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Case Report

Timely tibiotalar fusion after utilization of Masquelet technique guided by in-hospital 3D printing

Ahmed Nageeb Mahmoud[1,2], John Alexander Holbert[1], Benjamin Richards Wagner[1], Daniel Scott Horwitz[1]

1. Department of Orthopedic Surgery, Geisinger Medical Center, Danville, PA, USA.
2. Department of Orthopedic Surgery, Ain Shams University Faculty of Medicine, Cairo, Egypt.

Abstract

The following report describes a case of a 24-year-old female who presented with a traumatic open trimalleolar ankle fracture with severe distal tibial bone loss. She was submitted to a staged acute Masquelet technique, where the in-hospital 3D printing was utilized to guide the shaping and sizing of the antibiotic cement spacer and, subsequently, the bone allograft utilized two months later during tibiotalar fusion. Adequate bony consolidation was achieved at the 7-week follow-up, and the patient was able to bear weight at 12 weeks fully.

Level of Evidence V; Therapeutic studies; Case Report.

Keywords: Ankle; Arthrodesis; Printing, three-dimensional.

Introduction

The induced membrane technique, the Masquelet technique, typically comprises two-stage surgery using temporary antibiotic-loaded bone cement (Polymethyl methacrylate - PMMA) as a spacer to promote pseudo membrane formation in the surgical bed that enhances bone healing(1). Since its introduction, the Masquelet technique has been utilized in the management of multiple orthopedic conditions, including reconstruction of traumatic or pathological critical bone defects(1-5), among other indications, with excellent results.

Three-dimensional printing (3DP) is a rapidly evolving technology increasingly gaining popularity in several aspects of orthopedic surgery. Given its widespread utilization, efforts are made to improve the cost efficiency of 3DP in the health system. Several health institutions have integrated the radiology-based, in-hospital 3DP(6).

The benefit of combining 3DP applications with the Masquelet technique for surgical planning or manufacturing of implants and bone fillers has been reported to manage infections and traumatic bone defects(7). In this case study, we report a case of traumatic distal tibial bone loss that was managed successfully with 3DP-assisted, acute Masquelet technique(3) followed by tibiotalar fusion. Our aim is to add to the literature about the utility of in-hospital 3DP in acute trauma management and describe the effect of the Masquelet technique in achieving a timely bone consolidation after limb salvage arthrodesis. The patient signed the informed consent form and agreed to utilize the de-identified data for research purposes. To our knowledge, a similar case and surgical technique has not been published before.

Case description

An otherwise healthy 24-year-old female with a body mass index (BMI) of 32 presented to the emergency room of our level-1 trauma center with an open Gustilo grade III B, left Trimalleolar ankle fracture associated with a large anterior distal tibial bone loss and secondary ankle subluxation (Figure 1A-C), after a motor vehicle accident. After ensuring neurovascular integrity, emergency wound coverage, closed reduction, and splinting were performed (Figure 1D, E). After clearing the patient for surgery, the patient was taken for

Study performed at the Geisinger Medical Center, Danville, PA, USA.

Correspondence: Ahmed Nageeb Mahmoud. Geisinger Musculoskeletal Institute. 100 N Academy Ave Danville, PA 17821. **Email:** amahmoud@geisinger.edu.
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wound debridement and irrigation, an external fixator was placed, and an antibiotic bead pouch was applied (Figure 1F-H). Intraoperative findings (Figure 1A, H) and postoperative computed tomography (CT) scan (Figure 1I, J) showed a large triangular bone defect in the distal anterior tibia, representing approximately 40% of the articular surface. The patient returned to the OR for a second-look debridement and exchange of antibiotic delivery system.

Given the large area of articular bone, cartilage loss, and the wound condition, the decision was to continue using external fixation with the utilization of acute Masquelet technique with plans for a delayed ankle fusion after proper soft tissue healing. The consulting plastic surgeon decided on a free lateral femoral fasciocutaneous flap with a skin graft for coverage. To create a bone graft that would fit the bone defect during the fusion surgery, the surgery team decided that the antibiotic delivery system should precisely fit the bone defect to preserve the space for later fusion and, more importantly, create a similarly shaped and sized bone graft fragment during the planned fusion surgery. After performing a 3D reconstruction CT scan (Figure 2A), the in-hospital, radiology-based 3DP service was used to create a custom-made bone mold of the patient's distal tibia (Figure 2 B-D).

Two days later, the planned surgery was performed. The bone models were used intraoperatively inserted in sterile ultrasound bags (Figure 2E), and gentamicin and vancomycin-loaded bone cement (PALACOS® fast R+G) were utilized to create a cement spacer fragment that matched the size of the tibial bone defect (Figure 2 E, F). After wound re-debridement, irrigation, and adjustment of the external fixator, the cement spacer was fitted into the bone defect (Figure 2F-H). On the next day, the planned plastic surgery was performed. The patient was discharged after 14 days. After six weeks, soft tissue coverage was confirmed, and definitive fusion was planned.

The decision was to utilize the anterolateral ankle approach for performing the ankle fusion surgery[8], lateral to the edge of the flap, based on the native soft tissue that was

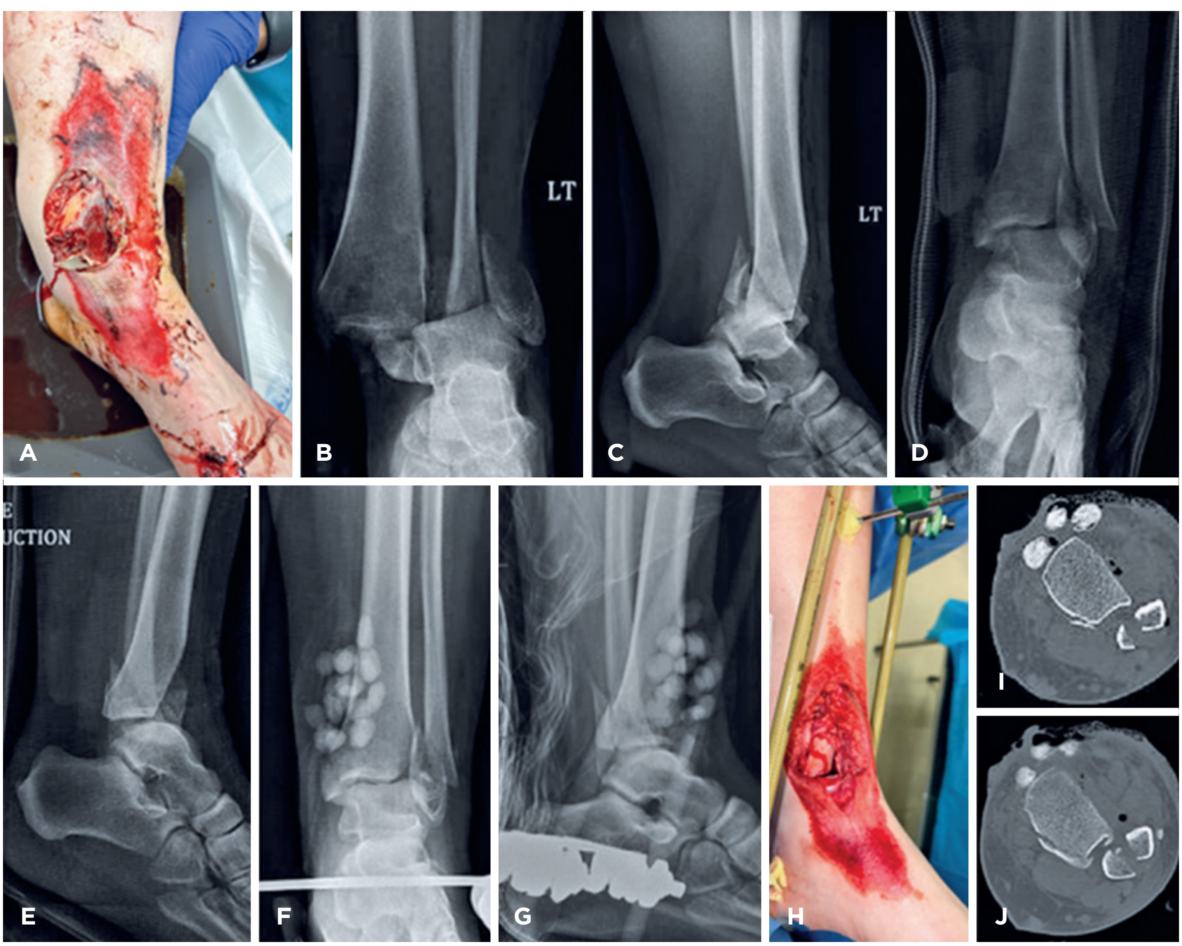

Figure 1. A) Clinical photo, and B, C) Plain radiographs of the limb upon presentation. D, E) Plain radiographs after closed reduction and splinting. F, G) Plain radiographs after debridement, antibiotic beads insertion, and placement of external fixator. H) Clinical photo after application of external fixator. I, J) Postoperative axial CT scan cuts showing anterior tibial bone loss.

not disturbed by the previous flap (Figure 3). After removal of the external fixator, incision and exposure of the bony articular surface were performed (Figure 3B-D), and the old cement spacer was removed and preserved in a sterile saline for reference. The ankle was then distracted using a laminar spreader, and the remaining articular surface was carefully prepared for arthrodesis by removing the remaining cartilage and subchondral bone, ensuring no damage to the fibrous pseudo membrane (Figure 3C). A calcaneal cross-section allograft was then shaped to the size of the extracted cement spacer (Figure 3E-H) and mixed with 10CC demineralized bone fiber and bone marrow aspirate concentrate. The ankle joint was irrigated, then compressed and fixed with preliminary pins in the appropriate, aligned position, and the custom allograft wedge was placed in the anterior defect. (Figure 3I). An anterolateral ankle fusion locking plate was utilized to stabilize the bone graft and fix the tibia to the talus (Figure 3J, K, and Figure 4A-C). The wound was then closed without a drain.

Postoperatively, the patient was instructed to wear a cam boot and maintain a non-weight-bearing status until the achievement of bone fusion, and the patient had biweekly follow-ups. At the 7-week follow-up radiographs, bony consolidation was observed (Figure 4D, E), and the patient began 20% weight bearing using an assistive device. Progressive radiological fusion was observed at 12-week radiographs, and the patient was allowed to advance weight-bearing in a cam boot with gradual progression to full weight-bearing. At the last follow-up, 28 weeks postoperatively (Figure 4L-N), the patient was pain-free, fully weight-bearing without assistive devices, and was cleared to return to work.

Discussion

This case study highlights the efficacy of the Masquelet technique in the achievement of timely, uneventful ankle fusion after reconstruction of severe distal tibial bone loss. The utilization of in-hospital 3DP allowed for the creation of a properly sized cement spacer and, more importantly, the allograft that fitted the bone defect during the fusion surgery.

Acute Masquelet technique[3] is a recent term that describes an existing procedure. It utilizes the induced membrane technique as a primary treatment of bone defects in the acute setting of open fractures[3-5]. In this technique, the bone defect secondary to trauma is filled with PMMA to create a pseudo membrane that can support and promote the bone

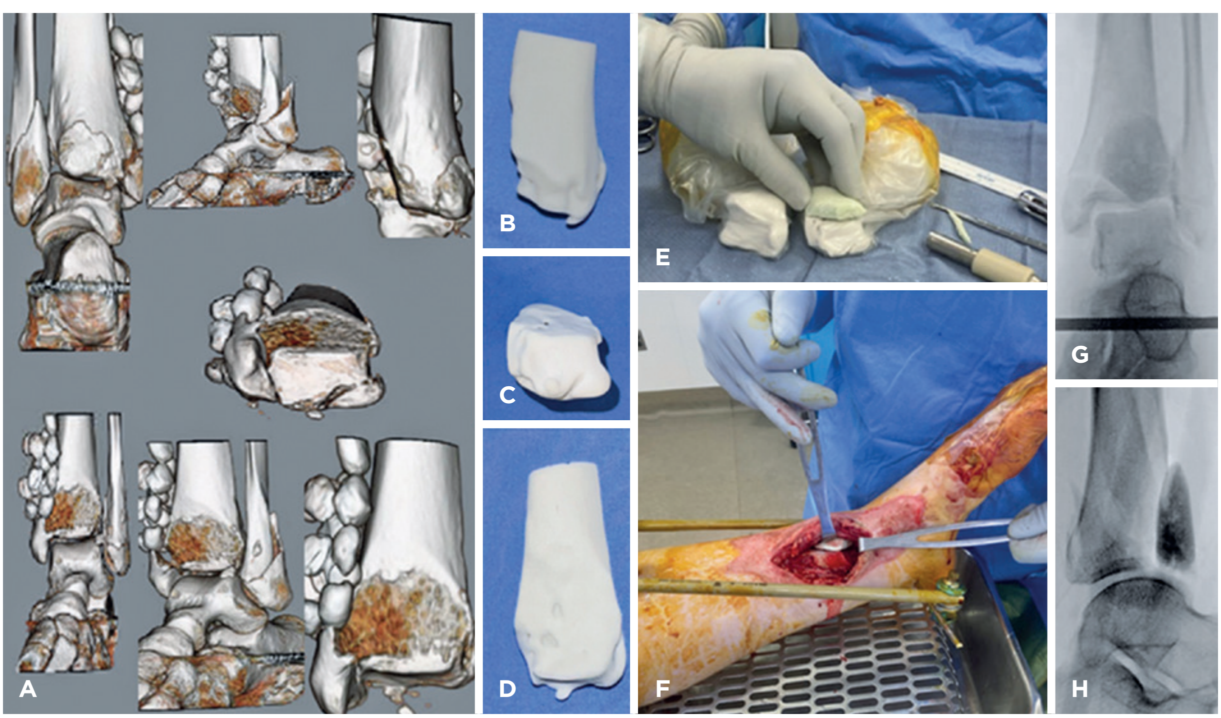

Figure 2. A) 3D CT cuts of the ankle and distal tibia showing distal tibial bone loss and fracture configuration. Note the cement beads on the medial side of the distal tibia B, C, D) 3D printed bone molds. E) The intraoperative clinical photo showing the formation of a cement spacer of the size of the bone defect and fitting it inside the wound. Note that the 3D molds were placed in sterile ultrasound bags. Also, note the right (normal) side mold used to size the spacer in the anteroposterior dimensions. G, H) Intraoperative C-arm radiographs showing properly fitting antibiotic spacer.

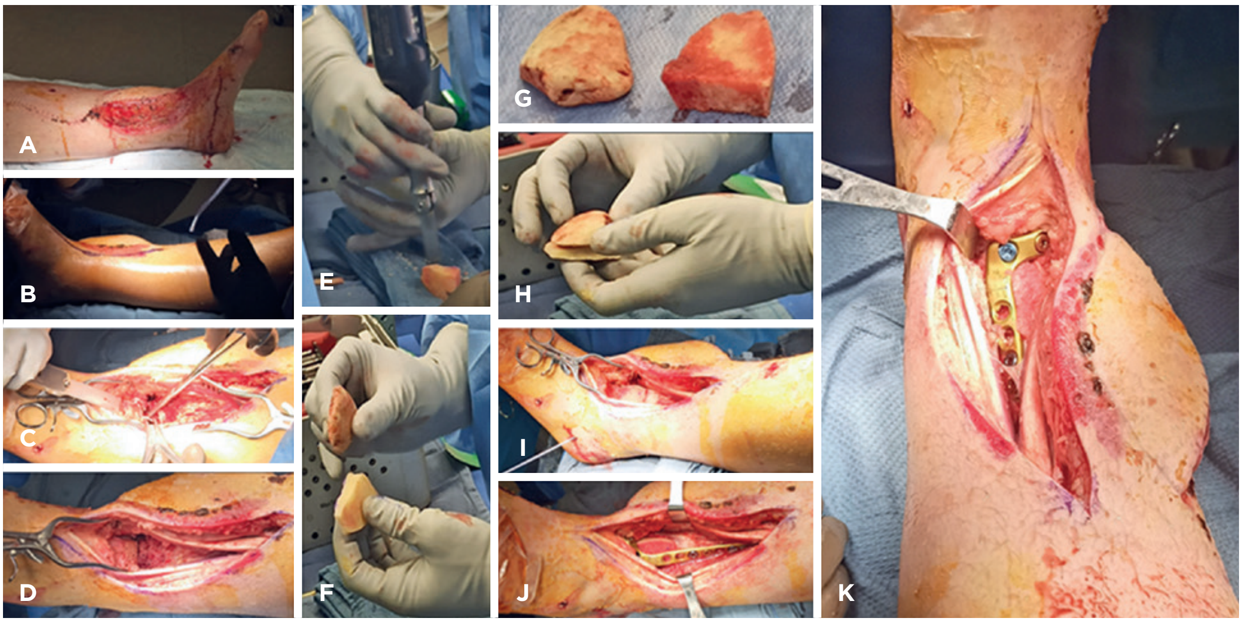

Figure 3. The ankle fusion surgery: A) Condition of the skin flap after external fixator removal. B) Skin marking for the anterolateral incision, lateral to the flap edge. C) After exposure, the articular cartilage is removed using a bone Rongeur. D) The articular surface is devoid of cartilage and drilled. E-H) Shaping and sizing of the allograft to the shape and size of the extracted cement spacer. I) The shaped bone graft fits into the bone defect. J, K) Fixation with anterolateral locking plate and screws over the bone graft.

Figure 4. A-C) Intraoperative C-arm radiographs showing plate placement during the ankle fusion surgery. D, E) A 7-week postoperative plain radiographs showing early progressive consolidation of the fused surfaces. F-H) 12-week, weight-bearing follow-up ankle radiographs showing almost complete fusion. I-K) 19-week, and L-N) 28-week weight-bearing radiographs showing stable fusion construct and complete healing of the fusion surfaces.

graft later in surgery. Several studies reported the success of this technique in acute trauma, particularly in decreasing the need for lengthier and/or potentially demanding reconstruction techniques such as bone transport and vascularized grafts. Hatashita et al.[3] reported seven femoral and tibial open fracture reconstruction cases using the acute Masquelet technique. They reported successful bone union in all of the seven cases despite the occurrence of deep infection in one case. The authors recommended the technique in open fractures with segmental bone loss or partial defects of less than 6 cm[3]. Ronga et al.[5] reported a proximal tibial acute traumatic bone defect of 6 cm in length that was successfully managed with the same technique. Luengo-Alonso et al.[4] reported 12 cases of open femoral and tibial fractures managed with the acute Masquelet technique. Bone consolidation was achieved in all but one case after a mean of 8.4 months. In all of the previous reports, however, none of the cases described subsequent arthrodesis, which was the final management in our case. Our report suggests that the acute Masquelet technique is a reasonable surgical procedure if fusion is planned. This result agrees with other reports highlighting the success of the Masquelet technique before joint fusion in the foot[9,10].

As described, applications of 3DP have been increasingly utilized in orthopedic and spine surgery during the last decade. Their use included manufacturing surgical guides, bone molds, custom-made implants, and bone grafts and scaffolds[6]. Combined with the Masquelet technique, 3DP has created cement spacers in a few reports. For example, Zhang et al. reported four cases of traumatic (three had associated infection) calcaneal bone defects that were reconstructed with the 3DP-guided Masquelet technique to create well-fitting antibiotic PMMA spacers. All the cases were reconstructed in the second stage surgery with bone graft to fill the defects, and successful consolidation was obtained in all cases[7].

In our case, the utilization of in-hospital 3DP helped in performing a sound surgical technique that led to a successful outcome. There are several other independent factors, however, that may have promoted the favorable outcome in this case, such as the patient's medical fitness, repeated surgical debridement, successful soft tissue coverage, and neurovascular integrity.

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