Reconstruction of a Traumatic Partial First-Ray Amputation with the Use of an Induced Pseudosynovial Membrane and Corticocancellous Autograft

A Case Report

Nathaniel L. P. Preston, DPM*
Trevor E. Black, DPM*†
Randall C. Thomas, DPM*‡

Reconstruction of large bone defects of the metatarsals, whether resulting from trauma, infection, or a neoplastic process, can be especially challenging when attempting to maintain an anatomical parabola and basic biomechanical stability of the forefoot. We present the case of a 42-year-old man with no significant medical history who presented to the emergency department following a severe lawnmower injury to the left forefoot resulting in a large degloving type injury along the medial aspect of the left first ray extending to the level of the medial malleolus. The patient underwent emergent debridement with application of antibiotic bone cement, external fixation, and a negative-pressure dressing. He was subsequently treated with split-thickness skin graft and iliac crest tricortical autograft using a locking plate construct for reconstruction of the distal first ray. Although the patient failed to advance to radiographic osseous union, clinically there was no motion at the attempted fusion site and no pain with ambulation, suggestive of a pseudoarthrosis. The patient has since progressed to full nonpainful weightbearing in regular shoes and has returned to normal activities of daily living. The patient returned to his preinjury level of work and has had complete resolution of all wounds including his split-thickness skin graft donor site. This case shows the potential efficacy of the Masquelet technique for spanning significant traumatic bone defects of the metatarsals involving complete loss of the metatarsophalangeal joint. (J Am Podiatr Med Assoc 110(2): 1-6, 2020)

Reconstruction of large bone defects of the metatarsals, whether resulting from trauma, infection, or a neoplastic process, can be especially challenging when attempting to maintain an anatomical parabola and basic biomechanical stability of the forefoot. Amputation is always a possible outcome and should be part of the preoperative discussion with the patient, as salvage is often a prolonged process fraught with difficulties. Surgical management is almost always indicated and can require several interventions to obtain osseous union.[1-3]

*Grant Medical Center Foot and Ankle Surgery Residency Program, Columbus, OH.
†Southeast Permanente Foot and Ankle Trauma and Reconstructive Fellowship, Atlanta, GA.
‡Private practice, Clintonville Foot and Ankle, Columbus, OH.
Corresponding author: Nathaniel L. P. Preston, DPM, PSC 482 Box 2511, FPO, AP 96362. (E-mail: preston.nate@gmail.com)

Literature Review

Current surgical treatment options include intercalary bone transport and distraction osteogenesis, vascularized bone transfer, massive cancellous autograft transfer, and synthetic calcium-based fillers. These options may also be augmented with the addition of demineralized bone matrix, allograft, or bone morphogenetic protein.[1,4-7] Nonvascularized autografts require a well-perfused recipient site for successful implantation, and there is an inherent potential for resorption with grafts larger than a few centimeters. Vascularized bone grafts have an improved rate of survival in a poorly vascularized bed; nevertheless, graft-site morbidity is a potential complication, and the operation requires microvascular skills.[8]

Another more recent surgical treatment option is autologous bone grafting within induced granulation tissue membranes for management of extensive bone loss.[9] Masquelet and colleagues developed the use of induced membrane-assisted massive autograft for segmental bony defects and successfully managed defects less than or equal to 25 cm with associated severe soft-tissue injury.[9,10] This two-stage technique, based on a foreign body reaction triggered by the presence of a polymethylmethacrylate (PMMA) spacer, is a viable option in both aseptic and septic conditions leading to substantial bone loss and requires no advanced skills in microvascular surgery. In the first stage, a thorough debridement of devitalized tissue is performed, the segmental bone defect is bridged by a tubularized construct of PMMA, and the bone is stabilized by orthopedic hardware, typically with external fixation. A thin fibrous membrane forms around the PMMA cement spacer within 4 to 6 weeks. In the second stage, performed 6 to 8 weeks later, the cement spacer is removed while preserving the membrane, and the contained void is filled with cancellous or corticocancellous autograft bone. One of the strengths of this technique is its simplicity, because it does not require special implant resources.[1,8,11-13]

In recent studies, bone union was achieved in 90% to 91% of reviewed cases treated with the Masquelet technique, with an average time to union of 8.5 to 14.9 months.[11,13] Kargera et al[12] reported that full weightbearing was possible in legs at a mean of 17.4 months after treatment of the bone defect, and 23.7 months after the initial trauma. They also reported that patients undergoing this technique returned to work a mean 32.8 months after the initial trauma and 25.3 months after treatment of the bone defect.[12]

Infection remains one of the major factors predicting the outcome of reconstruction of the lower extremity, as two-thirds of the patients with local infections experience a complication or a poor functional result.[2] Therefore, Azi et al[11] recommended use of PMMA bone cement intraoperatively mixed with antibiotics (3 g of gentamicin and 4 g of vancomycin per 40-g package of bone cement).[11] Our case presentation is unique in that the patient suffered a loss of both the distal half of the first metatarsal and the proximal half of his hallux resulting in complete loss of the metatarsophalangeal joint (MTPJ).

Case Report

A 42-year-old male nonsmoker with no significant medical history presented to the Grant Emergency Department following a severe lawnmower injury to the left foot; the primary surgeon (R.C.T.) was consulted. The patient presented to the emergency room within 2 hours of the inciting event and was found to have a large degloving type injury along the medial aspect of his left foot from the hallux to the level of the medial malleolus (Fig. 1). There was exposed bone along the entire medial column with greater than 10-cm soft-tissue loss consistent with Gustilo-Anderson type IIIB. There was gross contamination with grass, dirt, and gravel within the wound.

Physical examination revealed palpable dorsalis pedis and posterior tibial arteries. Capillary refill time was less than 3 sec to all digits, with mild dusky discoloration to the plantar arch. The patient's light touch was grossly intact to the level of the digits. Radiographic examination revealed a severely comminuted fracture of the first metatarsal and base of the first proximal phalanx and a nondisplaced transverse fracture of the medial malleolus (Fig. 2). The patient received a bedside washout with 1 L of normal saline, temporary dressing, and a posterior splint. He was started empirically on cefazolin (Ancef; SmithKline Beecham Pharmaceuticals, Philadelphia, Pennsylvania), gentamicin, and penicillin according to protocol for open fracture management within 2 hours of the inciting event.

The patient was taken to the operating room (OR) for emergent irrigation, debridement, the Masquelet technique, and stabilization. Gross debris was addressed first and thorough debridement was

Figure 1. Clinical preoperative image.

Figure 2. Anteroposterior preoperative radiograph.

Figure 3. Clinical intraoperative image.

performed. The posterior tibial tendon and posterior tibial artery were visible within the wound and noted to be intact. The wound was irrigated with 10 L of normal saline, 9 L using gravity lavage and an additional 1 L with pulse lavage given the level of debris that was present.

The distal half of the first metatarsal and base of the proximal phalanx were comminuted beyond repair. Multiple devitalized pieces of bone were present and were removed from the wound bed. This left a substantial gap in the first MTPJ, and it was determined appropriate to proceed with the Masquelet technique. The gap was filled with bone cement combined with 1 g of vancomycin and 1.2 g of tobramycin, and the distal soft-tissue defect was closed primarily (Fig. 3).

The first ray was then held out to length using a pin-to-bar external fixator (Fig. 4). The soft tissue was repaired distally; however, the proximal soft-tissue loss from the level of the talus to the medial malleolus was not amenable to primary repair and was covered with a nonadherent dressing and negative-pressure dressing (Fig. 5). Postoperatively, the patient continued intravenous (IV) antibiotics and then returned to the OR 3 days later for a second irrigation and debridement of the open proximal wound. At this time, the wound measured $10 \times 10.5 \times 0.2$ cm. Fibrotic and necrotic tissue was debrided and the wound was grafted with a pie-crusted bilayer bovine collagen tissue allograft. The patient was discharged 5 days later with negative-pressure therapy. He remained nonweightbearing to the operative extremity with posterior splint and crutches.

Two months later, the patient returned to the OR for definitive fixation performed by the primary surgeon (R.C.T.). The operative plan was for removal of antibiotic bone cement and pin-to-bar external fixator, first MTPJ fusion with tricortical autograft iliac crest graft, and split-thickness skin graft for the remaining soft-tissue defect. The iliac crest autograft and iliac bone marrow aspirate were

Figure 4. Clinical immediate postoperative image.

Figure 5. Anteroposterior immediate postoperative radiograph after initial debridement.

Figure 6. Anteroposterior immediate postoperative radiograph after staged grafting of the first ray.

harvested with the assistance of the consulted orthopedic spine surgeon.

Initially, the unirail external fixator was removed and an incision was placed through the healed cicatrix along the first MTPJ. The Masquelet technique had taken well and there was a thick pseudosynovial membrane around the antibiotic cement spacer. With the spacer removed, the deficit to the first MTPJ measured 4×1.2 cm. The distal residual first metatarsal and proximal phalangeal base were prepared with curettes and the gap was spanned with iliac crest autograft and bone marrow aspirate. The graft was then fixated using a dorsal locking plate with corresponding 2.7- and 3.5-mm locking and nonlocking screws (Fig. 6).

A split-thickness skin graft (STSG) was then harvested (0.012 inch) from the proximal thigh and applied to the medial left ankle wound that measured 6.5×5.5 cm with minimal depth. The patient was admitted postoperatively for pain control. During his admission, he received a bone stimulator, and continued vacuum-assisted closure therapy. He remained nonweightbearing in a posterior splint for a total of 6 weeks after internal fixation with use of a knee scooter. He then progressed to partial weightbearing to the heel in a CAM boot (Zinco Industries, Inc, Pasadena, California) with crutches for 4 weeks. At 10 weeks postoperatively, he returned to weightbearing as tolerated in normal shoes with custom cork orthotics.

The patient had 100% take of his STSG. However, 2 weeks after grafting, the patient developed a draining sinus tract to the dorsum of the first MTPJ that extended down to the level of the internal fixation. The patient was readmitted to the hospital at this time. Cultures grew *Serratia marcescens* and the patient was started on IV cefepime. Computed tomographic imaging at this time revealed a small abscess at the level of the graft. The patient subsequently required an incision and drainage with deep cultures performed by the primary surgeon (R.C.T.). Cultures continued to grow *Serratia marcescens* and the patient was continued on IV cefepime for a 6-week duration.

While the patient healed the initial sinus tract, he unfortunately developed two additional sinus tracts in the postoperative period. A repeated computed tomographic scan was obtained that showed only 5% union; however, with the concern for deep-seated infection, the decision was made to return to the OR to remove all hardware and obtain deep cultures and bone biopsy specimens (Fig. 7). The first MTPJ was stressed intraoperatively and there was clinically no motion. All biopsy specimens ultimately were found to be negative for osteomyelitis. With the exception of light growth of *Serratia marcescens* on the hardware, cultures were likewise negative. On discharge after hardware removal, the patient was continued on IV cefepime at 2,000 mg every 24 hours by means of percutaneous indwelling central catheter for an additional 6

Figure 7. Oblique postoperative follow-up radiograph after hardware removal and bone biopsies.

weeks. He remained weightbearing as tolerated to the heel in a CAM boot with crutches for 3 weeks after hardware removal, then returned to full weightbearing normal shoes.

After a course of IV antibiotics, 30 rounds of hyperbaric oxygen therapy, and closely monitored local wound care, the patient went on to complete healing of the soft-tissue wound (Fig. 8). Although the patient failed to advance to radiographic osseous union, clinically there was no motion at the attempted fusion site and no pain with ambulation suggestive of a pseudoarthrosis.

The patient completed his antibiotic therapy and progressed to full unrestricted weightbearing in regular shoes 6 months after his initial injury. The patient's final postoperative follow-up appointment was at 18 months, at which time he had returned to normal activities of daily living and preinjury level of work with complete resolution of all wounds, including his STSG donor site (Fig. 9).

Discussion

Reconstruction of large bone defects of the metatarsals, whether resulting from trauma, infection, or

Figure 8. Clinical image at postoperative follow-up.

Figure 9. Clinical image at final postoperative follow-up.

a neoplastic process, can be especially challenging when attempting to maintain an anatomical parabola and basic biomechanical stability of the forefoot. Essentially, the larger the defect, the greater the surgical challenge. However, in the specialty of limb salvage surgery, these can prove to be the most rewarding endeavors.

Before the development of the Masquelet technique in the 1980s, the Ilizarov method and vascularized bone transfer were the most frequently performed procedures for correction of large segmental diaphyseal bone defects. The Ilizarov method required great patience and took months for segmental defects, whereas vascularized bone grafts were technically difficult and often associated with significant graft resorption.[13] The Masquelet technique of pseudomembrane formation is novel in that the time to correction is independent from the severity or degree of bone lost. Subsequent histologic evaluation studies of the pseudomembrane have shown increased bone-stimulating factors and higher concentrations of stem cells compared with matched periosteum.[14,15]

Conclusions

Our case presented unique challenges for reconstructive surgical planning for limb salvage, as the inciting traumatic event had resulted in a severely contaminated wound bed and complete loss of the first MTPJ. Joint salvage or reconstruction in this instance was not an option given the severity of the defect. This case was not without its difficulties but serves to show the potential efficacy of the Masquelet technique in spanning significant bone defects of the metatarsals involving complete loss of the MTPJ.

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