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Valoración de la utilidad de la cirugía reconstructiva de lesiones osteocondrales de la rodilla mediante trasplante de aloinjerto osteocondral fresco

EDUARD RAMÍREZ BERMEJO

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TESIS DOCTORAL

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Eduard Ramírez Bermejo

DIRECTOR Y TUTOR DE TESIS

Dr. Pablo Eduardo Gelber Ghertner

Universitat Autònoma de Barcelona

Unidad Docente del Hospital de la Santa Creu i Sant Pau
Departamento de Cirurgía
Programa de doctorado en Cirurgía i Ciencias Morfológicas
Universitat Autònoma de Barcelona

BARCELONA 2023

Pablo Eduardo Gelber Ghertner

CERTIFICA:

Que el trabajo de investigación titulado
"Valoración de la utilidad de la cirugía reconstructiva de lesiones osteocondrales de la rodilla mediante trasplante de aloinjerto osteocondral fresco"

ha sido realizado bajo mi dirección y está en condiciones de ser presentado para su lectura y defensa ante el tribunal correspondiente para obtener el Grado de Doctor.

Y para que así conste a todos los efectos oportunos, firmo el presente documento en

Barcelona, a 1 de Febrero 2023

Dr. Pablo Eduardo Gelber Ghertner

Agradecimientos

A la Laura, per tot el recolzament i amor,
per ser el meu suport diari i per fer
de la vida junts quelcom extraordinari.

Al meu pare i a la meva mare, per haver-me
educat amb amor i constància, i ser els principals
responsables dels meus èxits.

Al meu germà, per donar-hi sempre
una visió diferent i encertada.

Als meus quatre avis,
per no deixar-me mai sol.

A Pablo,
por ser mi maestro y haberme descubierto
la pasión por la rodilla.

Al servei de COT de Sant Pau,
per haver-me transmès tot el coneixement
de la nostra especialitat.

Índice

Introducción

1

Introducción

1.1. Lesiones osteocondrales de la rodilla

1.1.1. Anatomía

La rodilla es la articulación sinovial más grande del cuerpo y la que posee una mayor área de cartílago articular hialino. Está formada por tres huesos (cóndilos femorales, platillos tibiales y rótula). La articulación de la rodilla posee dos superficies articulares principales, la articulación tibiofemoral (entre la tibia y los cóndilos femorales) y la articulación patelofemoral (entre la rótula y la tróclea).

El cartílago hialino recubre las superficies articulares de fémur, tibia y rótula, permitiendo el deslizamiento entre los huesos con una baja fricción, distribuyendo y soportando las cargas de la articulación.[1]

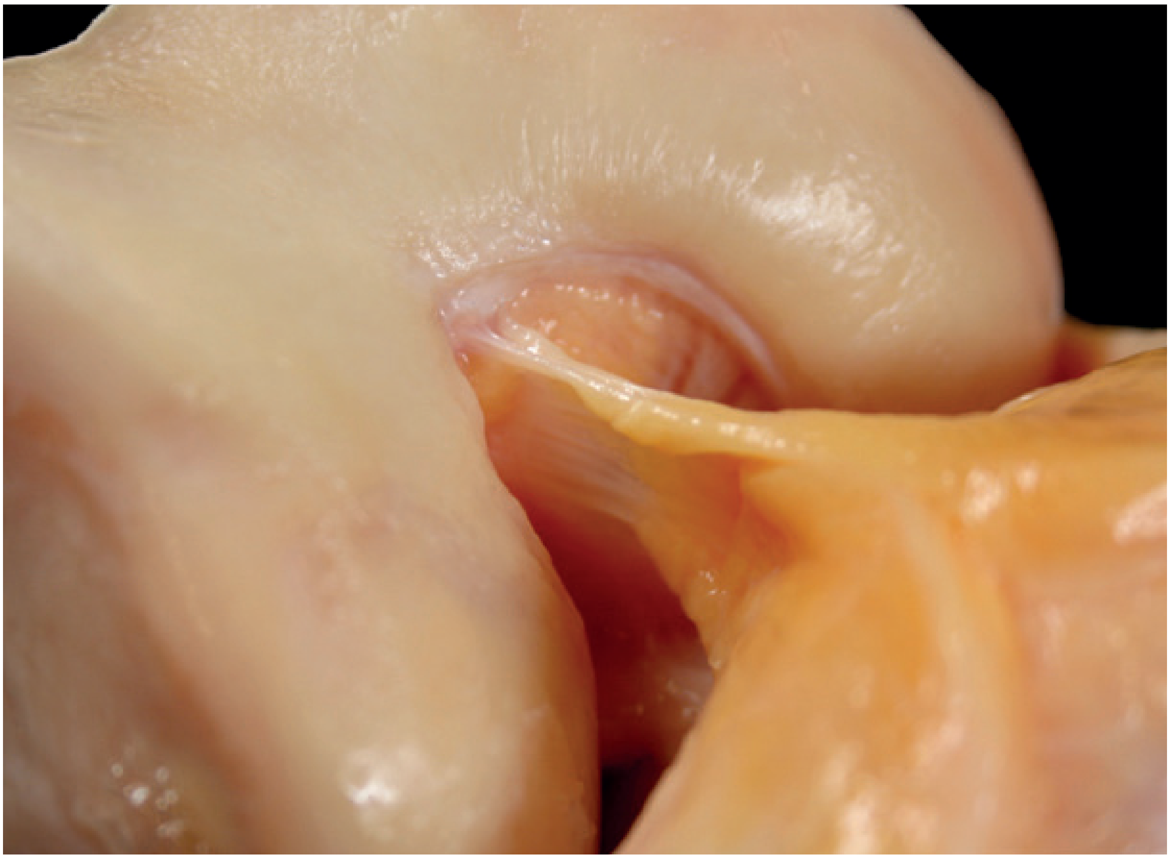


Figura 1: Imagen anatómica del cartílago en fémur. Imagen reproducida con el permiso de Iván Sáenz.

1.1.2. Estructura y función del cartílago articular hialino

El cartílago articular hialino es un tejido conectivo altamente especializado que recubre las superficies articulares. Se trata de un tejido avascular, aneural y alinfático. Se caracteriza por su viscoelasticidad, que permite la capacidad de resistencia, distribución y transmisión de fuerzas hacia el hueso subcondral con una baja fricción.[2]

El cartílago articular hialino está formado por células, denominadas condrocitos, y por la matriz extracelular. La matriz extracelular está constituida principalmente por agua (60-80%) y por macromoléculas, siendo las más importantes el colágeno (sobre todo tipos II, VI, IX y XI), los proteoglicanos y las proteínas no colágenas.[3]

A pesar de su compleja estructura, la capacidad de curación espontánea de las lesiones en el cartílago articular es muy limitada.[4]

1.1.3. Prevalencia

Las lesiones del cartílago articular de la rodilla son una patología cada vez más frecuente en nuestro entorno en pacientes jóvenes y activos.[5] En la literatura se ha objetivado una prevalencia de lesiones condrales del 60-66% durante la realización de una artroscopia de rodilla, siendo el 5-20% lesiones de alto grado. Las localizaciones más frecuentes de las lesiones condrales se describieron en cóndilo femoral medial (30-45%) y patela (20-34%).[6-8] La etiología predominante en pacientes jóvenes activos es la traumática y la osteocondritis disecante.

1.1.4. Clínica

En pacientes jóvenes, las lesiones condrales suelen producir un dolor insidioso asociado a inflamación, afectando a la vida diaria y a las actividades deportivas del paciente, generando por lo general un deterioro funcional progresivo. Las lesiones condrales sintomáticas han demostrado tener un efecto devastador en la calidad de vida, generando mayores dolencias incluso que las personas con rotura del ligamento cruzado anterior y una afectación de la calidad de vida similar a los pacientes programados para prótesis total de rodilla.[9]

Además, debido a la limitada capacidad de curación espontánea de estas lesiones, pueden conducir al desarrollo de artrosis a una edad temprana, lo que supone un problema importante en nuestra sociedad.

1.1.5. Diagnóstico y pruebas de imagen

El examen físico es crucial para el diagnóstico de lesiones del cartílago articular de la rodilla. En la historia clínica es necesario valorar el inicio y duración de los síntomas, así como descartar la presencia de factores de riesgo como el consumo de corticoesteroides. En la exploración física, es preciso evaluar la localización del dolor y la presencia de derrame articular y de síntomas mecánicos.[10] Además, es de suma importancia descartar inestabilidades concomitantes en la rodilla, así como desalineaciones del eje de las extremidades inferiores.[11]

Respecto a las pruebas de imagen, un estudio completo debería incluir radiografías, resonancia magnética y tomografía computarizada. La evaluación mediante radiografías incluye radiografías de ambas rodillas mediante proyecciones anteroposteriores en carga, laterales, axiales y radiografía telemétrica de toda la extremidad inferior para evaluación de la alineación. La resonancia magnética permite la evaluación precisa de la lesión condral, valorando su localización, tamaño y profundidad.

Además, permite la evaluación de lesiones ligamentosas y meniscales asociadas.[12] La tomografía computarizada es de utilidad para evaluar la displasia femoropatelar y para valorar la afectación ósea.

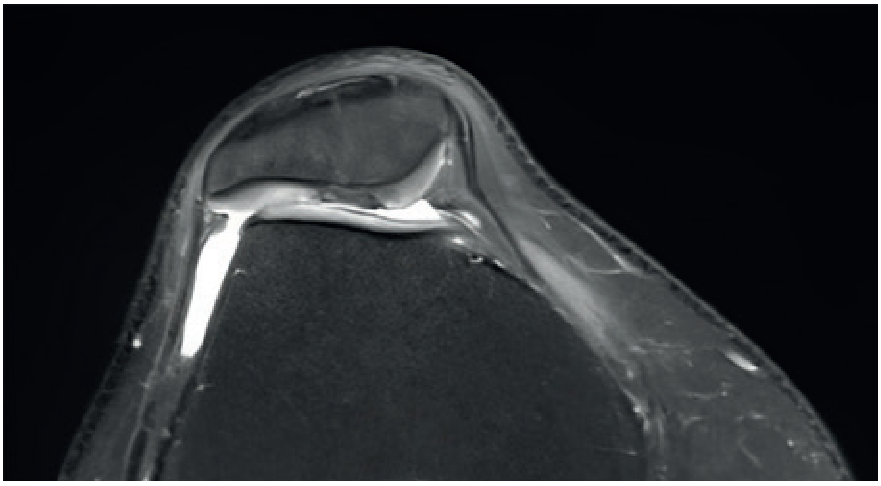


Figura 2: Imagen de resonancia magnética con lesión osteocondral en rótula.

1.1.6. Tratamiento

El tratamiento de las lesiones condrales y osteocondrales de la rodilla en pacientes jóvenes y activos continúa siendo un desafío para el cirujano ortopédico, ya que las prótesis de rodilla no ofrecen unos resultados óptimos en términos de satisfacción, funcionalidad y supervivencia del implante en este tipo de pacientes.[13]

Para el tratamiento de las lesiones del cartílago de la rodilla, en primer lugar, es necesario corregir cualquier patología concomitante que pueda afectar al posterior tratamiento del cartílago. Estos tratamientos de patologías concomitantes incluyen la corrección de eventuales desalineaciones de la extremidad inferior mediante osteotomías proximales tibiales, osteotomías distales femorales u osteotomías de la tuberosidad tibial anterior, restitución de la estabilidad en aquellas patologías afectadas por una lesión de ligamentos y la realización de trasplantes meniscales en casos de síndrome postmeniscectomía.

Para el tratamiento específico de las lesiones del cartílago, en primer lugar, es necesario valorar la profundidad de las lesiones, pudiendo dividirse en lesiones condrales (afectación aislada del cartílago articular) o lesiones osteocondrales (afectación concomitante de cartílago articular y del hueso subcondral). El tratamiento depende del tamaño de la lesión, profundidad y localización.

Para tratar lesiones condrales menores de 2 cm^2 hay numerosas alternativas válidas y muy extendidas. Un ejemplo de ellas son las microfracturas o nanofracturas, que consiste en la realización de pequeñas perforaciones a través de la lesión en el tejido subcondral para permitir un aporte sanguíneo y celular. Otras técnicas incluyen el trasplante de condrocitos autólogos, o diferentes tipos de mallas que ayudarían a generar un tejido fibrocartilaginoso dentro de la lesión tratada. Cuando la lesión también afecta el hueso subcondral, pero sigue siendo de un tamaño reducido ($<2cm^2$), uno de los tratamientos más extendidos es la transferencia de autoinjertos osteocondrales. En ella, se obtienen cilindros osteocondrales de la propia rodilla del paciente obtenidos de un área con menor exigencia mecánica, para su posterior implantación en la zona de la lesión.

En los casos de lesiones osteocondrales mayores a $2cm^2$, las opciones terapéuticas utilizadas en las lesiones más pequeñas ofrecen peores resultados. En pacientes mayores, podrían tener su lugar las sustituciones totales o parciales protésicas. Pero es en pacientes jóvenes, donde encuentra aquí su rol la técnica de trasplante de aloinjerto osteocondral fresco. Ella se define por la realización de un trasplante en bloque de cartílago y hueso subcondral adecuado para el tamaño de la lesión osteocondral, conservado a una temperatura y condiciones de cultivo adecuadas para permitir la viabilidad celular condral.[11]

1.2. Trasplante osteocondral fresco de rodilla

1.2.1. Indicaciones

El trasplante de aloinjerto osteocondral fresco (FOCA. Del inglés, *fresh osteochondral allograft*) implica la transferencia en bloque de un aloinjerto de cartílago y hueso subcondral desde un donante fallecido joven al paciente receptor. Esto permite obtener un cartílago hialino articular viable mediante un solo procedimiento quirúrgico sin limitaciones de tamaño, con el objetivo de obtener una mejoría sintomática y funcional con la posibilidad de retrasar o eliminar el momento de la cirugía protésica.[10]

Como resumen, el trasplante de FOCA está indicado en pacientes jóvenes y activos con lesiones osteocondrales sintomáticas mayores de 2cm^2. Los principales criterios de exclusión para la realización de este tratamiento incluyen artritis inflamatorias sistémicas, grandes lesiones degenerativas con afectación tricompartimental, infección activa, historia de osteomielitis o neoplasia activa.

1.2.2. Obtención

El "Banc de Sang i Teixits" suministra y realiza el procesamiento preoperatorio del aloinjerto osteocondral fresco. El aloinjerto osteocondral fresco es obtenido de donantes menores de 45 años durante las primeras 24 horas tras la asistolia. Una vez obtenido, se coloca en el medio de transporte (solución de Ringer lactato) y se preserva refrigerado entre 4ºC y 8ºC. Posteriormente se realiza la preparación y limpieza de los aloinjertos en una sala limpia de clase B bajo un flujo laminar clase A. El procesamiento de los injertos incluye la evaluación del cartílago, eliminación del tejido blando y periostio. Posteriormente son sometidos a un proceso de descontaminación que incluye lavado pulsátil de alta presión con solución salina estéril, centrifugación e inmersión en solución de preservación (Ringer lactato) junto con cóctel antibiótico.

Se realizan controles microbiológicos tanto al inicio de la manipulación (hisopado, tioglicolato muestra injerto y hemocultivo solución transporte) como a los 3-5 días post-descontaminación (hisopado, tioglicolato muestra injerto y hemocultivo solución preservación). Finalmente, los injertos son mantenidos, hasta el momento del implante en el paciente, refrigerados a 4°C y 8°C durante un periodo máximo de 3 semanas desde su obtención.

1.2.3. Técnica

La técnica para la realización del trasplante osteocondral fresco de rodilla depende del tamaño y la localización de la lesión. Habitualmente se realiza mediante una artrotomía parapatelar medial o lateral.[14]

Previamente a la realización propiamente dicha del trasplante osteocondral fresco de la rodilla, se realiza una artroscopia para la evaluación completa de la rodilla y para confirmar la localización y tamaño de las lesiones osteocondrales. Asimismo, es necesario corregir cualquier deformidad anatómica o alteración biomecánica de la articulación afectada mediante osteotomías o reconstrucciones ligamentosas.

El tratamiento mediante cilindros osteocondrales (bone-dowel o bone-plug technique, del inglés) es adecuado en el caso de lesiones aisladas en regiones de fácil acceso de la rodilla. Estas regiones incluyen los cóndilos femorales, la parte central de la rótula y la tróclea no displásica. En primer lugar, se realiza una medición de la lesión osteocondral, posteriormente se realiza un fresado de la lesión hasta una profundidad de 8-10mm. Seguidamente se realiza un cilindro osteocondral del tamaño adecuado en el aloinjerto fresco, y posteriormente se retiran los tejidos blandos adheridos y se realiza un lavado pulsátil de alta presión durante 15 minutos para minimizar cualquier posible reacción inmunológica. Finalmente, se introduce el cilindro osteocondral en la región de la lesión, obteniéndose habitualmente una fijación a presión.[10]

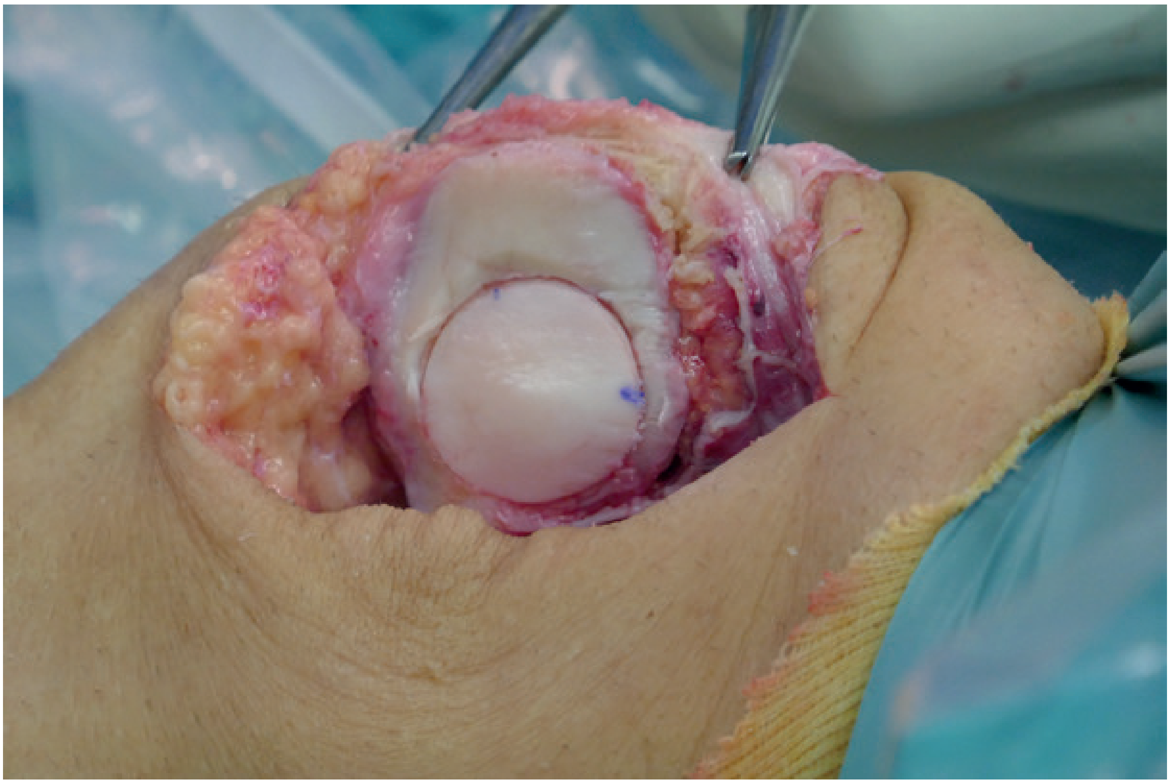
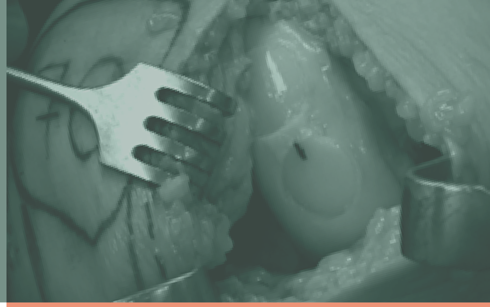


Figura 3: Imagen de cilindro osteocondral en parte central de rótula.

En caso de lesiones en regiones asimétricas (rótula completa o tróclea displásica) se realiza la técnica de la concha (shell technique) o resuperficialización, permitiendo la restauración precisa de la anatomía. En el caso de las lesiones de rótula completa se realiza la resección completa del cartílago y parte de su hueso subcondral afectado, así como la obtención en el aloinjerto, con la ayuda de una guía estándar de corte patelar de las prótesis de rodilla. Posteriormente se realiza la fijación con pines bioabsorbibles de 1,5mm de diámetro desde la superficie articular.[15,16]

Figura 4: Imagen de técnica de la concha en rótula durante la fijación con pines bioabsorbibles.

En casos de lesiones postraumáticas de la meseta tibial con afectación meniscal, se realiza el trasplante de la meseta tibial completa con menisco. La fijación habitualmente se realiza con un par de tornillos a compresión de 4–5mm de diámetro.[17,18]



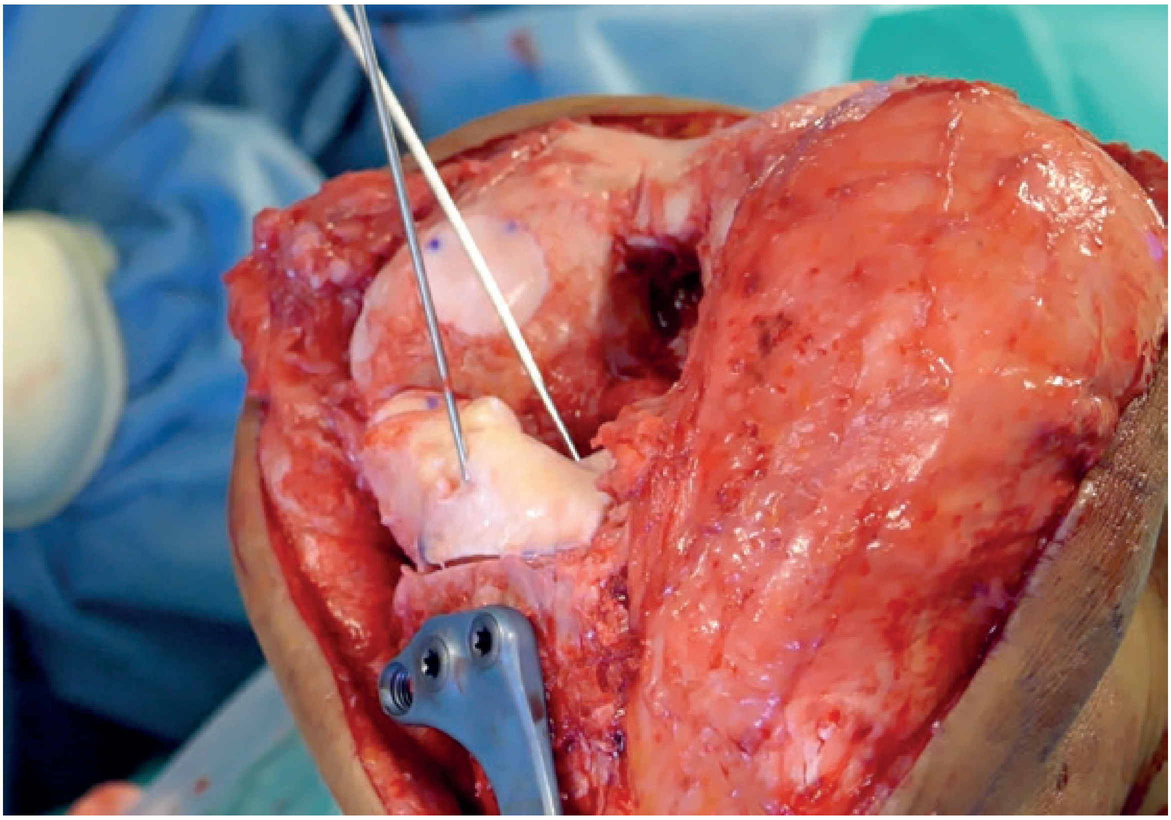


Figura 5: Imagen de técnica de trasplante de la meseta tibial completa con menisco.

1.2.4. Resultados clínicos

Los estudios sobre el trasplante de aloinjertos osteocondrales frescos en la rodilla han demostrado buenos resultados clínicos y de supervivencia del implante, siendo la mayoría de estudios dirigidos a patología femoral, con un menor número de estudios dirigidos a patología tibial y patelofemoral. La supervivencia a largo plazo depende de la presencia de condrocitos viables, de una correcta matriz extracelular y de una correcta integración del injerto en el hueso del huésped.[17,19–23]

En la literatura se ha demostrado la viabilidad a largo plazo de los condrocitos de los aloinjertos osteocondrales en fresco. Un hecho fundamental es la ausencia de respuesta inmunológica de rechazo, valorada en estudios experimentales e histológicos. Por ello, este tipo de trasplante no requiere la administración de inmunosupresores ni la realización de estudios de histocompatibilidad o grupo sanguíneo entre donante y receptor.[24,25]

Se han observado peores resultados postoperatorios en pacientes con IMC elevados, elevado número de cirugías previas, grandes lesiones (>10 cm^2) y trasplantes bipolares, definidos por trasplantes osteocondrales que incluyen 2 superficies articulares opuestas (cóndilo femoral y tibia, así como rótula y tróclea).[22,26–28]

1.2.5. Estudios de imagen postoperatorios

Durante el seguimiento postoperatorio, los estudios de imagen, conjuntamente con los resultados clínicos, son esenciales para evaluar la correcta evolución del trasplante de aloinjerto osteocondral fresco en la rodilla. No obstante, en la literatura existe un número limitado de estudios que valoren conjuntamente los resultados clínicos y radiológicos tras la realización de un trasplante de aloinjerto osteocondral.[17,21,29–33]

Actualmente, la Resonancia Magnética (RM) es considerada la prueba de imagen "gold standard" ya que permite evaluar el cartílago articular, cambios subcondrales, integración periférica y lesiones circundantes. Para el seguimiento de los aloinjertos osteocondrales frescos de rodilla existen dos escalas de RM. La escala MOCART (Magnetic Resonance Observation of Cartilage Repair Tissue) se diseñó para evaluar estas características, pero no existen pruebas sólidas sobre su fiabilidad para la predicción de los resultados clínicos.[34,35] Recientemente se ha descrito la escala OCAMRISS (Osteochondral Allograft MRI Scoring System) para la evaluación específica de los trasplantes osteocondrales frescos de rodilla. No obstante, sus resultados no se han correlacionado significativamente con las puntuaciones de los resultados clínicos.[36–38]

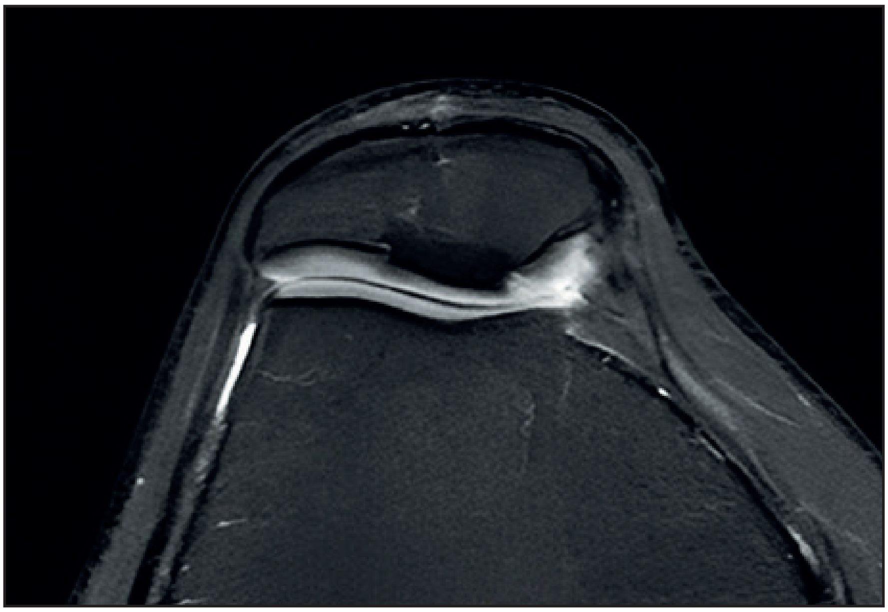


Figura 6: Imagen postoperatoria por resonancia magnética de cilindro osteocondral en parte central de rótula.

Respecto a la evaluación mediante Tomografía Computarizada (TC), es importante destacar la mayor resolución espacial respecto a la RM.[39] En la literatura se ha demostrado la gran importancia de los aspectos óseos, como la integración ósea y los cambios quísticos, para la supervivencia del aloinjerto tras la realización de un trasplante osteocondral fresco de rodilla, por lo que sería razonable su utilización como seguimiento postoperatorio.[23] No obstante, el número de estudios que evalúan los aloinjertos mediante TC es muy limitado en la literatura, y no existe en la actualidad ninguna escala de TC validada para la evaluación postoperatoria de los trasplantes osteocondrales frescos de rodilla.[40,41]

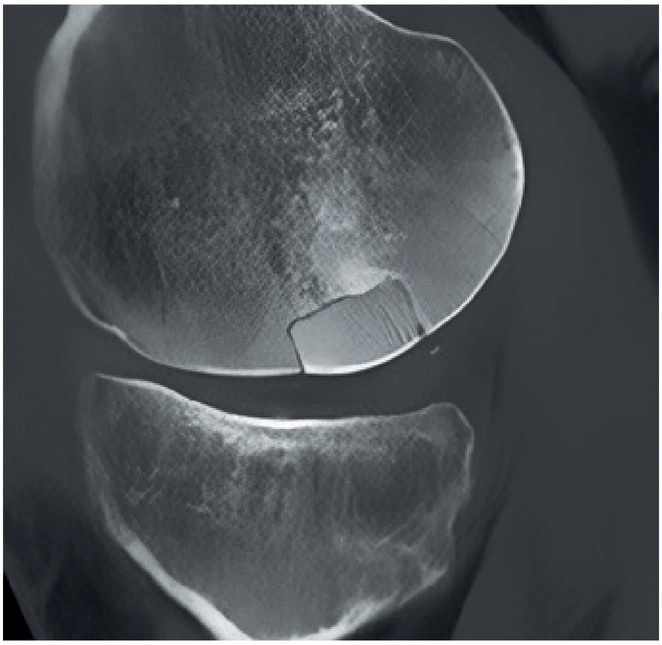


Figura 7: Imagen postoperatoria por resonancia magnética de cilindro osteocondral en cóndilo femoral.

Fundamento de los estudios

2

Fundamento de los estudios

Los estudios incluidos para esta investigación se centran en la evaluación postoperatoria de los aloinjertos osteocondrales frescos mediante Tomografía Computarizada.

El primer estudio incluido para esta propuesta de tesis doctoral (A new computed tomography scoring system to assess osteochondral allograft transplantation for the knee: inter-observer and intra-observer agreement - Un nuevo sistema de puntuación por tomografía computarizada para la evaluar el trasplante de aloinjertos osteocondrales para la rodilla: concordancia interobservador e intraobservador) tiene como objetivo la descripción y validación de una nueva escala de TC para la evaluación postoperatoria tras la realización de un trasplante de aloinjerto osteocondral de la rodilla. Este trabajo tiene su fundamento en la ausencia en la literatura actual de una escala validada para la evaluación postoperatoria mediante TC de los aloinjertos osteocondrales de rodilla. La literatura respalda la importancia clave de los aspectos óseos para unos buenos resultados clínicos tras la realización de un trasplante osteocondral de rodilla, así como la mayor resolución espacial del TC respecto a la RM. No obstante, la mayoría de estudios realizan su evaluación mediante RM, cuyas escalas no han demostrado una correlación significativa con las puntuaciones de los resultados clínicos. Por tanto, en este primer estudio, el objetivo fue describir un nuevo sistema de puntuación semicuantitativo por TC para el análisis multifactorial de la reparación de lesiones osteocondrales de la rodilla mediante aloinjertos osteocondrales y evaluar su variabilidad interobservador e intraobservador.

Tras los resultados obtenidos en el primer estudio, en el segundo estudio incluido para esta propuesta de tesis doctoral (*Computerized tomography scan evaluation after fresh osteocondral allograft transplantation of the knee correlates with clinical outcomes - La evaluación mediante tomografía computarizada tras la realización de un trasplante de aloinjerto osteocondral fresco de la rodilla se correlaciona con los resultados clínicos*) se evalúa la correlación entre los resultados de imagen mediante la escala de TC descrita y validada en el primer estudio (escala ACTOCA), y los resultados clínicos. Este trabajo tiene su fundamento en la importancia clave de la evaluación conjunta de los resultados clínicos y radiológicos tras la realización de un trasplante de aloinjerto

osteocondral, debido al número limitado de estudios sobre este aspecto en la literatura, así como en la ausencia de estudios sobre la evaluación conjunta de los resultados clínicos y de imagen mediante una escala de TC validada. Por tanto, en este segundo estudio, el objetivo fue determinar la correlación entre el sistema de puntuación mediante TC validado en el primer estudio (escala ACTOCA) y la puntuación de los resultados clínicos para valorar su uso en la práctica clínica.

En el tercer estudio incluido para esta propuesta de tesis doctoral (*Early postoperative CT Scan provides prognostic data on clinical outcomes of fresh osteochondral transplantation of the knee – La tomografía computarizada postoperatoria temprana proporciona datos pronósticos sobre los resultados clínicos del trasplante osteocondral fresco de rodilla*) se evalúa la capacidad de predicción de resultados clínicos de la escala ACTOCA, validada en el primer estudio y estudiada su correlación clínica en el segundo estudio. Este trabajo tiene su fundamento en la ausencia de información en la literatura actual con respecto a la capacidad de los estudios de imagen para predecir los resultados clínicos después de la realización de un trasplante de aloinjerto osteocondral de la rodilla. Por tanto, en este tercer estudio, el objetivo fue determinar el valor del TC precoz para predecir el resultado clínico futuro del trasplante de aloinjerto osteocondral de la rodilla mediante la puntuación de TC denominada ACTOCA.

Finalmente, se incluyeron otros dos artículos como material complementario para esta tesis. El primero de ellos (*Fresh osteochondral resurfacing of the patellofemoral joint – Trasplante osteocondral fresco de la articulación femoropatelar*) es una nota de técnica quirúrgica sobre la realización de trasplante osteocondral fresco bipolar de la rótula y la tróclea. El segundo artículo (*Salvage Procedures: Last chance before arthroplasty – Procedimientos de rescate: última oportunidad antes de la artroplastia*) es una revisión sobre las técnicas quirúrgicas y resultados de los trasplantes osteocondrales bipolares de rodilla.

Los tres artículos de esta propuesta de tesis doctoral fueron publicados en revistas ortopédicas de alto impacto, y se realizaron en el campo del estudio de los aloinjertos osteocondrales de rodilla mediante TC. Los dos artículos incluidos como material complementario también fueron publicados en revistas ortopédicas de alto factor de impacto.

Objetivo e hipótesis

3

Objetivo e hipótesis

3.1. Estudio 1

Título: *A new computed tomography scoring system to assess osteochondral allograft transplantation for the knee: inter-observer and intra-observer agreement.*

Objetivo: Describir un nuevo sistema de puntuación semicuantitativo por TC para el análisis multifactorial de la reparación de lesiones osteocondrales de la rodilla mediante aloinjertos osteocondrales y evaluar su variabilidad interobservador e intraobservador.

Hipótesis: La nueva escala de puntuación de TC (ACTOCA) mostrará suficiente fiabilidad interobservador e intraobservador para apoyar su uso en la práctica clínica tras la realización de un trasplante osteocondral de rodilla.

3.2. Estudio 2

Título: *Computerized tomography scan evaluation after fresh osteocondral allograft transplantation of the knee correlates with clinical outcomes.*

Objetivo: Determinar la correlación entre el sistema de puntuación mediante TC validado en el primer estudio (escala ACTOCA) y la puntuación de los resultados clínicos para valorar su uso en la práctica clínica tras la realización de un trasplante osteocondral de rodilla.

Hipótesis: La puntuación de TC mediante la escala ACTOCA mostrará suficiente correlación con los resultados clínicos para apoyar su uso en la práctica clínica tras la realización de un trasplante osteocondral de rodilla.

3.3. Estudio 3

Título: *Early postoperative CT Scan provides prognostic data on clinical outcomes of fresh osteochondral transplantation of the knee.*

Objetivo: Determinar el valor del TC para predecir el resultado clínico del trasplante de aloinjerto osteocondral de la rodilla mediante la puntuación de TC denominada ACTOCA.

Hipótesis: Una evaluación postoperatoria precoz mediante TC después de un trasplante osteocondral de rodilla mediante la escala ACTOCA permite predecir resultados clínicos posteriores.

Material y métodos

4

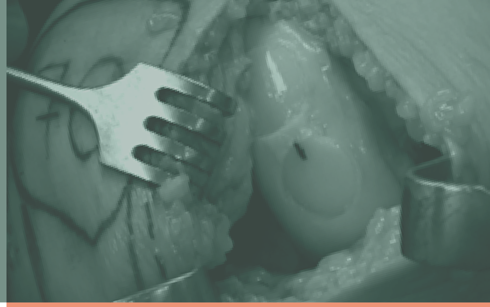
4.1. Estudio 1

A new computed tomography scoring system to assess osteochondral allograft transplantation for the knee: inter-observer and intra-observer agreement.

En el primer estudio, se diseñó un sistema de puntuación semicuantitativo mediante TC para la evaluación postoperatoria de los aloinjertos osteocondrales de la rodilla denominado ACTOCA (assessment computed tomography osteochondral allograft). El sistema de puntuación incluye cinco características de TC: Densidad relativa al hueso del huésped, integración en la unión del injerto del huésped, porcentaje de superficie con hendidura discernible en la unión del injerto del huésped, cambios quísticos y fragmentos intraarticulares. La variabilidad interobservador fue calculada mediante tres observadores cegados a la historia clínica y al tratamiento del paciente. También se determinó la variabilidad intraobservador.

4.1.1. Criterios de inclusión y exclusión

Todos los pacientes que se sometieron a un trasplante osteocondral de rodilla en nuestro centro entre 2017 y 2019 fueron estudiados retrospectivamente. Los criterios de inclusión fueron pacientes jóvenes menores de 50 años, con lesiones focales del todo el espesor condral o lesiones osteocondrales mayores de $2cm^2$. En el caso de trasplante osteocondral tibiofemoral, la desalineación tibiofemoral mayor de 3° del eje mecánico neutro en el compartimento afecto fue corregida mediante una osteotomía concomitante de realineación. En el caso de trasplante osteocondral femoropatelar, el maltracking femoropatelar fue corregido mediante osteotomía de la tuberosidad tibial anterior y, en caso necesario, reconstrucción del ligamento patelofemoral medial para restaurar la estabilidad de la rótula.



Los criterios de exclusión fueron las artritis inflamatorias, grandes lesiones degenerativas afectando a los tres compartimentos, IMC > 30 kg/m^2, diabetes mellitus, enfermedades sistémicas inflamatorias, infección o historia de osteomielitis en el área receptora, y neoplasia activa.

4.1.2. Técnica de TC

Las Tomografías Computarizadas fueron realizadas a los 3 y 12 meses postoperatorios. Los estudios de TC fueron realizados en un "16-multidetector system (Brillance, Philips Healthcare)" utilizando un protocolo de dosis reducida, con la longitud de exploración mínima necesaria para incluir el aloinjerto. Las imágenes multiplanares reformateadas sagitales y coronales contiguas de 2 mm se obtuvieron posteriormente. La colimación se realizó para todos los TC con el fin de aumentar la calidad de la imagen y reducir la exposición general a la radiación del paciente.

4.1.3. Sistema de puntuación de TC

Basado en la reportada experiencia del equipo en el tratamiento mediante trasplante osteocondral de rodilla[16,18], se diseñó un sistema de puntuación semicuantitativo mediante TC para la evaluación postoperatoria de los aloinjertos osteocondrales de la rodilla denominado ACTOCA (assessment computed tomography osteochondral allograft). ACTOCA incluye cinco características de TC relativas al aspecto del aloinjerto trasplantado y al hueso receptor (Tabla 1). Se utilizaron cortes axiales para evaluar la articulación femoropatelar, así como cortes sagitales para evaluar los cóndilos femorales.

Características del TC	Puntuación
1. Densidad del injerto en relación con el hueso huésped	0: Equivalente
	1: Superior
	2: Inferior
2. Integración ósea en la unión huésped-injerto	0: Trabéculas cruzadas
	1: Hendidura discernible <3mm
	2: Hendidura discernible >3mm
3. Porcentaje de superficie con una hendidura discernible en la unión huésped-injerto	0: <30%
	1: >30%
4. Cambios quísticos del injerto y/o unión huésped-injerto	0: Ausente
	1: Presente <3mm
	2: Presente >3mm
5. Presencia de fragmentos intrarticulares	0: Ausente
	1: Presente

Tabla 1: Sistema de puntuación ACTOCA

Características del TC evaluadas:

1. Densidad del injerto en relación con el hueso huésped: La señal del injerto aparece equivalente (0), superior (1), o inferior (2) al hueso huésped.
2. Integración ósea en la unión huésped-injerto: La integración ósea es evaluada en la unión huésped-injerto, buscando trabéculas óseas cruzadas sin hendidura discernible (0), o presencia de hendidura discernible <3mm (1) 0 >3mm (2).

3. Porcentaje de superficie con una hendidura discernible en la unión huésped-injerto: Se evalúa la presencia de menos de un 30% (0) o más de un 30% (1) de la superficie con una hendidura discernible en la unión huésped-injerto.
4. Cambios quísticos del injerto y/o unión huésped-injerto: Se valora la presencia de cambios quísticos en el injerto y/o en la unión huésped-injerto buscando ausencia de quistes (0), quistes menores de 3mm (1), o quistes mayores de 3mm (2).
5. Presencia de fragmentos intrarticulares: Se evalúa la ausencia (0) o presencia (1) de fragmentos intrarticulares.

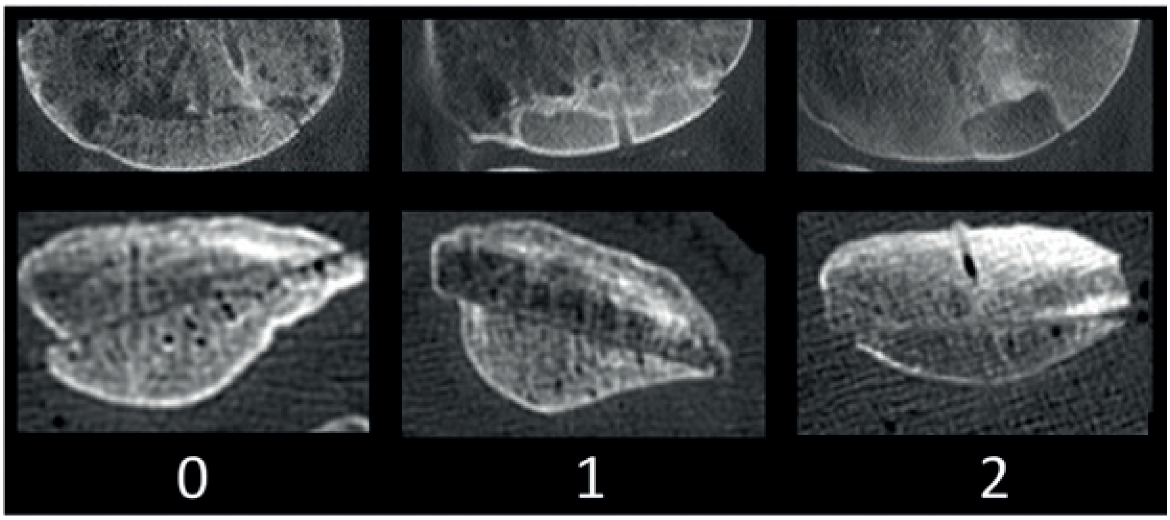


Figura 8: Densidad del injerto en relación con el hueso huésped

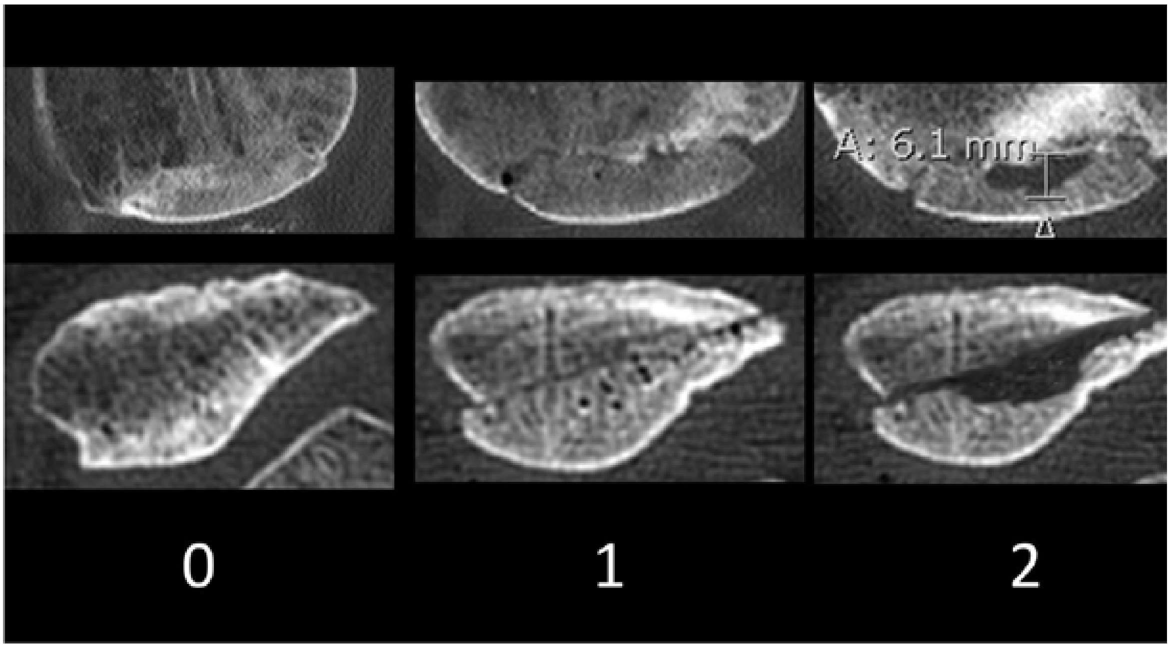


Figura 9: Integración ósea en la unión huésped-injerto

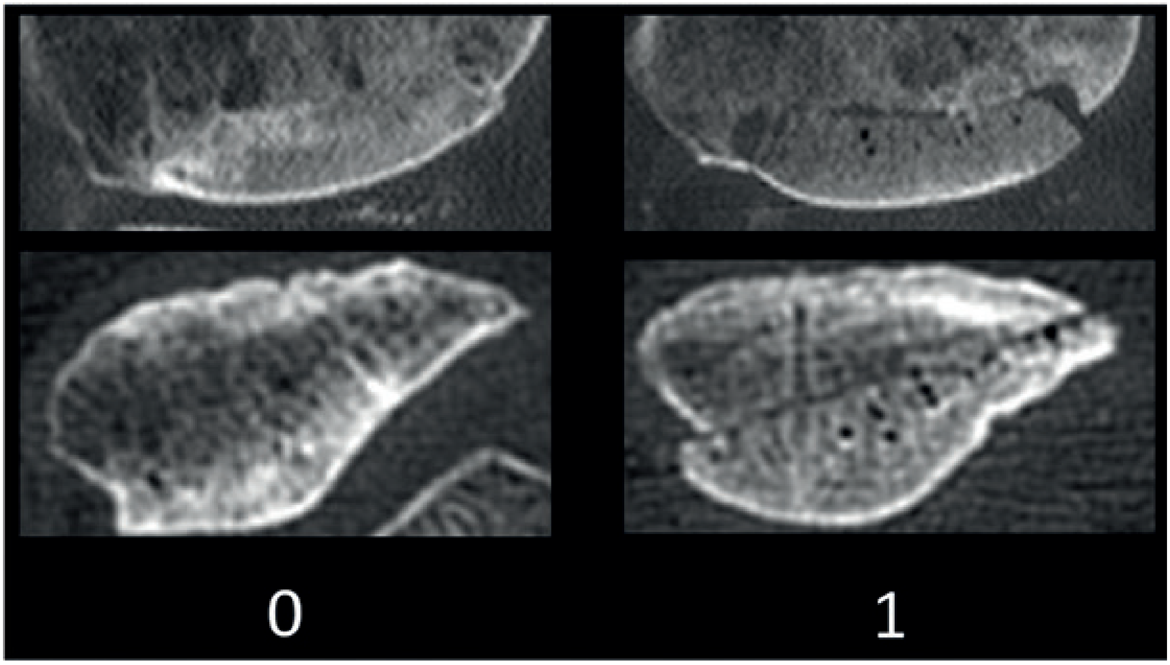


Figura 10: Porcentaje de superficie con una hendidura discernible en la unión huésped-injerto

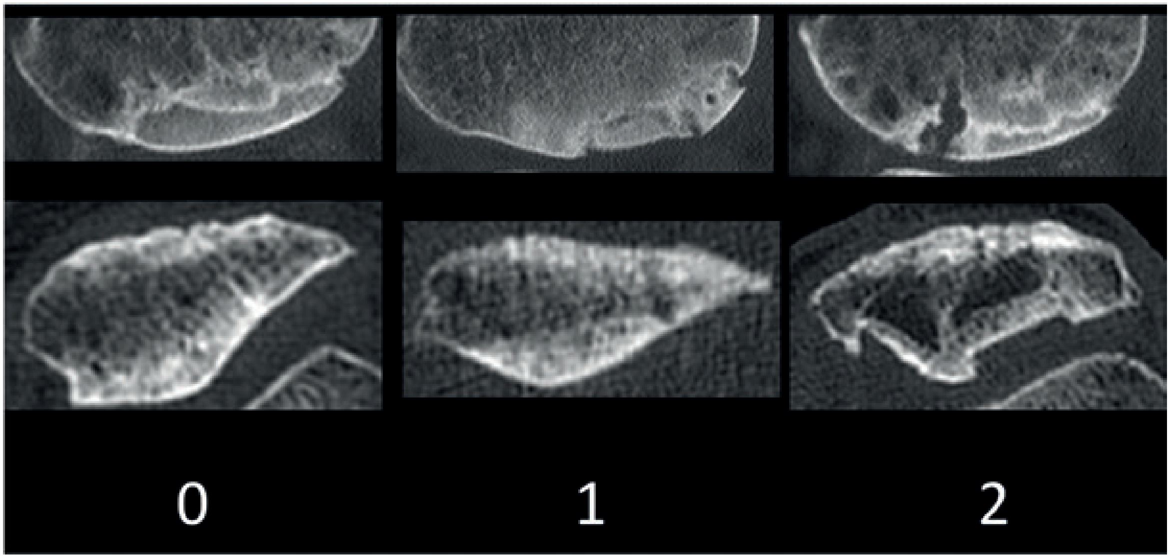


Figura 11: Cambios quísticos del injerto y/o unión huésped-injerto

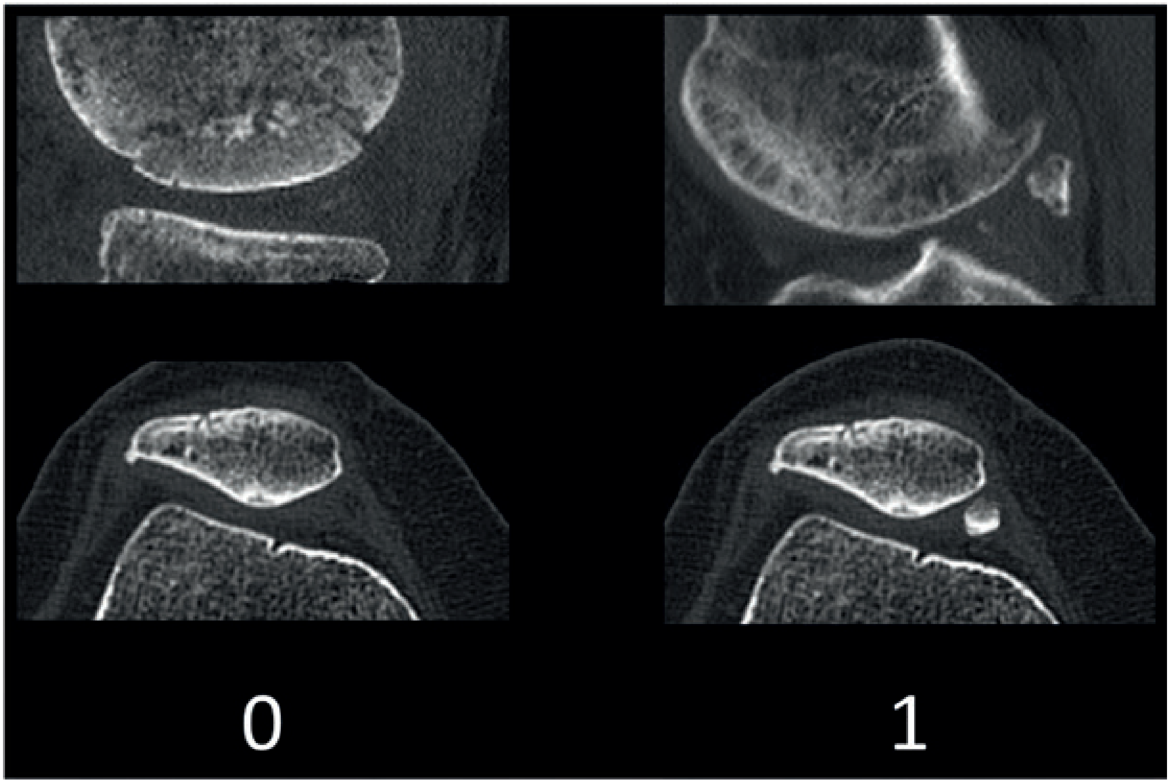


Figura 12: Presencia de fragmentos intrarticulares

4.1.4. Análisis estadístico

El análisis estadístico fue realizado mediante SPSS 19 (SPSS, Chicago, IL) e incluyó dos cálculos: variabilidad interobservador y variabilidad intraobservador en el sistema de clasificación de TC denominado ACTOCA. El coeficiente kappa (κ) fue calculado para analizar la concordancia del sistema de acuerdo con tres observadores (concordancia interobservador) y de un observador en dos momentos de tiempo (concordancia intraobservador).[42]

El coeficiente kappa (κ) ofrece una medida de la proporción de veces que los observadores coinciden, modificada para tener en cuenta el acuerdo que se produciría sólo por casualidad. Los valores se interpretan como <0,21 leve; 0,21–0,4 regular; 0,41–0,6 moderado; 0,61–0,8 sustancial; y 0,81–1,0 casi perfecto.[43,44]

Para determinar la variabilidad interobservador del sistema de clasificación por TC (ACTOCA), todos los TC fueron evaluados independientemente por tres observadores cegados a la historia clínica y tratamiento del paciente. Uno de ellos era un cirujano ortopédico senior, otro era un cirujano ortopédico junior, y otro era un radiólogo musculoesquelético. Previamente, un observador independiente había seleccionado las imágenes más representativas de cada TC. Ninguno de los tres observadores estaba involucrado en el tratamiento de estos pacientes. Antes de puntuar, se realizaron dos horas de sesiones de capacitación por consenso para calibrar y estandarizar la puntuación en un conjunto de datos independiente.

Para determinar la variabilidad intraobservador, un observador evaluó todas las imágenes de TC en dos ocasiones, con 15 días de diferencia.

4.2. Estudio 2

Computerized tomography scan evaluation after fresh osteocondral allograft transplantation of the knee correlates with clinical outcomes.

En el segundo estudio, se recogieron prospectivamente los datos de todos los pacientes que se sometieron consecutivamente a un trasplante osteocondral fresco por lesiones osteocondrales de rodilla y que tenían un seguimiento mínimo de dos años. Las exploraciones por TC se realizaron a los tres, seis y 24 meses postoperatorios. Un radiólogo musculoesquelético ciego a la historia clínica de los pacientes evaluó las exploraciones utilizando el sistema de puntuación ACTOCA. Los resultados clínicos recopilados preoperatoriamente y a tres, seis y 24 meses postoperatorios se evaluaron mediante el International Knee Documentation Committee (IKDC), Kujala, Western Ontario Meniscal Evaluation Tool (WOMET) y la Tegner Activity Scale.

4.2.1. Criterios de inclusión y exclusión

En este estudio prospectivo, se incluyó a todos los pacientes que se sometieron consecutivamente a reparación de cartílago mediante trasplante osteocondral fresco por lesiones osteocondrales de rodilla entre agosto de 2017 y agosto de 2019. La cirugía fue realizada por un único cirujano en un centro médico académico, y todos los pacientes tuvieron un seguimiento mínimo de dos años.

Los criterios de inclusión fueron pacientes menores de 50 años sometidos a reparación de cartílago con trasplante osteocondral fresco por lesiones osteocondrales sintomáticas de rodilla de inicio crónico tras un mínimo de seis meses de tratamiento conservador de acuerdo con la práctica clínica estándar de nuestra institución. El tratamiento quirúrgico se indicó en pacientes con lesiones condrales de espesor completo y lesiones osteocondrales focales grandes (> 2 cm^2) en la meseta tibial, cóndilos femorales, tróclea, y/o rótula.

Se realizó osteotomía de realineación concomitante en casos de trasplante osteocondral tibiofemoral con malalineación tibiofemoral superior a 3° desde el eje mecánico neutro en el compartimento afectado. En las articulaciones patelofemorales con una distancia de TAGT superior a 15 mm se realizó una osteotomía de anteromedialización en la tuberosidad tibial anterior. La ausencia de menisco concomitante se corrigió mediante el trasplante de aloinjerto meniscal lateral o medial, según fuera necesario. Los criterios de exclusión fueron artritis inflamatoria, lesiones degenerativas grandes que comprendían los tres compartimentos, IMC >30 kg/m^2, diabetes, enfermedades inflamatorias sistémicas, infección o antecedentes de osteomielitis en la zona receptora del injerto y neoplasia activa.

4.2.2. Técnica quirúrgica

Se realizó una evaluación artroscópica de todos los compartimentos de la rodilla para confirmar el tamaño y la profundidad de la lesión y para abordar cualquier patología intraarticular concurrente. Cualquier deformidad anatómica o alteración biomecánica de la articulación tibiofemoral y/o la articulación patelofemoral se corrigió para evitar una mayor degradación del cartílago del injerto.

El defecto del cartílago articular fue dimensionado y fresado a una profundidad de aproximadamente 8 a 10mm. Se obtuvieron aloinjertos osteocondrales frescos según los requisitos de selección y procesamiento del banco de tejidos local autorizado. El aloinjerto osteocondral fue irrigado mediante lavado pulsátil. Se realizó una técnica mediante cilindros osteocondrales para defectos aislados con un área afectada bien definida en una superficie de fácil acceso de la rodilla, como los cóndilos femorales, la región central de la rótula, o la tróclea. La técnica de la concha se utilizó para lesiones asimétricas, como las que afectaban a toda la rótula o las que afectaban a una tróclea displásica de alto grado.

En los casos de lesiones complejas postraumáticas de la meseta tibial con una deficiencia meniscal concomitante, se trasplantó una meseta tibial medial o lateral de 10 mm de altura, incluido el menisco correspondiente. Los cilindros osteocondrales son fijados a presión. El resto de técnicas requirieron fijación con pines bioabsorbibles o tornillos interfragmentarios.[16,18,45]

En la primera fase de la rehabilitación, de cero a seis semanas, el objetivo era la protección del injerto evitando la carga. El día después de la cirugía, se iniciaron los ejercicios de balance articular progresivo con un dispositivo de movimiento pasivo continuo. El peso y balance articular se modificaron en función de distintas variables, pero el objetivo era evitar el estrés del injerto trasplantado. Se permitió una transición gradual a carga parcial y completa tras un periodo de seis a diez semanas.[10]

4.2.3. Evaluación por TC

Las exploraciones por TC se realizaron postoperatoriamente el primer día postoperatorio para descartar cualquier error técnico y, a continuación, a los tres, seis y 24 meses. Los estudios por TC postoperatorios se obtuvieron en un "16-multidetector system (Brillance, Philips Healthcare)" utilizando un protocolo de dosis reducida, con la longitud de exploración mínima necesaria para incluir el aloinjerto. Las imágenes multiplanares reformateadas sagitales y coronales contiguas de 2 mm se obtuvieron posteriormente. La colimación se realizó para todos los TC con el fin de aumentar la calidad de la imagen y reducir la exposición general a la radiación del paciente.

Para este estudio de imágenes, se utilizó la escala de puntuación ACTOCA, previamente publicada y validada.[46] La escala ACTOCA incluye cinco características de TC relativas al aspecto del injerto trasplantado y el hueso huésped; densidad de señal del injerto, integración ósea, porcentaje de superficie con hendidura discernible, cambios quísticos y presencia de fragmentos intraarticulares.

Se utilizaron cortes axiales para evaluar la articulación patelofemoral y cortes sagitales para evaluar los cóndilos femorales y la tibia. Se calificó cada parámetro y se calculó la suma total. Una puntuación total más baja indica una mejor incorporación del injerto, con puntuaciones posibles que van de cero a ocho.

Todos los TC fueron evaluados por un radiólogo musculoesquelético cegado a la historia médica del paciente.

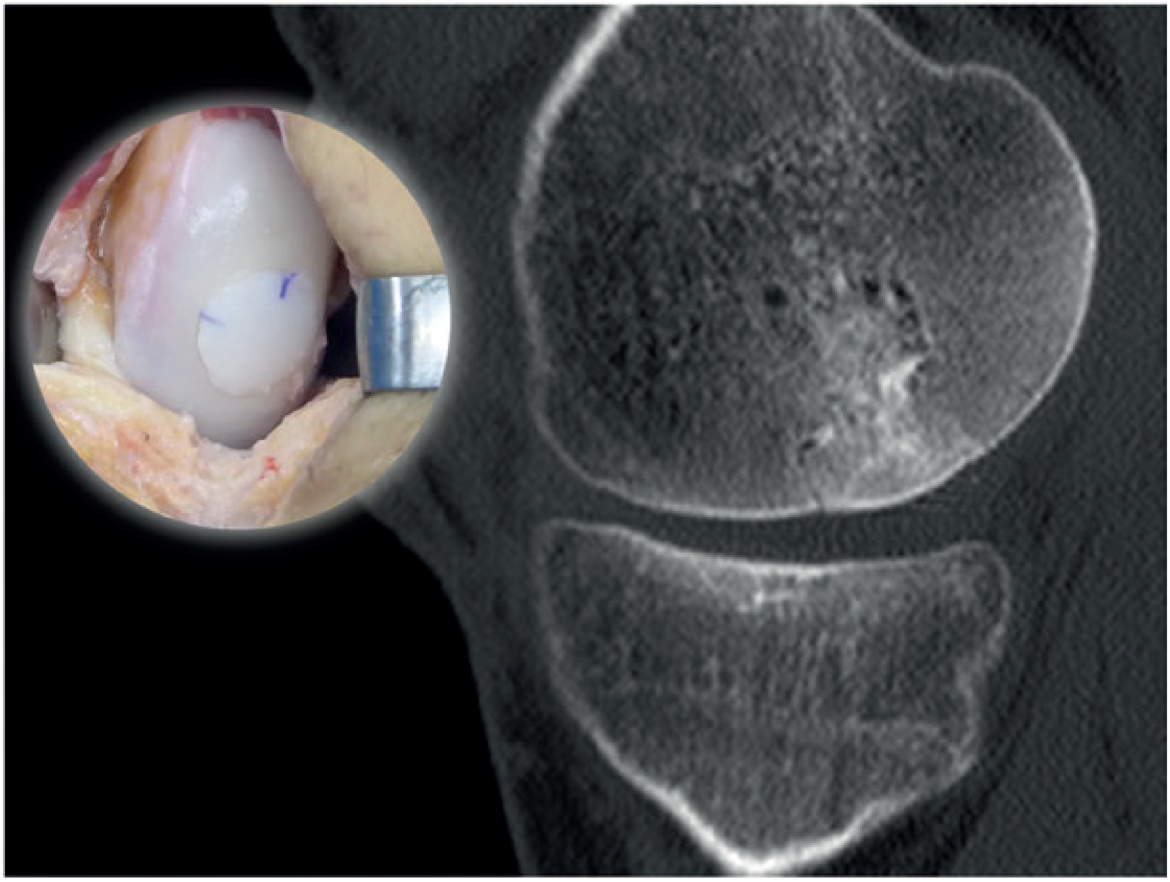


Figura 13: TC realizado a los 6 meses e imagen quirúrgica de un trasplante osteocondral de cóndilo femoral medial obteniendo una baja puntuación en la escala ACTOCA (1 punto)

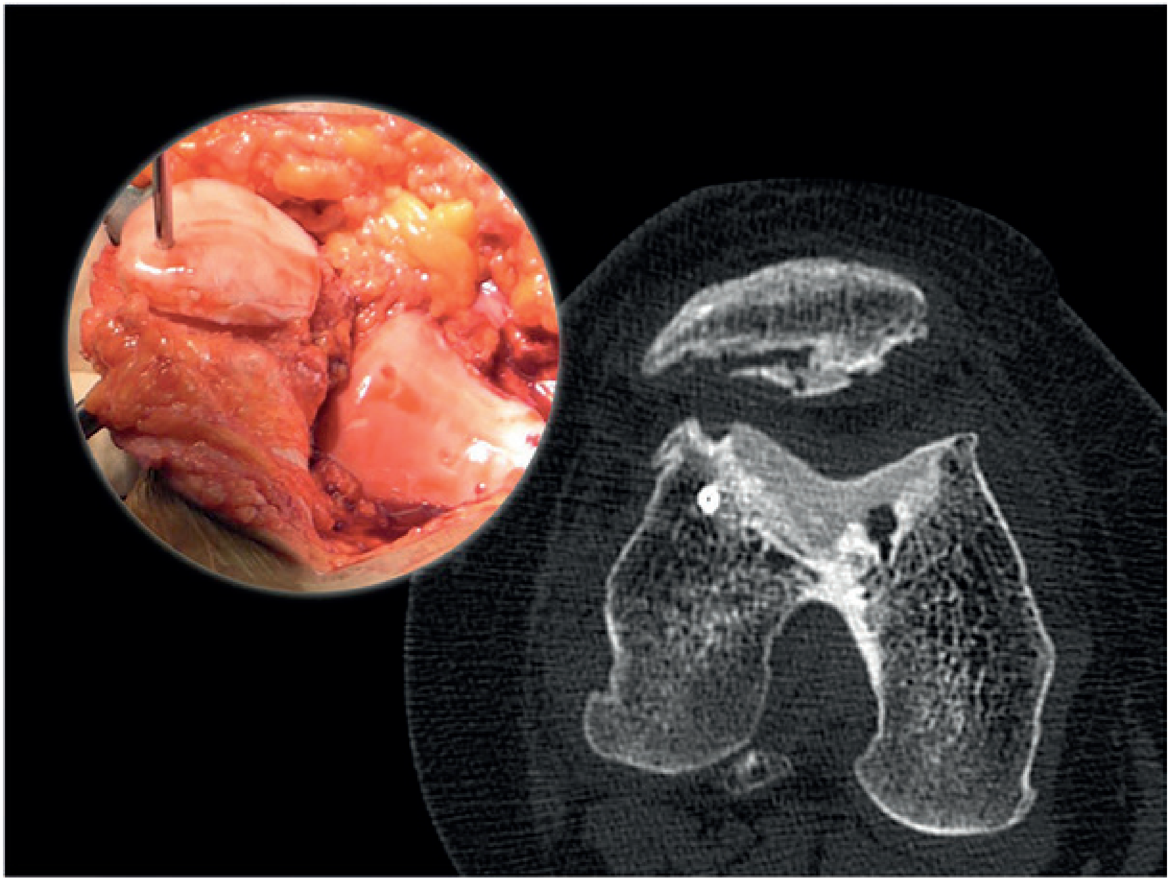


Figura 14: TC realizado a los 24 meses e imagen quirúrgica de un trasplante osteocondral de rótula y tróclea obteniendo una alta puntuación en la escala ACTOCA (6 puntos)

4.2.4. Evaluación funcional

Los resultados clínicos se recogieron preoperatoriamente y a los tres, seis y 24 meses postoperatorios. En cada momento, los participantes autocompletaron varias escalas clínicas para medir los resultados clínicos. Las escalas utilizadas fueron el IKDC, Kujala, WOMET, y la escala de actividad Tegner.[47–50]

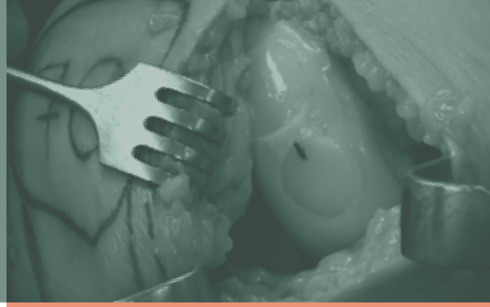
4.2.5. Resultados secundarios

Se recopilaron datos sociodemográficos al inicio del estudio para caracterizar la muestra y explorar la edad, el sexo al nacer, el lado implicado y el IMC como posibles variables de confusión. Los procedimientos concomitantes (osteotomía, reparación ligamentosa o reconstrucción, trasplante de aloinjerto meniscal) se registraron en el momento de la cirugía. También se observó el tipo de aloinjerto osteocondral (patelofemoral, cóndilo femoral o tibial).

4.2.6. Análisis estadístico

El análisis estadístico se realizó utilizando el paquete estadístico IBM SPSS V26.0 (IBM Corp. Armonk, NY). Se utilizaron estadísticas descriptivas para determinar las características del paciente y de la lesión. Los resultados se dan como un número de casos y/o porcentaje para los datos categóricos, y como media, desviación estándar y rango para los datos cuantitativos. Las variables repetidas durante el ensayo (escalas funcionales y TAC) se analizaron mediante test ANOVA para mediciones repetidas con corrección de Greenhouse–Geisser para evitar la esfericidad. La correlación entre resultados clínicos y los resultados de imágenes se analizó mediante el coeficiente de correlación de Pearson. El nivel general de significancia se fijó en 0.05 para las pruebas de dos niveles.

El cálculo de la potencia se realizó según el IKDC desde el preoperatorio hasta los 24 meses posteriores a la intervención. Se estableció a priori un umbral de 5 puntos de relevancia clínica. Este número es, de hecho, más bajo que varios estudios notificados para detectar cambios mínimos y similar a lo que se informó en un estudio reciente de Magnuson.[51] Según el cálculo de potencia, para generar una potencia del 80%, una alfa de 0.05 y una desviación estándar de 10 puntos, este estudio requirió 30 pacientes.



4.3. Estudio 3

Early postoperative CT Scan provides prognostic data on clinical outcomes of fresh osteochondral transplantation of the knee.

En el tercer estudio, se recopilaron de forma prospectiva los datos de todos los pacientes intervenidos consecutivamente de trasplante osteocondral fresco por lesiones osteocondrales de rodilla en un único centro entre agosto 2017 y agosto 2019. En todos los pacientes se realizó un seguimiento mínimo de 2 años. Las exploraciones por TC realizadas 6 meses después de la cirugía fueron evaluadas por un radiólogo musculoesquelético mediante el sistema de puntuación ACTOCA. El radiólogo no conocía la historia clínica del paciente. Los resultados clínicos se evaluaron preoperatoriamente y a los 12 y 30 meses postoperatoriamente mediante la puntuación del International Knee Documentation Committee (IKDC), la puntuación de Kujala, la escala de actividad de Tegner, y la puntuación de Western Ontario Meniscal Evaluation Tool (WOMET).

4.3.1. Criterios de inclusión y exclusión

Se realizó un estudio prospectivo de serie de casos que incluyó a todos los pacientes que se sometieron consecutivamente a reparación de cartílago mediante trasplante osteocondral fresco por lesiones osteocondrales de rodilla en un centro médico académico entre agosto de 2017 y agosto de 2019. Todas las cirugías fueron realizadas por un único cirujano (P.E.G.).

Los criterios de inclusión fueron los siguientes: pacientes con edades comprendidas entre 18 y 50 años intervenidos de trasplante osteocondral fresco por lesiones osteocondrales de rodilla. La indicación principal para el trasplante osteocondral fresco de rodilla fueron lesiones focales condrales de espesor completo y lesiones osteocondrales focales grandes (> 2 cm^2) en cóndilo femoral, tróclea y/o rótula.

Se realizó osteotomía de realineación concomitante en casos de trasplante osteocondral tibiofemoral con malalineación tibiofemoral superior a 3° desde el eje mecánico neutro en el compartimento afectado. En caso de maltracking patelofemoral se realizó una osteotomía de la tuberosidad tibial anterior en casos de TAGT superior a 15 mm. Los criterios de exclusión fueron los siguientes: ausencia meniscal, artritis inflamatoria, lesiones degenerativas grandes que comprendían los tres compartimentos, IMC >30 kg/m^2, enfermedades inflamatorias sistémicas, infección o antecedentes de osteomielitis en la zona receptora del injerto y neoplasia activa.

El estudio fue aprobado por el comité de ética de nuestra institución (IIBSP-ALO-2018-21) y se realizó de conformidad con las normas éticas establecidas en la Declaración de Helsinki de 1964 y sus modificaciones posteriores. Se obtuvo el consentimiento informado de todos los participantes incluidos en el estudio.

4.3.2. Técnica quirúrgica

En todos los casos, se realizó una evaluación artroscópica completa de todos los compartimentos de la rodilla para confirmar el tamaño y profundidad de la lesión y para tratar cualquier patología intraarticular simultánea. Cualquier alteración anatómica o biomecánica de las articulaciones tibiofemoral y/o patelofemoral se corrigió para evitar una mayor degradación del cartílago del injerto.

El banco local de tejidos autorizado suministró los aloinjertos y realizó todo el procesamiento preoperatorio del injerto.[16,18,45] Los injertos osteocondrales se obtuvieron de donantes de menores de 45 años, con una edad media de 31 años (rango, 18-44 años). Una vez que un donante estaba disponible, los injertos fueron extraídos dentro de las primeras 12 horas de la muerte. El aloinjerto osteocondral se colocó en un medio de transporte (solución de Ringer lactato) y se conservó y refrigeró entre 4°C y 8°C. A su llegada al banco de tejidos, el injerto fue preparado y limpiado en

una sala limpia de clase A. Luego se extirpó el tejido blando y el periostio. El lavado pulsátil a alta presión y centrifugación en seco se realizaron con solución salina tamponada con fosfato estéril. Se realizaron pruebas microbiológicas tanto en el injerto como en la última solución de lavado. El aloinjerto se colocó entonces en una solución con Ringer lactato y un cóctel antibiótico consistente en vancomicina (50 mg/ml), tobramicina (3 mg/ml), cotrimoxazol (160 mg/ml) y anfotericina (125 mg/ml). Cinco días después, se realizaron de nuevo pruebas microbiológicas tanto en la solución de preservación como en el injerto. El injerto se mantuvo refrigerado entre 4ºC y 8ºC hasta el implante a un máximo de 3 semanas desde la extracción.

Después de dimensionar el defecto articular con una regla estéril, colocamos una fresa sobre la lesión identificada y lentamente avanzamos a una profundidad de aproximadamente 8 a 10 mm con irrigación salina fría continua. El trasplante osteocondral fresco fue preparado y lavado mediante lavado pulsátil de alta presión para eliminar el mayor número posible de células sanguíneas. En los casos de defectos aislados con un área afectada bien circunscrita en una superficie de rodilla fácilmente accesible, como el cóndilo femoral, la región central de la rótula o la tróclea, se llevó a cabo una técnica de cilindros osteocondrales (JRF-Ortho Instrument Set, JRF Ortho). La técnica de la concha, se utilizó para lesiones asimétricas y extensas, como rótula completa y displasia troclear de alto grado.[16,18,45]

Se realizó rehabilitación inicial mediante balance articular progresivo en una máquina de movimiento pasivo continuo durante 6 semanas. El periodo de descarga y el balance articular progresivo variaban según el procedimiento; sin embargo, el objetivo era evitar el aumento de carga de compresión o cizallamiento en el área trasplantada. Se permitió una transición gradual a la carga completa según tolerancia a partir de las 6 a 8 semanas.[10]

4.3.3. Evaluación por TC

Para confirmar la ausencia de errores técnicos durante el procedimiento quirúrgico, se realizaron TC al 1r día postoperatorio y a los 6 meses postoperatorios. Los estudios por TC postoperatorios se obtuvieron en un "16-multidetector system (Brillance, Philips Healthcare)" utilizando un protocolo de dosis reducida, con la longitud de exploración mínima necesaria para incluir el aloinjerto. Las imágenes multiplanares reformateadas sagitales y coronales contiguas de 2 mm se obtuvieron posteriormente. La colimación se realizó para todos los TC con el fin de aumentar la calidad de la imagen y reducir la exposición general a la radiación del paciente. Se realizó TC desde el polo superior de la rótula hasta la tíbia proximal. La dosis-longitud fue entre 55 a 90 mGy-cm.

Para este estudio de imágenes, se utilizó la escala de puntuación ACTOCA, previamente publicada y validada.[46] La escala ACTOCA incluye cinco características de TC relativas al aspecto del injerto trasplantado y el hueso huésped; densidad de señal del injerto, integración ósea, porcentaje de superficie con hendidura discernible, cambios quísticos y presencia de fragmentos intraarticulares. Una puntuación total más baja indica una mejor incorporación del injerto, con puntuaciones posibles que van de cero a ocho. Todos los TC fueron evaluados por un radiólogo musculoesquelético cegado a la historia médica del paciente.

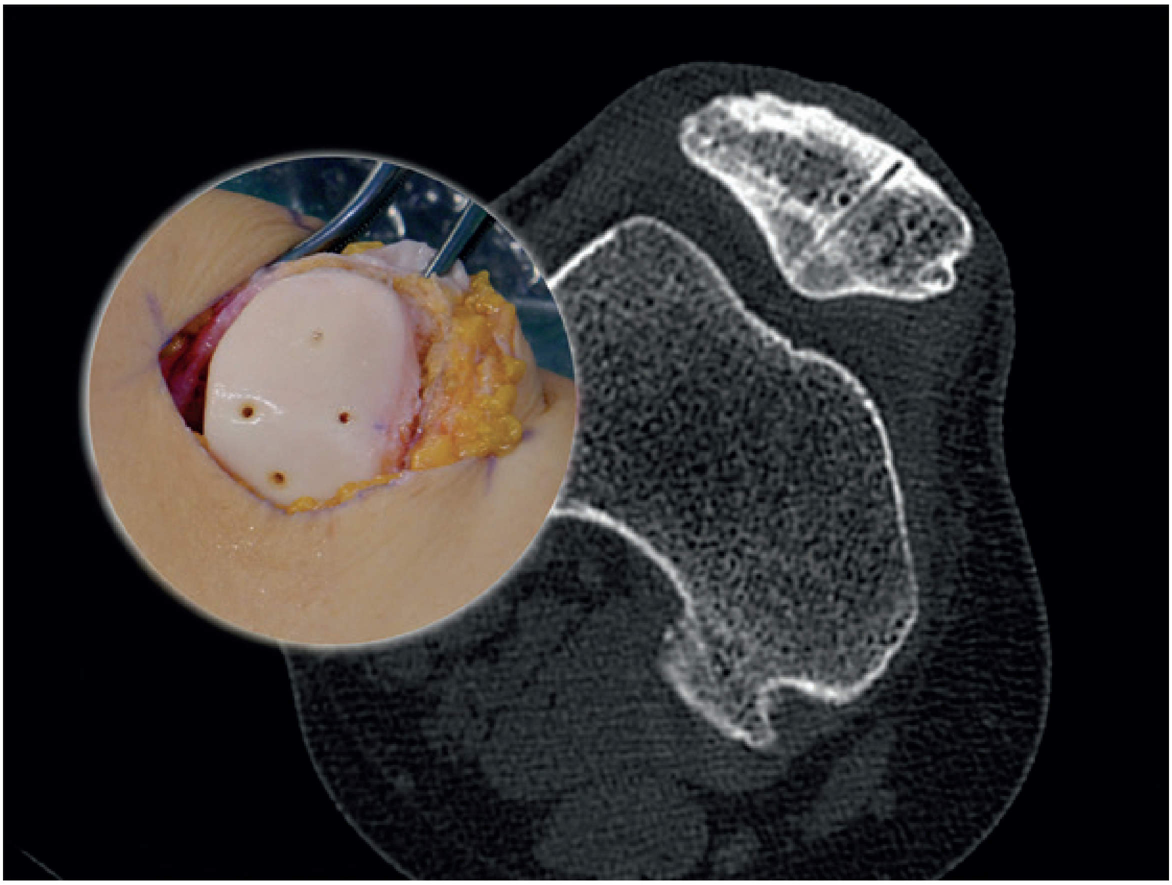


Figura 15: TC realizado a los 6 meses postoperatorios e imagen quirúrgica de un trasplante osteocondral fresco de rótula obteniendo una baja puntuación en la escala ACTOCA (1 punto — densidad superior del injerto en relación al hueso huésped).

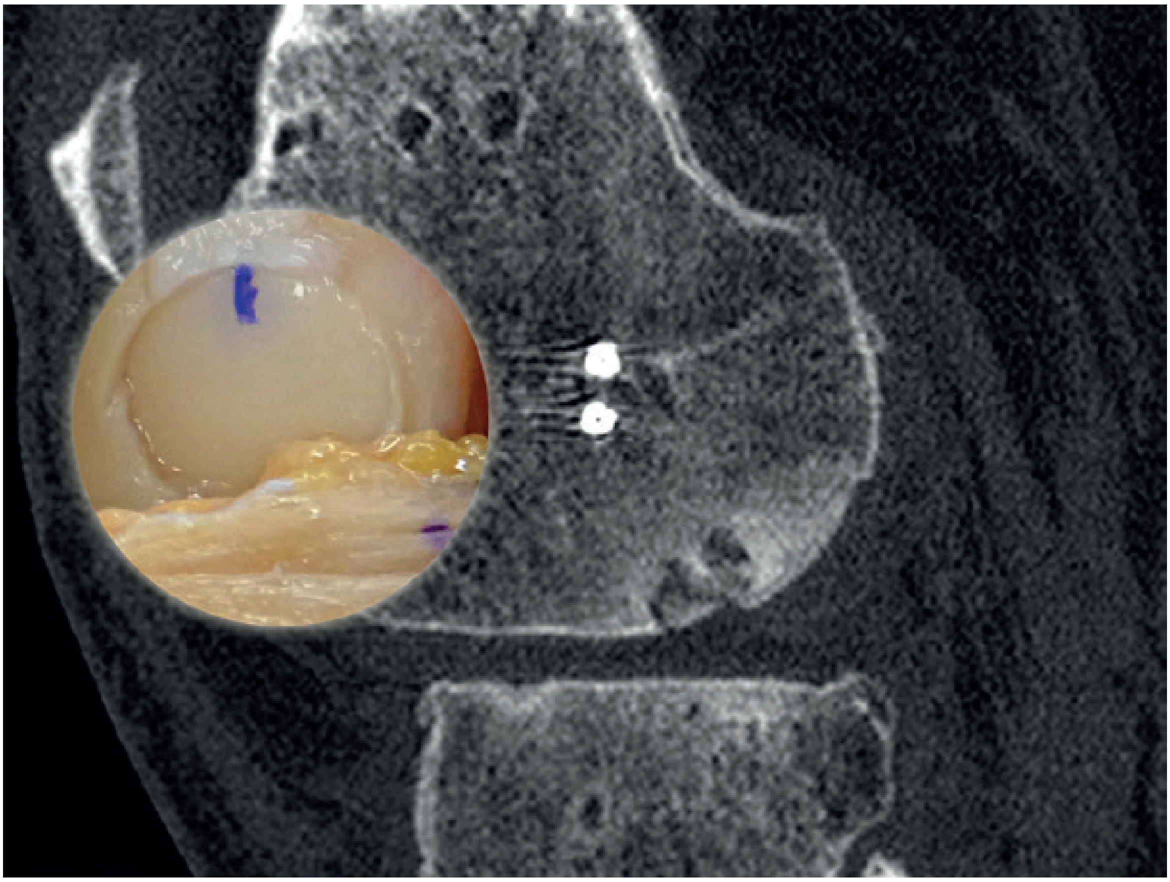


Figura 16: TC realizado a los 6 meses postoperatorios e imagen quirúrgica de un trasplante osteocondral fresco de cóndilo femoral obteniendo una alta puntuación en la escala ACTOCA (4 puntos – densidad superior del injerto en relación al hueso huésped, hendidura discernible <3mm, cambios quísticos >3mm).

4.3.4. Análisis estadístico

El análisis estadístico se realizó utilizando el paquete estadístico IBM SPSS V26.0 (IBM Corp). Se utilizaron estadísticas descriptivas para determinar las características del paciente y de la lesión. Los resultados se dan como un número de casos y/o porcentaje para los datos categóricos, y como media, desviación estándar y rango para los datos cuantitativos. Las variables repetidas durante el ensayo (escalas funcionales y TAC) se analizaron mediante test ANOVA para mediciones repetidas con corrección de Greenhouse—Geisser para evitar la esfericidad. La correlación entre resultados clínicos y los resultados de imágenes se analizó mediante el coeficiente de correlación de Pearson. El nivel general de significancia se fijó en 0.05 para las pruebas de dos niveles.

Resultados

5

Resultados

5.1. Estudio 1

A new computed tomography scoring system to assess osteochondral allograft transplantation for the knee: inter-observer and intra-observer agreement.

La concordancia interobservador fue moderado a sustancial para todos los componentes de la puntuación de TC y la concordancia intraobservador fue de moderado a casi perfecto para todos los componentes de la puntuación de TC ($\kappa > 0,5$; $p < 0,05$)

5.1.1. Datos

Los resultados se encuentran resumidos en la Tabla 2.

Características del TC	Concordancia interobservador (κ)	Concordancia intraobservador (κ)
1. Densidad del injerto en relación con el hueso huésped	0.537	1
2. Integración ósea en la unión huésped-injerto	0.778	1
3. Porcentaje de superficie con una hendidura discernible en la unión huésped-injerto	0.554	0.6
4. Cambios quísticos del injerto y/o unión huésped-injerto	0.646	0.677
5. Presencia de fragmentos intrarticulares	Perfecta	Perfecta

Tabla 2: Concordancia interobservador e intraobservador

5.1.2. Concordancia interobservador

Cada observador evaluó 50 imágenes. La concordancia fue de moderada a sustancial para todos los componentes de la puntuación de TC ($\kappa > 0{,}5$, $p < 0{,}05$). Fue moderada para las características 1 (densidad de señal del injerto en relación con el hueso huésped) y 3 (porcentaje de superficie con una hendidura discernible en la unión huésped-injerto), y sustancial para las características 2 (integración ósea en la unión del huésped-injerto) y 4 (cambios quísticos del injerto y/o unión huésped-injerto). A pesar de que la concordancia interobservador fue perfecta para la característica 5 (presencia de fragmentos intraarticulares), no se pudo calcular la κ debido a la falta de variabilidad, ya que los tres observadores obtuvieron la misma puntuación para todas las 50 imágenes (puntuación 0, ausencia de fragmentos intraarticulares).

5.1.3. Concordancia intraobservador

La concordancia fue de moderada a casi perfecta para todos los componentes de la puntuación de TC ($\kappa > 0{,}59$, $p < 0{,}05$). Fue casi perfecta para las características 1 y 2 (densidad de la señal del injerto en relación con el hueso huésped e integración ósea en la unión huésped-injerto), sustancial para la característica 4 (cambios quísticos del injerto y/o unión huésped-injerto) y moderada para la característica 3 (porcentaje de superficie con hendidura discernible en la unión huésped-injerto). Aunque la concordancia intraobservador fue perfecta para la característica 5 (presencia de fragmentos intraarticulares), no se pudo calcular la κ debido a falta de variabilidad.

5.2. Estudio 2

Computerized tomography scan evaluation after fresh osteocondral allograft transplantation of the knee correlates with clinical outcomes.

La puntuación media total de ACTOCA mostró una correlación estadísticamente significativa con el resultado clínico. La correlación fue óptima a los 24 meses. Encontramos una alta correlación negativa con el IKDC, Kujala y Tegner (−0,737; −0,757, y −0,781 respectivamente), y una moderada correlación negativa con WOMET (−0,566) ($p < 0,001$). Las puntuaciones de IKDC, Kujala, WOMET, y Tegner mostraron una mejoría continua significativa en todas las puntuaciones ($p < 0,001$).

5.2.1. Datos

Un total de 38 pacientes (24 varones; 63%) cumplieron los criterios de inclusión. El seguimiento postoperatorio medio fue de 38 meses (rango, 30—48 meses). La edad media de los pacientes fue de 36,63 ± 6,63 años (rango, 18—46 años). Treinta y uno de los 38 pacientes (81,6%) recibieron trasplantes osteocondrales frescos unipolares, definidos como una o más superficies articulares no opuestas, y 71 (18,4%) recibieron trasplantes bipolares, definidos como dos superficies articuladas opuestas. Los datos demográficos y las características clínicas se presentan en la Tabla 3.

Factor		
Edad (años)	36,63 ± 6,63	
IMC	23,93 ± 2,57	
Hombre / Mujer	24 / 14	
Localización de la lesión	Articulación femoropatelar (%)	55,3
	–Rótula aislada (%)	76
	–Rótula + Tróclea (%)	24
	Cóndilo femoral (%)	34,2
	–Medial (%)	70
	–Lateral (%)	30
	Tibia (%)	10,5
	–Medial (%)	75
	–Lateral (%)	25
Tipo de FOCA	Unipolar (%)	81,6
	Bipolar (%)	18,4
Técnica de FOCA	Cilindro osteocondral (%)	55,3
	Concha (%)	34,2
	Fragmento completo	10,5
Osteotomía TTA (%)	18,4	
Osteotomía valguizante de tibia (%)	18,4	

Tabla 3: Datos demográficos y datos de los FOCA (N = 38)

No se observaron diferencias estadísticamente significativas para la puntuación ACTOCA o las escalas funcionales (IKDC, Kujala, WOMET, o Tegner) según el sexo al nacer, la edad, el IMC, los procedimientos concomitantes o el tipo de aloinjerto osteocondral. En cuanto a osteotomías, no se encontraron diferencias estadísticamente significativas entre pacientes con o sin osteotomías en la evolución del TC (p = 0,819), evolución de IKDC (p = 0,139), evolución de Kujala (p = 0,158), evolución de WOMET (p = 0,299) y evolución de Tegner (p = 0,138).

5.2.2. Evolución de las escalas clínicas

Las comparaciones preoperatorias y postoperatorias de las puntuaciones clínicas a los 3, 6 y 24 meses mostraron una mejoría continua significativa en las puntuaciones de IKDC, Kujala, WOMET y Tegner (p < 0,001) (Tabla 4).

	Preop	3 meses	6 meses	24 meses	Greenhouse-Geisser
IKDC	31,26 ± 9,4 (15-53)	41 ± 10,95 (21-65)	47,58 ± 13,5 (20-76)	60,47 ± 18,81 (20-88)	<0,001
Kujala	38,84 ± 12,46 (17-63)	49,63 ± 12,87 (27-76)	58,13 ± 14,4 (30-94)	69,5 ± 17,1 (30-97)	<0,001
WOMET	38,74 ± 14,87 (13-79)	46,68 ± 15,07 (18-75)	53,13 ± 16,48 (14-87)	65,5 ± 18,2 (25-98)	<0,001
Tegner	1.97 ± 0,91 (1-4)	1,89 ± 0,89 (1-4)	2,08 ± 0,78 (1-4)	2,76 ± 1,03 (1-4)	<0,001

Tabla 4: Escalas clínicas

5.2.3. Evolución de la escala ACTOCA

Las puntuaciones en la escala ACTOCA mejoraron significativamente a los 3, 6 y 24 meses postoperatorios ($p < 0{,}001$). (Tabla 5)

	3 meses	6 meses	24 meses	Greenhouse-Geisser
ACTOCA	2,16 ± 0,92 (0–4)	1,34 ± 1,21 (0–4)	1,05 ± 1,33 (0–4)	<0,001

Tabla 5: Valores ACTOCA. Los resultados se muestran con la media ± desviación estándar, con los rangos entre parén tesis.

5.2.4. Correlación entre resultados clínicos y resultados ACTOCA

El resultado final ACTOCA mostró correlación con los resultados clínicos. (Tabla 6)

Se observó una correlación negativa moderada con la puntuación de IKDC a los seis meses (coeficiente de correlación de Pearson, – 0,535; $p = 0{,}001$) y una correlación negativa elevada con IKDC a los 24 meses (coeficiente de correlación de Pearson, – 0,737; $p < 0{,}001$). Se observó una correlación negativa baja con la puntuación de Kujala a los seis meses (coeficiente de correlación de Pearson, – 0,343; $p = 0{,}035$) y una correlación negativa alta con Kujala a los 24 meses (coeficiente de correlación de Pearson, – 0,757; $p < 0{,}001$). La correlación con WOMET a los 24 meses mostró una correlación negativa baja (coeficiente de correlación de Pearson, – 0,566; $p < 0{,}001$), y la correlación con Tegner a los 24 meses mostró una correlación negativa alta (coeficiente de correlación de Pearson, – 0,781; $p < 0{,}001$).

		Coeficiente de correlación de Pearson	Valor p
IKDC	3 meses	– 0,116	0,488
	6 meses	– 0,535	0,001*
	24 meses	– 0,737	<0,001*
Kujala	3 meses	– 0,027	0,872
	6 meses	– 0,343	0,035*
	24 meses	– 0,757	<0,001*
WOMET	3 meses	– 0,069	0,682
	6 meses	– 0,274	0,096
	24 meses	– 0,566	<0,001*
Tegner	3 meses	– 0,177	0,287
	6 meses	– 0,313	0,056
	24 meses	– 0,781	<0,001*

Tabla 6: Correlación entre puntuación total ACTOCA y resultados en escalas clínicas.

5.3. Estudio 3

Early postoperative CT Scan provides prognostic data on clinical outcomes of fresh osteochondral transplantation of the knee.

Se incluyeron un total de 38 casos. La puntuación ACTOCA a los 6 meses de la cirugía mostró una correlación estadísticamente significativa con los resultados clínicos a los 12 y 30 meses. La correlación fue mejor a los 30 meses, mostrando una alta correlación negativa con la puntuación IKDC (–,663) y una moderada correlación negativa con las puntuaciones Kujala, WOMET y Tegner (–,593; –,547, y –,593, respectivamente) (P < 0,001).

5.3.1. Datos

Este estudio incluyó a 38 pacientes. El seguimiento postoperatorio medio fue de 38 meses (rango, 30–48 meses). La edad media fue de 36,63 ± 6,6 años (rango, 18–46 años), y el IMC medio fue de 23,9 ± 2,6 (rango, 20–30). Además, el 63% de los pacientes (n = 24 casos) eran hombres.

La localización más frecuente de la lesión fue la articulación femoropatelar (n = 23 casos; 60,5%), seguida del cóndilo femoral (n = 15 casos; 39,5%) dividido en el 67% del cóndilo femoral medial y el 33% del cóndilo femoral lateral. Además, 31 pacientes (81,6%) recibieron trasplantes unipolares y 7 pacientes (18,4%) recibieron trasplantes bipolares, definidos por 2 superficies articuladas opuestas, incluido el cóndilo femoral – tibia y la rótula-tróclea. En el 65,8% de los casos se realizó una técnica de cilindros óseos. En el 34,2% restante de los casos se realizó una técnica de la concha. Se realizaron procedimientos concomitantes en 14 pacientes (36,8%), incluyendo osteotomía de la tuberosidad tibial anterior en 7 casos (18,4%) y osteotomía valguizante de tibia en otros 7 casos (18,4%).

5.3.2. Evolución de las escalas clínicas

Las comparaciones preoperatorias y postoperatorias de las puntuaciones mostraron mejoras significativas en las puntuaciones IKDC, Kujala, WOMET y Tegner a los 12 y 30 meses postoperatorios ($p < 0,001$) (Tabla 7).

	Preop	12 meses	30 meses	Greenhouse-Geisser
IKDC	31,26 ± 9,4 (15-53)	53,76 ± 16,7 (21-83)	64,68 ± 20,52 (20-89)	<0,001
Kujala	38,84 ± 12,46 (17-63)	63,21 ± 16,4 (29-96)	72,13 ± 19,09 (26-98)	<0,001
WOMET	38,74 ± 14,87 (13-79)	59,05 ± 17,2 (19-90)	70,47 ± 19,3 (24-98)	<0,001
Tegner	1,97 ± 0,91 (1-4)	2,58 ± 1,03 (1-5)	2,92 ± 1,12 (1-5)	<0,001

Tabla 7: Resultados clínicos

5.3.3. Resultados escala ACTOCA

Todos los TC fueron realizados a los 6 meses tras la cirugía. La puntuación media total de la escala ACTOCA fue 1,34 ± 1,21 puntos (rango, 0-4 puntos).

5.3.4. Valor pronóstico de la escala ACTOCA

La puntuación total de ACTOCA a los 6 meses se correlacionó con los resultados clínicos a los 12 y 30 meses (tablas 8 y 9).

La puntuación ACTOCA total a los 6 meses mostró una correlación negativa moderada con la puntuación IKDC a los 12 meses (coeficiente de correlación de Pearson, –0,507; p = 0,001) y alta correlación negativa a los 30 meses (coeficiente de correlación de Pearson, –0,663; p < 0,001).

La puntuación total de ACTOCA a los 6 meses mostró una correlación moderada negativa con la puntuación de Kujala a los 12 meses (coeficiente de correlación de Pearson, –0,439; p = 0,006) y una correlación negativa moderada a los 30 meses (coeficiente de correlación de Pearson, –0,597; p < 0,001).

La puntuación total de ACTOCA a los 6 meses mostró una correlación moderada negativa con la puntuación de WOMET a los 12 meses (coeficiente de correlación de Pearson, –0,407; p = 0,011) y una correlación negativa moderada a los 30 meses (coeficiente de correlación de Pearson, –0,547; p < 0,001).

La puntuación total de ACTOCA a los 6 meses mostró una correlación moderada negativa con la puntuación de Tegner a los 12 meses (coeficiente de correlación de Pearson, –0,465; p = 0,003) y una correlación negativa moderada a los 30 meses (coeficiente de correlación de Pearson, –0,593; p =0.001).

	Coeficiente de Correlación de Pearson	**p**
IKDC	– 0,507	0,001
Kujala	– 0,439	0,006
WOMET	– 0,407	0,011
Tegner	– 0,465	0,003

Tabla 8: Correlación entre puntuación total ACTOCA a los 6 meses y puntuación en escalas clínicas a los 12 meses.

	Coeficiente de Correlación de Pearson	p
IKDC	– 0,663	<0,001
Kujala	– 0,597	<0,001
WOMET	– 0,547	<0,001
Tegner	– 0,593	<0,001

Tabla 9: Correlación entre puntuación total ACTOCA a los 6 meses y puntuación en escalas clínicas a los 30 meses.

5.3.5. Análisis subgrupo

No se observaron diferencias estadísticamente significativas para la escala ACTOCA o las escalas funcionales (IKDC, Kujala, WOMET, y Tegner) según el IMC (todos los IMC <30), edad, sexo al nacimiento, tipo de FOCA o procedimientos concomitantes (Tabla 10).

	IMC (p)	Edad (p)	Sexo (p)	FOCA (p)	Fulkerson (p)	HTO (p)
TC 6m	0,608	0,761	0,260	0,939	0,971	0,167
IKDC 12m	0,178	0,627	0,823	0,873	0,580	0,740
IKDC 30m	0,385	0,541	0,777	0,195	0,797	0,685
Kujala 12m	0,034	0,309	0,427	0,329	0,076	0,685
Kujala 30m	0,376	0,182	0,643	0,272	0,555	0,632
WOMET 12m	0,339	0,186	0,520	0,723	0,768	0,506
WOMET 30m	0,292	0,272	0,273	0,929	0,768	0,317
Tegner 12m	0,219	0,212	0,800	0,551	0,395	0,416
Tegner 30m	0,480	0,156	0,622	0,606	0,854	0,265

Tabla 10: Análisis subgrupo

Discusión

6

Discusión

6.1. Estudio 1

A new computed tomography scoring system to assess osteochondral allograft transplantation for the knee: inter-observer and intra-observer agreement.

El sistema de puntuación ACTOCA que se presenta aquí es un sistema de puntuación por TC semicuantitativo para el análisis de la reparación de defectos de cartílago para la rodilla mediante aloinjertos osteocondrales. Mientras que los sistemas de puntuación existentes hasta el momento se basan en RM y radiografía, éste es el primer sistema de puntuación basado en la exploración de TAC. El sistema de puntuación ACTOCA mostró una concordancia interobservador de moderada a sustancial y una concordancia intraobservador de moderada a casi perfecta en los cinco aspectos incluidos ($\kappa > 0,5$; $p < 0,05$).

El uso de aloinjertos osteocondrales frescos para el tratamiento lesiones osteocondrales mayores de 2 cm^2 es una técnica bien establecida.[11] Se ha demostrado que la supervivencia a largo plazo depende de la viabilidad de los condrocitos, una matriz extracelular intacta y la incorporación óptima del injerto en el hueso huésped.[23]

Se han utilizado varias modalidades de imagen para evaluar la incorporación del injerto. Actualmente, el "gold standard" es la resonancia magnética. La resonancia magnética se puede evaluar utilizando la puntuación MOCART[35] o la escala descrita recientemente denominada OCAMRISS.[37] Estudios recientes, no obstante, no han logrado proporcionar pruebas sólidas con respecto a si la RM es o no una herramienta confiable para relacionarlo con el resultado clínico después de la reparación del cartílago.[34,36] Se ha demostrado que la integración ósea y los cambios quísticos tienen un gran impacto en la supervivencia a largo plazo de los trasplantes de FOCA. En comparación con la RM, la exploración por TC ofrece una mejor resolución espacial, lo que permite una evaluación más detallada de los cambios óseos[39,52]. Sorprendentemente, hay escasez de estudios que hayan utilizado la TC para evaluar el trasplante de aloinjertos osteocondrales.[40,41] Por ello, el sistema de

puntuación ACTOCA fue diseñado para aprovechar estas ventajas de la tomografía computarizada sobre la resonancia magnética. Evalúa cinco aspectos de la imagen por TC. Con respecto a la densidad de la señal del injerto en relación con el hueso huésped (característica 1), este estudio mostró una concordancia interobservador moderada y una concordancia intraobservador casi perfecta. La integración ósea en la unión huésped-injerto (característica 2) mostró una concordancia interobservador sustancial y una concordancia intraobservador casi perfecta. El porcentaje de superficie con hendidura discernible en la unión huésped-injerto (característica 3) mostró una concordancia intraobservador e interobservador moderada. En cuanto a los cambios quísticos del injerto y/o unión huésped-injerto (característica 4), la concordancia interobservador e intraobservador fue sustancial. Sin embargo, teniendo en cuenta que la perfecta concordancia interobservador e intraobservador para la presencia de fragmentos intraarticulares (característica 5) fue debida a la falta de variabilidad entre los lectores en cuanto a las puntuaciones, el valor de κ no pudo calcularse. En resumen, todos los aspectos evaluados mostraron una buena concordancia. A pesar de ello, la concordancia fue mayor para la integración ósea en la unión huésped-injerto (característica 2), lo que pone de relieve las ventajas de la exploración por TC para evaluar la integración ósea.

La concordancia interobservador con el sistema OCAMRISS se ha evaluado en dos estudios. Sin embargo, mientras que uno de ellos reportó un alto grado de concordancia interobservador ($k > 0,8$) en el 65% de las comparaciones, los autores no especificaron los resultados de cada característica.[38] El segundo estudio encontró una concordancia sustancial a casi perfecta ($k > 0,7$) para todos los componentes de la puntuación de RM, excepto la integración ósea, que no se pudo calcular.[37]

Este estudio tiene varias limitaciones. En primer lugar, para evaluar las imágenes y, con el fin de lograr un análisis homogéneo, los observadores recibieron imágenes de TC específicas en lugar del estudio de TC completo. Sin embargo, esto puede haber aumentado la concordancia interobservador e intraobservador ya que la muestra podría haber subestimado la heterogeneidad de los aloinjertos.

En segundo lugar, no se pudo calcular la κ a para la característica 5 (presencia de fragmentos intraarticulares), ya que todos los lectores dieron a las 50 imágenes las mismas puntuaciones (ausencia de fragmentos intraarticulares) debido a la ausencia de complicaciones postoperatorias en forma de fragmentos intraarticulares. Y, en tercer lugar, las tomografías computarizadas exponen a los pacientes a altas dosis de radiación. Sin embargo, esta limitación se puede reducir significativamente con un protocolo de colimación óptimo.[53]

6.2. Estudio 2

Computerized tomography scan evaluation after fresh osteocondral allograft transplantation of the knee correlates with clinical outcomes.

El principal hallazgo de este estudio fue que la puntuación de ACTOCA mostró una correlación estadísticamente significativa con el resultado clínico. Esta correlación entre la puntuación media total de ACTOCA y el resultado clínico fue más alta a los 24 meses después de la cirugía. En este momento, IKDC, Kujala, y Tegner mostraron una alta correlación negativa con la puntuación ACTOCA y una correlación negativa moderada con WOMET.

Según nuestro conocimiento, este es el primer estudio en analizar la correlación entre los resultados de TC mediante las puntuaciones ACTOCA y los resultados clínicos. Hasta la fecha, la prueba de imagen "gold standard" para valorar la integración del injerto tras la realización de un trasplante osteocondral fresco ha sido la RM. Sin embargo, estudios recientes han demostrado que la puntuación total de la RM no se correlaciona significativamente con las puntuaciones de los resultados clínicos. En una revisión sistemática y metanálisis de 32 estudios realizados para evaluar la correlación entre el resultado clínico y la RM después de la reparación del cartílago, Windt et al.[34] encontraron evidencia concluyente sobre la ausencia de esa correlación. En otro estudio, Wang et al.[36] analizaron 43 pacientes tratados con FOCA después de un procedimiento quirúrgico previo de reparación de cartílago. Encontraron que la puntuación total de OCAMRISS, una de las puntuaciones de RM más utilizadas, no se correlacionaba significativamente con las puntuaciones de resultados clínicos. Otros autores tampoco han podido encontrar una correlación entre las puntuaciones de RM y los resultados clínicos.[28,33] A diferencia de estos resultados con RM, con el sistema de puntuación ACTOCA, encontramos una alta correlación entre la exploración por TC y los resultados clínicos. Esta diferencia puede deberse a que las tomografías computarizadas ofrecen una mejor evaluación de la integración ósea y los cambios quísticos que han demostrado tener un gran impacto en los resultados clínicos después del FOCA.

Discusión

El sistema de puntuación ACTOCA recientemente desarrollado y validado[46] incluye cinco características de TC: Densidad del injerto en relación con el hueso del huésped, integración ósea en la unión huésped-injerto, porcentaje de superficie con una hendidura discernible en la unión huésped-injerto, cambios quísticos y fragmentos intraarticulares. La concordancia interobservador fue de moderada a sustancial para todos los componentes de la puntuación de TC, y la concordancia intraobservador fue de moderada a casi perfecta para todos los componentes de la puntuación de TC ($\kappa > 0{,}5$, $p < 0{,}05$), mostrando que el sistema de puntuación ACTOCA es un sistema de puntuación fiable para evaluar los trasplantes de aloinjertos osteocondral.

Aunque la evaluación por imagen de aspectos óseos como la integración ósea y los cambios quísticos son de gran importancia para la supervivencia del injerto después del trasplante de FOCA, pocos estudios han evaluado este trasplante mediante TC. Anderson et al.[54] recientemente desarrolló un sistema de puntuación por TC y evaluó la relación de los parámetros óseos del trasplante osteocondral medidos en TC con los resultados clínicos. Sin embargo, a diferencia de nuestro estudio, sólo se recogió una tomografía computarizada postoperatoria (con una media de 5,8 meses después de la cirugía) y se utilizó la puntuación clínica más cercana a los hallazgos de la tomografía computarizada. Esta puntuación, por lo tanto, reflejaba un período postquirúrgico diferente para cada paciente, y esto podría haber hecho que sus resultados fueran menos concluyentes.

Brown et al.[41] investigó la integración ósea y resultados clínicos tempranos tras FOCA con injertos cilíndricos en el cóndilo femoral. La evaluación por TC se informó como un porcentaje de incorporación y encontraron que el nivel medio de incorporación de todos los injertos era de grado 2 (50–75%). Sin embargo, no evaluaron la correlación entre los resultados clínicos y el porcentaje de incorporación en TC. Cook et al.[40] informaron de los resultados de una serie de 18 pacientes a los que se les sometió a mosaicoplastia en el cóndilo femoral, evaluando artrogramas por TC postoperatorios. De forma similar a otros estudios de imágenes de procedimientos FOCA, los artrogramas de TC no se correlacionaron con los resultados funcionales. Puede ser porque sólo evaluaron la integración ósea y la congruencia articular.

En nuestro estudio, utilizando el sistema de puntuación ACTOCA para evaluar FOCA a partir de imágenes de TC, encontramos una correlación estadísticamente significativa con los resultados clínicos. Además, las puntuaciones clínicas preoperatorias y postoperatorias a los tres, seis y 24 meses reflejaron una mejora significativa y continua en las puntuaciones de IKDC, Kujala, WOMET y Tegner.

El presente estudio tiene varias limitaciones. En primer lugar, no había ningún grupo de comparación y el tamaño de la muestra era pequeño. Además, la cohorte fue relativamente heterogénea con respecto al tipo de aloinjerto osteocondral y los procedimientos concomitantes. Sin embargo, no se observaron diferencias estadísticamente significativas para ACTOCA o escalas funcionales (IKDC, Kujala, WOMET o Tegner) según el sexo al nacer, la edad, el IMC, los procedimientos concomitantes o el tipo de aloinjerto osteocondral.

La ausencia de diferencias entre pacientes con o sin osteotomía puede estar relacionada con el hecho de que las osteotomías se realizaron sólo en casos de FOCA tibiofemoral con malalineación tibiofemoral mayor de 3° desde el eje mecánico neutro hacia el compartimento afectado o en el caso de FOCA patelofemoral con una distancia de TAGT superior a 15mm. Los casos restantes tuvieron valores preoperatorios normales. Por lo tanto, los pacientes con osteotomía y sin osteotomía presentaron una alineación comparable una vez operados.

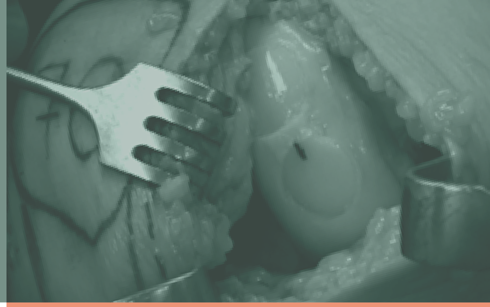
En segundo lugar, todos los TC fueron evaluadas por un único radiólogo musculoesquelético ciego a la historia clínica del paciente. Sin embargo, un estudio reciente demostró que ACTOCA proporciona una concordancia interobservador entre moderada y sustancial y una concordancia intraobservador entre moderada y casi perfecta.[46] Y, en tercer lugar, las exploraciones por TC exponen a los pacientes a altas dosis de radiación. Sin embargo, esta limitación se redujo significativamente con el protocolo de colimación óptimo utilizado.

6.3. Estudio 3

Early postoperative CT Scan provides prognostic data on clinical outcomes of fresh osteochondral transplantation of the knee.

La puntuación ACTOCA para la evaluación de TC a los 6 meses mostró correlación con los resultados clínicos, especialmente a los 30 meses. Se encontró una correlación negativa alta con la puntuación del IKDC y una correlación negativa moderada con las puntuaciones de Kujala, WOMET y Tegner a los 30 meses, confirmando la hipótesis del estudio sobre el valor pronóstico de la escala de puntuación ACTOCA.

Hay una escasez de estudios que predicen los desenlaces clínicos de los FOCA basados en las pruebas de imagen. Wang et al.[36] revisaron los resultados clínicos y las exploraciones de RM de 36 pacientes sometidos a FOCA, con un seguimiento mínimo de 2 años; el seguimiento medio postoperatorio fue de 3,5 años. Los resultados clínicos obtenidos en el último seguimiento se correlacionaron con las RM realizadas alrededor de 1 año después de la cirugía. La puntuación media total del sistema de puntuación OCAMRISS[37], una de las puntuaciones de RM más utilizadas, mostró una ligera correlación (coeficiente de correlación de Pearson, −0,36; $p = 0{,}035$) con la escala de funcionalidad SF-36. Ninguna otra sección del SF-36 u otras puntuaciones mostraron ninguna correlación con esta evaluación de RM. En otro estudio, Lin et al[28] estudiaron a 20 pacientes después de un FOCA de la rótula mediante aloinjertos de cóndilo femorales. Las exploraciones de RM se obtuvieron a una media de 11,4 meses (intervalo, 6–22 meses) postoperatorios y los resultados clínicos se recopilaron a una media de 46,5 meses (intervalo, 24-85 meses) postoperatorios. No encontraron ninguna correlación estadísticamente significativa entre las puntuaciones de OCAMRISS y las puntuaciones clínicas. En la misma línea, otros autores también han notificado que no hay correlación entre las puntuaciones de RM y los resultados clínicos.[33,34] Pocos estudios[40,41] han evaluado el FOCA mediante TAC y ninguno de ellos ha encontrado una correlación entre TC y los resultados clínicos. A diferencia de los hallazgos de estos estudios, en nuestro estudio



encontramos una correlación estadísticamente significativa entre las puntuaciones de ACTOCA a los 6 meses y las puntuaciones clínicas a los 30 meses. Este hallazgo respalda el valor pronóstico de esta puntuación. Cabe señalar que la correlación fue mejor en el seguimiento a los 30 meses que en el seguimiento a los 12 meses. Esto probablemente se debió a que las puntuaciones funcionales aún estaban en la curva ascendente hacia un resultado más estable y favorable en la evaluación de seguimiento más larga.

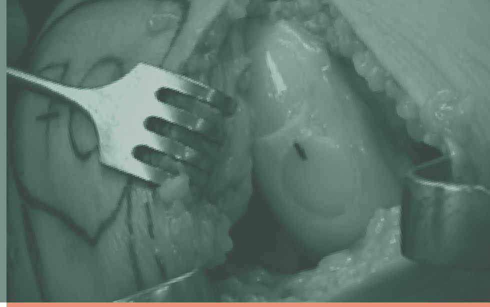
También se realizó una TC a los 6 meses postoperatorios y se determinaron puntuaciones clínicas a los 12 y 30 meses postoperatorios en todos los pacientes. El hecho de que hayamos realizado estos seguimientos al mismo tiempo postoperatorios en todos los pacientes es de especial interés, ya que ha proporcionado un seguimiento más preciso y reproducible. La disponibilidad de una herramienta predictiva que puede ayudar a ajustar el tratamiento tan pronto como 6 meses después del procedimiento FOCA permite al cirujano ajustar las expectativas e identificar posibles fallos. Se consideró un fracaso cualquier reoperación que resulte en la extracción del injerto, así como la revisión del aloinjerto o cualquier forma de artroplastia.[22]

Recientemente se ha demostrado que el sistema de puntuación ACTOCA tiene alta reproducibilidad.[46] En el presente estudio, este sistema de puntuación también confirmó su valor pronóstico para evaluar el resultado después del trasplante de FOCA. Conocer los parámetros que están relacionados con los peores resultados clínicos es de gran importancia. Frank et al[26] revisaron a 180 pacientes tratados con trasplante de aloinjerto ostoeocondral con un seguimiento mínimo de 2 años. Encontraron una tasa de reoperación del 37% y una tasa de supervivencia del aloinjerto del 87% a una media de 5 años después de un trasplante de FOCA. Observaron que un mayor número de procedimientos quirúrgicos ipsilaterales previos (3,75 frente a 2,28; $p < 0,001$) y un IMC superior (29,42 frente a 26; $p = 0,003$) eran predictivos del fracaso. Familiari et al[22] informaron de los resultados de una revisión sistemática sobre los resultados clínicos después del trasplante de aloinjerto osteocondral en la rodilla. Concluyeron que los casos de revisión, las lesiones rotulianas y las lesiones bipolares se asociaron con peores tasas de supervivencia. Nuelle et al[55] revisaron retrospectivamente a 75 pacientes sometidos a un trasplante de FOCA. Encontraron que los pacientes activos y aquellos con un IMC <35 tenían una probabilidad significativamente mayor de tener un resultado exitoso que los pacientes mínimamente activos (p = 0,023; p = 0,01). En contraste, en nuestro estudio, no se observaron diferencias estadísticamente significativas para la ACTOCA o las escalas funcionales (IKDC, Kujala, WOMET y Tegner) según el sexo al nacimiento, edad, IMC (todos los IMC <30), procedimientos concomitantes, o tipo de aloinjerto osteocondral.

En relación con los resultados de la escala Tegner, la puntuación preoperatoria media de Tegner aumentó de 1,97 ± 0,91 puntos (rango, 1–4 puntos) a 2,58 ± 1,03 puntos (rango 1–5 puntos) a los 12 meses postoperatorios y a 2,92 ± 1,12 puntos (rango, 1–5 puntos) a los 30 meses postoperatorios. A pesar de la mejoría postoperatoria, 2,5 se considera un bajo nivel de actividad. En estudios similares, las puntuaciones de Tegner han mostrado una mejora considerablemente mayor después de la cirugía.[26,56] Sin embargo, mientras que estos estudios anteriores compararon la puntuación preoperatoria inmediata de Tegner, en nuestro estudio se tuvo en cuenta el nivel de actividad antes de la lesión.

De forma similar a nuestros resultados, varias revisiones en la literatura han encontrado buenos resultados clínicos y funcionales después del trasplante de FOCA en la rodilla.[22,57] En el presente estudio, comparando las puntuaciones clínicas preoperatorias y postoperatorias a los 30 meses, también encontramos una mejora estadísticamente significativa en las puntuaciones de IKDC, Kujala, WOMET y Tegner (p < 0,001).

Nuestro estudio tiene algunas limitaciones. En primer lugar, no hubo un grupo de comparación y el tamaño de la muestra era pequeño. En segundo lugar, el 36,8% de los pacientes se sometió a una osteotomía además de un trasplante de FOCA. Sin embargo, no consideramos que esto sea una limitación, ya que permite una alineación comparable en todos los casos posteriores a la cirugía. En tercer lugar, sólo 1 radiólogo musculoesquelético evaluó las exploraciones por TC. En un estudio reciente, sin embargo, se demostró que ACTOCA proporciona una correlación interobservador de moderada a sustancial y una correlación intraobservador de moderada a casi perfecta.[46]



En cuarto lugar, aunque no observamos diferencias estadísticamente significativas entre la escala ACTOCA y las escalas funcionales (IKDC, Kujala, WOMET, Y Tegner) según el sexo al nacer, la edad, el IMC, los procedimientos concomitantes, o el tipo de aloinjerto osteocondral, es probable que el tamaño de la muestra sea insuficiente para realizar el análisis de subgrupos. En quinto lugar, como el fallo se definió como el que requería una reintervención, cualquier paciente con fallo clínico que no hubiera optado por la reintervención podría haberse perdido. En sexto lugar, se excluyeron los pacientes cuyo IMC era >30; por lo tanto, el estudio no puede comentar este grupo de pacientes. En séptimo lugar, la puntuación ACTOCA ha demostrado ser fiable en estudios anteriores, pero no ha sido completamente validada. Y octavo, las exploraciones por TC exponen a los pacientes a altas dosis de radiación. Sin embargo, esta limitación se redujo significativamente con un protocolo de colimación óptimo.

Conclusiones

7

Conclusiones

7.1. Estudio 1

A new computed tomography scoring system to assess osteochondral allograft transplantation for the knee: inter-observer and intra-observer agreement.

El sistema de puntuación ACTOCA es un sistema comprensivo y semicuantitativo de puntuación por TC que se puede utilizar como una herramienta fiable para evaluar los cambios óseos después de los trasplantes de aloinjerto osteocondral. Además, puede ayudar a estandarizar los informes de exploración por TC cuando se trasplanta un aloinjerto osteocondral en la rodilla.

7.2. Estudio 2

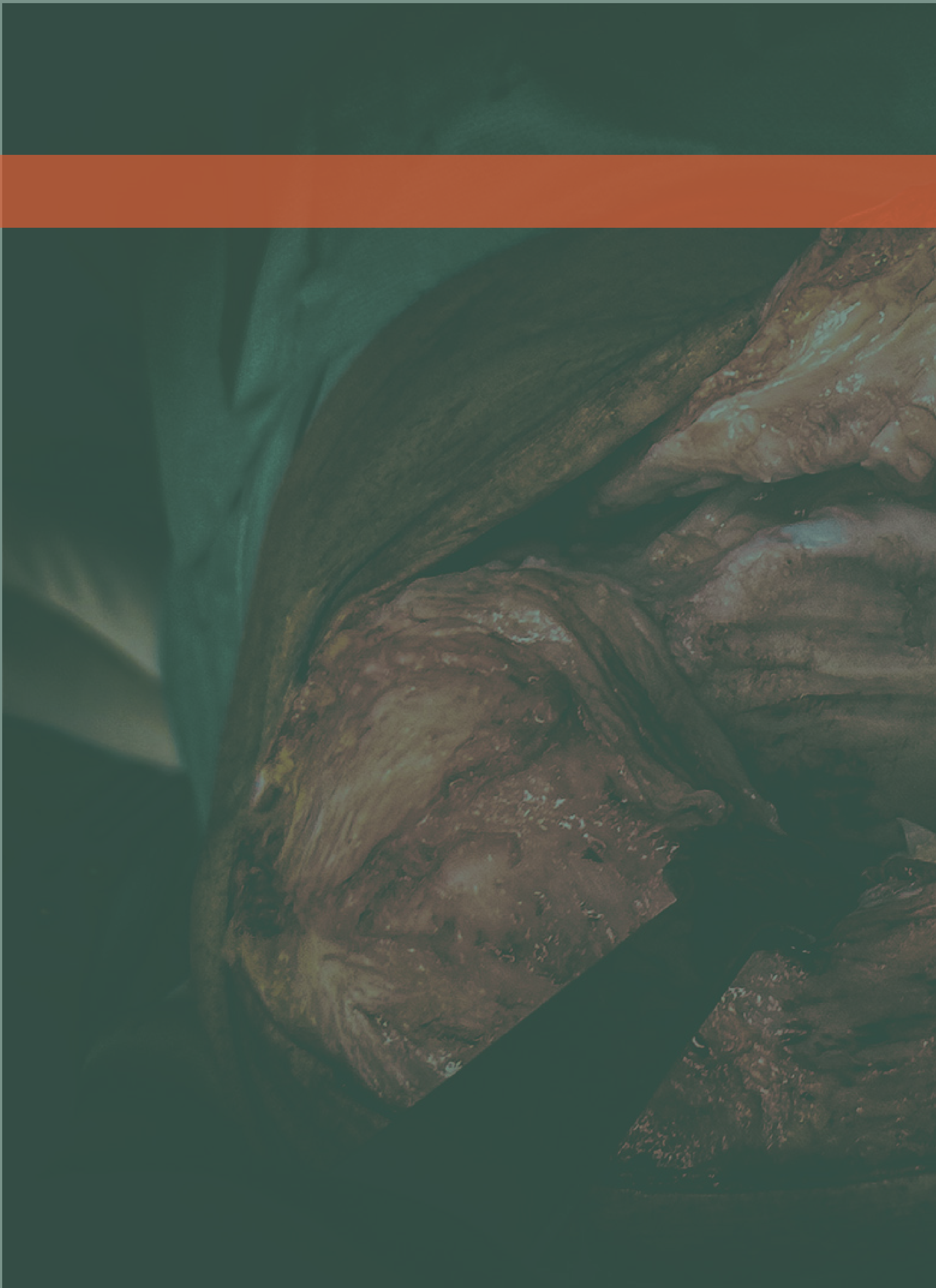
Computerized tomography scan evaluation after fresh osteocondral allograft transplantation of the knee correlates with clinical outcomes.

La puntuación media total de ACTOCA mostró una correlación lineal con los resultados clínicos en las puntuaciones IKDC, Kujala, WOMET y Tegner, siendo la más alta a los 24 meses después de la cirugía. Este hallazgo respalda el uso de ACTOCA para estandarizar los informes de exploración por TC después de un trasplante de aloinjerto osteocondral fresco en la rodilla.

7.3. Estudio 3

Early postoperative CT Scan provides prognostic data on clinical outcomes of fresh osteochondral transplantation of the knee.

La puntuación media de ACTOCA en TC a los 6 meses mostró una correlación estadísticamente significativa con los resultados clínicos en las puntuaciones de IKDC, Kujala, WOMET y Tegner a los 30 meses, confirmando el valor predictivo de la puntuación de ACTOCA para su uso en la práctica clínica.



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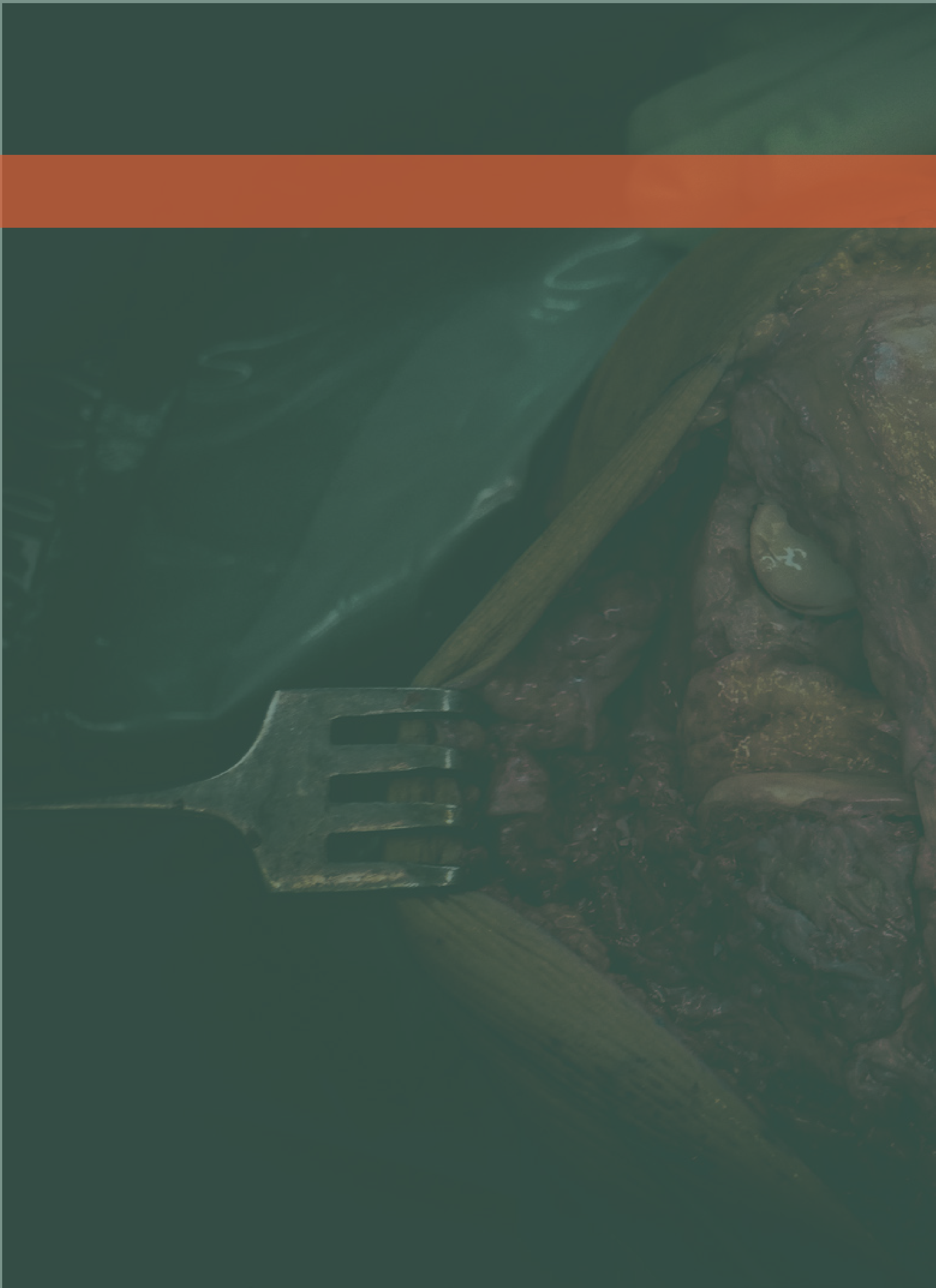

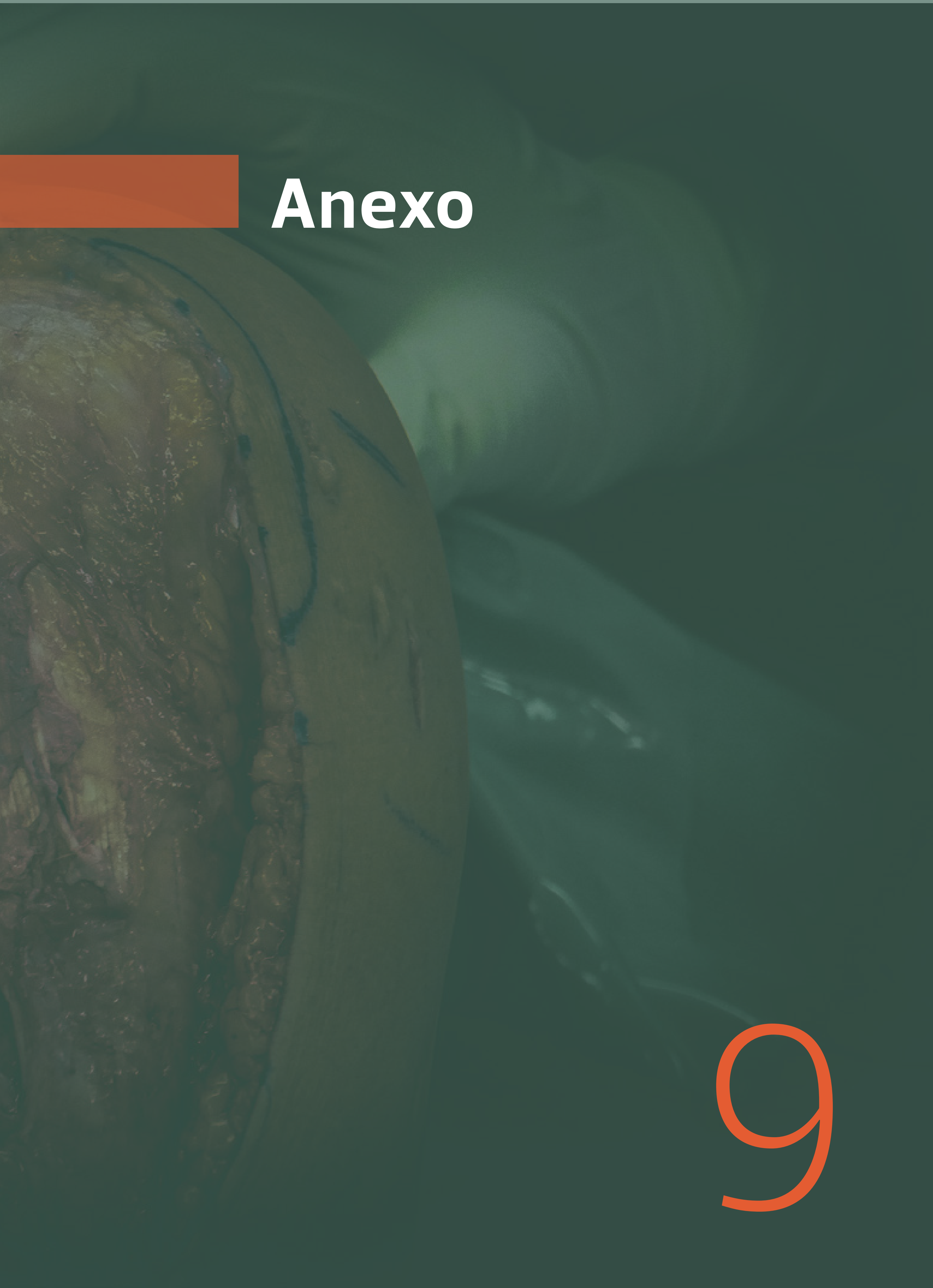

Anexo

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9.1. Estudio 1

International Orthopaedics
https://doi.org/10.1007/s00264-020-04927-w

ORIGINAL PAPER

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A new computed tomography scoring system to assess osteochondral allograft transplantation for the knee: inter-observer and intra-observer agreement

Pablo Eduardo Gelber[1,2] · Eduard Ramírez-Bermejo[1] · Alex Grau-Blanes[1] · Aránzazu Gonzalez-Osuna[1] · Jaume Llauger[3] · Oscar Fariñas[4]

Received: 23 October 2020 / Accepted: 29 December 2020

Abstract

Aim of the study To describe a new semiquantitative computed tomography (CT) scoring system for multi-feature analysis of cartilage defect repair by osteochondral allografts for the knee and to assess its intra-observer and inter-observer variability.

Method A semiquantitative assessment CT osteochondral allograft (ACTOCA) scoring system was designed based on fresh osteochondral allograft transplantations for the knee. The system includes five CT features: density relative to host bone, integration at the host-graft junction, surface percentage with a discernible cleft at the host-graft junction, cystic changes, and intra-articular fragments. Inter-observer variability was calculated by three observers blinded to the patient's medical history and treatment. Intra-observer variability was also determined.

Results Inter-observer agreement was moderate to substantial for all CT score components and intra-observer agreement was moderate to almost perfect for all CT score components ($\kappa > 0.5, p < 0.05$).

Conclusion The ACTOCA score is a reliable tool to evaluate integration of osteochondral allograft transplantations. It provides an accurate evaluation of bone changes and may help to standardize CT scan reports following *osteochondral allograft transplantation* for *the knee*.

Keywords Osteochondral allograft · Cartilage repair · CT scoring system · Fresh OCA · Transplantation

Introduction

Treatment of osteochondral knee injuries in active young people is a continuous focus of research. Large symptomatic osteochondral lesions in these patients have a devastating effect on their quality of life, both in daily life and in sporting activities [1]. Fresh osteochondral allograft (FOCA) transplantation is indicated for osteochondral lesions larger than 2 cm. This technique involves the transfer of osteochondral cores from a size-matched, fresh cadaver to the patient's knee injury [2].

High long-term survival of osteochondral allograft transplantation is related to the presence of viable chondrocytes, a maintained extracellular matrix and a well-incorporated graft into the host bone [3]. Several imaging modalities have been advocated to assess graft healing and survival. Magnetic resonance imaging (MRI) is considered the gold standard as it can evaluate articular cartilage characteristics, subchondral bone changes, peripheral integration, and surrounding lesions. The Magnetic Resonance Observation of Cartilage Repair Tissue (MOCART) [4] was designed to take these details into consideration but strong evidence is lacking as to whether it is reliable to predict clinical outcomes after cartilage repair [5]. More recently, the Osteochondral Allograft MRI Scoring System (OCAMRISS) was described to specifically evaluate the results of FOCA transplantations based on MRI [6, 7]. This system evaluates five aspects of primary cartilage, four aspects of primary bone, and four aspects of ancillary aspects. Unfortunately, the total score on

✉ Pablo Eduardo Gelber
personal@drgelber.com

1 Department of Orthopaedic Surgery, Hospital de la Santa Creu i Sant Pau, Universitat Autonoma de Barcelona, C/Sant Quintí, 89 08041 Barcelona, Catalunya, Spain

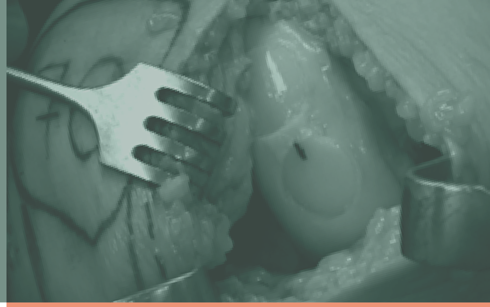
2 ICATME-Hospital Universitari Dexeus, Universitat Autonoma de Barcelona, Barcelona, Spain

3 Radiology Department, Hospital de la Santa Creu i Sant Pau, Universitat Autonoma de Barcelona, Barcelona, Spain

4 Barcelona Tissue Bank, Banc de Sang i Teixits, Barcelona, Spain

Published online: 08 January 2021

Springer



OCAMRISS has not been meaningfully correlated with clinical outcome scores [8]. However, imaging assessment of bone aspects such as osseous integration and cystic changes has shown to be key to graft survival after FOCA transplantation [3]. To accurately evaluate these aspects, computed tomography (CT) has been found to have a considerably higher spatial resolution than standard MRI [9, 10]. On this basis, the aim of the present study was to create a semiquantitative CT scoring system for multi-feature analysis of cartilage defect repair using osteochondral allografts and to assess its reproducibility. The hypothesis was that this new ACTOCA score would show sufficient inter-observer and intra-observer reliability to support its use in clinical practice.

Material and methods

All patients who underwent FOCA transplantation for osteochondral knee lesions between 2017 and 2019 were retrospectively studied. Inclusion criteria were patients younger than 50 years, with large focal full-thickness chondral and osteochondral defects (> 2 cm^2). In case of tibiofemoral FOCA, tibiofemoral malalignment greater than 3° from the neutral mechanical axis into the involved compartment was corrected with a concomitant realignment osteotomy. In case of patellofemoral FOCA, patellofemoral maltracking was also addressed with tibial tubercle osteotomy and, if necessary, medial patellofemoral ligament reconstruction to restore patellar stability. Exclusion criteria were inflammatory arthritis, large degenerative lesions comprising all three compartments, BMI > 30 kg/m^2, diabetes, systemic inflammatory diseases, infection or history of osteomyelitis in the graft recipient area, and active neoplasia.

The study was approved by the ethics committee of our institution (IIBSP-ALO-2018-21). Informed consent was obtained from each patient following the guidelines laid down by our local ethics committee.

CT technique

CT scans were performed post-operatively at three and 12 months.

CT studies were performed on a 16-multidetector system (Brillance, Philips Healthcare) using a reduced dose protocol, with the minimum scan length required to include the allograft. Multiplanar reformatted 2-mm contiguous sagittal and coronal images were later obtained. Collimation was performed for all CTs to increase image quality and reduce the patient's overall radiation exposure.

CT classification system

Based on the reported experience with FOCA transplantation for osteochondral knee lesions [11–13], a semiquantitative assessment computed tomography osteochondral allograft (ACTOCA) scoring system was created. The ACTOCA includes five CT features relative to the aspect of the transplanted graft and the host bone (Table 1). Axial views were used to evaluate the patellofemoral joint, while sagittal views were used to evaluate the femoral condyles.

Evaluated features

Graft signal density relative to host bone The graft signal density appears equivalent (0), superior (1), or inferior (2) to host bone (Fig. 1).

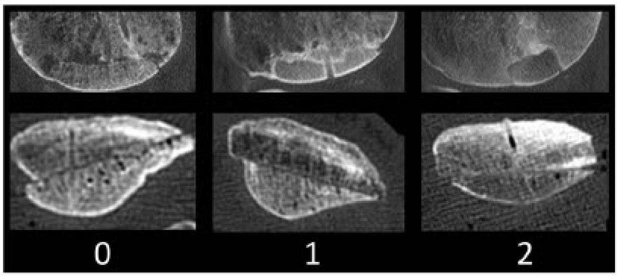
Osseous integration at the host-graft junction Osseous integration is evaluated at the host-graft junction, looking for

Table 1 ACTOCA (Assessment Computed Tomography Osteochondral Allograft) Scoring System

CT features	CT Score
1. Graft signal density relative to host bone	0: equivalent
	1: superior
	2: inferior
2. Osseous integration at host-graft junction	0: crossing trabeculae
	1: discernible cleft < 3 mm
	2: discernible cleft > 3 mm
3. Surface percentage with a discernible cleft at host-graft junction	0: < 30%
	1: > 30%
4. Cystic changes of graft and/or host-graft junction	0: absent
	1: present < 3 mm
	2: present > 3 mm
5. Presence of intra-articular fragments	0: absent
	1: present

Anexo

Fig. 1 Graft signal density relative to host bone. **0** Equivalent. **1** Superior. **2** Inferior



crossing trabeculae without a discernible cleft (0), or presence of a discernible cleft < 3 mm (1) or > 3 mm (2) (Fig. 2).

Surface percentage with a discernible cleft at the host-graft junction The presence of less than 30% (0) or more than 30% (1) of surface with a discernible cleft at the host-graft junction is evaluated (Fig. 3).

Cystic changes of graft and/or host-graft junction The presence of cystic changes is evaluated at the graft and/or host-graft junction looking for absence of cysts (0), cysts smaller than 3 mm (1), and cysts larger than 3 mm (2) (Fig. 4).

Presence of intra-articular fragments The absence (0) or presence (1) of intra-articular fragments is evaluated (Fig. 5).

Statistical analysis

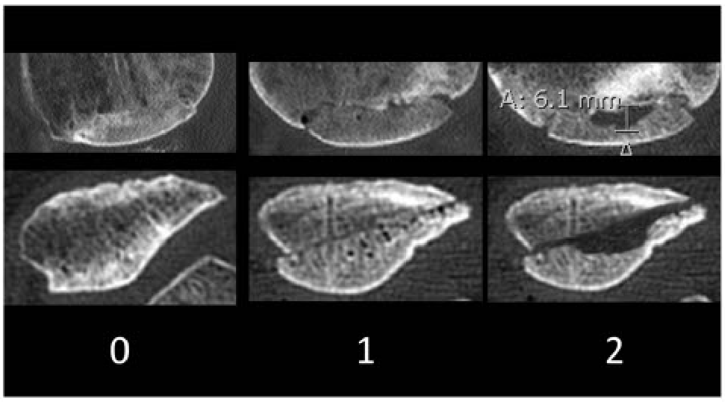
Statistical analysis was performed using SPSS 19 (SPSS, Chicago, IL) and included two calculations: inter-observer and intra-observer variability in the CT classification system (ACTOCA). The kappa coefficient (κ) was calculated to analyze reliability of the system according to three observers (inter-observer reliability) and by one observer on two separate occasions (intra-observer reliability) [14].

The kappa statistic (κ) provides a measure of the proportion of times that the observers agree, modified to take into account the agreement that would occur only by chance [15]. The values were interpreted as < 0.21 slight; 0.21-0.4 fair; 0.41-0.6 moderate; 0.61-0.8 substantial; and 0.81-1.0 almost perfect [16].

Inter-observer variability

To determine the inter-observer variability of the CT classification system (ACTOCA), all CT scans were assessed independently by three observers blinded to the patient's medical history and treatment. One of the three was a senior orthopaedic surgeon, one was a junior orthopaedic surgeon, and one was a musculoskeletal radiologist. Previously, an independent observer had selected the most

Fig. 2 Osseous integration at the host-graft junction. **0** Crossing trabeculae. **1** Discernible cleft < 3 mm. **2** Discernible cleft > 3 mm



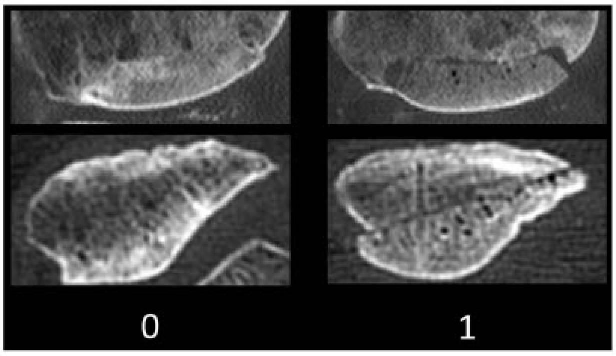


Fig. 3 Surface percentage with a discernible cleft at the host-graft junction. **0** < 30%. **1** > 30%

representative views of each CT. None of the observers had been involved in the treatment of these patients. Prior to scoring, two hours of consensus training sessions was performed to calibrate and standardize scoring on an independent data set.

Intraobserver variability

To determine intraobserver reliability, one observer evaluated all the CT images on two occasions, 15 days apart.

Results

Results are summarized in Table 2.

A total of 50 FOCA were performed between 2017 and 2019 in our institution. There were 27 males and 23 females with a mean age of 35.9 ± 7.11 (range 17-48) years at the time of index surgery with a mean BMI 24.6 ± 2.98 (range 18-29).

Inter-observer agreement

Each observer assessed 50 images. Agreement was moderate to substantial for all CT score components ($\kappa > 0.5$, $p < 0.05$). It was moderate for features 1 (graft signal density relative to host bone) and 3 (surface percentage with a discernible cleft at host-graft junction), and substantial for features 2 (osseous integration at the host-graft junction) and 4 (cystic changes of graft and/or host-graft junction). Although inter-observer agreement was perfect for feature 5 (presence of intra-articular fragments), κ could not be calculated because of lack of variability as the three readers scored the same for all 50 images (score 0, absence of intra-articular fragments).

Intra-observer agreement

Agreement was moderate to almost perfect for all CT score components ($\kappa > 0.59$, $p < 0.05$). It was almost perfect for features 1 and 2 (graft signal density relative to host bone and osseous integration at host-graft junction respectively), substantial for feature 4 (cystic changes of graft and/or host-graft

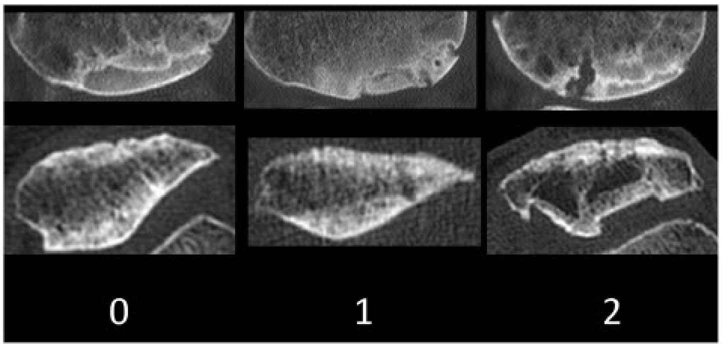


Fig. 4 Cystic changes of graft and/or host-graft junction. **0** Absent. **1** Present < 3 mm. **2** Present > 3 mm

Anexo

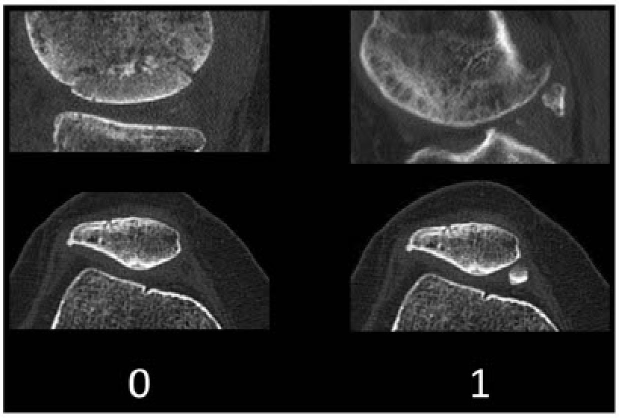


Fig. 5 Presence of intra-articular fragments. **0** Absent. **1** Present

junction), and moderate for feature 3 (surface percentage with a discernible cleft at host-graft junction). Although intra-observer agreement was perfect for feature 5 (presence of intra-articular fragments), κ could not be calculated due to the lack of variability.

Discussion

The ACTOCA scoring system presented here is a semiquantitative CT scoring system for analysis of cartilage defect repair for the knee using osteochondral allografts. While a number of scores to evaluate osteochondral allograft transplantations have been designed based on MRI and standard radiography, this is the first to be based on the CT scan. The ACTOCA scoring system showed moderate-to-substantial inter-observer agreement and moderate-to-almost-perfect intra-observer agreement in the five included aspects ($\kappa > 0.5$; $p < 0.05$).

The use of fresh osteochondral allograft (FOCA) tissue for osteochondral lesions larger than 2 cm^2 is a well-established technique [2]. Long-term survival using this approach has been shown to depend on chondrocyte viability, an intact extracellular matrix, and optimal graft incorporation into the host bone [3]. Several imaging modalities have been used to assess graft incorporation. Currently, the gold standard is MRI. MRI can be evaluated using either the MOCART score [4] or the recently described Osteochondral Allograft MRI Scoring System (OCAMRISS) [7]. Recent studies, however, have failed to provide strong evidence regarding whether or not MRI is a reliable tool to predict the clinical outcome after cartilage repair [5, 8].

Bone integration and cystic changes have been shown to have a great impact on the long-term survival of FOCA transplantations. Compared to MRI, CT scan offers better spatial resolution, allowing a more detailed assessment of bone changes [9, 10]. Surprisingly, there is a paucity of studies that have used CT to evaluate FOCA transplantation [17, 18]. The ACTOCA was thus designed to take advantage of the superiority of CT scan over MRI. It assesses five CT imaging aspects.

With regard to graft signal density relative to host bone (feature 1), this study showed moderate inter-observer agreement and almost-perfect intra-observer agreement. Osseous integration at the host-graft junction (feature 2) showed substantial inter-observer agreement and almost perfect intra-observer agreement.

Table 2 Interobserver and intraobserver agreement

CT features	Interobserver agreement (κ)	Intraobserver agreement (κ)
1. Graft signal density relative to host bone	0.537	1
2. Osseous integration at host-graft junction	0.778	1
3. Surface percentage with a discernible cleft at host-graft junction	0.554	0.6
4. Cystic changes of graft and/or host-graft junction	0.646	0.677
5. Presence of intraarticular fragments	Perfect	Perfect

The surface percentage with a discernible cleft at the host-graft junction (feature 3) showed moderate inter-observer and intra-observer agreement. With regard to cystic changes of graft and/or host-graft junction (feature 4), interobserver and intra-observer agreement was substantial. Nevertheless, as the perfect inter-observer and intra-observer agreement for the presence of intra-articular fragments (feature 5) was due to the lack of variability between readers regarding scores, κ could not be calculated. In summary, all the evaluated aspects showed good agreement. Notwithstanding, agreement was highest for the osseous integration at the host-graft junction (feature 2), highlighting the benefits of the CT scan to assess bone integration. Inter-observer agreement with the OCAMRISS system has been assessed in two studies. However, while one of them reported a high inter-observer agreement ($k > 0.8$) in 65% of comparisons, the authors did not specify the results of each feature [6]. The second study found substantial-to-almost-perfect agreement (k > 0.7) for all MRI score components except osseous integration, which could not be calculated [7].

This study has a number of limitations. First, to evaluate the images and in order to achieve a homogeneous analysis, the observers were given specific CT views rather than the whole CT study. However, this may have increased the inter-observer and intra-observer agreement because the sample might have underestimated the heterogeneity of the allografts.

Second, κ could not be calculated for feature 5 (presence of intra-articular fragments) as all the readers gave the 50 images the same scores (absence of intra-articular fragments) due to the absence of post-operative complications in the form of intra-articular fragments. And third, CT scans expose patients to high doses of radiation. This limitation, however, can be significantly reduced with an optimal collimation protocol [19].

Conclusions

The ACTOCA score presented here is a comprehensive, semi-quantitative CT scoring system that can be used as a reliable tool to evaluate bone changes after osteochondral allograft transplantations. Furthermore, it may help to standardize CT scan reports when an osteochondral allograft is transplanted in the knee.

Acknowledgments This study was developed within the Surgery and Morphological Sciences Doctorate framework of the Universitat Autònoma de Barcelona.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study was approved by the clinical research ethics committee of our institution (IIBSP-ALO-2018-21) and conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Informed consent was obtained from all individual participants included in the study.

Consent to participate The study was approved by the ethics committee of our institution.

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Anexo

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9.2. Estudio 2

International Orthopaedics
https://doi.org/10.1007/s00264-022-05373-6

ORIGINAL PAPER

Computerized tomography scan evaluation after fresh osteochondral allograft transplantation of the knee correlates with clinical outcomes

Pablo Eduardo Gelber[1,2] · Eduard Ramírez-Bermejo[1] · Alex Grau-Blanes[1] · Aránzazu Gonzalez-Osuna[1] · Oscar Fariñas[3]

Received: 16 December 2021 / Accepted: 6 March 2022

Abstract

Purpose To determine the correlation between the assessment computed tomography osteochondral allograft (ACTOCA) scoring system and clinical outcomes scores. The hypothesis was that the ACTOCA score would show sufficient correlation to support its use in clinical practice.

Methods We prospectively collected data from all consecutive patients who underwent cartilage restitution with fresh osteochondral allograft (FOCA) transplantation for osteochondral lesions of the knee and had a minimum follow-up of two years. CT scans were performed at three, six and 24 months post-operatively. A musculoskeletal radiologist blinded to the patients' medical history evaluated the scans using the ACTOCA scoring system. Clinical outcomes collected preoperatively and at three, six and 24 months postoperatively were evaluated using the International Knee Documentation Committee (IKDC), Kujala, the Western Ontario Meniscal Evaluation Tool (WOMET), and the Tegner Activity Scale.

Results The mean total ACTOCA score showed a statistically significant correlation with the clinical outcome. The correlation was optimal at 24 months. We found a high negative correlation with the IKDC, Kujala and Tegner (−0.737; −0.757, and −0.781 respectively), and a moderate negative correlation with WOMET (−0.566) ($p < 0.001$). IKDC, Kujala, WOMET, and Tegner scores showed a significant continuous improvement in all scores ($p < 0.001$).

Conclusion The mean total ACTOCA score showed a linear correlation with clinical results in IKDC, Kujala, WOMET, and Tegner scores, being the highest at 24 months post-surgery. This finding supports the use of ACTOCA to standardize CT scan reports following fresh osteochondral allograft transplantation in the knee.

Keywords Osteochondral allograft · Cartilage repair · CT · Fresh OCA · Transplantation · Correlation

Introduction

Osteochondral knee lesions in active young patients have a devastating effect on daily life [1]. Large symptomatic osteochondral lesions are a complex treatment challenge [2]. If untreated, progressive worsening of tibiofemoral osteochondral lesions and evolution to osteoarthritis can be expected [3]. In patellofemoral osteochondral lesions, an evolution to osteoarthritis has not been described [4], but surgery of symptomatic osteochondral lesions in the patellofemoral joint have to be considered when non-operative treatment fails [5].

Osteochondral lesions larger than 2 cm^2 are the main indication for FOCA transplantation where osteochondral cores from a size-matched, fresh cadaver are matched to the patient's knee injury [6]. Good clinical and functional outcomes can be expected after FOCA transplantation, even at longer follow-up [7–10].

The imaging assessment of bone aspects such as cystic changes and osseous integration is key to graft survival after FOCA transplantation [2]. As strong evidence is lacking as to whether magnetic resonance imaging (MRI) is reliable to correlate with clinical outcome scores [11, 12], a semiquantitative ACTOCA scoring system was recently developed and validated [13]. The ACTOCA includes five CT features

✉ Pablo Eduardo Gelber
personal@drgelber.com

1 Department of Orthopaedic Surgery, Hospital de La Santa Creu I Sant Pau, Universitat Autonoma de Barcelona, C/Sant Quintí 89, 08041 Barcelona, Catalunya, Spain

2 ICATME-Hospital Universitari Dexeus, Universitat Autonoma de Barcelona, Barcelona, Spain

3 Barcelona Tissue Bank, Banc de Sang I Teixits, Barcelona, Spain

Published online: 12 April 2022

Springer

relative to the aspect of the transplanted graft and the host bone (graft signal density, osseous integration, surface percentage with a discernible cleft, cystic changes, and presence of intra-articular fragments). However, the correlation between ACTOCA scores and clinical outcome scores has not yet been explored.

The objective of this study was to determine the correlation between ACTOCA scores and clinical outcome scores. The hypothesis was that the ACTOCA score would show sufficient correlation to support its use in clinical practice.

Material and methods

In this prospective study, we included all consecutive patients undergoing cartilage repair with FOCA transplantation for osteochondral knee lesions between August 2017 and August 2019. Surgery was carried out by a single surgeon at an academic medical centre, and all patients had a minimum follow-up of two years.

Inclusion criteria were patients younger than 50 years undergoing cartilage repair with FOCA transplantation for symptomatic osteochondral knee lesions with chronic onset after a minimum of six months of non-operative treatment in accordance with standard clinical practise at our institution. The surgical procedure was indicated in patients with large focal full-thickness chondral and osteochondral defects (>2 cm^2) on the tibial plateau, femoral condyles, trochlea, and/or patella.

Concomitant realignment osteotomy was performed in cases of tibiofemoral FOCA with tibiofemoral malalignment greater than 3° from the neutral mechanical axis into the involved compartment. Patellofemoral joints with a TTTG distance greater than 15 mm had an associated tibial tubercle anteromedialization osteotomy. Concomitant meniscal insufficiency was corrected with lateral or medial meniscal allograft transplantation, as needed. Exclusion criteria were inflammatory arthritis, large degenerative lesions comprising all three compartments, BMI >30 kg/m^2, diabetes, systemic inflammatory diseases, infection or history of osteomyelitis in the graft recipient area, and active neoplasia.

The study was approved by the ethics committee of our institution (IIBSP-ALO-2018–21). Informed consent was obtained from each patient following the guidelines laid down by our local ethics committee.

Surgical technique

An arthroscopic evaluation of all compartments of the knee was performed to confirm the size and depth of the lesion and to address any concurrent intra-articular pathology.

Any anatomic deformity or biomechanical alteration of the tibiofemoral joint and/or patellofemoral joint was corrected to avoid further cartilage degradation of the graft.

The articular cartilage defect was sized and reamed to a depth of approximately 8 to 10 mm. Fresh osteochondral allografts were obtained following screening and processing requirements of the local authorized tissue bank. The osteochondral allograft was irrigated using pulsatile lavage. A bone-dowel technique was performed for isolated defects with a well-defined affected area in an easily accessible surface of the knee such as the femoral condyles, mid-patella, or trochlea. The shell technique was used for asymmetric lesions, such as those involving the whole patella or those affecting a high-degree dysplastic trochlea. In cases of post-traumatic complex lesions of the tibial plateau with a concomitant meniscal deficiency, we transplanted a 10-mm-high medial or lateral tibial plateau including the corresponding meniscus. The bone-dowel technique obtained a press-fit fixation. Other techniques required fixation with bioabsorbable pins or interfragmentary screws [14–16].

In the first phase of rehabilitation, from zero to six weeks, the goal was graft protection by avoidance of weight-bearing. The day after surgery, progressive range of motion (ROM) exercises using a continuous passive motion device were started. Weight-bearing and ROM varied based on several variables but the goal was to avoid stressing the transplanted graft. A gradual transition to partial and full weight-bearing was allowed after six to ten weeks. [9]

CT assessment

CT scans were performed postoperatively on day one to rule out any technical errors and then at three, six and 24 months. Post-operative CT studies were obtained on a 16-multidetector system (Brillance, Philips Healthcare) using a reduced dose protocol with the lowest scan length required to include the allograft. Multiplanar reformatted 2-mm contiguous sagittal and coronal images were later obtained. Collimation was performed for all CTs to increase image quality and reduce the patient's overall radiation exposure.

For this imaging study, we used the previously published and validated comprehensive ACTOCA score [13]. The ACTOCA includes five CT features relative to the aspect of the transplanted graft and the host bone; graft signal density, osseous integration, surface percentage with a discernible cleft, cystic changes, and presence of intra-articular fragments. Axial views were used to evaluate the patella-femoral joint, and sagittal views were used to evaluate the femoral condyles and tibia. Each parameter was scored, and the total summation was calculated. A lower total score indicates better incorporation of the graft, with possible scores ranging from zero to eight (Table 1, Figs. 1 and 2).

Table 1 ACTOCA scoring system

CT features	CT score
1. Graft signal density relative to host bone	0: Equivalent 1: Superior 2: Inferior
2. Osseous integration at host-graft junction	0: Crossing trabeculae 1: Discernible cleft < 3 mm 2: Discernible cleft > 3 mm
3. Surface percentage with a discernible cleft at host-graft junction	0: < 30% 1: > 30%
4. Cystic changes of graft and/or host-graft junction	0: Absent 1: Present < 3 mm 2: Present > 3 mm
5. Presence of intraarticular fragments	0: Absent 1: Present

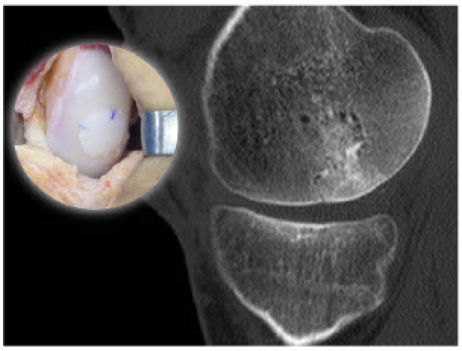

Fig. 1 CT scan taken at 6 months and surgical image of a medial femoral condyle FOCA obtaining a low ACTOCA score (1 point)

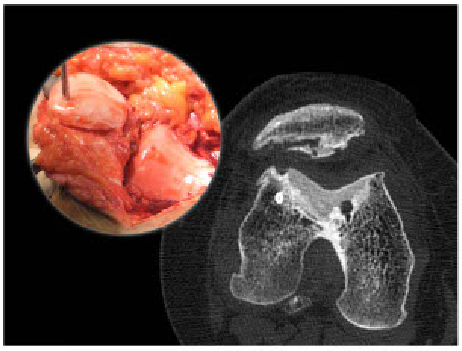

Fig. 2 CT scan taken at 24 months and surgical image of a trochlear and patellar FOCA obtaining a high ACTOCA score (6 points)

All CT scans were evaluated by a musculoskeletal radiologist blinded to the patient's medical history.

Functional evaluation

Clinical results were collected preoperatively and at three, six and 24 months post-operatively.

At each time point, participants completed several patient-reported outcome instruments to measure clinical results. The scores used were the IKDC, Kujala, WOMET, and the Tegner activity scale [17–20].

Secondary outcomes

Sociodemographic data were collected at baseline to characterize the study sample and explore age, sex at birth, involved side, and BMI as potential confounding variables. Concomitant procedures (osteotomy, ligamentous repair/reconstruction, meniscal allograft transplantation) were recorded at the time of surgery. Osteochondral allograft type (patellofemoral, femoral condyle, or tibial) was also noted.

Statistical analysis

Statistical analysis was performed using the statistical package IBM SPSS V26.0 (IBM Corp. Armonk, NY). Descriptive statistics were used to determine patient and lesion characteristics. The results are given as a number of cases and/or percentage for categorical data, and as mean, standard deviation and range for quantitative data. Variables repeated during the trial (functional scales and CT) were analysed using ANOVA tests for repeated measures with Greenhouse–Geisser correction to avoid sphericity. The correlation between clinical results and imaging results was analysed by Pearson's correlation coefficient. The overall level of significance was set at 0.05 for two-sided tests.

The power calculation was done according to IKDC from preoperative to 24 months postoperatively. A 5-point threshold for clinical relevance was set a priori. This number is in fact lower than multiple reported studies to detect minimal changes and similar to what was reported in a recent study by Magnuson et al. [21]. According to the power calculation, to generate a power of 80%, an alpha of 0.05, and a standard deviation of 10 points, this study required 30 patients.

Table 2 Patient demographics and specific knee data ($N=38$)

Factor		
Age (years)	36.63 ± 6.63	
BMI	23.92 ± 2.57	
Male/female	24/14	
Lesion location		
	Femoropatellar joint (%)	55.3
	-Isolated patella (%)	76
	-Femoral groove + patella (%)	24
	Femoral condyle (%)	34.2
	-Medial (%)	70
	-Lateral (%)	30
	Tibia (%)	10.5
	-Medial (%)	75
	-Lateral (%)	25
FOCA type		
	Unipolar (%)	81.6
	Bipolar (%)	18.4
FOCA technique		
	Plug (%)	55.3
	Shell (%)	34.2
	Small fragment (%)	10.5
Tibial tubercle osteotomy (%)	18.4	
High tibial osteotomy (%)	18.4	

Results

A total of 38 patients (24 males; 63%) met the inclusion criteria. The mean post-operative follow-up was 38 months (range, 30–48 months). Patients' mean age was 36.63 ± 6.63 years (range, 18–46 years). Thirty-one of the 38 patients (81.6%) received unipolar OCA transplants, defined as involving ≥ one non-apposing articulating surfaces, and 71 (18.4%) received bipolar transplants, defined as involving two opposing articulating surfaces. Baseline demographic data and clinical characteristics are presented in Table 2.

No statistically significant differences were noted for ACTOCA or functional scales (IKDC, Kujala, WOMET, or Tegner) according to sex at birth, age, BMI, concomitant procedures, or osteochondral allograft type. Regarding osteotomies, no statistically significant differences were found between patients with or without osteotomies on CT evolution ($p=0.819$), IKDC evolution ($p=0.139$), Kujala evolution ($p=0.158$), WOMET evolution ($p=0.299$), and Tegner evolution ($p=0.138$).

Evolution of clinical scores

Pre-operative and post-operative comparisons of clinical scores at three, six and 24 months showed a significant continuous improvement in IKDC, Kujala, WOMET, and Tegner scores ($p<0.001$) (Table 3).

Table 4 ACTOCA scores

	3 months	6 months	24 months	Greenhouse–Geisser (p)
ACTOCA	2.16 ± 0.92 (0–4)	1.34 ± 1.21 (0–4)	1.05 ± 1.33 (0–4)	< 0.001

The values are given as the mean ± standard deviation with the range in parentheses

Table 3 Clinical scores

	Preop	3 months	6 months	24 months	Greenhouse–Geisser
IKDC	31.26 ± 9.4 (15–53)	41 ± 10.95 (21–65)	47.58 ± 13.5 (20–76)	60.47 ± 18.81 (20–88)	<0.001
Kujala	38.84 ± 12.46 (17–63)	49.63 ± 12.87 (27–76)	58.13 ± 14.4 (30–94)	69.5 ± 17.1 (30–97)	<0.001
WOMET	38.74 ± 14.87 (13–79)	46.68 ± 15.07 (18–75)	53.13 ± 16.48 (14 – 87)	65.5 ± 18.2 (25–98)	<0.001
Tegner	1.97 ± 0.91 (1–4)	1.89 ± 0.89 (1–4)	2.08 ± 0.78 (1–4)	2.76 ± 1.03 (1–4)	<0.001

ACTOCA evolution

The ACTOCA scores improved significantly at three, six and 24 months post-surgery ($p<0.001$) (Table 4).

Correlation between clinical outcomes and mean ACTOCA score

The total ACTOCA score correlated with the clinical results (Table 5).

We observed a moderate negative correlation with the IKDC score at six months (Pearson correlation coefficient, −0.535; $p=0.001$) and a high negative correlation with IKDC at 24 months (Pearson correlation coefficient, −0.737; $p<0.001$). There was a low negative correlation with the Kujala score at six months (Pearson correlation coefficient, −0.343; $p=0.035$) and a high negative correlation with Kujala at 24 months (Pearson correlation coefficient, −0.757; $p<0.001$). The correlation with WOMET at 24 months showed a low negative correlation (Pearson correlation coefficient, −0.566; $p<0.001$), and the correlation with Tegner at 24 months showed a high negative correlation (Pearson correlation coefficient, −0.781; $p<0.001$).

Discussion

The main finding of this study was that the ACTOCA score showed a statistically significant correlation with the clinical outcome. This correlation between the mean total ACTOCA score and the clinical outcome was the highest at 24 months after surgery. At this time, IKDC, Kujala, and Tegner showed a high negative correlation with the ACTOCA score and a moderate negative correlation with WOMET.

To our knowledge, this is the first study to analyse the correlation between CT and clinical outcomes using ACTOCA scores. To date, the gold standard imaging modality to assess graft incorporation after fresh osteochondral allograft has been MRI. However, recent studies have shown that the MRI total score does not correlate meaningfully with clinical outcome scores. In a systematic review and meta-analysis of 32 studies carried out to evaluate the correlation between clinical outcome and MRI after cartilage repair, Windt et al. [22] found conclusive evidence that such correlation was lacking. In another study, Wang et al. [12] investigated 43 patients treated with FOCA after a previous cartilage repair surgical procedure. They found that the total OCAMRISS score, one of the most widely used MRI scores, did not correlate meaningfully with clinical outcome scores. Other authors have also failed to find a correlation between MRI scores and clinical results [23, 24]. In contrast with these results using MRI, using the ACTOCA scoring system, we found a high correlation between CT scan and clinical results. This difference may be due to CT scans offering a better evaluation of bone integration and cystic changes that have been shown to have a great impact on clinical results after FOCA.

The recently developed and validated ACTOCA scoring system [13] includes five CT features: density relative to host bone, integration at the host-graft junction, surface percentage with a discernible cleft at the host-graft junction, cystic changes, and intra-articular fragments. Interobserver agreement was found to be was moderate to substantial for all CT score components, and intra-observer agreement was moderate to almost perfect for all CT score components ($\kappa>0.5$, $p<0.05$), showing that ACTOCA score is a reliable scoring system to evaluate osteochondral allograft transplants.

Although imaging assessment of bone aspects such as osseous integration and cystic changes is of great importance to graft survival after FOCA transplantation, few studies have evaluated this transplantation using CT. Anderson et al. [25] recently developed a CT scoring system and evaluated the relationship of OCA bone parameters measured on CT with clinical outcomes. However, unlike our study, only one postoperative CT scan was collected (at a mean of 5.8 months after surgery), and the clinical score the closest to CT findings was used. This score, therefore, reflected a different post-surgery period for each patient, and this could have made their results less conclusive.

Brown et al. [26] investigated osseous integration and early clinical results following FOCA with cylindrical grafts to the femoral condyle. They reported an overall CT assessment of graft incorporation as a percentage of incorporation based on CT images and found the mean level of incorporation of all grafts was grade 2 (50–75%). They did not, however, evaluate the correlation between clinical outcomes

Table 5 Correlation between total ACTOCA score and clinical outcomes scores

		Pearson correlation coefficient	p value
IKDC	3 months	−0.116	0.488
	6 months	−0.535	0.001*
	24 months	−0.737	<0.001*
KUJALA	3 months	−0.027	0.872
	6 months	−0.343	0.035*
	24 months	−0.757	<0.001*
WOMET	3 months	−0.069	0.682
	6 months	−0.274	0.096
	24 months	−0.566	<0.001*
TEGNER	3 months	−0.177	0.287
	6 months	−0.313	0.056
	24 months	−0.781	<0.001*

*Significant

and the percentage of incorporation on CT. Cook et al. [27] reported their results of a series of 18 patients who underwent OATS to the femoral condyle, evaluating CT arthrograms post-operatively. Similarly to other imaging studies of FOCA procedures, again CT arthrograms did not correlate with functional outcomes. It may be because they only evaluated bony integration and articular congruity.

In our study, using the ACTOCA scoring system to evaluate FOCA from CT images, we found a statistically significant correlation with clinical outcomes. Furthermore, the pre-operative and post-operative clinical scores at three, six and 24 months reflected a significant, continuous improvement on IKDC, Kujala, WOMET, and Tegner scores.

The present study has several limitations. First, there was no comparison group, and the sample size was small. In addition, the cohort was relatively heterogeneous with respect to osteochondral allograft type and concomitant procedures. However, no statistically significant differences were noted for ACTOCA or functional scales (IKDC, Kujala, WOMET, or Tegner) according to sex at birth, age, BMI, concomitant procedures, or osteochondral allograft type.

The absence of differences between patients with or without osteotomy may be related to the fact that osteotomies were performed only in cases of tibiofemoral FOCA with tibiofemoral malalignment greater than 3° from the neutral mechanical axis into the involved compartment or in case of patellofemoral FOCA with TTTG distance greater than 15 mm. The remaining cases had normal preoperative values. Therefore, patients with osteotomy and without osteotomy presented a comparable alignment once operated.

Second, all CT scans were evaluated by a single musculoskeletal radiologist blinded to the patient's medical history. Nevertheless, a recent study showed that ACTOCA provides a moderate to a substantial interobserver agreement and a moderate-to-almost-perfect intra-observer agreement [13]. And third, CT scans expose patients to high doses of radiation. This limitation, however, was significantly reduced with the optimal collimation protocol used.

Conclusions

The mean total ACTOCA score showed a linear correlation with clinical results in IKDC, Kujala, WOMET, and Tegner scores, being the highest at 24 months post-surgery. This finding supports the use of ACTOCA to standardize CT scan reports following fresh osteochondral allograft transplantation in the knee.

Acknowledgements This study was developed within the framework of the Doctorate in Surgery and Morphological Sciences of the Universitat Autònoma de Barcelona.

Author Contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Pablo Eduardo Gelber and Eduard Ramírez-Bermejo. The first draft of the manuscript was written by Eduard Ramírez-Bermejo and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding Open Access Funding provided by Universitat Autonoma de Barcelona.

Declarations

Ethical approval The study was approved by the clinical research ethics committee at our institution (IIBSP-ALO-2018-21) and conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Informed consent was obtained from all individual participants included in the study.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent to publish The authors affirm that human research participants provided informed consent for publication of the images in Figs. 1 and 2; and Tables 1, 2, 3, 4 and 5.

Competing interests The authors declare no competing interests.

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9.3. Estudio 3

Early Postoperative CT Scan Provides Prognostic Data on Clinical Outcomes of Fresh Osteochondral Transplantation of the Knee

Pablo Eduardo Gelber,*†‡ MD, PhD, Eduard Ramírez-Bermejo,† MD, and Oscar Fariñas,§ MD
Investigation performed at Hospital de la Santa Creu i Sant Pau, Barcelona, Spain

Background: There is a lack of information regarding the ability of imaging studies to predict clinical outcomes after fresh osteochondral allograft (FOCA) transplantation of the knee.

Purpose: To determine the value of computed tomography (CT) scans to predict the clinical outcome of FOCA transplantation using the assessment computed tomography osteochondral allograft (ACTOCA) score.

Study Design: Cohort study; Level of evidence, 3.

Methods: We prospectively collected data from all consecutive patients who underwent FOCA transplantation for osteochondral knee lesions at one institution between August 2017 and August 2019. All patients were followed up for a minimum of 2 years. CT scans performed 6 months after surgery were evaluated by a musculoskeletal radiologist using the ACTOCA scoring system. The radiologist was blinded to the patient's medical history. Clinical outcomes were assessed preoperatively and at 12 and 30 months postoperatively using the International Knee Documentation Committee (IKDC) score, the Kujala score, the Tegner activity scale, and the Western Ontario Meniscal Evaluation Tool (WOMET) score.

Results: A total of 38 cases were included. The ACTOCA score at 6 months after surgery showed a statistically significant correlation with clinical results at 12 and 30 months. The correlation was better at 30 months, showing a high negative correlation with the IKDC score (−0.663) and a moderate negative correlation with the Kujala, WOMET, and Tegner scores (−0.593; −0.547, and −0.593, respectively) ($P < .001$).

Conclusion: A statistically significant correlation between the mean ACTOCA score on CT scans at 6 months and the clinical results measured by the IKDC, Kujala, WOMET, and Tegner scores at 30 months confirmed the predictive value of the ACTOCA score for use in clinical practice.

Keywords: cartilage repair; computed tomography scoring system; osteochondral allograft; prognostic value

Fresh osteochondral allograft (FOCA) transplantation is a useful treatment option for focal osteochondral lesions larger than 2 cm^2 in the knee. It achieves good clinical outcomes, including an improvement in range of motion (ROM) and a high probability of return to play.[6,23,26,29] Previous studies suggest that age, body mass index (BMI), previous surgical procedures in the involved knee, uncorrected malalignment, bipolar transplantations, and large (>10 cm^2) and chronic lesions are associated with less favorable results[9,10,20,22]; however, the ability to predict the clinical outcome is limited. Several imaging modalities have been performed to assess the transplanted allograft but none have yet been shown to clinically predict outcomes.

Imaging assessment of bone aspects, such as cystic changes and osseous integration, is key to determining graft survival after FOCA transplantation.[1,16] Magnetic resonance imaging (MRI), unfortunately, has not provided strong evidence to predict clinical outcomes after this procedure,[8,28] and computed tomography (CT) has demonstrated

*Address correspondence to Pablo E. Gelber, MD, PhD, Department of Orthopaedic Surgery, Hospital de la Santa Creu i Sant Pau, Universitat Autonoma de Barcelona, C/Sant Quintí 89, Barcelona, Catalunya, 08041, Spain (email: personal@drgelber.com).
†Department of Orthopaedic Surgery, Hospital de la Santa Creu i Sant Pau, Universitat Autonoma de Barcelona, Barcelona, Spain.
‡ICATME–Hospital Universitari Dexeus, Universitat Autonoma de Barcelona, Barcelona, Spain.
§Barcelona Tissue Bank, Banc de Sang i Teixits, Barcelona, Spain.

Submitted February 17, 2022; accepted August 16, 2022.
The authors declared that they have no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

The American Journal of Sports Medicine
1–7
DOI: 10.1177/03635465221129601

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a considerably higher spatial resolution to accurately evaluate bone aspects like osseous integration and cystic changes.[24,27] Recently, a semiquantitative assessment computed tomography osteochondral allograft (ACTOCA) scoring system was developed and shown to be reliable.[11] This new score includes 5 CT features that are relative to the aspect of the host bone and the transplanted graft (graft signal density, osseous integration, surface percentage with a discernible cleft, cystic changes, and presence of intra-articular fragments). Early prediction of these FOCA features that will likely present lower clinical scores is of high clinical relevance.

The purpose of this study was to determine the value of CT scans using the ACTOCA score to predict the clinical outcome of FOCA transplantation of the knee. The hypothesis was that an early assessment after FOCA transplantations using the ACTOCA score would help to predict later clinical outcomes.

METHODS

We performed a prospective case series study that included all consecutive patients who underwent cartilage repair with FOCA transplantation for osteochondral knee defects at an academic medical center between August 2017 and August 2019. All surgeries were performed by a single surgeon (P.E.G.).

The inclusion criteria were as follows: patients aged between 18 and 50 years who had a FOCA transplantation for osteochondral knee lesions. The main indication for FOCA transplantation was large, focal full-thickness chondral and osteochondral defects (>2 cm^2) on the femoral condyles, trochlea, and/or patella.

Concomitant realignment osteotomy was performed in the case of tibiofemoral FOCA with tibiofemoral malalignment $>3°$ from the neutral mechanical axis into the involved compartment. Patellofemoral maltracking was also addressed with tibial tubercle osteotomy if the TT-TG distance was >15 mm.

The exclusion criteria were as follows: concomitant meniscal insufficiency; inflammatory arthritis; large degenerative lesions comprising all 3 compartments; BMI >30; systemic inflammatory diseases; infection or history of osteomyelitis in the graft recipient area; and active neoplasia.

The study was approved by the clinical research ethics committee at our institution (IIBSP-ALO-2018-21) and conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Informed consent was obtained from all individual participants included in the study.

Surgical Technique

In all cases, a complete arthroscopic evaluation of all the compartments of the knee was conducted to confirm the size and depth of the lesion and to address any concurrent intra-articular pathology. Any anatomic or biomechanical alteration of the tibiofemoral and/or patellofemoral joints was corrected to avoid further cartilage degradation of the graft.

The local authorized tissue bank supplied the allografts and performed all the preoperative graft processing.[12-14] Osteochondral grafts were obtained from donors aged <45 years, with a mean age of 31 years (range, 18-44 years). Once a donor was available, grafts were harvested within the first 12 hours of death. The osteochondral allograft (OCA) was placed into a transport medium (lactated Ringer solution) and preserved and refrigerated between 4°C and 8°C. On arrival at the tissue bank, the graft was prepared and cleansed in a Class A clean room. Soft tissue and periosteum were then removed. High-pressure pulsatile lavage irrigation and dry centrifugation and centrifugation were performed with sterile phosphate-buffered saline. Microbiological testing was performed on both the graft and the last wash solution. The allograft was then placed in a solution with lactated Ringer solution and an antibiotic cocktail consisting of vancomycin (50 mg/mL), tobramycin (3 mg/mL), cotrimoxazole (160 mg/mL), and amphotericin (125 m g/mL). Five days later, microbiological testing was again performed on both the preservation solution and the graft. The graft was kept refrigerated between 4°C and 8°C until implant at a maximum of 3 weeks from harvesting.

After sizing the articular defect using a sterile ruler, we placed a reamer over the identified lesion and slowly advanced to a depth of approximately 8 to 10 mm with continuous cold saline irrigation. The FOCA was accordingly prepared and washed with high-strength pulsatile lavage to eliminate as many blood cells as possible. In cases of isolated defects with a well-circumscribed affected area in an easily accessible surface of the knee—such as the femoral condyle, midpatella, or trochlea—a bone-dowel technique was performed (JRF-Ortho Instrument Set, JRF Ortho). The shell technique was used for asymmetrical and extensive lesions, such as whole patellar and high-degree trochlear dysplasia. Press-fit fixation was obtained with bone-dowel techniques, whereas the shell technique required fixation with interfragmentary screws or bioabsorbable pins.[12-14]

Early progressive ROM exercises were performed on a continuous passive motion machine for 6 weeks. Weightbearing status and progressive ROM varied depending on the procedure; however, the goal was to avoid placing shear or compressive stress on the transplanted area. A gradual transition to weightbearing as tolerated was allowed after 6 to 8 weeks.[25]

CT Assessment

To confirm that there were no technical errors in the surgical procedure, CT scans were performed on the day after surgery and at 6 months postoperatively. All CT scans were obtained on a 16-multidetector system (Brillance; Philips Healthcare) using a reduced dose protocol, with the minimum scan length required to include the allograft. Multiplanar reformatted 2-mm contiguous sagittal and coronal images were later obtained. In all cases, collimation was performed for all CT scans to improve image quality and reduce overall radiation exposure. The patients

TABLE 1
ACTOCA Scoring System[a]

CT Features	CT Score
1. Graft signal density relative to host bone	0: Equivalent 1: Superior 2: Inferior
2. Osseous integration at host-graft junction	0: Crossing trabeculae 1: Discernible cleft ≤3 mm 2: Discernible cleft >3 mm
3. Surface percentage with a discernible cleft at host-graft junction	0: ≤30% 1: >30%
4. Cystic changes of graft and/or host-graft junction	0: Absent 1: Present ≤3 mm 2: Present >3 mm
5. Presence of intra-articular fragments	0: Absent 1: Present

[a]ACTOCA, assessment computed tomography osteochondral allograft; CT, computed tomography.

were scanned from the superior pole of the patella to the proximal tibia. The dose-length products were between 55 and 90 mGy.cm.

For this imaging study, we used the recently published ACTOCA score, which has been shown to be reliable.[11] The ACTOCA scoring system includes 5 CT features relative to the aspect of the transplanted graft and the host bone—graft signal density, osseous integration, surface percentage with a discernible cleft, cystic changes, and presence of intra-articular fragments (Table 1). A lower total score indicates better incorporation of the graft, with possible scores ranging from 0 to 8. All CTs were evaluated by a musculoskeletal radiologist blinded to the patient's medical history (Figures 1 and 2).

Functional Evaluation

Clinical results were collected preoperatively and at 12 and 30 months after surgery. All participants completed the following patient-reported outcome instruments to measure clinical results: the International Knee Documentation Committee form (IKDC); the Kujala score; the Western Ontario Meniscal Evaluation Tool (WOMET); and the Tegner activity scale.[15,17-19] Although this was not meniscal surgery, we chose the WOMET scale because it is widely used after meniscal surgery in young patients and because there are not any other scales specifically designed for OCA surgery.

Secondary Outcomes

Sociodemographic questions were recorded at baseline to characterize the study sample and explore age, sex assigned at birth, side of the lesion (left, right), and BMI as potential confounding variables. Concomitant procedures (eg, osteotomy, ligamentous repair/reconstruction, and meniscal allograft transplantation) and OCA type (patellar, femoral, or tibial) were recorded at the time of surgery.

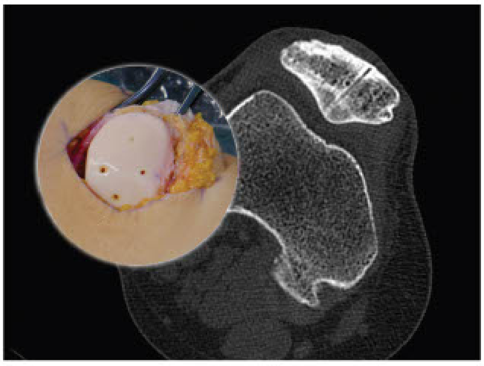

Figure 1. A computed tomography scan taken 6 months after surgery and a surgical image of a patellar fresh osteochondral allograft obtaining a low assessment computed tomography osteochondral allograft score (1 point—superior graft signal density relative to the host bone).

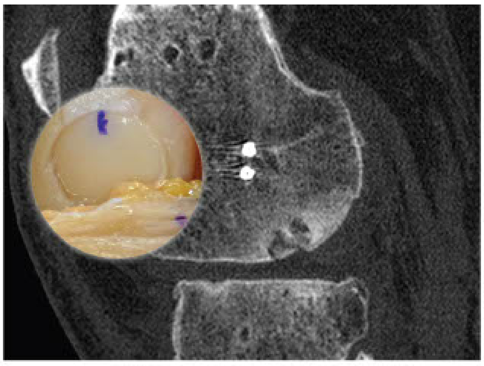

Figure 2. A computed tomography scan taken at 6 months after surgery and a surgical image of a medial femoral condyle fresh osteochondral allograft obtaining a high assessment computed tomography osteochondral allograft score (4 points—superior graft signal density relative to the host bone, discernible cleft ≤3 mm, cystic changes of graft >3 mm).

Statistical Analysis

The statistical analysis was performed using the statistical package SPSS Version 26.0 (IBM Corp). Descriptive statistics were used to determine patient and lesion characteristics. For categorical data, the results are given as the number of cases and/or percentage; and, for quantitative variables, as mean, standard deviation, and range. Variables repeated during the trial (functional scales) were

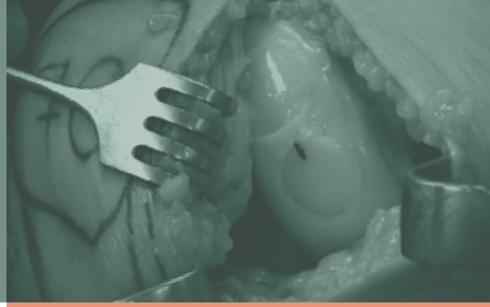

TABLE 2
Clinical Scores[a]

	Preoperative	12 Months	30 Months	Greenhouse-Geisser, *P* Value
IKDC	31.26 ± 9.4 (15-53)	53.76 ± 16.7 (21-83)	64.68 ± 20.52 (20-89)	<.001
Kujala	38.84 ± 12.46 (17-63)	63.21 ± 16.4 (29-96)	72.13 ± 19.09 (26-98)	<.001
WOMET	38.74 ± 14.87 (13-79)	59.05 ± 17.2 (19-90)	70.47 ± 19.3 (24-98)	<.001
Tegner	1.97 ± 0.91 (1-4)	2.58 ± 1.03 (1-5)	2.92 ± 1.12 (1-5)	<.001

[a]The values are given as mean ± SD (range). IKDC, the International Knee Documentation Committee; WOMET, Western Ontario Meniscal Evaluation Tool.

TABLE 3
Correlation Between Total ACTOCA Score at 6 Months and Clinical Outcomes Scores at 12 Months[a]

	Pearson Correlation Coefficient	*P* Value
IKDC	−0.507	.001[b]
Kujala	−0.439	.006[b]
WOMET	−0.407	.011[b]
Tegner	−0.465	.003[b]

[a]ACTOCA, assessment computed tomography osteochondral allograft; IKDC, International Knee Documentation Committee; WOMET, Western Ontario Meniscal Evaluation Tool.
[b]Significant—clinical outcomes at 12 months.

TABLE 4
Correlation Between Total ACTOCA Score at 6 Months and Clinical Outcomes Scores at 30 Months[a]

	Pearson Correlation Coefficient	*P* Value
IKDC	−0.663	<.001[b]
Kujala	−0.597	<.001[b]
WOMET	−0.547	<.001[b]
Tegner	−0.593	<.001[b]

[a]ACTOCA, assessment computed tomography osteochondral allograft; IKDC, International Knee Documentation Committee; WOMET, Western Ontario Meniscal Evaluation Tool.
[b]Significant—Clinical outcomes at 30 months.

analyzed by analysis of variance tests for repeated measures with Greenhouse-Geisser correction to avoid sphericity. The correlation between clinical results and imaging results was analyzed using the Pearson correlation coefficient. The overall level of significance was set at .05 for 2-sided tests.

RESULTS

This study included 38 patients. The mean postoperative follow-up was 38 months (range, 30-48 months). The mean age was 36.63 ± 6.6 years (range, 18-46 years), and the mean BMI was 23.9 ± 2.6 (range, 20-30). Also, 63% of the patients (n = 24 cases) were men.

The most frequent location of the lesion was the patellofemoral joint (n = 23 cases; 60.5%), followed by the femoral condyle (n = 15 cases; 39.5%) divided into 67% medial femoral condyle and 33% lateral femoral condyle. Also, 31 patients (81.6%) received unipolar FOCA transplants and 7 patients (18.4%) received bipolar transplants—defined as involving 2 opposing articulating surfaces, including the tibial-femoral condyle and the patella-trochlea. A bone-dowel technique was performed in 65.8% of the cases. A shell technique was done in the remaining 34.2% of the cases. Concomitant procedures were performed in 14 patients (36.8%), including tibial tubercle osteotomy in 7 cases (18.4%) and high tibial osteotomy in another 7 cases (18.4%).

Clinical Scores Evolution

The preoperative and postoperative comparisons of the scores showed significant improvements according to the IKDC, Kujala, WOMET, and Tegner scores at 12 and 30 months postoperatively ($P < .001$) (Table 2).

ACTOCA Scores

All CT scans were performed 6 months after surgery. The mean total ACTOCA score was 1.34 ± 1.21 points (range, 0-4 points).

ACTOCA Prognostic Value

The total ACTOCA score at 6 months correlated with clinical results at 12 and 30 months (Tables 3 and 4).

The total ACTOCA score at 6 months showed a moderate negative correlation with the IKDC score at 12 months (Pearson correlation coefficient, −0.507; $P = .001$) and a high negative correlation at 30 months (Pearson correlation coefficient, −0.663; $P < .001$).

The total ACTOCA score at 6 months showed a moderate negative correlation with the Kujala score at 12 months (Pearson correlation coefficient, −0.439; $P = .006$) and a moderate negative correlation at 30 months (Pearson correlation coefficient, −0.597; $P < .001$).

TABLE 5
Subgroup Analysis[a]

	BMI *P*	Age *P*	Sex *P*
CT, 6 mo	.608	.761	.260
IKDC, 12 mo	.178	.627	.823
IKDC, 30 mo	.385	.541	.777
Kujala, 12 mo	.034	.309	.427
Kujala, 30 mo	.376	.182	.643
WOMET, 12 mo	.339	.186	.520
WOMET, 30 mo	.292	.272	.273
Tegner, 12 mo	.219	.212	.800
Tegner, 30 mo	.48	.156	.622
	OCA Type *P*	**Tibial Tubercle Osteotomy *P***	**High Tibial Osteotomy *P***
CT, 6 mo	.939	.971	.167
IKDC, 12 mo	.873	.580	.740
IKDC, 30 mo	.195	.797	.685
Kujala, 12 mo	.329	.076	.685
Kujala, 30 mo	.272	.555	.632
WOMET, 12 mo	.723	.768	.506
WOMET, 30 mo	.929	.768	.317
Tegner, 12 mo	.551	.395	.416
Tegner, 30 mo	.606	.854	.265

[a]BMI, body mass index; CT, computed tomography; IKDC, International Knee Documentation Committee; OCA, osteochondral allograft; WOMET, Western Ontario Meniscal Evaluation Tool.

The total ACTOCA score at 6 months showed a moderate negative correlation with the WOMET score at 12 months (Pearson correlation coefficient, −0.407; P = .011) and a moderate negative correlation at 30 months (Pearson correlation coefficient, −0.547; P < .001).

The total ACTOCA score at 6 months showed a moderate negative correlation with the Tegner score at 12 months (Pearson correlation coefficient, −0.465; P = .003) and a moderate negative correlation at 30 months (Pearson correlation coefficient, −0.593; P < .001).

Subgroup Analysis

No statistically significant differences were noted for the ACTOCA or functional scales (IKDC, Kujala, WOMET, and Tegner) according to BMI (all BMI <30), age, sex at birth, OCA type, or concomitant procedures (Table 5).

DISCUSSION

The ACTOCA score evaluating CT at 6 months showed a statistically significant correlation with clinical outcomes, particularly at 30 months. We found a high negative correlation with the IKDC score and a moderate negative correlation with the Kujala, WOMET, and Tegner scores at 30 months, confirming the study's hypothesis that the ACTOCA score has a prognostic value.

There is a paucity of studies predicting clinical outcomes of the FOCA based on imaging modalities. Wang et al[28] reviewed clinical outcomes and MRI scans from 36 patients who underwent FOCA, with a minimum follow-up of 2 years; the mean postoperative follow-up was 3.5 years. The clinical outcomes obtained at the last follow-up were correlated with MRI scans performed around 1 year after surgery. The mean total Osteochondral Allograft MRI Scoring System (OCAMRISS) score, one of the most widely used MRI scores,[4] showed a slight correlation (Pearson correlation coefficient, −0.36; P = .035) with the 36-Item Short Form Health Survey (SF-36) physical function score. No other section of the SF-36 or other scores showed any correlation with this MRI evaluation. In another study, Lin et al[21] studied 20 patients after a FOCA transplant of the patella using femoral condylar allografts. MRI scans were obtained at a mean of 11.4 months (range, 6-22 months) postoperatively and clinical outcomes were collected at a mean of 46.5 months (range, 24-85 months) postoperatively. They found no statistically significant correlation between OCAMRISS scores and clinical scores. Along the same lines, other authors have also reported no correlation between MRI scores and clinical results.[2,8] Few studies[3,5] have evaluated FOCA transplantation using CT and none of them reported a correlation between CT and clinical results. Unlike the findings in these studies, we found a statistically significant correlation between ACTOCA scores at 6 months and clinical scores at 30 months. This finding supports the prognostic value of this score. It is of note that the correlation was better at the 30-month follow-up than at the 12-month follow-up. This was probably because the functional scores were still in the ascending curve toward a more stable and favorable outcome at the longer follow-up evaluation.

We also performed a CT at 6 months postoperatively and determined clinical scores at 12 and 30 months postoperatively in all patients. The fact that we conducted these follow-ups at the same time postoperatively in all patients is of particular interest, as it provided a more accurate and reproducible follow-up. The availability of a predictive tool that can help to adjust treatment as early as 6 months after the FOCA procedure allows the surgeon to adjust expectations and identify potential failures. A failure was considered any reoperation resulting in the removal of the graft, such as allograft revision or any form of arthroplasty.[9]

The ACTOCA score has recently been shown to have high reproducibility.[11] In the present study, this score also confirmed its prognostic value to evaluate outcome after FOCA transplantation. Knowing the parameters that are related to poorer clinical outcomes is of great importance. Frank et al[10] reviewed 180 patients treated with OCA transplantation at a minimum follow-up of 2 years. They found a 37% reoperation rate and an 87% allograft survival rate at a mean of 5 years after a FOCA transplant. They observed that a greater number of previous ipsilateral surgical procedures (3.75 vs 2.28; P < .001) and higher BMI (29.42 vs 26; P = .003) were independently predictive of failure. Familiari et al[9] reported the results of

a systematic review of clinical outcomes after OCA transplantation in the knee. They concluded that revision cases, patellar lesions, and bipolar lesions were associated with worse survival rates. Nuelle et al[22] retrospectively reviewed 75 patients who underwent a FOCA transplant. They found that active patients and those with a BMI <35 were significantly more likely to have a successful outcome than minimally active patients (P = .023; P = .01). In contrast, in our study, we did not note any statistically significant differences for the ACTOCA or functional scales (IKDC, Kujala, WOMET, and Tegner) according to sex at birth, age, BMI (all BMI <30), concomitant procedures, or osteochondral allograft type.

In relation to the Tegner scale results, the mean preoperative Tegner score increased from 1.97 ± 0.91 points (range, 1-4 points) to 2.58 ± 1.03 points (range 1-5 points) at 12 months postoperatively and to 2.92 ± 1.12 points (range, 1-5 points) at 30 months postoperatively. Despite postoperative improvement, 2.5 is considered a low activity level. In similar studies, Tegner scores have shown considerably larger improvement after surgeries.[10,29] However, while these previous studies compared the immediate preoperative Tegner score, we considered the preinjury activity level.

Similar to our results, several reviews in the literature have found good clinical and functional outcomes after FOCA transplantation in the knee.[7,9] In the present study, comparing the preoperative and postoperative clinical scores at 30 months, we also found a statistically significant improvement in the IKDC, Kujala, WOMET, and Tegner scores (P < .001).

Our study has some limitations. First, there was no comparison group and the sample size was small. Second, 36.8% of patients had an osteotomy in addition to a FOCA transplant. However, we do not consider this to be a limitation, as it allows a comparable alignment in all of the cases after surgery. Third, CT scans were evaluated by only 1 musculoskeletal radiologist. In a recent study, however, it was shown that the ACTOCA provides a moderate to substantial interobserver agreement and a moderate to almost perfect intraobserver agreement.[11] Fourth, even though we did not note any statistically significant differences between the ACTOCA and functional scales (IKDC, Kujala, WOMET, and Tegner) according to sex at birth, age, BMI, concomitant procedures, or osteochondral allograft type, the sample size is likely insufficiently powered to perform subgroup analysis. Fifth, as failure was defined as requiring reoperation, any patients with clinical failure who did not choose to have reoperation could have been missed. Sixth, patients whose BMI was >30 were excluded; thus, the study cannot comment on this group of patients. Seventh, the ACTOCA score has been shown to be reliable in previous studies, but it has not been fully validated. And eighth, CT scans expose patients to high doses of radiation. This limitation, however, was significantly reduced with an optimal collimation protocol.

CONCLUSION

The mean ACTOCA score on CT at 6 months showed a statistically significant correlation with the clinical results in the IKDC, Kujala, WOMET, and Tegner scores at 30 months, confirming the predictive value of the ACTOCA score for use in clinical practice.

ACKNOWLEDGMENT

This study was developed within the Surgery and Morphological Sciences Doctorate framework of the Universitat Autònoma de Barcelona.

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9.4. Material complementario 1

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Technical Note

Fresh Osteochondral Resurfacing of the Patellofemoral Joint

Pablo Eduardo Gelber, M.D., Ph.D., Eduard Ramírez-Bermejo, M.D., Maximiliano Ibañez, M.D., Alex Grau-Blanes, M.D., Oscar Fariñas, M.D., and Juan Carlos Monllau, M.D., Ph.D.

Abstract: Large osteochondral lesions of the knee in young patients continue to be a challenge for orthopaedic surgeons and the focus of continual research. This is particularly true if the injury is a consequence of a dysplastic trochlea and involves both articular surfaces of the biomechanically complex patellofemoral joint. To obtain a healthy and congruent patellofemoral joint, the use of a bipolar fresh osteochondral allograft transplantation of the patella and trochlea is one of the few options to biologically treat these injuries. This would achieve a replacement of the entire articular surface of the patellofemoral joint with a high number of viable chondrocytes and respect the unique structural characteristics of the cartilage. The aim of this study was to obtain symptomatic and functional improvements while delaying the timing of prosthetic surgery. We present a reproducible although demanding surgical technique to perform a bipolar fresh osteochondral allograft transplantation of the patella and trochlea.

Treatment of osteochondral knee injuries in young and active patients continues to be a challenge for the orthopaedic surgeon and the focus of continual research. Chondral lesions on the patella and trochlea are particularly difficult to manage because of their biomechanical characteristics, shape, and size.[1-4]

The goal of surgical treatment is to correct the biomechanical alterations and anatomic deformities and to treat the chondral lesions in accordance with their location, extension, and depth.[1,2] The treatment options for patellofemoral chondral lesions range from simple arthroscopic debridement and microfracture to more invasive procedures[5] such as osteochondral autograft transplantation,[6] osteochondral allograft (OCA) transplantation, autologous chondrocyte implantation,[7] matrix-induced autologous chondrocyte implantation,[8] and patellofemoral arthroplasty.[9]

When the defect is focal and localized in an area with good stability, thus with better integration, osteochondral grafts can be of a relatively small size. In the case of large or multifocal lesions, particularly with a highly dysplastic trochlea, full osteochondral resurfacing of the patellofemoral joint would not only approach the cartilage defect but also address the cause of the injury.[10]

Having viable chondrocytes guarantees the viability of the graft after transplantation.[11] Among all the different tissue bank storage techniques, fresh allografts are the only ones that provide for the long-term viability of the chondrocytes.[12] However, the allografts must be transplanted within 14 to 28 days after procurement for maximum chondrocyte viability.[13]

Most authors have reported osteochondral transplantation of the trochlea using large plugs. Even so, a dysplastic trochlea must be addressed differently. A trochleoplasty is performed for patellofemoral instability. However, it is contraindicated in the presence of large cartilage defects. Therefore, a combination of a large cartilage injury and a dysplastic trochlea can only

From the Department of Orthopaedic Surgery, Hospital de la Santa Creu i Sant Pau (P.E.G., E.R-B., A.G-B.), and ICATME—Hospital Universitari Dexeus (P.E.G., M.I., J.C.M.), Universitat Autònoma de Barcelona; and Barcelona Tissue Bank—Banc de Sang i Teixits (O.F.), Barcelona, Spain.

The authors report the following potential conflicts of interest or sources of funding: P.E.G. is a consultant for ConMed. J.C.M. receives grants/grants pending from Spanish Ministerio de Economia,Industria y Competitividad (National Programme for Research Aimed at the Challenges of Society), and payments for lectures from Smith & Nephew. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received June 1, 2019; accepted July 18, 2019.

Address correspondence to Pablo Eduardo Gelber, M.D., Ph.D., Department of Orthopaedic Surgery, Hospital de la Santa Creu i Sant Pau, Universitat Autònoma de Barcelona, C/Sant Quintí 89, 08041 Barcelona, Spain E-mail: personal@drgelber.com

2212-6287/19708

https://doi.org/10.1016/j.eats.2019.07.017

be biologically treated by a total resurfacing osteochondral transplantation.

The purpose of this technical note is to present a reproducible technique to address large osteochondral defects of the patellofemoral joint with a fresh OCA transplantation in the presence of a dysplastic trochlea. This technique aims to reduce the symptoms and to delay the need for a prosthetic implant in an otherwise healthy young patient.

Indication

Fresh osteochondral transplantation of both complete articular surfaces of the patella and trochlea is indicated in subjects younger than 50 years. They will have an extensive cartilage or osteochondral lesion in the patella and trochlea (kissing lesion) with Dejour type C or D trochlear dysplasia that cannot be treated with other, less aggressive techniques. Only patients with severe chronic pain that limits their daily activities and without reasonable improvement with conservative treatment are candidates for this option.

The main exclusion criteria are advanced osteoarthritis of other compartments of the knee and general conditions such as infections, tumors, locally aggressive rheumatic disease, diabetes, and vasculitis. Relative contraindications are a body mass index greater than 30 and age older than 50 years, although a clear age cutoff has not yet been defined. Smoking must be stopped 30 days prior to the surgical procedure and abstained from for at least 6 months after the operation.

Preoperative Study

All patients undergo the following radiologic evaluation:

- A long-standing radiograph, with lateral and axial views of both knees
- Magnetic resonance imaging to assess the chondral or subchondral status of the patellofemoral joint, as well as to look for any potential concomitant injuries
- A computed tomography scan to provide the most accurate information on bone loss and allow for measurement of the defect and disorders of the patellofemoral joint

Fresh Allograft Harvesting

The local authorized tissue bank supplied the allografts and performed the preoperative graft processing. The fresh OCA should be obtained from donors younger than 45 years. The limit for harvesting fresh grafts is within the first 12 hours of death. However, the period can be extended by an extra 12 hours if the donor's body is kept refrigerated at 4°C for the first 4 to 6 hours after death.

The harvested OCA is placed into transport medium (lactated Ringer solution) and preserved refrigerated between 4°C and 8°C. Once in the local authorized tissue bank, preparation and cleaning of the grafts are performed in a class A clean room. This consists of the evaluation of the cartilage surface, removal of the soft tissue and periosteum, shaping of the grafts, and high-pressure pulsatile lavage irrigation with sterile saline solution. The finals grafts are subjected to a decontamination process consisting of dry centrifugation, followed by centrifugation with sterile phosphate-buffered saline solution. Microbiological tests are then carried out on the grafts and on the last wash solution. Finally, the allografts are submerged in a preservative solution consisting of lactated Ringer solution and an antibiotic cocktail that includes amphotericin (125 µg/mL), tobramycin (3 mg/mL), vancomycin (50 mg/mL), and co-trimoxazole (160 mg/mL). After 5 days, new microbiological tests are performed on the allografts and on the preservative solution. From its arrival at the tissue bank until the time of implantation in the patient, the allograft is kept refrigerated between 4°C and 8°C.

Currently, the estimated risk of infectious disease transmission is 1 case in 420,000 donations for hepatitis C virus, 1 in 175,000 for human immunodeficiency virus, and 1 in 100,000 for hepatitis B virus.[14] Allograft sizing is performed in accordance with a preoperative computed tomography scan (both of the patient and of the graft) and anthropometric agreement between the donor and recipient.

Surgical Technique

Positioning

The patient is placed in the supine position with a support for the foot and a lateral support for the thigh to maintain the knee at around 45° of flexion. The contralateral limb is placed in full extension.

Donor Graft Preparation

The distal femoral and patellar grafts are first warmed up to room temperature and then inspected to ensure the absence of macroscopic damage. The articular side of the patella is resected using a standard cutting patellar guide such as that used in total knee arthroplasty (Fig 1). Only 6 to 8 mm of the subchondral bone tissue is resected with the guide. This step is of utmost importance because the thicker the bone tissue of the graft, the greater the possibility of an immunoreaction and bone resorption. In addition, osteochondral integration is only achieved because of the creeping substitution phenomenon in the first 8- to 12-mm layer of bone tissue.[15] It is crucial to minimize any potential immunologic reaction by removing all the remaining soft tissue and by washing with a 6-L high-pressure pulsatile lavage irrigation system inside a proper tube-like recipient. Lavage is performed for at least 15 minutes. A mark is made at the proximal and lateral

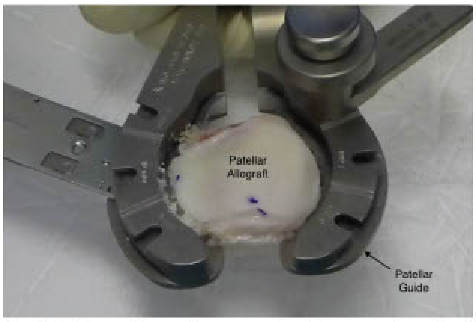

Fig 1. Right patellar graft preparation. The articular side of the patella is resected using a standard patellar guide such as that used in total knee arthroplasty.

part of the patellar graft with a sterile skin marker to aid in its proper placement later in the recipient area.

The articular side of the trochlear graft is outlined with the sterile skin marker. Three 3 Kirschner wires, on each lateral side of the trochlear joint surface oriented to 45° toward the center of the trochlea from anterior to posterior (Fig 2), serve as cutting guides. The articular side of the trochlea is then resected with a saw and chisels. It is also crucial to remove all the unnecessary soft tissue and perform high-pressure pulsatile lavage irrigation with sterile saline solution to decrease graft immunogenicity.

Arthroscopic Assessment

The tourniquet is now inflated. An arthroscopic evaluation of all compartments of the knee is first performed to reconfirm that bipolar fresh OCA transplantation of the patella and trochlea is suitable and that there are no excluding criteria that may have been overlooked preoperatively.

Any anatomic deformity or biomechanical alteration of the patellofemoral joint must be corrected to avoid further cartilage degradation of the graft. These corrections may be addressed either in a previous operation or, preferably, concomitantly with the procedure.

Receiving Area Preparation

A longitudinal midline incision is used, and either a standard medial parapatellar approach or a subvastus approach can be performed. Dissection of soft tissues is performed to allow for patellar eversion, with care taken not to excessively remove tissue from the Hoffa fat pad because it is a source of vascularization for the knee extensor apparatus.

The knee is fully extended and the patella is kept everted by twisting it with 2 atraumatic clamps at the level of the insertions of the patellar and quadriceps tendons. Careful measurement of the patellar thickness is performed with a caliper. Superior-inferior and medial-lateral measures are also assessed to check that they match the donor's size and to avoid any instability or pain due to mismatching or overhang. Circumferential denervation on the medial, lateral, and proximal aspects of the patella is performed to decrease post-operative anterior knee pain.

At this point, using the same cutting guide and saws used to prepare the patellar allograft, the articular side of the patella is resected (Fig 3). It is crucial that the resected thickness is never less than that of the allograft; otherwise, an overstuffed patella might increase the patellofemoral joint pressure.

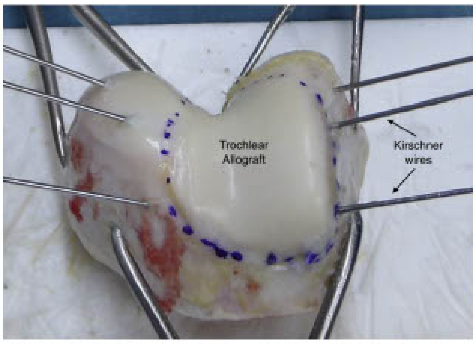

Fig 2. Right trochlear graft preparation. The articular side of the trochlea is outlined with a sterile skin marker. The osteotomy will be performed guided by 3 K-wires placed on each side of the joint surface and oriented to 45° toward the center of the trochlea from anterior to posterior.

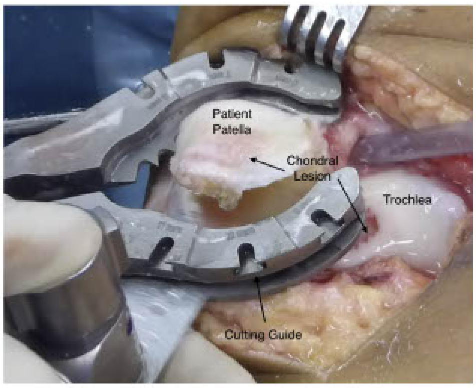

Fig 3. Medial view of right knee. The patellar osteotomy is performed using a standard cutting guide. Care is also taken to position the cutting guide to eliminate only 6 to 8 mm of the subchondral bone tissue.

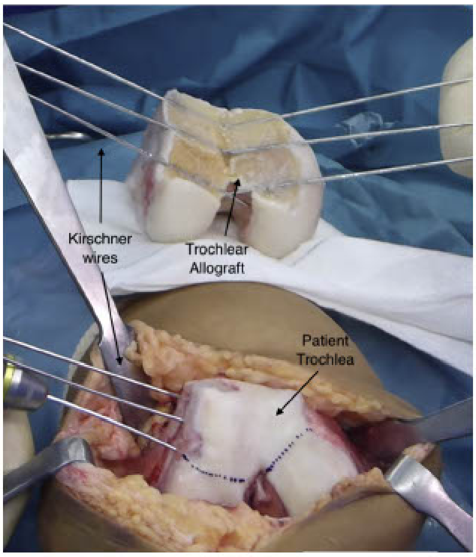

Fig 4. Frontal view of right knee. The knee is flexed at 45° and the patella is everted, exposing the trochlea. The shape and size of the allograft's trochlea are reproduced in the patient's trochlea using a sterile skin marker.

Subsequently, the knee is flexed at 45° and the patella is everted, exposing the trochlea. The shape and size of the allograft's trochlea are reproduced in the patient's trochlea using a sterile skin marker (Fig 4). Preparation of the trochlea's resection is performed by the same technique used to prepare the trochlear allograft. Meticulous trimming and smoothing of both the recipient and donor subchondral bones must be performed to ensure a perfect match and full bone contact.

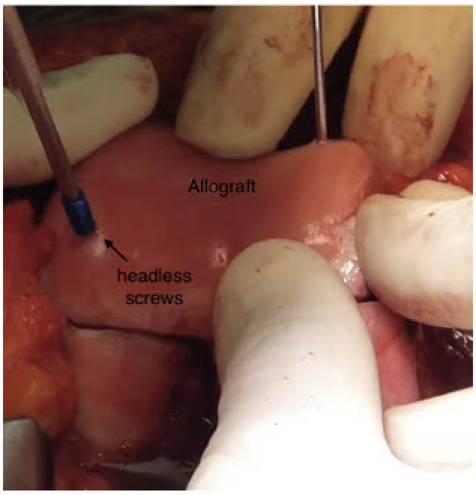

Fig 5. Frontal view of right knee. Trochlear allograft fixation is accomplished with two 3.5-mm headless titanium compression screws.

Graft Placement

When the best position for the trochlear transplant is determined, fixation is accomplished with two 3.5-mm headless titanium compression screws with various thread pitches (Acutrak Standard; Acumed, Hillsboro, OR) to provide strong fixation. This is complemented with three or four 2-mm-diameter by 20- to 25-mm-long absorbable pins (SmartNail; ConMed, Largo, FL) (Fig 5).

Once the best position for the patellar transplant is visually determined, temporarily fixing it with two 1.8-mm K-wires positioned on the dorsal aspect of the patella (anterior to posterior) is recommended while care is taken to avoid cartilage tissue piercing (Fig 6). After that, final fixation of the graft can be carried out. Absorbable pins, 1.5 mm in diameter by 16 to 20 mm long (SmartNail), positioned in an anterograde manner through the cartilage surface (from posterior to anterior), are recommended to minimize chondral damage and allow for postoperative magnetic resonance imaging evaluation. We suggest using 4 absorbable pins at the level of each corner of the patella to give proper stability without damaging the cartilage surface implicated in gliding over the trochlear groove. Fixation from the dorsal aspect of the patella with small metal screws can also be performed as an alternative. Once the patellar graft is fixed, the K-wires are removed (Fig 7).

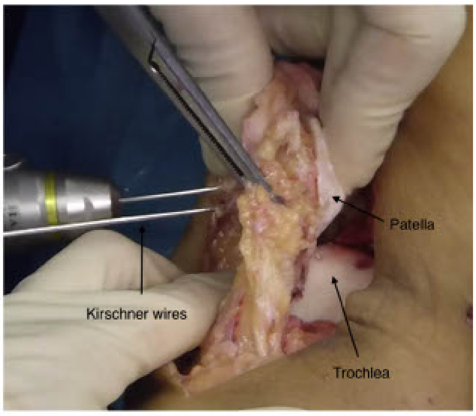

Fig 6. Temporary fixation of the patellar graft is accomplished with two 1.8-mm K-wires positioned on the dorsal aspect of the patella (anterior to posterior) while care is taken to avoid cartilage tissue piercing.

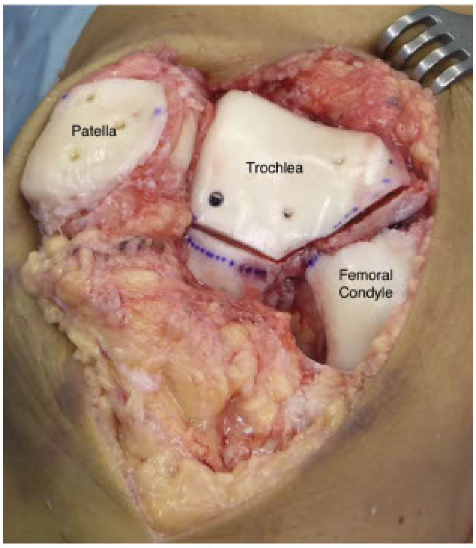

Fig 7. Frontal view of right knee. Final disposition of patellar and trochlear grafts.

Intra-articular drainage is left in place, and the incision is closed. Special attention should be paid to respecting the synovium and the capsular layer. If needed, the vastus medialis muscle may be partially advanced over the patella to decrease lateral facet pressure. The knee is finally immobilized in a brace locked in full extension.

A step-by-step description of the surgical technique is summarized in Table 1. Table 2 provides pearls and pitfalls of performing this procedure. Video 1 shows the whole technique in detail.

Rehabilitation Protocol

Controlled continuous passive motion is started within the first hours after the intervention and is used for more than 6 hours per day during the first 6 weeks. Full range of motion is allowed from the beginning. Isometric strengthening of the quadriceps and hamstring muscles is also recommended starting from the first days after graft implantation. Full weight bearing is allowed but only with a brace locked in full extension during the first 6 weeks. At that point, rehabilitation focuses on restoring full range of motion and strengthening.

Pivoting and strenuous activities are not recommended. It is imperative that the patient be made aware of such limitations before OCA transplantation of the patella and trochlea is considered.

Discussion

The treatment of large, symptomatic chondral defects of dysplastic patellofemoral joints in young patients with full bipolar fresh OCA transplantation of the patella and trochlea provides a high number of vital chondrocytes within the extracellular matrix of the cartilage while restoring the normal patellofemoral shape and biomechanics. It permits achieving symptomatic and functional improvement with the possibility of delaying or eliminating the need for prosthetic surgery.

Table 1. Step-by Step Fresh Osteochondral Allograft Resurfacing of Patella and Trochlea

Step	Description
1	The patient is positioned supine on the operating table, with 45° of knee flexion, using a distal foot support and a lateral support for the thigh. An arthroscopic evaluation of all compartments of the knee is first performed to reconfirm that bipolar fresh osteochondral allograft transplantation of the patella and trochlea is suitable.
2	A standard medial parapatellar approach or a subvastus approach can be used.
3	The knee is extended and the patella is kept everted by twisting it with 2 atraumatic clamps at the level of the insertions of the quadriceps and patellar tendons.
4	Careful measurement of the patellar thickness is performed with a caliper to maintain the offset of the patellofemoral joint.
5	An osteotomy is performed using a standard patellar guide such as that used in total knee arthroplasty. Care is also taken to position the cutting guide to eliminate only 6 to 8 mm of the subchondral bone tissue.
6	Circumferential denervation of the patella is finally performed to decrease postoperative anterior knee pain.
7	The graft is cut to a thickness that is the same as or slightly less than that of the tissue removed from the patient's patella to maintain the patellofemoral offset. With a sterile skin marker, short lines are drawn on the proximal and lateral part of the graft to aid in its proper placement.
8	Once the most appropriate position for the transplant is visually determined, fixation is achieved with two to three 1.8-mm K-wires positioned on the dorsal aspect of the patella (anterior to posterior) while care is taken to avoid cartilage tissue piercing
9	The use of 4 absorbable pins at the level of each corner of the patella is suggested to give absolute stability without damaging the cartilage surface implicated in gliding over the trochlear groove. Once the graft is fixed, the K-wires are removed and patellofemoral tracking, as well as implant stability, is tested again.
10	The articular side of the trochlear allograft is outlined with a sterile skin marker. The preparation of the trochlea's allograft is performed by fixing 3 K-wires on each lateral side of the joint surface oriented 45° toward the center of the trochlea from anterior to posterior.
11	The articular side of the trochlea is resected with a saw and chisels, following the guide of the K-wires. The preparation of the trochlea's receiving area resection is performed using the same technique used to prepare the trochlear allograft.
12	The approach is closed with attention paid to respecting the synovium and the capsular layer.

Table 2. Pearls, Pitfalls, and Risks

- Pearls
  - Obtaining osteochondral tissue from donors aged >45 yr is not recommended.
  - Allograft sizing is performed in accordance with a preoperative CT scan (both of the patient and of the graft) and anthropometric agreement between the donor and recipient.
  - The tourniquet should only be inflated once the graft preparation has been finished.
  - Care should be taken to position the cutting guide to eliminate only 6-8 mm of the subchondral bone tissue. This step is of utmost importance because the thicker the bone tissue, the greater the possibility of an immunoreaction.
  - Correction of any anatomic deformity or biomechanical alteration of the patellofemoral joint is mandatory to avoid further cartilage degradation of the graft. Any preoperative TT-TG distance can be used as a guide, but one should consider substantial changes after the new trochlea has been transplanted.
  - To help diminish some degree of immunoreaction, the surgeon should carefully remove remnant soft tissue, use a high-pressure pulsatile irrigation system to eliminate any trace of blood, and transplant a graft with the least amount of bone possible.
  - Suction drainage is used to minimize the risk of hematoma.
  - Circumferential denervation of the patella further helps in preventing residual anterior knee pain.
- Pitfalls and risks
  - There are no cutting guides for the trochlea. This is a demanding technique.
  - There is a risk of distal osteochondral fracture while preparing the trochlear recipient area near the intercondylar notch.
  - Perfect matching can take several steps by trimming and smoothing the subchondral bone.
  - Should the graft, by any chance, fall on the floor, we recommend a new washing process with the high-pressure pulsatile irrigation system for no less than 20 min, with subsequent immersion in vancomycin solution, 1 g/100 mL, for 10 min.
  - Athletic activity should be limited to light sports. Pivoting and strenuous activities are not recommended.
  - Potentially, the procedure can lead to some degree of immunoreaction.

CT, computed tomography; TT-TG, tibial tuberosity–trochlear groove.

Preventing the migration of multipotent cells from the subchondral bone of the host is achieved by the lack of chondral tissue vascularization and the hard consistency of its matrix. Thus, a graft with the best chondrocyte viability is the best option.[16] Fresh-frozen and cryopreservation storage techniques have the advantage of being widely available and allowing for the preservation of the graft for several months. However, it has been shown that these techniques affect the biomechanics and viability of the chondral layer of the graft in an irreversible manner.[17]

Conversely, fresh OCAs are biomechanically and histologically comparable with autografts and retain viable chondrocytes.[18] Thus, fresh allografts are preferred. The downside of fresh allografts is the logistic limitation because the storage time is limited to a few weeks from harvesting.[13,19]

A list including the main advantages and disadvantages of the described technique is shown in Table 3.

Some tricks and pearls that help to diminish the degree of immunoreaction in the transplant are (1) the use of high-pressure pulsatile lavage irrigation with sterile saline solution to help to eliminate any trace of blood, (2) careful removal of remnant soft tissue, and (3) transplanting a graft with a bone layer no thicker than 6 to 10 mm. In addition, osteochondral integration is only achieved owing to the creeping substitution phenomenon in this thin layer of bone. The bone will be subjected to a necrosis process with subsequent revascularization during the healing progress.[15]

Correction of any anatomic deformity or biomechanical alteration of the patellofemoral joint is mandatory to avoid further cartilage degradation of the graft. Special attention must be paid to the tibial tuberosity–trochlear groove distance because the transplanted trochlea will modify the preoperative value. Subsequently, a proper intraoperative assessment of patellofemoral tracking must be performed. Any obvious maltracking with a high Q angle can be corrected with tibial tuberosity medialization.

Studies on bipolar OCA transplantation of the patella and trochlea are few and have been limited to fewer than 20 patients. In addition, most of them have reported surgical techniques using bone plugs instead of the described resurfacing technique. Risk of failure is increased because of the size of the joint. However, patients with surviving allografts showed significant

Table 3. Advantages and Limitations

- Advantages
  - The treatment is biological.
  - The procedure is indicated in young subjects with extensive cartilage or osteochondral lesions in the patella and trochlea (kissing lesions) with Dejour type C or D trochlear dysplasia that cannot be treated with other, less aggressive techniques.
  - Good results are achieved when performed with a surgical technique that follows a few standard steps to maintain the long-term viability of the graft.
  - Fresh osteochondral allografts are biomechanically and histologically comparable with autografts and retain viable chondrocytes.
  - Implantation of a patellofemoral arthroplasty is prevented.
- Limitations
  - The use of fresh allografts carries considerable logistic limitations, and this material is not easily available worldwide.
  - The main exclusion criteria are advanced osteoarthritis of other compartments of the knee and general conditions such as infections, tumors, locally aggressive rheumatic disease, diabetes, and vasculitis.
  - Relative contraindications are BMI >30 and age >50 yr. Smoking must be stopped 30 d before surgery and abstained from for at least 6 mo after the operation.
  - Only patients who have severe chronic pain that limits their daily activities and see no improvement with rehabilitative treatment are candidates for this treatment.
  - The technique is not intended for patients seeking to return to demanding pivoting activities.

BMI, body mass index.

improvements in functional outcomes, pain relief, and range of motion.[20-25]

In conclusion, the current technique is a valid option for severe anterior knee pain due to large cartilage defects in both the patella and the dysplastic trochlea in young patients. Although the technique is relatively demanding, it can be performed perfectly well by following the described steps. This would allow for delaying or even avoiding the need for an onlay-design patellofemoral arthroplasty.

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9.5. Material complementario 2

ELSEVIER

Operative Techniques in
Sports Medicine

Salvage Procedures: Last Chance Before Arthroplasty

Pablo E. Gelber,*,† and Eduard Ramírez-Bermejo*

Lower-extremity misalignment hastens the development of chondral and osteochondral knee lesions. In active young patients with bipolar osteochondral lesions, the bipolar fresh osteochondral allograft procedure is a useful salvage treatment option. Although the surgical technique is technically demanding and high reoperation and failure rates are expected, patients with surviving allografts show a significant clinical improvement. Careful patient selection is key to delivering desired results. In this review, we present and discuss recent surgical techniques and developments in bipolar fresh osteochondral allograft procedures.
Oper Tech Sports Med 30:150937 © 2022 Elsevier Inc. All rights reserved.

KEYWORDS osteochondral allograft, cartilage repair, fresh OCA, transplantation

Introduction

Lower-extremity malalignment alters load distribution across the knee, facilitating the development of unicompartmental chondral and osteochondral knee lesions.[1] Such lesions in young and active individuals cause major problems and the effect on daily life can be more devastating than in patients with anterior cruciate ligament-deficient knee.[2]

In cases of osteochondral knee injuries in the young, it is crucial to address any concomitant alteration of the knee that affects the cartilage. Proximal tibial, distal femoral and/or tibial tubercle osteotomies should be considered to address malalignment, ligament repair or reconstruction in cases of instability, and meniscal transplant in cases of significant meniscal tissue deficiency.[3] In young patients with unicompartmental knee injuries secondary to lower-extremity misalignment, osteotomy to unload the articular cartilage should be considered in order to decrease symptoms, improve subchondral healing, and optimize cartilage preservation.[4]

Treating osteochondral knee injuries in active young patients is a complex challenge for which extensive research remains to be done. If untreated, cartilage defects tend to progress and evolve to osteoarthritis.[5] The choice of surgical treatment depends on location, depth and size of the lesion. In cases of osteochondral lesions of less than 2cm^2, osteochondral autograft transfer from a non-weightbearing surface is sufficient in most cases. However, for lesions greater than 2cm^2, an external source is required. In this line, fresh osteochondral allograft (FOCA) transplantation is a valid option to consider. This approach involves the transfer of size-matched allograft viable hyaline cartilage and subchondral bone into these large and deep osteochondral knee lesions in a single procedure. The goal is to relieve symptoms and improve function, delaying or eliminating the need for future arthroplasty.[6,7] Most reports of FOCA procedures involve unipolar graft transplantation and results have shown that show this treatment for large osteochondral knee defects is safe and effective in long-term follow-up.[8-10]

In cases of bipolar osteochondral lesions, defined as lesions involving 2 opposing articulating surfaces (proximal tibial and femoral lesion or patella and trochlea lesion), treatment is a complex challenge. In older and non-active patients, unicompartmental knee arthroplasty (UKA) or total knee arthroplasty (TKA) is the gold standard. However, these 2 approaches are a poor option in young active patients due to a high risk of early revision surgery.[11] To delay arthroplasties for a later stage in these cases, a bipolar FOCA procedure may be attempted, but outcomes have been less favorable

*Department of Orthopaedic Surgery, Hospital de la Santa Creu i Sant Pau, Universitat Autonoma de Barcelona, Barcelona, Spain.
†ICATME- Hospital Universitari Dexeus, Universitat Autonoma de Barcelona, Barcelona, Spain.
The authors report no conflicts of interest or sources of funding with regard to the present study.
Address reprint requests to Pablo E. Gelber, MD, PhD, Department of Orthopaedic Surgery, Hospital de la Santa Creu i Sant Pau, Universitat Autonoma de Barcelona, C/Sant Quinti 89, 08041 Barcelona, Catalunya, Spain. E-mail: personal@drgelber.com

https://doi.org/10.1016/j.otsm.2022.150937

than with unipolar FOCA.[12] Notwithstanding, clinically relevant improvements in mid-term patient-reported outcomes have also been reported in cases of bipolar FOCA.[13] In recent times, the use of FOCA for knee salvage procedures has increased thanks to improvements in allograft harvesting, processing, storage, and surgical techniques.[14]

Indications

A salvage procedure using bipolar FOCA transplantation is indicated in patients younger than 50 years with osteochondral defects larger than 2cm^2 and involving 2 opposing articulating surfaces.

Exclusion criteria are inflammatory arthritis, large degenerative lesions comprising all 3 compartments, BMI >30 kg/m2, diabetes, systemic inflammatory diseases, infection, history of osteomyelitis in the graft recipient area, and active neoplasia.[15]

Surgical Techniques

Patients are placed in the supine position on a radiolucent table. In all cases, an arthroscopic evaluation of all knee compartments must first be performed to address any concurrent intra-articular pathology and to confirm the size and depth of the lesion. Any anatomic or biomechanical alteration of the tibio-femoral joint and/or patella-femoral joint that affects the cartilage should be addressed to avoid cartilage degradation of the graft.

Fresh osteochondral grafts are obtained after screening and processing in accordance with the local authorized tissue bank.

Osteochondral Resurfacing of the Patellofemoral Joint

Two scenarios are possible.

Non-Dysplastic Trochlea

A bone-dowel technique is preferred. The patellar graft and the trochlear graft are measured and the correct diameter is selected (Fig. 1). The JRF-Ortho instrument set (CO, USA) allows to select diameters between 12 and 26mm. The bone layer included in the graft should not exceed 8-9mm to allow for creeping substitution to occur. Optimal orientation of the trochlear graft is sometime demanding, and a perfect match between donor and patient is mandatory (Fig. 2).

Trochlea Dysplasia

A shell technique is the treatment of choice.[16] A patellar graft is prepared using a standard cutting patellar guide such as that used in TKA. The articular side of the patella is resected with only 6-8 mm of the subchondral bone tissue (Fig. 3). The patellar allograft is marked at the proximal and lateral part of the graft to ensure correct positioning. The articular side of the trochlear graft is prepared using 6 Kirschner wires (3 medial and 3 lateral) oriented 45° towards the center of the trochlea from anterior to posterior and serving as cutting guides to create a V-shaped resection (Fig. 4). After a medial parapatellar arthrotomy is performed, full extension is maintained and the patella is everted. Two atraumatic clamps are placed. Patellar thickness is then measured with a calliper. Medial-lateral and superior-inferior measures are performed to check matching with the graft, and to avoid pain or instability due to mismatching or overhang. To decrease postoperative anterior knee pain, the patella is denervated. The articular side of the patella is then resected using the same standard cutting patellar guide. At this point, the knee is flexed at 45°, exposing the trochlea and maintaining patellar

Figure 1 A variety of graft diameters can be selected iikto perform bone-dowel technique. In this case, a 26 mm bone-dowel of the trochlea was chosen (Color version of figure is available online.)

Anexo

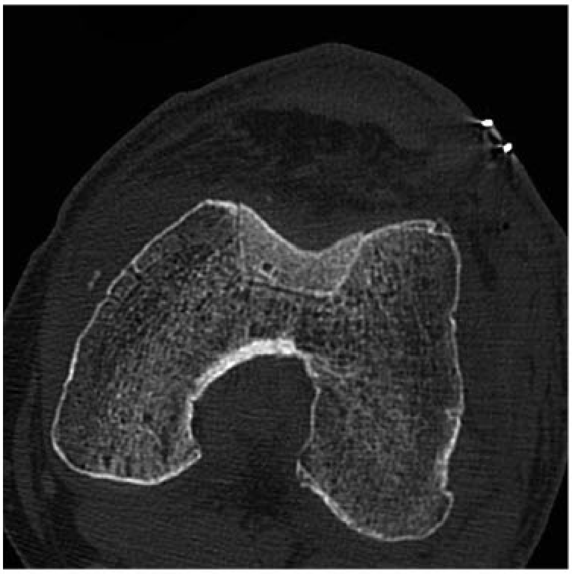

Figure 2 Postoperative CT scan of a bone-dowel FOCA of the trochlea. Note the excellent congruency between the graft and the surrounding host surface.

eversion. The shape and size of the allograft's trochlea is reproduced in the patient's trochlea using a sterile skin marker. The articular trochlea is then resected using the same technique as that used to prepare the trochlear graft (Fig. 5), ensuring a perfect match and full bone contact.

When the best position for the patellar transplant is determined, the graft is temporarily fixed using 2 1.8- mm K-wires positioned on the dorsal aspect of the patella (anterior to posterior) to avoid cartilage damage. Final fixation is then conducted using 4 absorbable pins at the level of each corner,

Figure 3 The articular side of the patellar graft is resected with the help of a standard cutting patellar guide such as those used in TKA (Color version of figure is available online.)

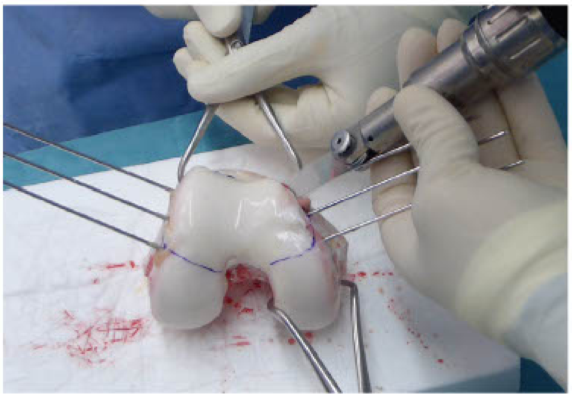

Figure 4 In case of trochlear dysplasia, the trochlear graft is fully transplanted. The cut can be performed with the help of 4 to 6 k-wires placed at 45° working as cutting guides (Color version of figure is available online.)

1.5 mm in diameter by 16-20 mm long (SmartNail), positioned from posterior to anterior through the cartilage. At the end of fixation, K-wires are removed. Trochlear graft fixation is performed with two 3.5-mm headless titanium compression screws with various thread pitches (Acutrak Standard; Acumed, Hillsboro, OR) and complemented with four 2-mm-diameter by 20- to 25-mm-long absorbable pins (SmartNail; ConMed, Largo, FL) (Fig. 6).

Osteochondral Resurfacing of the Tibiofemoral Lesions

In case of a esion in the femoral condyle and tibial plateau, fresh osteochondral tibial plateau and meniscus (FOTAM) transplantation associated with fresh osteochondral femoral condyle is indicated.[17]

If a realignment osteotomy is needed, this is usually the first step of the whole procedure. In most cases, at least part of the deformity is intraarticular. This must be taken into consideration when the femoral or tibial osteotomy is planned. The FOCA procedure itself can correct some degree of the deformation. To avoid overcorrection, some flexibility during the surgery should be expected to fine tune gap size. In most cases, the valgus deviation is corrected on the femoral side, and the varus is corrected on the tibial side. The goal is to obtain 2°-3° of overcorrection.

Regarding the FOCA procedure itself, a longitudinal anterolateral or anteromedial skin incision and arthrotomy is performed, depending on the location of the lesion. When the posterior aspect of the lateral femoral condyle is involved, a tibial tuberosity osteotomy is needed to ensure proper access (Fig. 7). A vertical cut is performed in the center of the

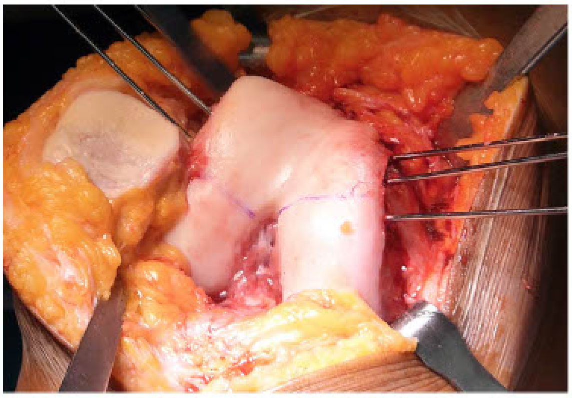

Figure 5 The patient's injured dysplastic trochlea is resected in a V-shape with the help of several k-wires placed at 45° (Color version of figure is available online.)

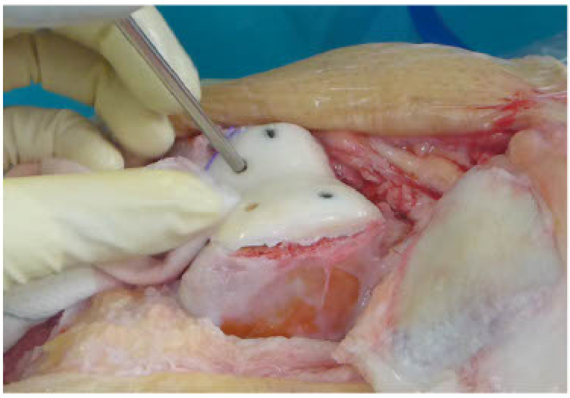

Figure 6 The transplanted trochlea in the resurfacing technique must be congruent with the surrounding articular surface (Color version of figure is available online.)

corresponding tibial eminence, taking care to avoid damaging the anterior cruciate ligament. The horizontal osteotomy is then performed using a free-hand technique, resecting bone and the remnant meniscus. It is of utmost importance to resect only a minimum amount of bone to obtain a flat surface with healthy bleeding cancellous bone. The articular cartilage lesion on the femoral condyle is then identified. If it can be treated with a single dowel graft, a bone-dowel technique can be performed using the JRF-Ortho instrument set (CO, USA). If the femur is not amenable to a single circular dowel graft, either 2 dowel grafts using the same instrument set (Fig. 8) or a single graft that covers all the severely affected articular cartilage (BioUni, Arthrex, USA) (Fig. 9) are used.

The articular cartilage defect is sized and reamed to a depth of approximately 8-10 mm.

Graft preparation of the tibial plateau is performed according to the measures of the recipient site to properly fit into the created defect (Fig. 10). On the lateral side, the meniscus does not require repair to the capsule. On the medial side, the posterior horn is secured to the capsule with sutures and tightened with sliding knots.

High-pressure pulsatile lavage is then performed. The tibial graft is positioned in the prepared zone. At this point, a fluoroscopic evaluation is performed. Tibial osteochondral fixation can be achieved with 2 headless titanium compression screws with a variable threaded pitch, (Acutrak Standard; Acumed, Hillsboro, OR). Meniscal sutures are tightened to the capsule with simple stitches, after which the femoral condyle graft is introduced and kept in place with a press fit fixation.

Figure 7 Tibial tuberosity osteotomy to ensure proper access to the posterior aspect of the lateral femoral condyle (Color version of figure is available online.)

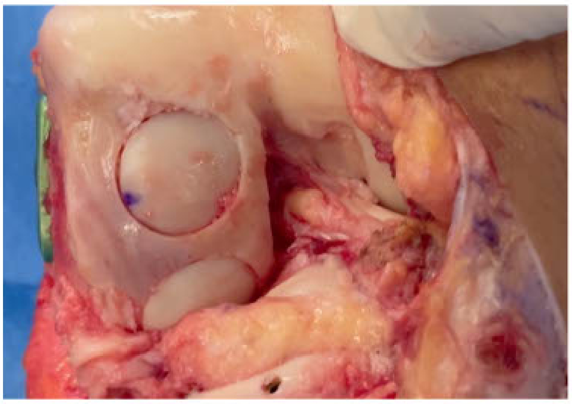

Figure 8 Large femoral condyle defects can be treated with 2 or 3 independent bone-dowels (Color version of figure is available online.)

Outcomes

Literature reporting outcomes after salvage procedures is limited. Gowd et al.[18] recently published a systematic review including patients with bipolar chondral lesions of the patella-femoral joint treated with cartilage restoration procedures. They analyzed ten studies, including 4 articles about OCA. In most cases, concomitant procedures were performed, with tibial tubercle osteotomy and lateral retinacular release being the most common. Results were heterogeneous, with failures in 0%-50% of cases, while conversion to arthroplasty was reported in 9%-50% of cases.

Gowd et al.[19] also performed a systematic review concerning tibiofemoral bipolar lesions. They analyzed 4 articles that included a total of 152 knees. Fifty-eight knees were treated with OCA transplantation, another 58 knees were treated with ACI, 20 were treated with femoral OCA and tibial debridement, and the remaining 16 cases were treated with femoral OCA and tibial microfractures. Failure rates ranged from 0% to 44%. However, midterm survivorship rates were between 55% and 100%, delaying the need for a secondary arthroplasty.

With regard to large bipolar OCA transplantation in combination with realignment osteotomies, Zitsch et al.[20] recently published a prospective study to compare outcomes among patients with concurrent or staged realignment osteotomy. Twenty-three patients were included and no significant differences were observed regarding complication rates between concurrent and staged osteotomies. However, PROMs were consistently higher in cases of concurrent osteotomies.

Figure 9 Ideally, long femoral condyle injuries can be treated with the BioUni system by Arthrex (Fl, USA). See the obtained smooth surface in the postoperative CT-scan (Color version of figure is available online.)

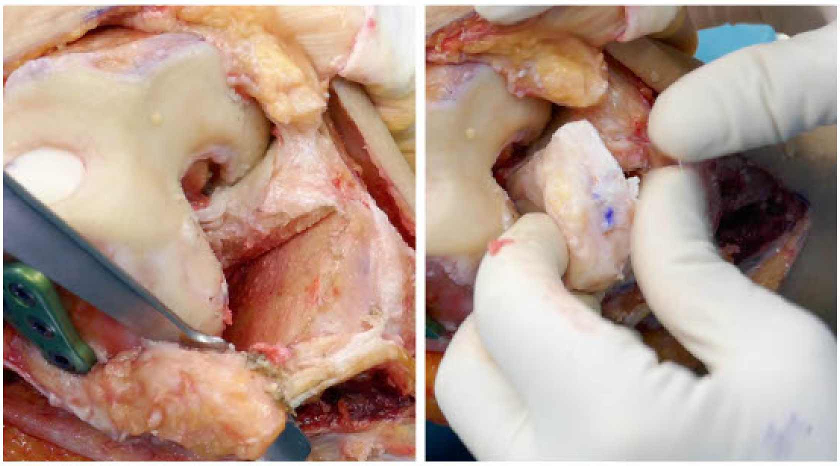

Figure 10 Transplantation of the tibial plateau can be achieved after proper preparation of the recipient site socket (left picture). The prepared allograft is then introduced (right picture) and fixed (Color version of figure is available online.)

Cook et al.[21] analyzed 37 athletes who underwent large single-surface, bipolar or multi-surface OCA transplantation. Sixty-eight percent returned to sport and 68% of these patients performed at the same or higher level of sport as during their highest preinjury level.

Melugin et al.[13] performed a systematic review that included patients who underwent surgery for bipolar cartilage lesions of the knee. The 14 studies involved included 156 OCA, 138 autologous chondrocyte implantation (ACI) and 7 osteochondral autograft transfer system (OATS). Post-operative improvements in patient-reported outcomes were noted. Fresh OCA survivorship ranged from 40% to 100%, with a low rate of major complications. Concomitant procedures were frequently performed with OCA transplantation. Lesions involving tibiofemoral compartment were associated with higher failure rates. However, the measures were highly heterogeneous.

Meric et al.[22] published a case series of 48 OCA patients who underwent implants for bipolar knee lesions. There were 34 tibiofemoral lesions and 14 patellofemoral lesions. Survivorship of the bipolar OCA was 64.1% at 5 years and the clinical improvement was statistically significant.

In a systematic review, Familiari et al.[8] reported clinical outcomes and failure rates after all types of OCA transplantation. The review included 19 studies with a total of 1036 patients. An overall 10-year survival rate of 78.8% was observed. The postoperative improvement was significant. Revision cases, patellar lesions, and bipolar lesions showed worse results, with a reoperation rate of 30.2% and a failure rate of 18.2%. Stannard et al.[23] also found that failures were significantly higher in bipolar cases.

Conclusion

Osteochondral allograft transplantation is a useful salvage treatment option for bipolar osteochondral knee lesions. Although the surgical technique is technically demanding and high reoperation and failure rates are to be expected, patients with surviving allografts show a significant clinical improvement. Careful patient selection is key to improving results.

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