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INTRODUCTION

After failed fixation of ankle fractures, salvage arthrodesis of the tibiotalar as well as the subtalar joint represents a good treatment option. This case report discusses the operative management of an open ankle fracture-dislocation initially managed with ORIF. After development of a nonunion and secondary loss of reduction, initial efforts to achieve tibiotalocalcaneal (TTC) arthrodesis failed. In subsequent years, a low-grade infection with partial osteomyelitic destruction of the talus developed. Successful fusion was ultimately achieved using the Masquelet technique, external ring fixation, and staged autogenous

femoral bone graft supplementation harvested by the reamer-irrigator-aspirator (RIA, Synthes).

CASE REPORT

The patient was a healthy, non-obese 47-year-old male suffering a third degree open, displaced trimalleolar ankle fracture-dislocation after a motorcycle accident. Additionally, the patient suffered an ipsilateral first degree open forearm fracture as well as an ipsilateral first degree open patella fracture. The patient had no past medical history, was a non-smoker, non-diabetic and had no other comorbidities associated with an increased risk of infection. Alcohol overconsumption was the only relevant risk factor. Initial management included closed reduction and external fixation with irrigation, debridement and NPWT of the ankle. The forearm and patella fractures were immediately definitively managed with compression plating and a tension-band, respectively. A wide spectrum antibiotic therapy was prophylactically administered. Three days after trauma the ankle was again irrigated and debrided. After swelling subsided, the trimalleolar fracture was definitively treated through a posterolateral approach to fix the Volkmann fragment and treat the lateral malleolus with neutralization plating and lag screw-osteosynthesis. The medial malleolus was fixed with a posteromedial 1/3 tubular plate and the medial soft tissue defect was treated with a microvascular gracilis flap. Postoperative healing was unspectacular with no signs of infection and no flap necrosis.

At 6 month follow-up, a nonunion with hardware failure and secondary fracture dislocation due to patient noncompliance with excessive early weight-bearing was diagnosed without renewed trauma. An allograft-interposition tibio-talar arthrodesis with a 95-degree blade plate and revision ORIF with a 1/3-tubular

plate of the fibula was performed. A low-grade infection through multiple intraoperative biopsies was ruled out. The soft tissue flap was healed and well perfused. Unfortunately, a nonunion persisted and 16 months postoperatively the blade plate was removed and a TTC fusion with an arthrodesis nail (Stryker) and reamed tibial cancellous bone augmentation was performed. After an additional six months, fusion was not achieved, and a further revision with an ankle-arthrodesis plate (Synthes) medially and a 3.5mm-T-LCP laterally after nail removal was performed. Allograft adipose-derived mesenchymal stem cells combined with partially demineralized allograft bone (Allostem/ Neutromedics) were used to facilitate fusion. During this surgery, a single soft-tissue culture grew low levels of *Staphylococcus lugdunensis*. Antibiotic therapy with clindamycin and ciprofloxacin due to a presumed penicillin allergy was initiated for 12 weeks.

Unfortunately, 18 months later and three and a half years after initial trauma, fusion was still not achieved and the patient was largely wheel-chair bound due to painful weight-bearing and persisting ankle instability. A persisting low-grade chronic osteomyelitis due to failed fusion and extensive osteolysis of the talus was presumed. A Masquelet treatment plan with full hardware removal, meticulous bone and soft-tissue debridement, application of an external fixator and placement of an appropriate antibiotic spacer with endomedullary extension was performed. Multiple biopsies were obtained, which again showed a low-grade *Staphylococcus lugdunensis* infection. Antibiotic treatment consisted of floxacillin and ciprofloxacin for 14 weeks.

Nearly four months postoperatively with no sign of infection, a well-healed soft tissue flap, and radiographic evidence of initial bony fusion of the fibula, a final revision was performed. At the time, the patient could walk a maximum of 200

meters with two crutches. The external fixator and the cement spacer were removed. Cancellous autogenous bone graft was harvested from the ipsilateral femur using RIA. Although the infection was deemed eradicated, harvesting from the tibia was not desirable due to the fear of contaminated bone as well as previous reaming of the tibia. The bone graft was placed in the tibiotalar and subtalar joints. To limit further morbidity, despite an increased risk of renewed infection, an allograft bone block was used in lieu of an autologous bone block to fill the bony defect at the level of the talus. Renewed internal fixation was deemed too risky and the ankle was therefore definitively stabilized and compressed with a ring-fixator (True-Lok-Ring-Fixation-System; Orthofix). The patient was allowed partial weight bearing of up to 15 kg for three months postoperatively. Image 1 shows treatment progression from the initial injury up to and including the final TTC arthrodesis revision. After six months, the patient reported markedly decreased pain with weight-bearing and bony fusion of both joints was confirmed radiographically (Image 2). Fusion was achieved with good hindfoot alignment in slight valgus and no sign of latent infection (Image 3). The ring-fixator was removed and intensive physical therapy to further improve gait was continued. Although fusion was achieved with marked improvement in mobility and return to activities of daily living, complete weight bearing was not achieved and a slight limp with intermittent use of crutches persisted at 36-month follow-up after fusion. The clinical course is summarized in a timeline (Figure 1).

DISCUSSION

Normally, TTC arthrodesis is a rescue operation in the setting of severe destruction, posttraumatic arthritis or other complex issues of the tibiotalar and/or subtalar joints.⁽¹⁾ If, however, in the setting of a severe fracture about the ankle,

multiple or major risk factors exist with a high chance of postoperative complications, a primary TTC arthrodesis may also be considered.(2-6) In the literature, persisting nonunion rates after intramedullary nail arthrodesis average about 12% with a range of zero to 43% with the subtalar joint more likely to develop a persisting nonunion.(2, 3, 5, 7, 8) The most frequent risk factors associated with failed fusion were past operations, age and higher-risk medical comorbidities.(1, 4, 9-12) Postoperative complications in open fractures of the ankle and TTC arthrodesis are common. In a study by Goebel et al. an overall complication rate of 21% was observed.(2) Hammett et al. reported an overall complication rate of 59%, with 25% of them being major complications.(13) Chou et al. showed complications in 35% of patients.(4)

Next to eradication of infection, bone graft supplementation is the most important supporting aspect in the treatment of nonunions. Application of autogenous bone graft, particularly iliac crest, remains the gold standard and most common method for treating bone defects as it exhibits all components necessary for successful bone augmentation including osteoinductive and angiogenic growth factors, living osteogenic osteoblasts and an osteoconductive bone matrix.(14) Iliac crest harvesting is, however, not without complications and RIA provides an excellent, minimally invasive source of autograft while providing ample graft volume without compromising biomechanical properties of the harvest location.(13, 15, 16) RIA of the tibia is an elegant harvesting technique for use in primary intramedullary nail TTC arthrodesis.(17) This was, however, not an option in this case due to lack of remaining bone stock in the previously reamed tibia and a potential risk of dissemination in the setting of chronic osteomyelitis.

The Masquelet technique has been shown to enhance non-union fracture consolidation due to the prevention of fibrous ingrowth, and promotion of an

osteoinductive, vascularized scar tissue.(18-20) It has become a popular treatment modality in non-union fracture care, especially in the setting of bone defects.(21) It has also been used in hindfoot reconstruction with Huffmann et al. reporting good results in combination with RIA harvested autograft.(22)

In this case, an external ring fixator was used to improve the chance of infection eradication by removing all hardware about the ankle and to more effectively compress the arthrodesis. Biomechanical studies have shown more lasting compression with external fixators versus arthrodesis nails, which may not maintain sustained compression.(23-26) Antibiotic-coated nails have also shown good rates of fusion in the setting of low-grade infections and would also have been a valid option.(27) However, we felt comfortable with the ring fixator in this case as it provides excellent stability and compression of the arthrodesis.

Fusion in this difficult case was achieved through the combination of infection eradication and osteoinductive potential provided by the Masquelet technique, the superior properties of RIA harvested autogenous cancellous bone graft, removal of all implants at the operative site, good hindfoot stability and compression provided by the ring fixator and a conservative postoperative management regimen with restricted weight-bearing for three months and a prolonged course of immobilization for six months.

CONCLUSION

In this case report, TTC fusion in the setting of chronic osteomyelitis years after a severe third degree open ankle fracture-dislocation was achieved using a staged Masquelet technique with stabilization through an external ring fixator and bone graft reconstruction including femoral harvested autograft using RIA. To our knowledge this technique has not been described before. Despite multiple

revisions after failed ORIF and subsequent failed fusion, radiographic fusion was quickly achieved and mobility markedly improved by six month follow-up. This reconstructive salvage technique may be helpful in complex TTC arthrodesis in the setting of a significant bony defect due to chronic osteomyelitis.

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Image 1: Injury Progression (t= time since injury)

A: initial post injury; B: after initial ORIF (t=7 weeks); C: hardware failure and loss of reduction (t=6 months); D: 95-degree blade-plate arthrodesis with allograft (t=8 months); E: S/P revision with an arthrodesis nail (t=21 months); F: S/P revision with arthrodesis plates (t=36 months); G-H: Masquelet revision (t=45 months); I-J: S/P final revision with ring-fixator and RIA autograft (t=46 months)

Image 2: Successful fusion (t=62 months since injury)
 A: lateral radiograph; B: ap radiograph; C: SPECT CT showing eradication of infection

Image 3: Soft-tissues (t=time since injury)
 A: application ring-fixator (t=46 months); B-C: soft tissues at follow-up (t=62 months)

Figure 1: Clinical course timeline (in months since injury)