	max
E 184 N10334P	Shukba	Natufian	P4	max
E 184 N10334P	Shukba	Natufian	M1	max
E 185.1 PB-058	Shukba	Natufian	C	man
E 185.1 PB-058	Shukba	Natufian	P3	man
E 185.1 PB-058	Shukba	Natufian	P4	man
E 185.1 PB-058	Shukba	Natufian	M1	man
E 185.1 PB-059	Shukba	Natufian	M1	max
T. aswad 1 ind 1	Tell Aswad	PPNB	M1	man
T. aswad 2 ind 1	Tell Aswad	PPNB	M2	man
T. aswad 3 ind 1	Tell Aswad	PPNB	P4	man
T. aswad 4 ind 1	Tell Aswad	PPNB	M2	man
T. aswad 6 k140 us 668 st 672	Tell Aswad	PPNB	M1	man

T. aswad 6 k140 us 668 st 672	Tell Aswad	PPNB	M2	man
T. aswad 7 k140 us 668 st 672	Tell Aswad	PPNB	P3	man
T. aswad 7 k140 us 668 st 672	Tell Aswad	PPNB	P4	man
T. aswad 8 k140 us 668 st 672	Tell Aswad	PPNB	M3	max
T. aswad 9 k 125 locus 126-127 us 798 st 796-1	Tell Aswad	PPNB	P4	man
T. aswad 9 k 125 locus 126-127 us 798 st 796-1	Tell Aswad	PPNB	M1	man
T. aswad 10 ind 5	Tell Aswad	PPNB	M2	man
T. aswad 11 ind 5	Tell Aswad	PPNB	M1	max
T. aswad 12 ind 2	Tell Aswad	PPNB	M2	man
T. aswad 13 ind 2	Tell Aswad	PPNB	M1	man
T. aswad 14 ind 2	Tell Aswad	PPNB	M1	man
T. aswad 14 ind 2	Tell Aswad	PPNB	M2	man
T. aswad 15 ind 2	Tell Aswad	PPNB	M3	man
T. aswad 16 ind 2	Tell Aswad	PPNB	M3	man
T. aswad 17 ind 11	Tell Aswad	PPNB	P3	man
T. aswad 17 ind 11	Tell Aswad	PPNB	P4	man
T. aswad 17 ind 11	Tell Aswad	PPNB	M1	man
T. aswad 17 ind 11	Tell Aswad	PPNB	M2	man
T. aswad 18 ind 11	Tell Aswad	PPNB	P3	man
T. aswad 18 ind 11	Tell Aswad	PPNB	P4	man
T. aswad 18 ind 11	Tell Aswad	PPNB	M1	man
T. aswad 19 ind 12	Tell Aswad	PPNB	M2	man
T. aswad 19 ind 12	Tell Aswad	PPNB	M1	man
T. aswad 19 ind 12	Tell Aswad	PPNB	M3	man
T. aswad 21 ind 6	Tell Aswad	PPNB	P4	man
T. aswad 21 ind 6	Tell Aswad	PPNB	M1	man
T. aswad 21 ind 6	Tell Aswad	PPNB	M2	man
T. aswad 21 ind 6	Tell Aswad	PPNB	M3	man
T. aswad 22 ind 6	Tell Aswad	PPNB	M2	man
T. aswad 23 ind 6	Tell Aswad	PPNB	P3	man
T. aswad 24 ind 6	Tell Aswad	PPNB	P3	man
T. aswad 24 ind 6	Tell Aswad	PPNB	P4	man
T. aswad 25 M-N 13g us 720-423	Tell Aswad	PPNB	P4	man
T. aswad 26 M-N 13g us 720-423	Tell Aswad	PPNB	P3	man
T. aswad 27 ind 3	Tell Aswad	PPNB	P4	man
T. aswad 27 ind 3	Tell Aswad	PPNB	M1	man
T. aswad 27 ind 3	Tell Aswad	PPNB	M2	man
T. aswad 28 ind 3	Tell Aswad	PPNB	M2	man
T. aswad 29 k 140 locus k140 us 668 st 672	Tell Aswad	PPNB	P4	man
T. aswad 31 k 140 locus k 140 us 668 st 672	Tell Aswad	PPNB	M1	man
T. aswad 30 k 140 locus k 140 us 668 st 672	Tell Aswad	PPNB	M2	man
T. aswad 32k 128-129 us 785 st 786	Tell Aswad	PPNB	M2	man
T. aswad 33 k128-129 us 785 st	Tell Aswad	PPNB	M1	man
T. aswad 34 k125 locus M 126-127 us 798 st 796	Tell Aswad	PPNB	M1	max
T. aswad 35 k125locus M 126-127 us 798 st 796	Tell Aswad	PPNB	M3	max
T. aswad 36 k 125 locus m 126-127 US 798 ST 796	Tell Aswad	PPNB	P4	max
T. aswad 37 ind 10	Tell Aswad	PPNB	C	man
T. aswad 37 ind 10	Tell Aswad	PPNB	P3	man
T. aswad 38 ind 10	Tell Aswad	PPNB	M2	max
T. aswad 38 ind 10	Tell Aswad	PPNB	M3	max
T. aswad 39 ind 10	Tell Aswad	PPNB	M?	-
T. aswad 40 ind 10	Tell Aswad	PPNB	P?	-
N1 TH 03/05 E87 4H	Tell Halula	PPNB	M1	max
N2 TH 03/05 E87 4H	Tell Halula	PPNB	M2	man
N3 TH 03/05 E87 4H	Tell Halula	PPNB	P3	man
N4 TH 03/05 E87 4H	Tell Halula	PPNB	M3	man
N5 TH E88	Tell Halula	PPNB	P4	max
N6 TH E88	Tell Halula	PPNB	P3	man
N7 TH E88	Tell Halula	PPNB	M1	man
N8 TH E88	Tell Halula	PPNB	P4	man
N9 TH E88	Tell Halula	PPNB	M2	man
N10 TH E88	Tell Halula	PPNB	M1	max
N11 TH E88	Tell Halula	PPNB	M1	man
N12 TH E88	Tell Halula	PPNB	M1	max
N13 TH E88	Tell Halula	PPNB	M1	man
N14 TH E88	Tell Halula	PPNB	M1	max

N15 TH 02 E57 4H	Tell Halula	PPNB	M2	man
N16 TH 02 E57 4H	Tell Halula	PPNB	P4	man
N17 TH 02 E57 4H	Tell Halula	PPNB	M1	man
N18 TH 02 E57 4H	Tell Halula	PPNB	M1	man
N1 TH E203	Tell Halula	PPNB	M1	man
TH E 203	Tell Halula	PPNB	P3	man
N3 Th E203	Tell Halula	PPNB	I1	max
N4 TH E203	Tell Halula	PPNB	P4	man
N5 TH E203	Tell Halula	PPNB	P3	max
N6 TH E203	Tell Halula	PPNB	C	man
N7 TH E203	Tell Halula	PPNB	I1	man
N8 TH03 203 41	Tell Halula	PPNB	I2	max
N10 TH03 E203 41	Tell Halula	PPNB	C	max
N12 TH03 E203 41	Tell Halula	PPNB	I2	man
N13 TH03 E203 41	Tell Halula	PPNB	I1	man
N14 TH03 E203 41	Tell Halula	PPNB	I2	max
N15 TH03 E203 41	Tell Halula	PPNB	P3	max
N16 TH03 E203 41	Tell Halula	PPNB	P4	max
N17 TH03 E203 41	Tell Halula	PPNB	C	max
N18 TH03 E203 41	Tell Halula	PPNB	I2	max
N19 TH03 E203 41	Tell Halula	PPNB	C	man
N20 E222	Tell Halula	PPNB	I1	max
N21 E222	Tell Halula	PPNB	P4	man
N22 E222	Tell Halula	PPNB	I1	man
N23 E222	Tell Halula	PPNB	M1	man
N24 TH E109	Tell Halula	PPNB	I2	man
N24 TH E109	Tell Halula	PPNB	C	man
N25 TH E109	Tell Halula	PPNB	C?	-
N26 TH E109	Tell Halula	PPNB	C	man
N26 TH E109	Tell Halula	PPNB	-	-
N27 TH E109	Tell Halula	PPNB	M1	man
N28 TH E109	Tell Halula	PPNB	I1	man
N29 TH E221	Tell Halula	PPNB	P3	man
N31 TH E221	Tell Halula	PPNB	M1	max
N32 TH 03 A8 4J	Tell Halula	PPNB	M1	man
N1 TH E200	Tell Halula	PPNB	I1	man
N2 TH E200	Tell Halula	PPNB	P4	man
N3 TH E200	Tell Halula	PPNB	M1	man
N3 TH E200	Tell Halula	PPNB	-	man
N4 TH E200	Tell Halula	PPNB	P3	man
N5 TH E200	Tell Halula	PPNB	M1	max
N6 TH E96 4D	Tell Halula	PPNB	M1	max
N7 TH E96 4D	Tell Halula	PPNB	P4	max
N8 TH03/10 E108 4H	Tell Halula	PPNB	I1	man
N9 TH03/10 E108 4H	Tell Halula	PPNB	I1	max

N10 TH03/10 E108 4H	Tell Halula	PPNB	C	max
N11 TH03/10 E108 4H	Tell Halula	PPNB	I1	man
N12 TH03/10 E108 4H	Tell Halula	PPNB	I1	max
NL85 TH	Tell Halula	PPNB	C	man
NL85 TH	Tell Halula	PPNB	P3	man
NL85 TH	Tell Halula	PPNB	P4	man
NL85 TH	Tell Halula	PPNB	M1	man
NL85 TH	Tell Halula	PPNB	M2	man
NL85 TH	Tell Halula	PPNB	P3	man
NL85 TH	Tell Halula	PPNB	P4	man
NL85 TH	Tell Halula	PPNB	M1	man
NL85 TH	Tell Halula	PPNB	M2	man
NL85 TH	Tell Halula	PPNB	M3	man
N1 THE 03/32	Tell Halula	PPNB	P4	max
N1 THE 03/32	Tell Halula	PPNB	M1	max
N1 THE 03/32	Tell Halula	PPNB	M2	max
N10 TH 03/27	Tell Halula	PPNB	-	-
N11 TH 03/27	Tell Halula	PPNB	M2	max
N12 TH 03/27	Tell Halula	PPNB	M1	max
N13 TH 03/27	Tell Halula	PPNB	-	-
N2 THE 03/32	Tell Halula	PPNB	P3	max
N2 THE 03/32	Tell Halula	PPNB	P4	max
N3 TH 03/2A(b)	Tell Halula	PPNB	P4	man
N4 TH 03/2A(b)	Tell Halula	PPNB	M2	man
N5 TH 03/2A(b)	Tell Halula	PPNB	M2	man
N6 TH 03/27	Tell Halula	PPNB	P3	man
N7 TH 03/27	Tell Halula	PPNB	P3	max
N8 TH 03/27	Tell Halula	PPNB	P4	max
N9 TH 03/27	Tell Halula	PPNB	P3	max
NL90 TH	Tell Halula	PPNB	M1	man
NL91 TH	Tell Halula	PPNB	M1	max
NL92 TH	Tell Halula	PPNB	I1	max
NL96 TH	Tell Halula	PPNB	C	man
NL97 TH	Tell Halula	PPNB	I1	max
N15 TH 03/19	Tell Halula	PPNB	P4	man
N17 TH 03/21	Tell Halula	PPNB	I2	max
N18 TH 03/22	Tell Halula	PPNB	I2	man
N19 TH 03/23	Tell Halula	PPNB	I1	max
N20TH 03/05	Tell Halula	PPNB	-	-
N21 TH 03/05	Tell Halula	PPNB	I2	man
N22 TH 03/05	Tell Halula	PPNB	M1	man
N23 TH 03/05	Tell Halula	PPNB	M1	man

N24 TH 03/05	Tell Halula	PPNB	M1	man
N24 TH 03/05	Tell Halula	PPNB	M2	man
N25 TH 03/02	Tell Halula	PPNB	M1	max
N26 TH 03/02	Tell Halula	PPNB	M1	max
N27 TH 03/17	Tell Halula	PPNB	I1	man
N28 TH 03/17	Tell Halula	PPNB	I2	man
N29 TH 03/17	Tell Halula	PPNB	C	max
N30 TH 03/17	Tell Halula	PPNB	I1	man
N31 TH 03/17	Tell Halula	PPNB	I1	max
N32 TH 03/17	Tell Halula	PPNB	C	man
N33 TH 03/24	Tell Halula	PPNB	P3	man
N34 TH 03/24	Tell Halula	PPNB	C	max
N35 TH 03/24	Tell Halula	PPNB	C	man
N35 TH 03/24	Tell Halula	PPNB	P3	man
N35 TH 03/24	Tell Halula	PPNB	P4	man
N35 TH 03/24	Tell Halula	PPNB	M1	man
N35 TH 03/24	Tell Halula	PPNB	M2	man
N36 TH 03/24	Tell Halula	PPNB	M1	man
N37 TH 03/01	Tell Halula	PPNB	M1	max
N38 TH 03/01	Tell Halula	PPNB	M2	max
N39 TH 03/01	Tell Halula	PPNB	I1	max
N40 TH 03/01	Tell Halula	PPNB	P3	man
N40 TH 03/01	Tell Halula	PPNB	P4	man
N41 TH 03/01	Tell Halula	PPNB	P3	max
N42 TH 03/01	Tell Halula	PPNB	M1	man
N43 TH 03/01	Tell Halula	PPNB	M2	man
N44 TH 03/01	Tell Halula	PPNB	-	-
N45 TH	Tell Halula	PPNB	M1	man
N46 TH	Tell Halula	PPNB	I1	max
N47 TH	Tell Halula	PPNB	P4	max
N47 TH	Tell Halula	PPNB	M1	max
N47 TH	Tell Halula	PPNB	M2	max
N48 TH	Tell Halula	PPNB	M1	man
N49 TH	Tell Halula	PPNB	M2	man
N50 TH	Tell Halula	PPNB	I2	max
N51 TH	Tell Halula	PPNB	I2	max
N52 TH	Tell Halula	PPNB	M1	man
N53 TH	Tell Halula	PPNB	M1	man
N54 TH	Tell Halula	PPNB	P3	man
N55 TH	Tell Halula	PPNB	M1	man
N56 TH	Tell Halula	PPNB	P3	man
N57 TH	Tell Halula	PPNB	M2	man
N58 TH	Tell Halula	PPNB	P3	man
N59 TH	Tell Halula	PPNB	I2	man
N60 TH	Tell Halula	PPNB	P3	man

N61 TH	Tell Halula	PPNB	I2	man
N62 TH	Tell Halula	PPNB	M1	man
N63 TH	Tell Halula	PPNB	M1	max
N64 TH	Tell Halula	PPNB	M1	max
N65 TH	Tell Halula	PPNB	M1	max
N66 TH	Tell Halula	PPNB	M2	max
N67 TH	Tell Halula	PPNB	I1	max
N68 TH	Tell Halula	PPNB	P4	max
N69 TH	Tell Halula	PPNB	P4	max
N70 TH	Tell Halula	PPNB	M1	man
N71 TH	Tell Halula	PPNB	P4	max
N72 TH	Tell Halula	PPNB	M1	max
N73 TH	Tell Halula	PPNB	P4	max
N73.2 TH	Tell Halula	PPNB	M1	max
N78 TH	Tell Halula	PPNB	M1	man
N79 TH	Tell Halula	PPNB	I1	max
N80 TH	Tell Halula	PPNB	I1	max
N85 TH	Tell Halula	PPNB	-	-
NL93 TH	Tell Halula	PPNB	M1	max
NL94 TH	Tell Halula	PPNB	M3	max
NL95 TH	Tell Halula	PPNB	P4	max
N16 TH 03/20	Tell Halula	PPNB	I2	man
N169 TH 03/12	Tell Halula	PPNB	P4	max
N169 TH 03/12	Tell Halula	PPNB	M1	max
N171 TH 03/12	Tell Halula	PPNB	M3	max
N171 TH 03/12	Tell Halula	PPNB	M1	max
N77 TH	Tell Halula	PPNB	M1	man
N81 TH 03/09	Tell Halula	PPNB	I1	max
N82 TH 03/09	Tell Halula	PPNB	P3	max
N83 TH 03/09	Tell Halula	PPNB	C	man
N84 TH 03/09	Tell Halula	PPNB	I1	max
no ref.	Tell Halula	PPNB	P4	man
no ref.	Tell Halula	PPNB	P4	man
no ref.	Tell Halula	PPNB	M1	man
no ref.	Tell Halula	PPNB	M3	man
no ref.	Tell Halula	PPNB	M1	man
no ref.	Tell Halula	PPNB	M2	man
no ref.	Tell Halula	PPNB	P3	man
no ref.	Tell Halula	PPNB	P3	man
no ref.	Tell Halula	PPNB	M1	man
no ref.	Tell Halula	PPNB	M2	man
no ref.	Tell Halula	PPNB	P4	max
no ref.	Tell Halula	PPNB	P3	man
no ref.	Tell Halula	PPNB	M2	man
no ref.	Tell Halula	PPNB	M1	man

no ref.	Tell Halula	PPNB	P3	man
no ref.	Tell Halula	PPNB	P3	man
no ref.	Tell Halula	PPNB	M3	man
no ref.	Tell Halula	PPNB	M3	man
N74 TH	Tell Halula	PPNB	M2	man
N75 TH	Tell Halula	PPNB	C	mam
N76 TH	Tell Halula	PPNB	M1	man
T. Ramad 1 (65-14)	Tell Ramad	PPNB	M2	man
T. Ramad 1 (65-14)	Tell Ramad	PPNB	M3	man
T. Ramad 2 (65-14)	Tell Ramad	PPNB	M1	man
T. Ramad 3 (65-14)	Tell Ramad	PPNB	P4	man
T. Ramad 3 (65-14)	Tell Ramad	PPNB	M1	man
T, Ramad 4 (65)	Tell Ramad	PPNB	M1	man
T. Ramad 5 (65)	Tell Ramad	PPNB	M1	man
T. Ramad 6 (65-3)	Tell Ramad	PPNB	M1	max
T. Ramad 6 (65-3)	Tell Ramad	PPNB	M2	max
T. Ramad 7 (65-3)	Tell Ramad	PPNB	M1	man
T. Ramad 8 (65-3)	Tell Ramad	PPNB	M2	max
T. Ramad 9 (65-4(2))	Tell Ramad	PPNB	P3	man
T. Ramad 10 (65-4(2))	Tell Ramad	PPNB	P4	man
T. Ramad 11 (65)	Tell Ramad	PPNB	M1	man
T. Ramad 11 (65)	Tell Ramad	PPNB	M2	man
T. Ramad 12 (65)	Tell Ramad	PPNB	M1	max
T. Ramad 13 (65)	Tell Ramad	PPNB	M1	max
T. Ramad 14 (65)	Tell Ramad	PPNB	M2	max
T. Ramad 15 (65)	Tell Ramad	PPNB	M2	max
T. Ramad 16 (65-6)	Tell Ramad	PPNB	m1 dec	max
T. Ramad 17 (65-8)	Tell Ramad	PPNB	m2 dec	man
T. Ramad 17 (65-8)	Tell Ramad	PPNB	M1	man
T. Ramad 18 (65-8)	Tell Ramad	PPNB	M1	man
T. Ramad 18 (65-8)	Tell Ramad	PPNB	m2	man
T. Ramad 19 (65-8)	Tell Ramad	PPNB	m2 dec	max
T. Ramad 19 (65-8)	Tell Ramad	PPNB	M1	max
T. Ramad 20 (65-8)	Tell Ramad	PPNB	M1	max
T. Ramad 21 (66-1)	Tell Ramad	PPNB	M1	max
T. Ramad 21 (66-1)	Tell Ramad	PPNB	M2	max
T. Ramad 21 (66-1)	Tell Ramad	PPNB	M3	max
T.Ramad 22 (66-1)	Tell Ramad	PPNB	M1	man
T.Ramad 22 (66-1)	Tell Ramad	PPNB	M2	man
T.Ramad 23 (66-1)	Tell Ramad	PPNB	M2	man
T. Ramad 24 (1970)	Tell Ramad	PPNB	M1	max
T. Ramad 24 (1970)	Tell Ramad	PPNB	M2	max
T. Ramad 25 (1970)	Tell Ramad	PPNB	M1	max
T. Ramad 26 (65-15)	Tell Ramad	PPNB	M3	man
T. Ramad 27 (65-15)	Tell Ramad	PPNB	M1	max
-	Tell Ramad	PPNB	M2	man
T. Ramad 28 (65-15)	Tell Ramad	PPNB	M1	man
-	Tell Ramad	PPNB	M1	man
T. Ramad 29 (65)	Tell Ramad	PPNB	M2	man
T. Ramad 32 (66)	Tell Ramad	PPNB	M1	man
T. Ramad 32 (66)	Tell Ramad	PPNB	m2 dec	man
T. Ramad 32 (66)	Tell Ramad	PPNB	M2	man
T. Ramad 33 (66)	Tell Ramad	PPNB	m2	man
T. Ramad 33 (66)	Tell Ramad	PPNB	M1	man
T. Ramad 33 (66)	Tell Ramad	PPNB	M2	man
T. Ramad 34 (66)	Tell Ramad	PPNB	M2?	max
T. Ramad 35 (66)	Tell Ramad	PPNB	M1	max
T. Ramad 36 (66) adult differ	Tell Ramad	PPNB	M1?	man
T. Ramad 36 (66) adult differ	Tell Ramad	PPNB	M2?	man
T. Ramad 37 (66-1)	Tell Ramad	PPNB	M1	max
T. Ramad 37 (66-1)	Tell Ramad	PPNB	M2	max
T. Ramad 38 (66-1)	Tell Ramad	PPNB	M1	man
T. Ramad 38 (66-1)	Tell Ramad	PPNB	M2	man
T. Ramad 39 (66-1)	Tell Ramad	PPNB	M1?	man
T. Ramad 39 (66-1)	Tell Ramad	PPNB	M2?	man
T. Ramad 40 (65-11)	Tell Ramad	PPNB	m1 dec	man
T. Ramad 41 (SIN)	Tell Ramad	PPNB	P4	man
T. Ramad 42 (SIN)	Tell Ramad	PPNB	P3	man
T. Ramad 42 (SIN)	Tell Ramad	PPNB	P4	man
T. Ramad 42 (SIN)	Tell Ramad	PPNB	M1	man
T. Ramad 42 (SIN)	Tell Ramad	PPNB	M2	man
T. Ramad 43 (SIN)	Tell Ramad	PPNB	M2	max
T. Ramad 44 (65-1)	Tell Ramad	PPNB	P3	man
T. Ramad 44 (65-1)	Tell Ramad	PPNB	P4	man
T. Ramad 44 (65-1)	Tell Ramad	PPNB	M1	man
T. Ramad 44 (65-1)	Tell Ramad	PPNB	M2	man
T. Ramad 44 (65-1)	Tell Ramad	PPNB	M3	man
T. Ramad 45 (65-1)	Tell Ramad	PPNB	M2	man
T. Ramad 46 (65-1)	Tell Ramad	PPNB	P3	man
T. Ramad 46 (65-1)	Tell Ramad	PPNB	P4	man
NL86 Tell Ramad	Tell Ramad	PPNB	M1	man
NL87 Tell Ramad	Tell Ramad	PPNB	P3	man

NL87 Tell Ramad	Tell Ramad	PPNB	P4	man
NL87 Tell Ramad	Tell Ramad	PPNB	M1	man
NL87 Tell Ramad	Tell Ramad	PPNB	M2	man
NL87 Tell Ramad	Tell Ramad	PPNB	P4	man
NL87 Tell Ramad	Tell Ramad	PPNB	M1	man
NL87 Tell Ramad	Tell Ramad	PPNB	M2	man
NL87 Tell Ramad	Tell Ramad	PPNB	M3	man
NL88 Tell Ramad	Tell Ramad	PPNB	M1	man
NL88 Tell Ramad	Tell Ramad	PPNB	M2	man
NL89 Tell Ramad	Tell Ramad	PPNB	P3	man
NL89 Tell Ramad	Tell Ramad	PPNB	P4	man
NL89 Tell Ramad	Tell Ramad	PPNB	M1	man
NL89 Tell Ramad	Tell Ramad	PPNB	M2	man
NL89 Tell Ramad	Tell Ramad	PPNB	M3	man
TP10 BB4-23	Tepecik ciftlik	PN	I1	man
TP10 BB4-53	Tepecik ciftlik	PN	I1	man
TP10 BB4-2	Tepecik ciftlik	PN	I1	man
TP10 BB4-2	Tepecik ciftlik	PN	I1	man
TP10 SK2010-3	Tepecik ciftlik	PN	I1	max
TP10 SK2010-3	Tepecik ciftlik	PN	I1	max
TP10 BB4-53	Tepecik ciftlik	PN	I1	max
TP10 BB4-23	Tepecik ciftlik	PN	I1	max
TP10 SK41	Tepecik ciftlik	PN	C	max
TP10 SK39B	Tepecik ciftlik	PN	C	max
TP10 BB4-23	Tepecik ciftlik	PN	C	max
TP10 BB4-53	Tepecik ciftlik	PN	C	max
TP12 SK70	Tepecik ciftlik	PN	C	max
TP10 SK41	Tepecik ciftlik	PN	P3	man
TP10 SK41	Tepecik ciftlik	PN	P3	man

TP10 SK2010-3	Tepecik ciftlik	PN	P3	man
TP10 SK2010-3	Tepecik ciftlik	PN	P3	man
TP10 BB4-23	Tepecik ciftlik	PN	P3	man
TP10 BB4-23	Tepecik ciftlik	PN	P3	man
TP10 BB2-22	Tepecik ciftlik	PN	P3	man
TP10 BB4-23	Tepecik ciftlik	PN	P3	man
TP10 BB4-53	Tepecik ciftlik	PN	P3	man
TP10 BB4-53	Tepecik ciftlik	PN	P3	man
TP10 SK39B	Tepecik ciftlik	PN	P3	man
TP10 SK39B	Tepecik ciftlik	PN	P3	man
TP09 16L SK72	Tepecik ciftlik	PN	P3	man
TP06 17J	Tepecik ciftlik	PN	P3	man
TP10 BB3-40	Tepecik ciftlik	PN	P3	man
TP10 BB3-40	Tepecik ciftlik	PN	P3	man
TP12 SK70	Tepecik ciftlik	PN	P3	man
TP12 SK70	Tepecik ciftlik	PN	P3	man
TP09 17K	Tepecik ciftlik	PN	P3	man
TP09 17K	Tepecik ciftlik	PN	P3	man
TP10 BB3-36	Tepecik ciftlik	PN	P3	man
TP12 SK58	Tepecik ciftlik	PN	P3	man
TP10 BB3-24mand	Tepecik ciftlik	PN	P3	man
TP10 BB2-11	Tepecik ciftlik	PN	P3	man

TP10 BB2-11	Tepecik ciftlik	PN	P3	man
TP09 N62	Tepecik ciftlik	PN	P3	man
TP09 N62	Tepecik ciftlik	PN	P3	man
TP10 BB2-16	Tepecik ciftlik	PN	P3	man
TP10 BB4-1	Tepecik ciftlik	PN	M1	man
TP10 BB4-1	Tepecik ciftlik	PN	M1	man
TP10 BB3-40	Tepecik ciftlik	PN	M1	man
TP10 BB3-25	Tepecik ciftlik	PN	M1	man
TP10 BB3-25	Tepecik ciftlik	PN	M1	man
TP10 SK39B	Tepecik ciftlik	PN	M1	man
TP10 SK39B	Tepecik ciftlik	PN	M1	man
TP10 SK2010-3	Tepecik ciftlik	PN	M1	man
TP10 SK2010-3	Tepecik ciftlik	PN	M1	man
TP07 18K	Tepecik ciftlik	PN	M1	man
TP07 18K	Tepecik ciftlik	PN	M1	man
TP10 BB4-23	Tepecik ciftlik	PN	M1	man
TP10 BB2-23	Tepecik ciftlik	PN	M1	man
TP10 BB2-23	Tepecik ciftlik	PN	M1	man
TP10 BB2-23	Tepecik ciftlik	PN	M1	man
TP10 BB2-22	Tepecik ciftlik	PN	M1	man
TP10 BB2-22	Tepecik ciftlik	PN	M1	man
TP10 BB4-23	Tepecik ciftlik	PN	M1	man

TP10 BB4-23	Tepecik ciftlik	PN	M1	man
TP10 BB4-53	Tepecik ciftlik	PN	M1	man
TP10 BB4-53	Tepecik ciftlik	PN	M1	man
TP10 BB4-35	Tepecik ciftlik	PN	M1	man
TP10 BB4-35	Tepecik ciftlik	PN	M1	man
TP10 SK41	Tepecik ciftlik	PN	M1	man
TP10 SK41	Tepecik ciftlik	PN	M1	man
TP12 20M	Tepecik ciftlik	PN	M1	man
TP10 DK21	Tepecik ciftlik	PN	M1	man
TP11 17L 4	Tepecik ciftlik	PN	M1	man
TP10 BB2-28	Tepecik ciftlik	PN	M1	man
TP10 BB2-28	Tepecik ciftlik	PN	M1	man
TP10 BB3-40	Tepecik ciftlik	PN	M1	man
TP10 BB3-40	Tepecik ciftlik	PN	M1	man
TP10 BB2-25	Tepecik ciftlik	PN	M1	man
TP10 BB2-25	Tepecik ciftlik	PN	M1	man
TP09 16L SK72	Tepecik ciftlik	PN	M1	man
TP09 16L SK72	Tepecik ciftlik	PN	M1	man
TP12 SK70	Tepecik ciftlik	PN	M1	man
TP12 SK70	Tepecik ciftlik	PN	M1	man
TP10 BB4-23	Tepecik ciftlik	PN	M1	man
TP10 BB2-11	Tepecik ciftlik	PN	M1	man

TP12 SK58	Tepecik ciftlik	PN	M1	man
TP06 17J	Tepecik ciftlik	PN	M1	man
TP10 BB3-24mand	Tepecik ciftlik	PN	M1	man
TP10 BB2-11	Tepecik ciftlik	PN	M1	man
TP10 BB4-2	Tepecik ciftlik	PN	M1	man
TP10 BB2-16	Tepecik ciftlik	PN	M1	man
TP12 SK58	Tepecik ciftlik	PN	M1	man
TP09 17L 3	Tepecik ciftlik	PN	M1	man
TP07 18K	Tepecik ciftlik	PN	M1	man
TP10 BB2-23	Tepecik ciftlik	PN	M2	man
TP10 BB2-23	Tepecik ciftlik	PN	M2	man
TP10 BB3-25	Tepecik ciftlik	PN	M2	man
TP10 BB3-25	Tepecik ciftlik	PN	M2	man
TP10 SK41	Tepecik ciftlik	PN	M2	man
TP10 SK39B	Tepecik ciftlik	PN	M2	man
TP11 17L 4	Tepecik ciftlik	PN	M2	man
TP11 17L 4	Tepecik ciftlik	PN	M2	man
TP10 SK2010-3	Tepecik ciftlik	PN	M2	man
TP10 SK2010-3	Tepecik ciftlik	PN	M2	man
TP10 BB4-23	Tepecik ciftlik	PN	M2	man
TP10 BB2-28	Tepecik ciftlik	PN	M2	man
TP10 BB2-28	Tepecik ciftlik	PN	M2	man
TP10 BB2-22	Tepecik ciftlik	PN	M2	man
TP10 BB2-22	Tepecik ciftlik	PN	M2	man
TP10 BB4-23	Tepecik ciftlik	PN	M2	man
TP10 BB4-53	Tepecik ciftlik	PN	M2	man
TP10 BB4-53	Tepecik ciftlik	PN	M2	man
TP10 BB4-35	Tepecik ciftlik	PN	M2	man
TP10 BB4-35	Tepecik ciftlik	PN	M2	man
TP10 SK39B	Tepecik ciftlik	PN	M2	man
TP10 DK21	Tepecik ciftlik	PN	M2	man
TP09 16L SK72	Tepecik ciftlik	PN	M2	man
TP09 16L SK72	Tepecik ciftlik	PN	M2	man
TP07 18K	Tepecik ciftlik	PN	M2	man
TP10 BB2-29	Tepecik ciftlik	PN	M2	man
TP10 BB2-29	Tepecik ciftlik	PN	M2	man
TP10 18L	Tepecik ciftlik	PN	M2	man
TP12 SK70	Tepecik ciftlik	PN	M2	man
TP06 17J	Tepecik ciftlik	PN	M2	man
TP06 17J	Tepecik ciftlik	PN	M2	man
TP09 17K	Tepecik ciftlik	PN	M2	man
TP09 17K	Tepecik ciftlik	PN	M2	man
TP10 BB3-40	Tepecik ciftlik	PN	M2	man
TP10 BB3-40	Tepecik ciftlik	PN	M2	man

TP10 BB4-2	Tepecik ciftlik	PN	M2	man
TP12 SK70	Tepecik ciftlik	PN	M2	man
TP10 BB3-36	Tepecik ciftlik	PN	M2	man
TP12 SK58	Tepecik ciftlik	PN	M2	man
TP10 BB2-11	Tepecik ciftlik	PN	M2	man
TP10 BB2-11	Tepecik ciftlik	PN	M2	man
TP09 N62	Tepecik ciftlik	PN	M2	man
TP10 BB2-16	Tepecik ciftlik	PN	M2	man
TP12 SK58	Tepecik ciftlik	PN	M2	man
TP10 BB3-36	Tepecik ciftlik	PN	M2	man
TP10 BB3-24mand	Tepecik ciftlik	PN	M2	man
TP10 BB2-16	Tepecik ciftlik	PN	M2	man
TP10 BB3-24mand	Tepecik ciftlik	PN	M2	man
TP11 17L 4	Tepecik ciftlik	PN	M3	man
TP11 17L 4	Tepecik ciftlik	PN	M3	man
TP12 SK70	Tepecik ciftlik	PN	M3	man
TP12 SK70	Tepecik ciftlik	PN	M3	man
TP10 18L	Tepecik ciftlik	PN	M3	man
TP12 SK58	Tepecik ciftlik	PN	M3	man
TP12 SK58	Tepecik ciftlik	PN	M3	man
TP09 17L 3	Tepecik ciftlik	PN	M3	man
TP10 BB3-24mand	Tepecik ciftlik	PN	M3	man

TP09 17L 3	Tepecik ciftlik	PN	M3	man
TP10 BB2-23	Tepecik ciftlik	PN	P4	max
TP10 BB2-23	Tepecik ciftlik	PN	P4	max
TP10 SK39B	Tepecik ciftlik	PN	P4	max
TP10 SK2010-3	Tepecik ciftlik	PN	P4	max
TP10 BB4-23	Tepecik ciftlik	PN	P4	max
TP10 BB4-53	Tepecik ciftlik	PN	P4	max
TP10 BB4-53	Tepecik ciftlik	PN	P4	max
TP10 BB3-41	Tepecik ciftlik	PN	P4	max
TP10 SK39B	Tepecik ciftlik	PN	P4	max
TP10 BB3-35	Tepecik ciftlik	PN	P4	max
TP11 17L 314	Tepecik ciftlik	PN	P4	max
TP12 SK70	Tepecik ciftlik	PN	P4	max
TP12 SK83d	Tepecik ciftlik	PN	P4	max
TP09 16I 5	Tepecik ciftlik	PN	P4	max
TP12 SK70	Tepecik ciftlik	PN	P4	max
TP10 16K SK74	Tepecik ciftlik	PN	P4	max
TP12 SK83b	Tepecik ciftlik	PN	M1	max
TP12 SK83b	Tepecik ciftlik	PN	M1	max
TP10 BB4-53	Tepecik ciftlik	PN	M1	max
TP10 BB3-25	Tepecik ciftlik	PN	M1	max
TP10 BB3-25	Tepecik ciftlik	PN	M1	max

TP10 BB3-41	Tepecik ciftlik	PN	M1	max
TP10 SK41	Tepecik ciftlik	PN	M1	max
TP10 SK41	Tepecik ciftlik	PN	M1	max
TP10 SK39B	Tepecik ciftlik	PN	M1	max
TP10 SK39B	Tepecik ciftlik	PN	M1	max
TP10 SK2010-3	Tepecik ciftlik	PN	M1	max
TP10 SK2010-3	Tepecik ciftlik	PN	M1	max
TP10 BB2-23	Tepecik ciftlik	PN	M1	max
TP10 BB4-23	Tepecik ciftlik	PN	M1	max
TP10 BB3-35	Tepecik ciftlik	PN	M1	max
TP11 17L 314	Tepecik ciftlik	PN	M1	max
TP10 BB4-23	Tepecik ciftlik	PN	M1	max
TP10 BB4-23	Tepecik ciftlik	PN	M1	max
TP10 BB3-35	Tepecik ciftlik	PN	M1	max
TP09 16L SK72	Tepecik ciftlik	PN	M1	max
TP10 BB3-36	Tepecik ciftlik	PN	M1	max
TP10 BB3-36	Tepecik ciftlik	PN	M1	max
TP12 SK70	Tepecik ciftlik	PN	M1	max
TP12 SK70	Tepecik ciftlik	PN	M1	max
TP12 SK83d	Tepecik ciftlik	PN	M1	max
TP10 16K SK74	Tepecik ciftlik	PN	M1	max
TP10 16K SK74	Tepecik ciftlik	PN	M1	max

TP09 16I 5	Tepecik ciftlik	PN	M1	max
TP09 16I 5	Tepecik ciftlik	PN	M1	max
TP10 BB2-23	Tepecik ciftlik	PN	M2	max
TP10 BB2-23	Tepecik ciftlik	PN	M2	max
TP10 BB3-25	Tepecik ciftlik	PN	M2	max
TP10 BB3-25	Tepecik ciftlik	PN	M2	max
TP10 SK41	Tepecik ciftlik	PN	M2	max
TP10 SK41	Tepecik ciftlik	PN	M2	max
TP10 SK39B	Tepecik ciftlik	PN	M2	max
TP10 SK39B	Tepecik ciftlik	PN	M2	max
TP10 SK2010-3	Tepecik ciftlik	PN	M2	max
TP10 SK2010-3	Tepecik ciftlik	PN	M2	max
TP12 SK83b	Tepecik ciftlik	PN	M2	max
TP10 BB4-23	Tepecik ciftlik	PN	M2	max
TP10 BB4-23	Tepecik ciftlik	PN	M2	max
TP10 BB4-53	Tepecik ciftlik	PN	M2	max
TP09 16L SK72	Tepecik ciftlik	PN	M2	max
TP11 17L 314	Tepecik ciftlik	PN	M2	max
TP10 BB4-23	Tepecik ciftlik	PN	M2	max
TP10 BB3-35	Tepecik ciftlik	PN	M2	max
TP10 BB3-35	Tepecik ciftlik	PN	M2	max
TP12 SK70	Tepecik ciftlik	PN	M2	max

TP12 SK70	Tepecik ciftlik	PN	M2	max
TP12 SK83d	Tepecik ciftlik	PN	M2	max
TP10 BB3-36	Tepecik ciftlik	PN	M2	max
TP12 SK83d	Tepecik ciftlik	PN	M2	max
TP10 16K SK74	Tepecik ciftlik	PN	M2	max
TP10 16K SK74	Tepecik ciftlik	PN	M2	max
TP09 16I 5	Tepecik ciftlik	PN	M2	max
TP09 16I 5	Tepecik ciftlik	PN	M2	max
TP12 SK70	Tepecik ciftlik	PN	M3	max
TP12 SK83d	Tepecik ciftlik	PN	M3	max
TP12 SK83d	Tepecik ciftlik	PN	M3	max
TP10 BB3-25	Tepecik ciftlik	PN	C	man
TP10 SK39B	Tepecik ciftlik	PN	C	man
TP10 SK39B	Tepecik ciftlik	PN	C	man
TP10 BB4-23	Tepecik ciftlik	PN	C	man
TP10 BB4-53	Tepecik ciftlik	PN	C	man
TP10 BB4-23	Tepecik ciftlik	PN	C	man
TP10 BB2-22	Tepecik ciftlik	PN	C	man
TP10 BB4-53	Tepecik ciftlik	PN	C	man
TP12 SK70	Tepecik ciftlik	PN	C	man
TP09 17K	Tepecik ciftlik	PN	C	man
TP10 BB4-23	Tepecik ciftlik	PN	C	man
TP10 BB3-36	Tepecik ciftlik	PN	C	man
TP10 BB4-2	Tepecik ciftlik	PN	C	man
TP09 N62	Tepecik ciftlik	PN	C	man
TP09 N62	Tepecik ciftlik	PN	C	man
TP10 BB2-23	Tepecik ciftlik	PN	P3	max
TP10 BB2-23	Tepecik ciftlik	PN	P3	max
TP10 SK41	Tepecik ciftlik	PN	P3	max
TP10 SK39B	Tepecik ciftlik	PN	P3	max
TP10 SK39B	Tepecik ciftlik	PN	P3	max
TP10 SK2010-3	Tepecik ciftlik	PN	P3	max
TP10 SK2010-3	Tepecik ciftlik	PN	P3	max
TP10 BB4-23	Tepecik ciftlik	PN	P3	max
TP10 BB4-53	Tepecik ciftlik	PN	P3	max
TP10 BB4-23	Tepecik ciftlik	PN	P3	max
TP12 SK70	Tepecik ciftlik	PN	P3	max
TP12 SK83d	Tepecik ciftlik	PN	P3	max
TP12 SK70	Tepecik ciftlik	PN	P3	max
TP10 BB4-23	Tepecik ciftlik	PN	I2	man
TP10 BB4-23	Tepecik ciftlik	PN	I2	man
TP10 BB4-23	Tepecik ciftlik	PN	I2	man
TP10 BB4-2	Tepecik ciftlik	PN	I2	man
TP10 BB4-2	Tepecik ciftlik	PN	I2	man

TP09 N62	Tepecik ciftlik	PN	I2	man
TP10 SK2010-3	Tepecik ciftlik	PN	I2	max
TP10 SK2010-3	Tepecik ciftlik	PN	I2	max
TP10 BB4-23	Tepecik ciftlik	PN	I2	max
TP10 BB2-23	Tepecik ciftlik	PN	P4	man
TP10 SK2010-3	Tepecik ciftlik	PN	P4	man
TP10 SK2010-3	Tepecik ciftlik	PN	P4	man
TP10 BB4-23	Tepecik ciftlik	PN	P4	man
TP10 BB4-23	Tepecik ciftlik	PN	P4	man
TP10 BB2-22	Tepecik ciftlik	PN	P4	man
TP10 BB4-23	Tepecik ciftlik	PN	P4	man
TP10 BB4-23	Tepecik ciftlik	PN	P4	man
TP10 BB4-53	Tepecik ciftlik	PN	P4	man
TP10 BB4-53	Tepecik ciftlik	PN	P4	man
TP10 SK39B	Tepecik ciftlik	PN	P4	man
TP10 SK39B	Tepecik ciftlik	PN	P4	man
TP09 16L SK72	Tepecik ciftlik	PN	P4	man
TP09 16L SK72	Tepecik ciftlik	PN	P4	man
TP12 SK70	Tepecik ciftlik	PN	P4	man
TP10 BB3-40	Tepecik ciftlik	PN	P4	man
TP10 BB2-22	Tepecik ciftlik	PN	P4	man
TP12 SK70	Tepecik ciftlik	PN	P4	man

TP09 17K	Tepecik ciftlik	PN	P4	man
TP09 17K	Tepecik ciftlik	PN	P4	man
TP10 BB3-36	Tepecik ciftlik	PN	P4	man
TP10 BB2-25	Tepecik ciftlik	PN	P4	man
TP12 SK58	Tepecik ciftlik	PN	P4	man
TP10 BB3-24mand	Tepecik ciftlik	PN	P4	man
TP10 BB2-11	Tepecik ciftlik	PN	P4	man
TP10 BB4-2	Tepecik ciftlik	PN	P4	man
TP09 N62	Tepecik ciftlik	PN	P4	man
TP09 N62	Tepecik ciftlik	PN	P4	man
TP12 SK58	Tepecik ciftlik	PN	P4	man
TP10 BB4-2	Tepecik ciftlik	PN	P4	man
TP10 BB2-16	Tepecik ciftlik	PN	P4	man
NK2639	Nemrik 9	PPNB	M1	man
NK2639.2	Nemrik 9	PPNB	M1	man
NK1890	Nemrik 9	PPNB	M1	man
NK1888	Nemrik 9	PPNB	M1	man
NK3404	Nemrik 9	PPNB	M1	man
NK2395/1	Nemrik 9	PPNB	M1	man
NK2393 85/D	Nemrik 9	PPNB	M1	man
NK2395 85D	Nemrik 9	PPNB	M1	man
NK2639 96B	Nemrik 9	PPNB	M1	man
NK2445	Nemrik 9	PPNB	M1	man
NK2639.2	Nemrik 9	PPNB	M2	man
NK1890	Nemrik 9	PPNB	M2	man
NK2395/1	Nemrik 9	PPNB	M2	man
NK2393 85/D	Nemrik 9	PPNB	M2	man
NK2393 85/D	Nemrik 9	PPNB	M2	man
NK2704 44B	Nemrik 9	PPNB	M2	man
NK2704 44B	Nemrik 9	PPNB	M2	man
NK3372	Nemrik 9	PPNB	M2	man
NK1890	Nemrik 9	PPNB	M2	man

NK2445	Nemrik 9	PPNB	M2	man
NK2423 85d	Nemrik 9	PPNB	M2	man
NK3401	Nemrik 9	PPNB	M2	man
NK1890	Nemrik 9	PPNB	M2	man
NK1888	Nemrik 9	PPNB	M1	max
NK2393 85/D	Nemrik 9	PPNB	M1	max
NK2393 85/D	Nemrik 9	PPNB	M1	max
NK2393 85/D	Nemrik 9	PPNB	M1	max
NK2395 85D	Nemrik 9	PPNB	M1	max
NK2511 96B	Nemrik 9	PPNB	M1	max
NK2445	Nemrik 9	PPNB	M1	max
NK2511	Nemrik 9	PPNB	M1	max
NK3406	Nemrik 9	PPNB	M2	max
NK2777	Nemrik 9	PPNB	M2	max
NK 2445	Nemrik 9	PPNB	M2	max
NK2732	Nemrik 9	PPNB	M2	max
KHA A L1 N14 1133	Kharaysin	PPNB	P3	man
KHA A L1 N14 1133	Kharaysin	PPNB	P3	man
KHA AC L1 C60 1109	Kharaysin	PPNB	M1	man
KHA AC L1 C60 1109	Kharaysin	PPNB	M1	man
KHA A L1 N14 1133	Kharaysin	PPNB	M1	man
KHA A L1 N14 1133	Kharaysin	PPNB	M1	man
KHA AC L5 N13 1108	Kharaysin	PPNB	M1	man
KHA AC L5 N13 1108	Kharaysin	PPNB	M1	man
KHA AC L1 C60 1109	Kharaysin	PPNB	M2	man
KHA A L1 N14 1133	Kharaysin	PPNB	M2	man
KHA A L1 N14 1133	Kharaysin	PPNB	M2	man
KHA AC L5 N13 1108	Kharaysin	PPNB	M2	man
KHA AC L5 N13 1108	Kharaysin	PPNB	M2	man
KHA A L1 N14 1133	Kharaysin	PPNB	P4	man
KHA A L1 N14 1133	Kharaysin	PPNB	P4	man
N9/361/G	Gre Filla	PPNA	P3	man
N9/361/G	Gre Filla	PPNA	P3	man
P9/211/G	Gre Filla	PPNB	P3	man
O9/337/G	Gre Filla	PPNB	P3	man
P9/140/G	Gre Filla	PPNB	P3	man
N9/361/G	Gre Filla	PPNA	P4	max
N9/361/G	Gre Filla	PPNA	P4	max
P9/211/G	Gre Filla	PPNB	P4	max
P9/211/G	Gre Filla	PPNB	P4	max
O9/337/G	Gre Filla	PPNB	P4	max
O9/337/G	Gre Filla	PPNB	P4	max
N9/361/G	Gre Filla	PPNA	M1	man
N9/361/G	Gre Filla	PPNA	M1	man
P8/607/G 2	Gre Filla	PPNB	M1	man

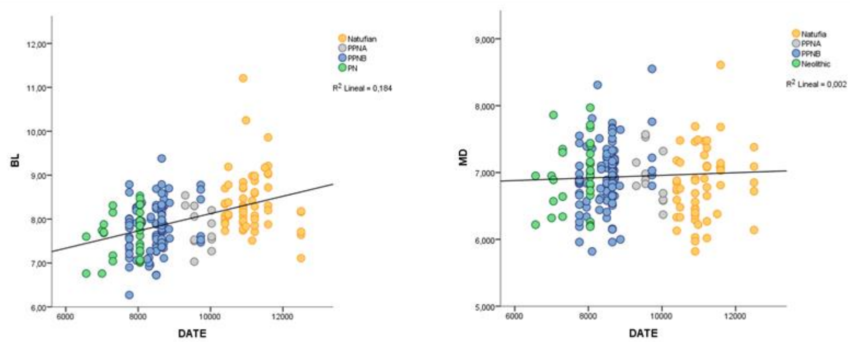
P8/616/G	Gre Filla	PPNB	M1	man
P9/600/G	Gre Filla	PPNB	M1	man
P8/232/G	Gre Filla	PPNB	M1	man
P9/211/G	Gre Filla	PPNB	M1	man
O9/337/G	Gre Filla	PPNB	M1	man
O9/337/G	Gre Filla	PPNB	M1	man
N9/361/G	Gre Filla	PPNA	M2	man
N9/361/G	Gre Filla	PPNA	M2	man
O9/370/G	Gre Filla	PPNA	M2	man
P8/607/G 2	Gre Filla	PPNB	M2	man
P9/211/G	Gre Filla	PPNB	M2	man
P9/211/G	Gre Filla	PPNB	M2	man
O9/337/G	Gre Filla	PPNB	M2	man
O9/337/G	Gre Filla	PPNB	M2	man
P9/140/G	Gre Filla	PPNB	M2	man
N9/361/G	Gre Filla	PPNA	M1	max
N9/361/G	Gre Filla	PPNA	M1	max
P8/249/G	Gre Filla	PPNA	M1	max
P8/616/G	Gre Filla	PPNB	M1	man
P8/616/G	Gre Filla	PPNB	M1	max
P8/616/G	Gre Filla	PPNB	M1	max
P9/600/G	Gre Filla	PPNB	M1	max
P9/600/G	Gre Filla	PPNB	M1	max
P8/232/G	Gre Filla	PPNB	M1	max
P9/211/G	Gre Filla	PPNB	M1	max
P9/211/G	Gre Filla	PPNB	M1	max
O9/337/G	Gre Filla	PPNB	M1	max
N9/361/G	Gre Filla	PPNA	M2	max
N9/361/G	Gre Filla	PPNA	M2	max
P8/232/G	Gre Filla	PPNB	M2	max
P9/211/G	Gre Filla	PPNB	M2	max
P9/211/G	Gre Filla	PPNB	M2	max
O9/337/G	Gre Filla	PPNB	M2	max
O9/337/G	Gre Filla	PPNB	M2	max
N9/361/G	Gre Filla	PPNA	P3	max
N9/361/G	Gre Filla	PPNA	P3	max
P8/232/G	Gre Filla	PPNB	P3	max
P9/211/G	Gre Filla	PPNB	P3	max
P9/211/G	Gre Filla	PPNB	P3	max
O9/337/G	Gre Filla	PPNB	P3	max
O9/337/G	Gre Filla	PPNB	P3	max
P9/211/G	Gre Filla	PPNB	P4	man
P9/211/G	Gre Filla	PPNB	P4	man
O9/337/G	Gre Filla	PPNB	P4	man
O9/337/G	Gre Filla	PPNB	P4	man

P9/140/G	Gre Filla	PPNB	P4	man
Mand 8	Ali Kosh	PPNB	P3	man
Skull5	Ali Kosh	PPNB	P3	man
Skull5	Ali Kosh	PPNB	P4	max
Skull 6	Ali Kosh	PPNB	P4	max
Skull 6	Ali Kosh	PPNB	P4	max
Mand 8	Ali Kosh	PPNB	M1	man
Mand 7	Ali Kosh	PPNB	M1	man
Skull 6	Ali Kosh	PPNB	M1	man
Mand 7	Ali Kosh	PPNB	M2	man
Mand 8	Ali Kosh	PPNB	M2	man
C 1567	Ali Kosh	PPNB	M2	man
Skull5	Ali Kosh	PPNB	M2	man
Skull 6	Ali Kosh	PPNB	M2	man
Skull 2	Ali Kosh	PPNB	M1	max
Skull5	Ali Kosh	PPNB	M1	max
Skull 6	Ali Kosh	PPNB	M1	max
Skull 6	Ali Kosh	PPNB	M1	max
Skull 3	Ali Kosh	PPNB	M2	max
Skull 6	Ali Kosh	PPNB	M2	max
Skull 6	Ali Kosh	PPNB	M2	max
Skull5	Ali Kosh	PPNB	P3	max
Skull 6	Ali Kosh	PPNB	P3	max
Skull 6	Ali Kosh	PPNB	P3	max
Skull5	Ali Kosh	PPNB	P4	man
Skull 6	Ali Kosh	PPNB	P4	man
Mand 8	Ali Kosh	PPNB	P4	man

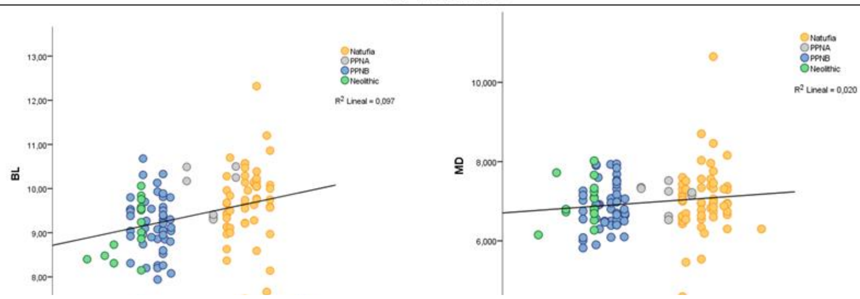
ANNEX 2.

Reduction of Buccolingual and Mesiodistal measurements graph of all postcanine teeth. Yellow-Natufian, Grey-PPNA, Blue-PPNB, Green-Pottery Neolithic.

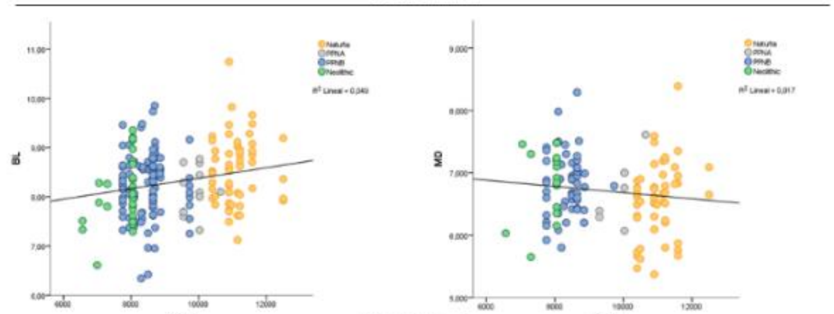
LOWER Pm3



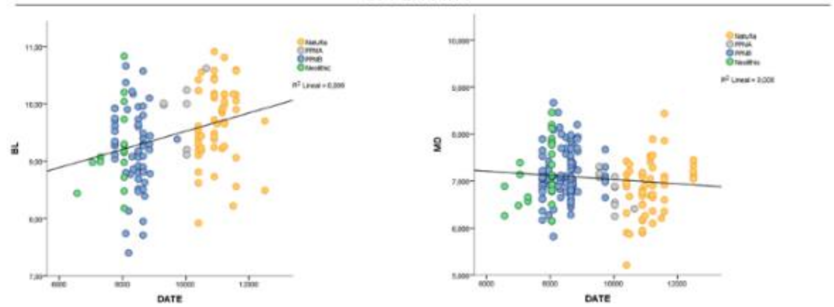
UPPER Pm3



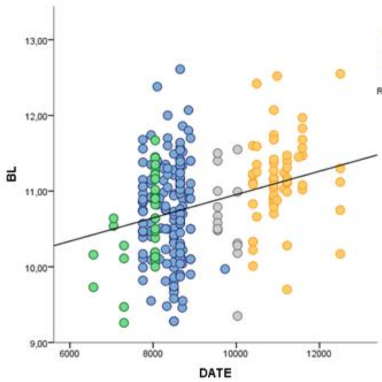
LOWER Pm4

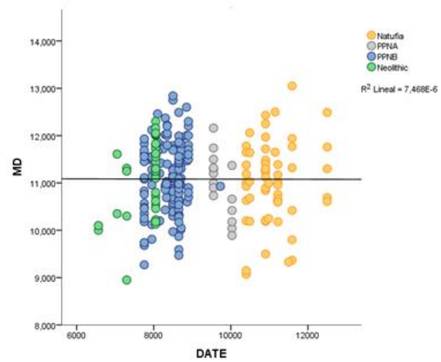


UPPER Pm4

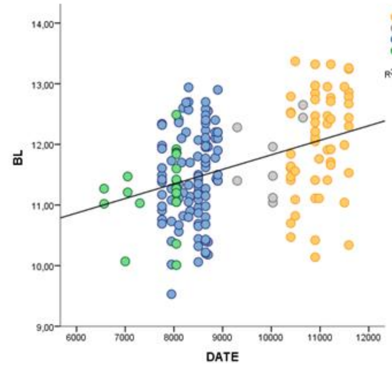


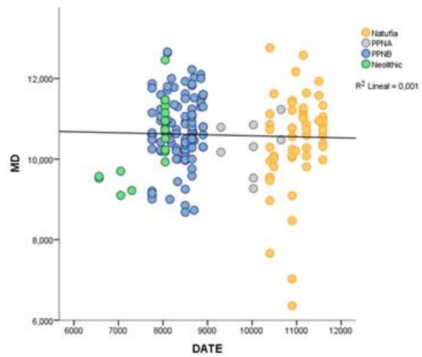
LOWER M1



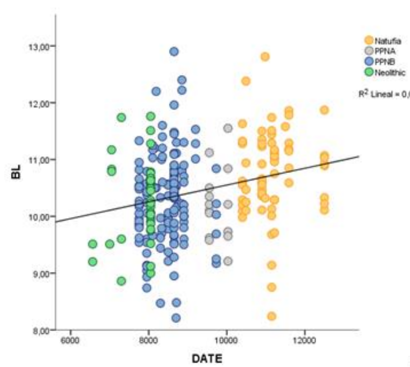


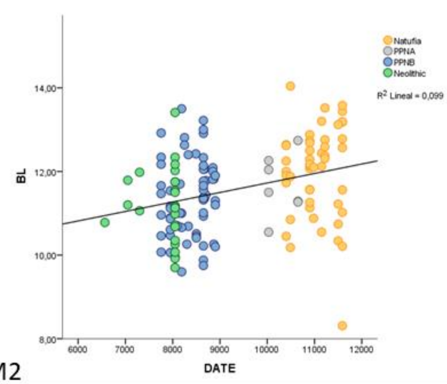
UPPER M1



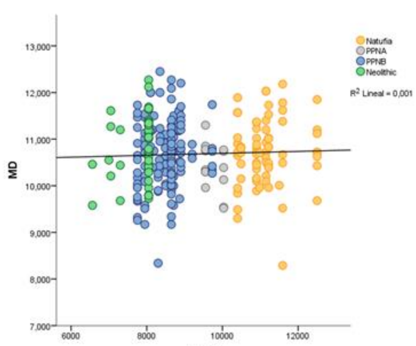


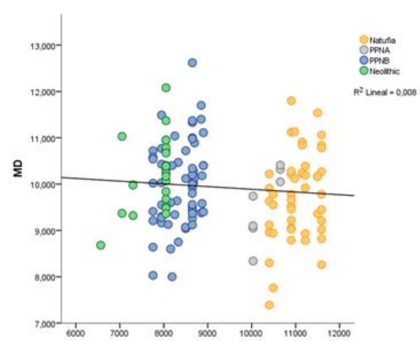
LOWER M2



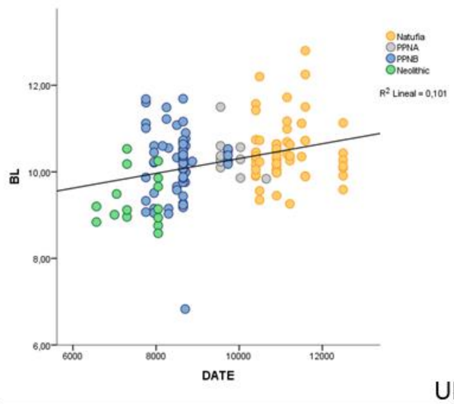


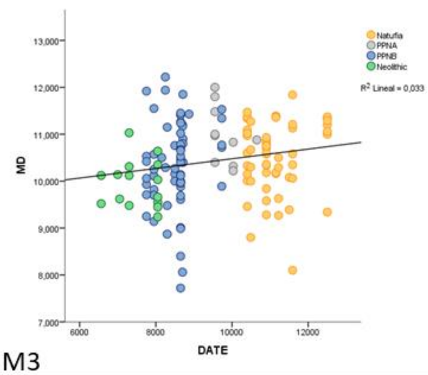
UPPER M2



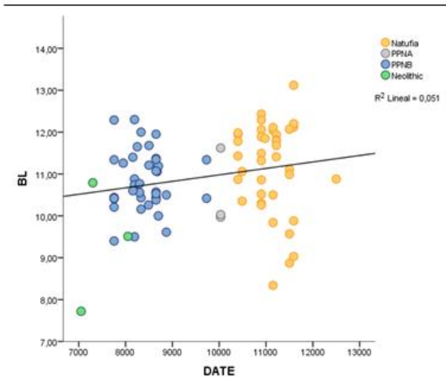


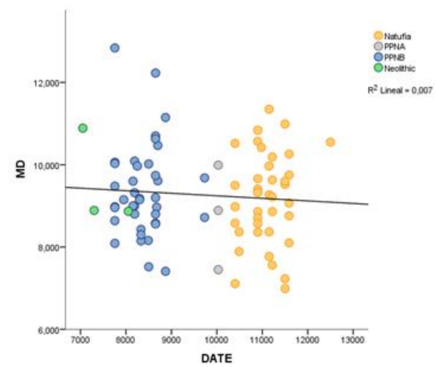
LOWER M3





UPPER M3





ANNEX 3.

One-way ANOVA revealed statistically significant differences by period in **M1 and M2** (ANOVA; $p < 0.05$).

ANOVA[a]

		Suma de cuadrados	gl	Media cuadrática	F	Sig.
DNE	Entre grupos	2501.294	2	1250.647	.623	.540
	Dentro de grupos	112492.719	56	2008.799		
	Total	114994.013	58			
RFI	Entre grupos	.131	2	.066	5.470	.007
	Dentro de grupos	.671	56	.012		
	Total	.803	58			
OPCR	Entre grupos	2651.503	2	1325.751	3.284	.045
	Dentro de grupos	22606.490	56	403.687		
	Total	25257.993	58			
PCV	Entre grupos	.040	2	.020	28.074	.000
	Dentro de grupos	.039	56	.001		
	Total	.079	58			

a. TOOTH = M1L

Comparaciones múltiples[a]

HSD Tukey

Variable dependiente			Diferencia de medias (I-J)	Error estándar	Sig.	95% Límite inferior	95% Límite superior
DNE	NAT	PPNB	14.419762	15.770491	.634	-23.54869	52.38822
		NEO	23.188571	22.087351	.549	-29.98813	76.36527
	PPNB	NAT	-14.419762	15.770491	.634	-52.38822	23.54869
		NEO	8.768810	18.297534	.881	-35.28366	52.82128
	NEO	NAT	-23.188571	22.087351	.549	-76.36527	29.98813
		PPNB	-8.768810	18.297534	.881	-52.82128	35.28366
RFI	NAT	PPNB	.024181	.038529	.806	-.06858	.11694
		NEO	-.123629	.053962	.065	-.25355	.00629
	PPNB	NAT	-.024181	.038529	.806	-.11694	.06858
		NEO	-,147810*	.044703	.005	-.25543	-.04018
	NEO	NAT	.123629	.053962	.065	-.00629	.25355
		PPNB	,147810*	.044703	.005	.04018	.25543
OPCR	NAT	PPNB	-9.524405	7.069677	.375	-26.54510	7.49629
		NEO	9.942857	9.901432	.577	-13.89547	33.78118
	PPNB	NAT	9.524405	7.069677	.375	-7.49629	26.54510
		NEO	19.467262	8.202513	.054	-.28081	39.21533
	NEO	NAT	-9.942857	9.901432	.577	-33.78118	13.89547
		PPNB	-19.467262	8.202513	.054	-39.21533	.28081
PCV	NAT	PPNB	-.014292033	.009335854	.284	-.03676869	.00818463
		NEO	,066810871*	.013075324	.000	.03533120	.09829054
	PPNB	NAT	.014292033	.009335854	.284	-.00818463	.03676869
		NEO	,081102905*	.010831819	.000	.05502461	.10718120
	NEO	NAT	-,066810871*	.013075324	.000	-.09829054	-.03533120
		PPNB	-,081102905*	.010831819	.000	-.10718120	-.05502461

*. La diferencia de medias es significativa en el nivel 0.05.

a. TOOTH = M1L

ANOVA[a]

		Suma de cuadrados	gl	Media cuadrática	F	Sig.
DNE	Entre grupos	4187.903	2	2093.951	1.272	.291
	Dentro de grupos	70809.186	43	1646.725		
	Total	74997.089	45			
RFI	Entre grupos	.068	2	.034	3.750	.032
	Dentro de grupos	.390	43	.009		
	Total	.458	45			
OPCR	Entre grupos	239.866	2	119.933	.575	.567
	Dentro de grupos	8964.562	43	208.478		
	Total	9204.428	45			
PCV	Entre grupos	.024	2	.012	18.604	.000
	Dentro de grupos	.028	43	.001		
	Total	.052	45			

a. TOOTH = M2L

Comparaciones múltiples[a]

HSD Tukey

Variable dependiente			Diferencia de medias (I-J)	Error estándar	Sig.	95% Límite inferior	95% Límite superior
DNE	NAT	PPNB	31.661360	19.879992	.260	-16.59612	79.91884
		NEO	27.414100	20.790993	.393	-23.05478	77.88298
	PPNB	NAT	-31.661360	19.879992	.260	-79.91884	16.59612
		NEO	-4.247260	12.991895	.943	-35.78430	27.28978
	NEO	NAT	-27.414100	20.790993	.393	-77.88298	23.05478
		PPNB	4.247260	12.991895	.943	-27.28978	35.78430
RFI	NAT	PPNB	-.056520	.046637	.453	-.16973	.05669
		NEO	-,119475*	.048774	.048	-.23787	-.00108
	PPNB	NAT	.056520	.046637	.453	-.05669	.16973
		NEO	-.062955	.030478	.109	-.13694	.01103
	NEO	NAT	,119475*	.048774	.048	.00108	.23787
		PPNB	.062955	.030478	.109	-.01103	.13694
OPCR	NAT	PPNB	3.565000	7.073526	.870	-13.60556	20.73556
		NEO	7.203125	7.397670	.597	-10.75427	25.16052
	PPNB	NAT	-3.565000	7.073526	.870	-20.73556	13.60556
		NEO	3.638125	4.622663	.713	-7.58311	14.85936
	NEO	NAT	-7.203125	7.397670	.597	-25.16052	10.75427
		PPNB	-3.638125	4.622663	.713	-14.85936	7.58311
PCV	NAT	PPNB	-.000887720	.012418179	.997	-.03103210	.02925666
		NEO	,047123525*	.012987243	.002	.01559777	.07864928
	PPNB	NAT	.000887720	.012418179	.997	-.02925666	.03103210
		NEO	,048011245*	.008115480	.000	.02831140	.06771109
	NEO	NAT	-,047123525*	.012987243	.002	-.07864928	-.01559777
		PPNB	-,048011245*	.008115480	.000	-.06771109	-.02831140

*. La diferencia de medias es significativa en el nivel 0.05.

a. TOOTH = M2L

ANNEX 4.

One-way ANOVA revealed statistically significant differences by geographical area in **M1 and M2** (ANOVA; $p < 0.05$).

ANOVA[a]

		Suma de cuadrados	gl	Media cuadrática	F	Sig.
DNE	Entre grupos	2718.494	4	679.624	.327	.859
	Dentro de grupos	112275.519	54	2079.176		
	Total	114994.013	58			
RFI	Entre grupos	.179	4	.045	3.883	.008
	Dentro de grupos	.623	54	.012		
	Total	.803	58			
OPCR	Entre grupos	5927.219	4	1481.805	4.139	.005
	Dentro de grupos	19330.774	54	357.977		
	Total	25257.993	58			
PCV	Entre grupos	.043	4	.011	16.225	.000
	Dentro de grupos	.036	54	.001		
	Total	.079	58			

a. TOOTH = M1L

Comparaciones múltiples[a]

HSD Tukey

Variable dependiente			Diferencia de medias (I-J)	Error estándar	Sig.	95% Límite inferior	95% Límite superior
DNE	Llevant	Euphrates	14.878393	16.798033	.901	-32.52700	62.28378
		Anatolia	23.188571	22.470933	.839	-40.22620	86.60334
		Desert	9.727286	22.470933	.992	-53.68748	73.14205
		Zagros	17.277714	22.470933	.938	-46.13705	80.69248
	Euphrates	Llevant	-14.878393	16.798033	.901	-62.28378	32.52700
		Anatolia	8.310179	19.268666	.993	-46.06754	62.68789
		Desert	-5.151107	19.268666	.999	-59.52882	49.22661
		Zagros	2.399321	19.268666	1.000	-51.97839	56.77704
	Anatolia	Llevant	-23.188571	22.470933	.839	-86.60334	40.22620
		Euphrates	-8.310179	19.268666	.993	-62.68789	46.06754
		Desert	-13.461286	24.373148	.981	-82.24426	55.32169
		Zagros	-5.910857	24.373148	.999	-74.69383	62.87212
	Desert	Llevant	-9.727286	22.470933	.992	-73.14205	53.68748
		Euphrates	5.151107	19.268666	.999	-49.22661	59.52882
		Anatolia	13.461286	24.373148	.981	-55.32169	82.24426
		Zagros	7.550429	24.373148	.998	-61.23254	76.33340
	Zagros	Llevant	-17.277714	22.470933	.938	-80.69248	46.13705
		Euphrates	-2.399321	19.268666	1.000	-56.77704	51.97839
		Anatolia	5.910857	24.373148	.999	-62.87212	74.69383
		Desert	-7.550429	24.373148	.998	-76.33340	61.23254
RFI	Llevant	Euphrates	.041764	.039579	.828	-.06993	.15346
		Anatolia	-.123629	.052946	.150	-.27305	.02579
		Desert	.028800	.052946	.982	-.12062	.17822
		Zagros	-.050771	.052946	.872	-.20019	.09865
	Euphrates	Llevant	-.041764	.039579	.828	-.15346	.06993
		Anatolia	-,165393*	.045401	.005	-.29352	-.03727
		Desert	-.012964	.045401	.999	-.14109	.11516
		Zagros	-.092536	.045401	.262	-.22066	.03559
	Anatolia	Llevant	.123629	.052946	.150	-.02579	.27305
		Euphrates	,165393*	.045401	.005	.03727	.29352
		Desert	.152429	.057428	.075	-.00964	.31449
		Zagros	.072857	.057428	.711	-.08921	.23492
	Desert	Llevant	-.028800	.052946	.982	-.17822	.12062
		Euphrates	.012964	.045401	.999	-.11516	.14109
		Anatolia	-.152429	.057428	.075	-.31449	.00964
		Zagros	-.079571	.057428	.639	-.24164	.08249
	Zagros	Llevant	.050771	.052946	.872	-.09865	.20019
		Euphrates	.092536	.045401	.262	-.03559	.22066
		Anatolia	-.072857	.057428	.711	-.23492	.08921
		Desert	.079571	.057428	.639	-.08249	.24164

OPCR	Llevant	Euphrates	-13.735714	6.970124	.294	-33.40596	5.93453
		Anatolia	9.942857	9.324020	.823	-16.37027	36.25599
		Desert	-12.396429	9.324020	.674	-38.70956	13.91670
		Zagros	10.192857	9.324020	.809	-16.12027	36.50599
	Euphrates	Llevant	13.735714	6.970124	.294	-5.93453	33.40596
		Anatolia	23,678571*	7.995281	.035	1.11525	46.24189
		Desert	1.339286	7.995281	1.000	-21.22404	23.90261
		Zagros	23,928571*	7.995281	.033	1.36525	46.49189
	Anatolia	Llevant	-9.942857	9.324020	.823	-36.25599	16.37027
		Euphrates	-23,678571*	7.995281	.035	-46.24189	-1.11525
		Desert	-22.339286	10.113319	.192	-50.87988	6.20131
		Zagros	.250000	10.113319	1.000	-28.29060	28.79060
	Desert	Llevant	12.396429	9.324020	.674	-13.91670	38.70956
		Euphrates	-1.339286	7.995281	1.000	-23.90261	21.22404
		Anatolia	22.339286	10.113319	.192	-6.20131	50.87988
		Zagros	22.589286	10.113319	.183	-5.95131	51.12988
	Zagros	Llevant	-10.192857	9.324020	.809	-36.50599	16.12027
		Euphrates	-23,928571*	7.995281	.033	-46.49189	-1.36525
		Anatolia	-.250000	10.113319	1.000	-28.79060	28.29060
		Desert	-22.589286	10.113319	.183	-51.12988	5.95131
PCV	Llevant	Euphrates	-.020094021	.009492800	.228	-.04688346	.00669542
		Anatolia	,066810871*	.012698634	.000	.03097431	.10264743
		Desert	-.009953557	.012698634	.934	-.04579012	.02588300
		Zagros	.004577443	.012698634	.996	-.03125912	.04041400
	Euphrates	Llevant	.020094021	.009492800	.228	-.00669542	.04688346
		Anatolia	,086904893*	.010888989	.000	.05617530	.11763449
		Desert	.010140464	.010888989	.883	-.02058913	.04087006
		Zagros	.024671464	.010888989	.172	-.00605813	.05540106
	Anatolia	Llevant	-,066810871*	.012698634	.000	-.10264743	-.03097431
		Euphrates	-,086904893*	.010888989	.000	-.11763449	-.05617530
		Desert	-,076764429*	.013773602	.000	-.11563463	-.03789422
		Zagros	-,062233429*	.013773602	.000	-.10110363	-.02336322
	Desert	Llevant	.009953557	.012698634	.934	-.02588300	.04579012
		Euphrates	-.010140464	.010888989	.883	-.04087006	.02058913
		Anatolia	,076764429*	.013773602	.000	.03789422	.11563463
		Zagros	.014531000	.013773602	.828	-.02433921	.05340121
	Zagros	Llevant	-.004577443	.012698634	.996	-.04041400	.03125912
		Euphrates	-.024671464	.010888989	.172	-.05540106	.00605813
		Anatolia	,062233429*	.013773602	.000	.02336322	.10110363
		Desert	-.014531000	.013773602	.828	-.05340121	.02433921

*. La diferencia de medias es significativa en el nivel 0.05.

a. TOOTH = M1L

ANOVA[a]

		Suma de cuadrados	gl	Media cuadrática	F	Sig.
DNE	Entre grupos	5426,642	4	1356,660	,800	,533
	Dentro de grupos	69570,447	41	1696,840		
	Total	74997,089	45			
RFI	Entre grupos	,068	4	,017	1,803	,147
	Dentro de grupos	,389	41	,009		
	Total	,458	45			
OPCR	Entre grupos	252,989	4	63,247	,290	,883
	Dentro de grupos	8951,440	41	218,328		
	Total	9204,428	45			
PCV	Entre grupos	,024	4	,006	9,102	,000
	Dentro de grupos	,027	41	,001		
	Total	,052	45			

a. TOOTH = M2L

ANOVA[a]

		Suma de cuadrados	gl	Media cuadrática	F	Sig.
DNE	Entre grupos	5426.642	4	1356.660	.800	.533
	Dentro de grupos	69570.447	41	1696.840		
	Total	74997.089	45			
RFI	Entre grupos	.068	4	.017	1.803	.147
	Dentro de grupos	.389	41	.009		
	Total	.458	45			
OPCR	Entre grupos	252.989	4	63.247	.290	.883
	Dentro de grupos	8951.440	41	218.328		
	Total	9204.428	45			
PCV	Entre grupos	.024	4	.006	9.102	.000
	Dentro de grupos	.027	41	.001		
	Total	.052	45			

a. TOOTH = M2L

Comparaciones múltiples[a]

HSD Tukey

Variable dependiente			Diferencia de medias (I-J)	Error estándar	Sig.	95% Límite inferior	95% Límite superior
DNE	Llevant	Euphrates	41.044600	22.976201	.395	-24.50349	106.59269
		Anatolia	27.414100	21.104989	.693	-32.79567	87.62387
		Desert	26.514236	22.217701	.755	-36.86995	89.89843
		Zagros	26.095200	26.052564	.853	-48.22935	100.41975
	Euphrates	Llevant	-41.044600	22.976201	.395	-106.59269	24.50349
		Anatolia	-13.630500	17.163633	.931	-62.59610	35.33510
		Desert	-14.530364	18.514751	.934	-67.35052	38.28979
		Zagros	-14.949400	22.976201	.966	-80.49749	50.59869
	Anatolia	Llevant	-27.414100	21.104989	.693	-87.62387	32.79567
		Euphrates	13.630500	17.163633	.931	-35.33510	62.59610
		Desert	-.899864	16.134147	1.000	-46.92847	45.12874
		Zagros	-1.318900	21.104989	1.000	-61.52867	58.89087
	Desert	Llevant	-26.514236	22.217701	.755	-89.89843	36.86995
		Euphrates	14.530364	18.514751	.934	-38.28979	67.35052
		Anatolia	.899864	16.134147	1.000	-45.12874	46.92847
		Zagros	-.419036	22.217701	1.000	-63.80323	62.96515
	Zagros	Llevant	-26.095200	26.052564	.853	-100.41975	48.22935
		Euphrates	14.949400	22.976201	.966	-50.59869	80.49749
		Anatolia	1.318900	21.104989	1.000	-58.89087	61.52867
		Desert	.419036	22.217701	1.000	-62.96515	63.80323
RFI	Llevant	Euphrates	-.056600	.054345	.835	-.21164	.09844
		Anatolia	-.119475	.049919	.138	-.26189	.02294
		Desert	-.052782	.052551	.852	-.20270	.09714
		Zagros	-.064600	.061622	.831	-.24040	.11120
	Euphrates	Llevant	.056600	.054345	.835	-.09844	.21164
		Anatolia	-.062875	.040597	.538	-.17869	.05294
		Desert	.003818	.043793	1.000	-.12112	.12875
		Zagros	-.008000	.054345	1.000	-.16304	.14704
	Anatolia	Llevant	.119475	.049919	.138	-.02294	.26189
		Euphrates	.062875	.040597	.538	-.05294	.17869
		Desert	.066693	.038162	.417	-.04218	.17556
		Zagros	.054875	.049919	.806	-.08754	.19729
	Desert	Llevant	.052782	.052551	.852	-.09714	.20270
		Euphrates	-.003818	.043793	1.000	-.12875	.12112
		Anatolia	-.066693	.038162	.417	-.17556	.04218
		Zagros	-.011818	.052551	.999	-.16174	.13810
	Zagros	Llevant	.064600	.061622	.831	-.11120	.24040
		Euphrates	.008000	.054345	1.000	-.14704	.16304
		Anatolia	-.054875	.049919	.806	-.19729	.08754
		Desert	.011818	.052551	.999	-.13810	.16174

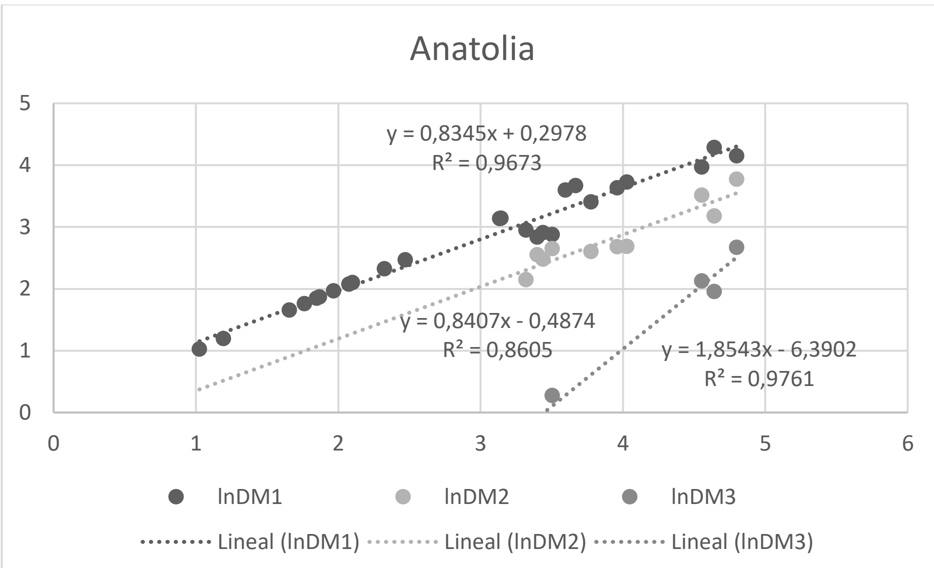
OPCR	Llevant	Euphrates	4.402778	8.241614	.983	-19.10947	27.91502
		Anatolia	7.203125	7.570406	.875	-14.39425	28.80050
		Desert	3.397727	7.969538	.993	-19.33832	26.13378
		Zagros	2.425000	9.345112	.999	-24.23538	29.08538
	Euphrates	Llevant	-4.402778	8.241614	.983	-27.91502	19.10947
		Anatolia	2.800347	6.156633	.991	-14.76372	20.36441
		Desert	-1.005051	6.641282	1.000	-19.95176	17.94166
		Zagros	-1.977778	8.241614	.999	-25.49002	21.53447
	Anatolia	Llevant	-7.203125	7.570406	.875	-28.80050	14.39425
		Euphrates	-2.800347	6.156633	.991	-20.36441	14.76372
		Desert	-3.805398	5.787354	.964	-20.31596	12.70517
		Zagros	-4.778125	7.570406	.969	-26.37550	16.81925
	Desert	Llevant	-3.397727	7.969538	.993	-26.13378	19.33832
		Euphrates	1.005051	6.641282	1.000	-17.94166	19.95176
		Anatolia	3.805398	5.787354	.964	-12.70517	20.31596
		Zagros	-.972727	7.969538	1.000	-23.70878	21.76332
	Zagros	Llevant	-2.425000	9.345112	.999	-29.08538	24.23538
		Euphrates	1.977778	8.241614	.999	-21.53447	25.49002
		Anatolia	4.778125	7.570406	.969	-16.81925	26.37550
		Desert	.972727	7.969538	1.000	-21.76332	23.70878
PCV	Llevant	Euphrates	-.005561600	.014392355	.995	-.04662110	.03549790
		Anatolia	,047123525*	.013220222	.008	.00940796	.08483909
		Desert	.002570945	.013917228	1.000	-.03713308	.04227497
		Zagros	-.000083800	.016319397	1.000	-.04664090	.04647330
	Euphrates	Llevant	.005561600	.014392355	.995	-.03549790	.04662110
		Anatolia	,052685125*	.010751347	.000	.02201294	.08335731
		Desert	.008132545	.011597690	.955	-.02495415	.04121924
		Zagros	.005477800	.014392355	.995	-.03558170	.04653730
	Anatolia	Llevant	-,047123525*	.013220222	.008	-.08483909	-.00940796
		Euphrates	-,052685125*	.010751347	.000	-.08335731	-.02201294
		Desert	-,044552580*	.010106474	.001	-.07338502	-.01572013
		Zagros	-,047207325*	.013220222	.008	-.08492289	-.00949176
	Desert	Llevant	-.002570945	.013917228	1.000	-.04227497	.03713308
		Euphrates	-.008132545	.011597690	.955	-.04121924	.02495415
		Anatolia	,044552580*	.010106474	.001	.01572013	.07338502
		Zagros	-.002654745	.013917228	1.000	-.04235877	.03704928
	Zagros	Llevant	.000083800	.016319397	1.000	-.04647330	.04664090
		Euphrates	-.005477800	.014392355	.995	-.04653730	.03558170
		Anatolia	,047207325*	.013220222	.008	.00949176	.08492289
		Desert	.002654745	.013917228	1.000	-.03704928	.04235877

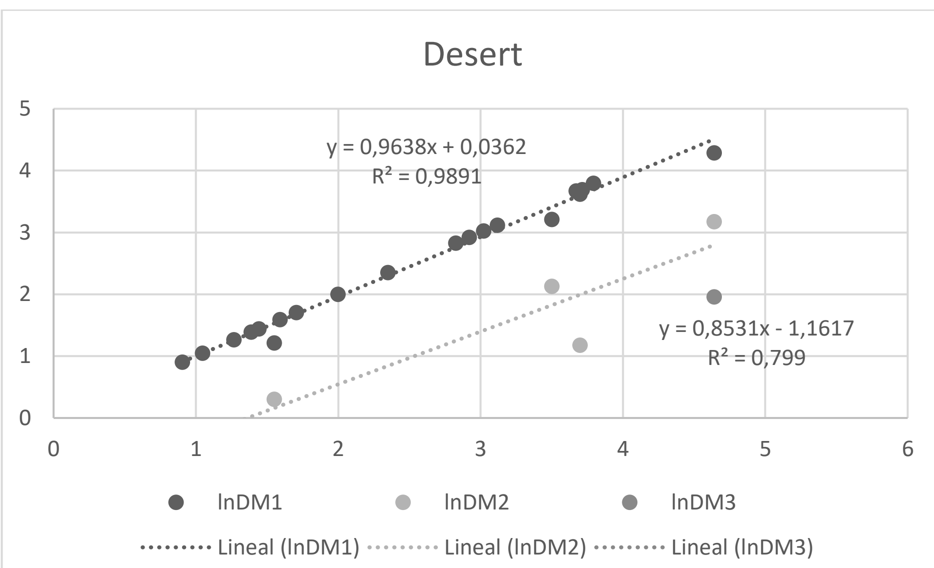
*. La diferencia de medias es significativa en el nivel 0.05.

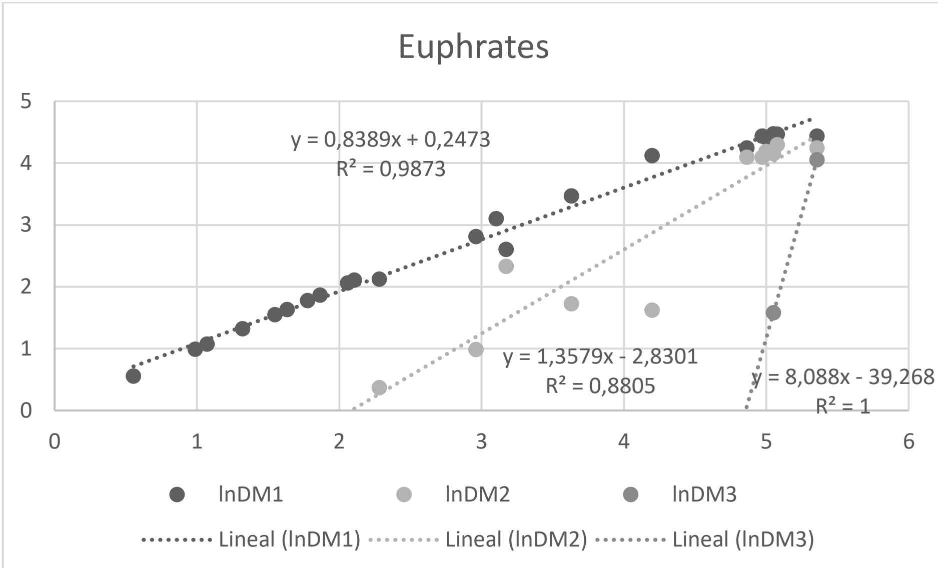
a. TOOTH = M2L

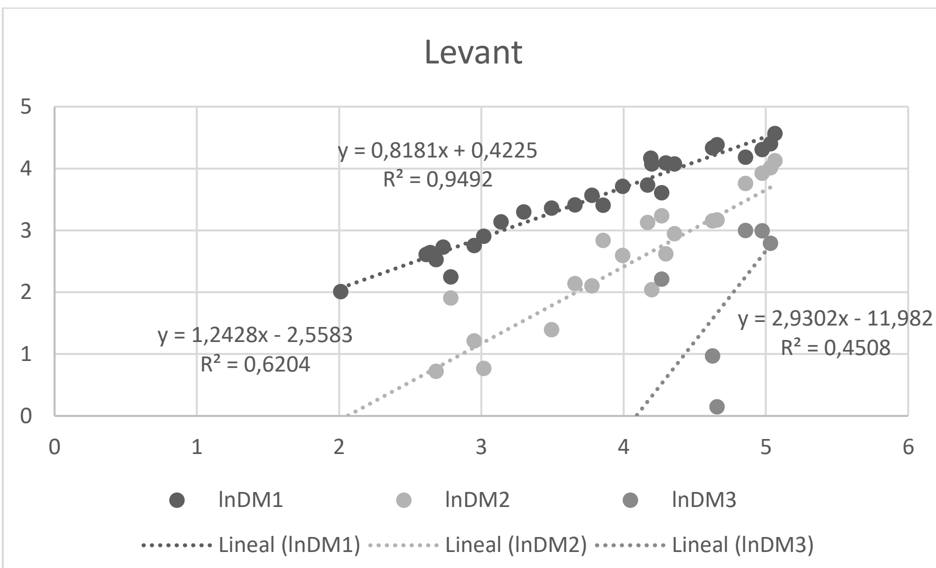
ANNEX 6

Linaer Regresion Graphics of the 6.3.3 The main case of Southwest Asia - Results






Euphrates
y = 0,8389x + 0,2473
R² = 0,9873
y = 1,3579x - 2,8301
R² = 0,8805
y = 8,088x - 39,268
R² = 1
lnDM1
lnDM2
lnDM3
Lineal (lnDM1)
Lineal (lnDM2)
Lineal (lnDM3)


Levant
y = 0,8181x + 0,4225
R² = 0,9492
y = 1,2428x - 2,5583
R² = 0,6204
y = 2,9302x - 11,982
R² = 0,4508
lnDM1
lnDM2
lnDM3
Lineal (lnDM1)
Lineal (lnDM2)
Lineal (lnDM3)