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CASE REPORT

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Treatment of Freiberg's disease using a reverse pedicled metatarsal bone flap: Case report

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Abstract

Despite no surgical procedures receiving unanimous support for treating Freiberg's disease, several surgical treatment options have been described. For the past few years, bone flaps have been shown in children to present promising regenerative properties. We report a novel technique using a reverse pedicled metatarsal bone flap from the first metatarsal to treat one case of Freiberg's disease in a 13-year-old female. The patient presented 100% involvement of the second metatarsal head, with a 6 × 2 mm defect, unresponsive to 16 months of conservative measures. A 7 mm × 3 mm pedicled metatarsal bone flap (PMBF) was obtained from the lateral proximal first metatarsal metaphysis, mobilized and pedicled distally. It was inserted at the dorsum of the distal metaphysis of the second metacarpal towards the center of the metatarsal head, reaching the subchondral bone. Initial favorable clinical and radiological results were maintained for over 36 months during the last follow-up. Based on the powerful vasculogenic and osteogenic properties of bone flaps, this novel technique could effectively induce bone revascularization and prevent further collapse of the metatarsal's head.

1 | INTRODUCTION

Freiberg's disease (Freiberg, 1914) is the fourth most common form of primary osteochondrosis, affecting the metatarsal head (MTH), most commonly the second, with significant predilection to the adolescent athletic female population (Carmont et al., 2009; Gillespie, 2010). Several surgical treatment options have been described to treat Freiberg's disease, with no evidence of any of them being superior to the others (Schade, 2015; Seybold & Zide, 2018). Recently, vascularized bone grafts and flaps have gained particular attention in reconstructive surgery because of how effective they promote healing when used to treat complex bone nonunion, avascular necrosis and other challenging scenarios in pediatric patients, owing to their high angiogenic and osteogenic potentials (Fontecha et al., 2016; Payatakes & Sotereanos, 2009; Urbaniak et al., 1995). We report a novel technique for metatarsal head revascularization using a retrograde bone flap harvested from the first metatarsal bone based on the first dorsal metatarsal vessels. We successfully used this technique in one case refractory to conservative measures.

2 | CASE REPORT

A 13-year-old female semi-professional contemporary dancer presented to our clinic with right forefoot pain. On physical examination, passive metatarsophalangeal joint extension and flexion were 20 degrees each. Radiographs showed a central subchondral cyst extending 2/3 of the transversal width of the MTH and a mild flattening of the coronal curvature (Figure 1a). Oblique radiograph view showed MTH flattening (Figure 1b). A Smillie stage III Freiberg's

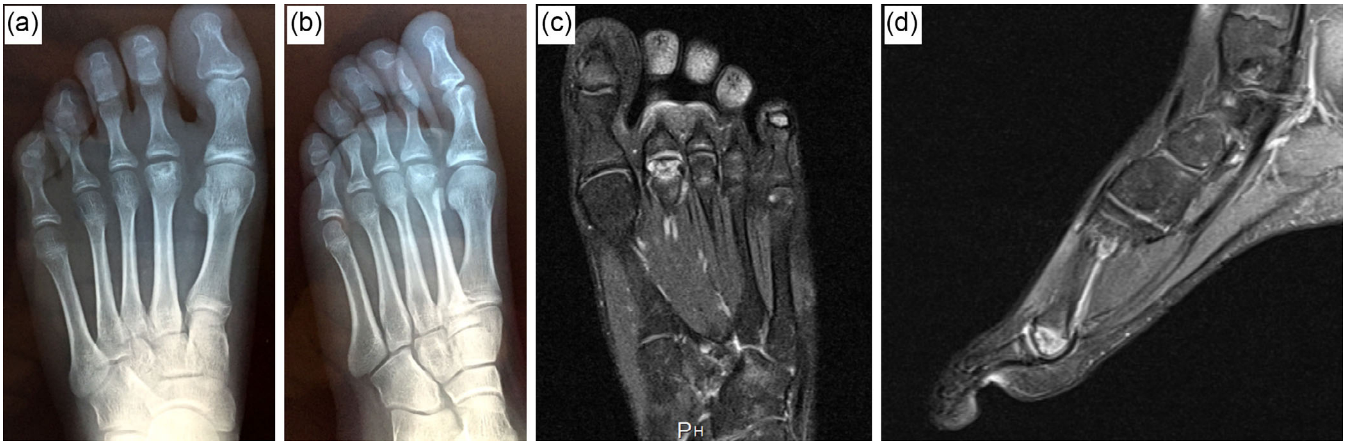

FIGURE 1 (a) A-P X-ray showing a central subchondral cyst at the metatarsal head (MTH) and a mild flattening of the coronal curvature. (b) Oblique X-ray showing MTH flattening. (c, d) T2-weighted-magnetic resonance shows osteonecrosis with abnormal intensity involving 100% of the axial area of the MTH.

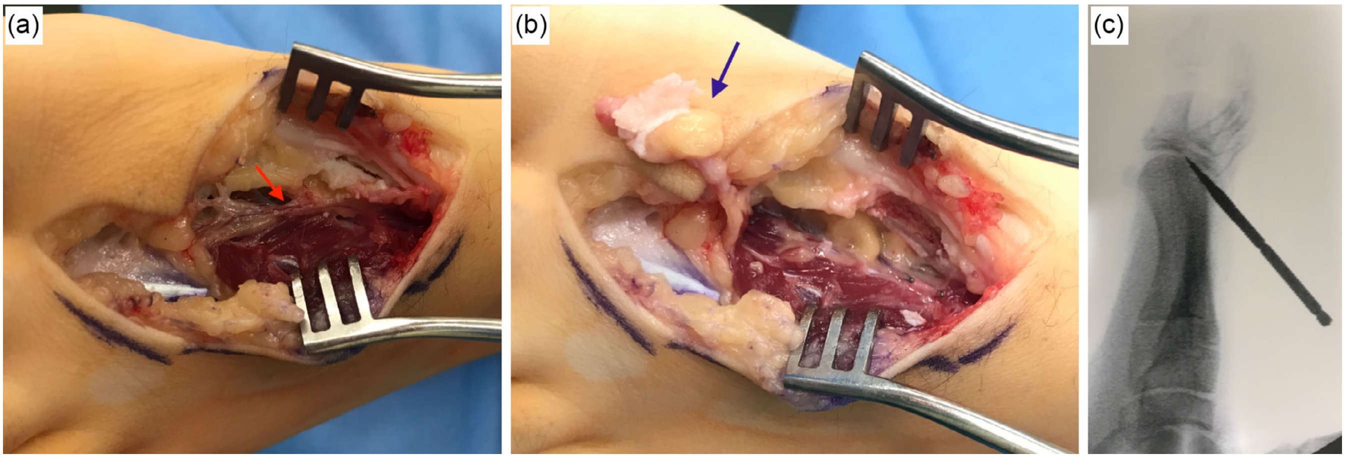

FIGURE 2 (a) Red arrow: First dorsal metatarsal vessels are identified running adjacent to the first metatarsal and superficial to the first dorsal interosseous muscle. (b) Blue arrow: a 7 mm × 3 mm pedicled metatarsal bone flap was obtained from the lateral proximal first metatarsal metaphysis with the aid of a chisel. (c) X-ray of the bone tunnel being made with a 3 mm cannulated drill entering at the dorsum of the distal metaphysis of the second metacarpal.

disease was diagnosed. MRI showed osteonecrosis with abnormal intensity involving 100% of the axial area of the metatarsal head (Figure 1c,d). Unresponsive to 16 months of conservative measures, including dancing cease, plantar foot orthosis and physical therapy, so surgical treatment was indicated.

Under general anesthesia and tourniquet without exsanguination, a dorsal zig-zag incision over the first intermetacarpal space was performed. The first dorsal metatarsal vessels (FDMV), of small caliber, were identified running adjacent to the first metatarsal and superficial to the first dorsal interosseous muscle (Figure 2a). FDMV provided several periosteal branches to the proximal first metatarsal metaphysis. A 7 mm × 3 mm pedicled metatarsal bone flap (PMBF) was obtained from the lateral proximal first metatarsal metaphysis with the aid of a chisel (Figure 2b). The PMBF was designed slightly larger than the bone defect (6 mm × 3 mm).

The FDMV was ligated proximally at its origin from the dorsalis pedis vessels, and the flap was mobilized and pedicled distally. Flap bleeding was verified after tourniquet release. A bone tunnel was performed with a 3 mm cannulated drill entering the dorsum of the distal metaphysis of the second metacarpal towards the center of the metatarsal head and reaching the subchondral bone (Figure 2). The bone graft was slightly reduced with the aid of a rongeur and introduced into the bone tunnel (Figure 2c). The flap can readily reach the site of implant, without being kinked or stretched during insetting. No fixation was used (Figure 3). Plantar pain resolved after surgery. No complications occurred.

A plaster splint was placed for 3 weeks, after which an orthosis preventing forefoot weight-bearing was placed. Six weeks after the intervention, the patient was allowed to bear full weight; X-ray imaging showed no donor site morbidity from the sustracted bone flap that

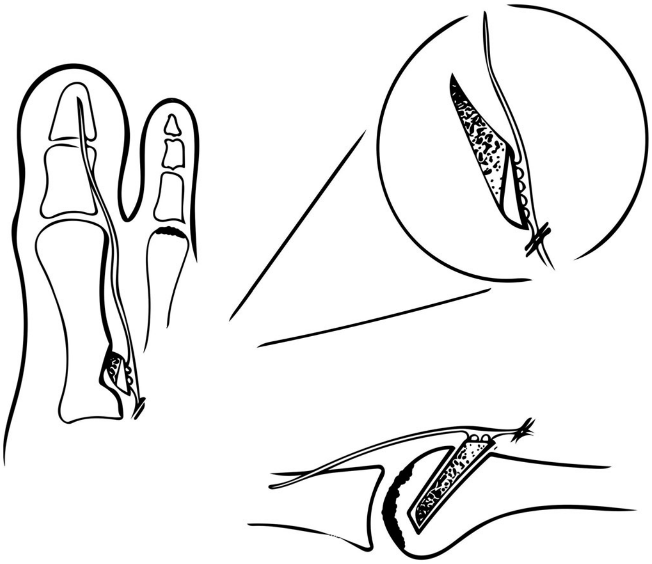

FIGURE 3 Schematic representation of the surgical technique. Graft harvesting from the first dorsal metatarsal vessels and bone tunnel with pedicled bone flap implantation.

could warrant against it (Figure 4a,b). No specific rehabilitation protocol was performed, and 4 months later, the patient resumed dancing. Twelve months after the intervention, MRI showed signal normalization, suggesting bone revascularization (Figure 4c,d). Dorsal and plantar active and passive second MTTP joint ROM was 45 and 60, and she has resumed her dancing activities. She has remained asymptomatic for the past 42 months (Figure 5).

3 | DISCUSSION

It is generally accepted that Freiberg's disease has a multifactorial cause, including trauma, foot mechanics, arterial insufficiency, systemic disorders and a genetic component (Blitz & Yu, 2005; Carmont et al., 2009; Wax & Leland, 2019). Conservative measures are the first line of treatment when managing symptomatic cases, and it is thought to be effective in pain relief in 60% of non-athletes (Mizel & Yodlowski, 1995). Given the poor prognosis for conservative treatment, various surgical alternatives divided into joint-preserving and joint-reconstructing procedures have been developed. In contrast, no

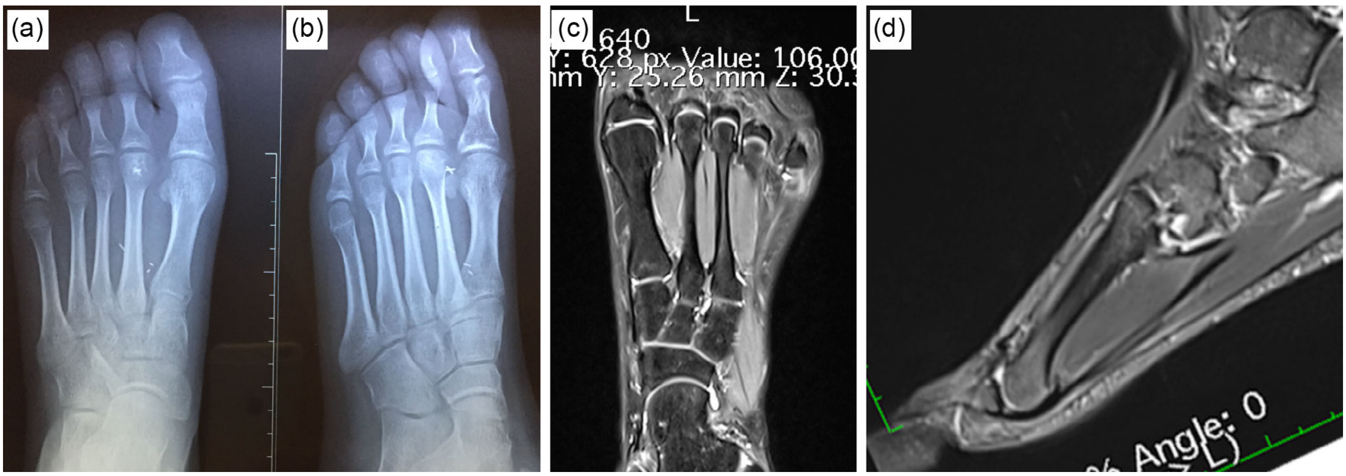

FIGURE 4 (a, b) A-P X-ray showing MTH revascularization; (c, d) T2-weighted-magnetic resonance shows normal intensity around the axial area of the MTH and complete healing of the donor's site.

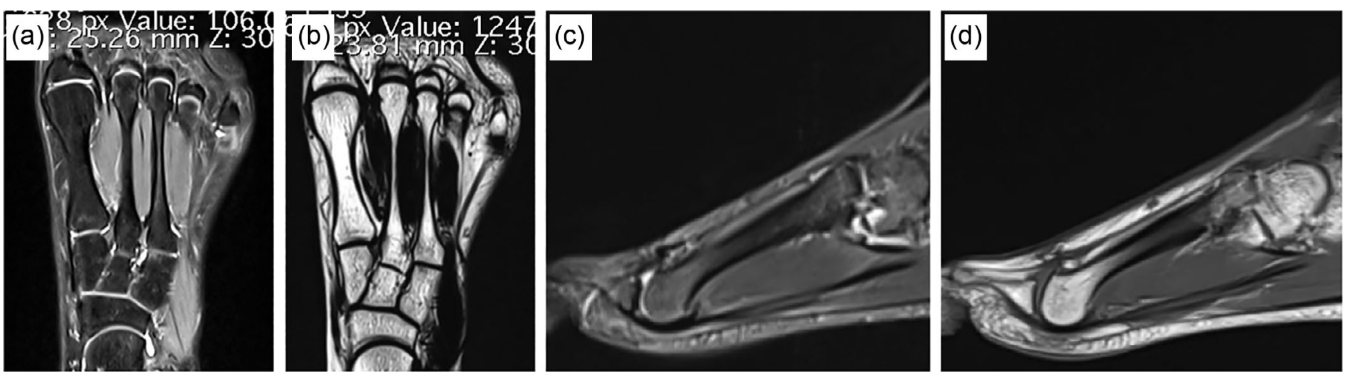

FIGURE 5 Magnetic resonance images at 42 months: (a, c) are T2-weighted and (b, d) are T1-weighted-magnetic resonance images that show normal intensity that resembles normal healthy bone at the second metatarsal's head and dorsum.

single operation has received unanimous support (Schade, 2015; Seybold & Zide, 2018). In a recent review, Schade found better outcomes in terms of complete resolution of pain and return to activity with joint-preserving procedures as opposed to joint-reconstructing ones (Schade, 2015).

Revascularizing techniques have proven effective in osteonecroses, such as osteonecrosis of the femoral head (ONFH), Kienböck's, Preiser's, proximal pole scaphoid osteonecrosis, among others (Payatakes & Sotereanos, 2009; Urbaniak et al., 1995). Our rationale for applying this technique follows free vascularized fibular grafting (FVFG) in ONFH by providing an angiogenic source and mechanical support (Fontecha et al., 2016; Urbaniak et al., 1995). FVFG, following debridement of the necrotic bone, by using an extra-articular tunnel and spongious bone grafting, has been shown to modify the natural history of this disease drastically (Eward et al., 2012; Korompilias et al., 2009; Urbaniak et al., 1995). This has been attributed to the spongious bone graft's revascularization and the fibula's cortices' mechanical support (Fontecha et al., 2016; Korompilias et al., 2009). Our technique, except for the necrotic bone debridement, was similar in that it was limited to the width of the tunnel. Moreover, following ONFH concepts, this patient had extensive transversal involvement without severe joint collapse.

The fact that the natural history of Freiberg's disease and the risk factors for joint collapse are not well known makes it problematic to propose evidence-based indications for revascularization techniques. This scientific dilemma occurs in different locations where osteonecrosis can occur (Payatakes & Sotereanos, 2009).

For the past years, the vascular anatomy of the dorsum of the foot has been described with a very constant pattern (Petersen et al., 2002). Since metatarsal heads are distally located, only grafts based on the dorsal metatarsal vessels can be transplanted. Bone flaps based on the lateral tarsal or arcuate vessels would not reach the metatarsal head. A dorsal metatarsal artery, originating from the arcuate vessels, is present in each intermetatarsal space. Thus, a vascularized bone flap can be harvested to revascularize any metatarsal head.

Similarly to Hou et al. (2013), we have found some variability of the first dorsal metatarsal artery (FDMA) regarding its origin, size and relationship with the first dorsal interosseous muscle (FDIM). In our case, we found a small FDMA arising from the dorsalis pedis artery providing proximal branches to the proximal first metacarpal and running distally, slightly covered by the FDIM. Some variants of the FDMA might not be amenable to harvesting this flap. In such cases, harvesting from the second dorsal metatarsal vessels remains an option. Soldado et al. (2013) described a vascularized periosteal flap obtained from the FDMA (with antegrade flow) that was also effective in revascularizing and preventing a collapse in osteonecrosis of the talus.

Some vascularized periosteal grafts and flaps have been described to treat foot and ankle osteonecrosis and avascular necrosis (Haddock et al., 2013). We opted for a bone flap owing to the difficulty of introducing a periosteal flap in a very narrow tunnel and because structural bone has proven to be mechanically beneficial in preventing further collapse (Fontecha et al., 2016).

Although less invasive techniques like joint debridement, core decompression, autogenous bone grafting and metatarsal osteotomies (Seybold & Zide, 2018) have also shown promising results regarding forefoot function and pain relief, these techniques have not shown any revascularization potential. On this matter, vascularized periosteal and bone flaps have shown revascularization properties in many challenging scenarios (Barrera-Ochoa et al., 2019; Urbaniak et al., 1995) based on the cambium layer's excellent osteogenic and angiogenic properties at this age (Gilbert & Mathoulin, 2000; Lin et al., 2014). Other properties of vascularized periosteal bone flaps in children include their ease of harvesting at a young age and the flap's elasticity readily permits it to conform to the recipient bed configuration. Although we used a technically more demanding technique than other described treatments, it was not more invasive.

Postoperative radiological studies suggested that the non-resected cancellous metatarsal bone was revascularized. In addition, the powerful osteogenic properties of the periosteum led to new bone formation, conferring mechanical support and early initiation of weight bearing.

The current study suffers from some limitations inherent to a case report, such as the small sample and the absence of comparisons with other treatment techniques as controls. The follow-up was short to assess some parameters, such as the development of osteoarthritis of the revascularized metatarsal head. Furthermore, we are applying concepts used in ONFH while Freiberg's natural history remains unknown and might differ significantly. Despite that, this technique was used in long-term refractory cases to conservative measures. A potential donor morbidity might be a fracture. However, considering the proportionally small size of the graft obtained from the proximal metaphysis of the first metacarpal, it might be negligible. Furthermore, a recent study has shown the value of indocyanine for detection and prediction of congestion of pedicled flaps (Yoshimatsu et al., 2023), we believe this technique could have given additional valuable information. Clinical resolution and radiological imaging indicated bone revascularization. Thus, our novel technique of using a vascularized bone graft to treat metatarsal's head osteonecrosis merits consideration, while future comparative studies might be of scientific value.

PMBF might be a valid alternative to other conventional joint-preserving procedures to treat Freiberg's infraction, given its excellent clinical and radiological results. The flap provides a revascularized environment that is favorable for healing.

CONFLICT OF INTEREST STATEMENT

Francisco Soldado is an Editorial Board member of Microsurgery and a co-author of this article. To minimize bias, they were excluded from all editorial decision-making related to the acceptance of this article for publication.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

CONSENT

The patient and parents were informed that data concerning the case would be submitted for publication (case report and any accompanying images) and provided consent.

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