Induced membrane technique for restoration of the first ray following a failed total joint implant: A case study

Allison Hamad, DPM¹, Michael D. Liette, DPM², Bryan Hall, DPM³, Alex Schaeffer, DPM⁴, Suhail Masadeh, DPM⁵

1 - Resident Physician University of Cincinnati Medical Center, Cincinnati, Ohio, USA.
2 - Assistant Professor of Surgery University of Cincinnati Medical Center, Cincinnati, Ohio, USA.
3 - Assistant Professor of Surgery University of Cincinnati Medical Center, Ohio, USA.
4 - Resident Physician University of Cincinnati Medical Center, Cincinnati, Ohio, USA.
5 - Associate Professor of Surgery University of Cincinnati Medical Center, Director of Podiatric Surgery Residency University of Cincinnati Medical Center, Chief of Surgical Podiatry, Cincinnati Veterans Affairs Medical Center, Cincinnati, Ohio, USA.

The induced membrane technique, also known as the masquelet technique, is a treatment strategy for the management of post traumatic bone defects. Management of segmental bone defects remains a challenging problem for the reconstructive surgeon. Autogenous bone grafting is often utilized for small areas of bone loss. Patients with substantial defects pose a significant reconstructive challenge for limb preservation. The induced membrane technique only requires two procedures and the reported results have been consistently favorable. We present a case of a large first ray segmental bone defect after a failed septic implant treated with the induced membrane technique with successful outcome. At 26 months follow-up, we were able to preserve the length and function of the first ray and the patient was able to return to the previous level of activity.

**Keywords**: lower extremity reconstruction, limb salvage, masquelet technique, osteomyelitis, septic joint, segmental bone defect

Osseous defects due to trauma or infection of the first ray often result in amputation with alterations in lower extremity biomechanics and pedal function [1-5]. Loss of the first ray is associated with poor functional outcome and high rates of conversion to a transmetatarsal amputation especially in patients with diabetes [6,7]. Traditionally small defects less than 0.5 cm, respond well to acute shortening, whereas defects of 1 to 2 cm can be treated with autogenous bone graft with adequate rates of salvage [8]. Bone defects greater than 2 cm are more challenging to manage with few published articles encompassing treatment methods for these large deficits.

Distraction osteogenesis is a well-known technique for the management of osseous defects that requires expertise in the application and management of external fixators. Furthermore, this technique relies heavily on patient compliance for the management of the daily distraction as well as an extended duration of treatment based on the size of the deficit. Alternatively, vascularized tissue transfer offers an excellent solution for the management of large defects. However, this requires microsurgical training as well as the sacrifice of a major arterial source. One method of managing large osseous defects is a staged procedure that creates a proper healing environment by relying on and manipulating the host response to a foreign body, leading to the production of the ideal growth factors for bone healing.

The induced membrane technique, which was originally described by Allen Masquelet, has been utilized for the successful management of large segmental defects throughout the appendicular skeleton [9,10]. We present a case of large first ray defect managed by utilization of the induced membrane technique with an excellent outcome and functional result. To our knowledge this is the largest segmental defect in the foot that has been managed with this technique and one of very few reports of this technique within the foot.
Case Report

A fifty-two-year-old male presented to the clinic with hallux rigidus. The patient had a past medical history significant for pre-diabetes, pancreatitis, hypertension, and hyperlipidemia. A 15-pack-year smoking history was noted but his social, family, and past surgical histories were otherwise non-contributory and he denied a history of any known allergies. On the physical exam, the first metatarsophalangeal joint was noted to have 40 degrees of dorsiflexion with tenderness on end point range-of-motion. There was a small osseous prominence located dorsally on the first metatarsal head. The exam was negative for ulcerations, erythema, or subcutaneous nodules. The dorsalis pedis and posterior tibial arteries were both palpable. The patients’ sensation was intact as tested with a 5.07g Semmes Weinstein monofilament. The initial radiographs showed mild first metatarsophalangeal joint arthritis with a first and second intermetatarsal angle of 12.8 degrees and a square with central ridge metatarsal head.

The patient failed conservative therapy consisting of carbon fiber inserts, physical therapy, and other conservative modalities. Surgical intervention was elected for and a shortening and plantarflexory and translational osteotomy of the first metatarsal head was initially performed. A subsequent 1st metatarsophalangeal joint total implant was later performed after continued to have persistent stiffness and pain. The patient then underwent a revision of the implant, tibial sesamoidectomy and cotton osteotomy due to inadequate resolution of symptoms with continued elevation of his first metatarsal. After 18 months, the implant became loose and painful with signs of osteolysis on radiographs as seen in Figure 1.

The patient underwent hardware removal and bone biopsy for suspected osteomyelitis and septic first metatarsophalangeal joint. Debridement of all nonviable bone resulted in a 4.2 cm segmental bone defect. An antibiotic spacer was then placed and temporarily pinned with two 0.062” kirschner wires to hold the position of the hallux in anatomic alignment as seen in Figures 2A and 2B.

Figure 1 Osteolysis adjacent to the site of first metatarsophalangeal joint arthroplasty.

Six weeks after placement of the polymethylmethacrylate spacer was placed, the antibiotic spacer was removed in pieces, carefully preserving the newly formed membrane from damage as seen in Figures 3A and 3B. This newly formed potential space was then packed with cancellous chips via a combination of autograft, harvested from the calcaneus, and allograft. The first ray was then stabilized with a monorail external fixator until consolidation occurred. Serial radiographs were taken on a bi-weekly basis to monitor for consolidation. The patient remained non-weight bearing during the consolidation period.
At the six-month mark, the external fixator was removed and subsequent CT scan was performed which showed adequate osseous consolidation as seen in Figure 4A and 4B. The patient was transitioned to weight bearing in a CAM boot with eventual return to normal shoe gear without pain. Salvage of the first ray was achieved with successful consolidation of the bone graft and maintenance of first ray length.

Discussion

Large osseous defects of the first ray are challenging to treat. Preservation of the first ray is critical for foot function and normal ambulation. Loss of the first ray is associated with high risk of complication especially in patients with diabetes to prevent future amputations. Studies have shown that one out of five patients having any level of first ray resection will go on to require a more proximal amputation [6,7]. High rates of transfer lesions and ulcerations have also been seen with up to 69% of patients developing a new ulceration after an average of 10.5 months from the initial amputation [6,7]. Furthermore, 42% of patients required a more proximal amputation within 2 years after first ray resection [6,7]. The poor patient outcomes highlight the importance of preserving first ray length to avoid significant patient morbidity.
The masquelet technique is often oversimplified with the notion that a spacer randomly placed in a defect is considered a "masquelet". The technique of spacer placement, removal, timing and stability are critical for a good outcome. Other treatments for large segmental bone defects include vascularized free flaps, bone transport, and distraction osteogenesis are often considered to be technically demanding, require longer periods of immobilization and typically have increased associated pain [2,11]. The induced membrane technique has a smaller learning curve but nonetheless requires a fundamental understanding of infection management, proper debridement, and osseous stability. The placement of the spacer is designed to mimic a joint capsule to ensure proper formation of the membrane and production of the necessary growth factors to promote osseous consolidation.

The masquelet technique was first described as a two-stage technique to manage post traumatic infected non-unions, but it may be applied for any segmental bone loss of the lower extremity [9,10]. The stages consist of appropriate debridement and application of an antibiotic spacer within the defect and subsequent removal of the spacer with packing of the newly formed synovial pseudomembrane with autologous and allogeneic bone graft. The membrane itself is key to the success of this technique as it is a highly vascularized pseudosynovial membrane that produces growth factors to enhance graft vascularization as well as osteoinduction [1,2,11]. The spacer prevents fibrosis or soft tissue deposition within the bone void as well as preventing reabsorption of the bone graft placed within the defect [1,2].

After the initial 2 weeks of inflammation, the membrane forms two layers with an inner cell layer and external fibrous layer. The membrane continues to mature until 6-8 weeks, at which time the inflammatory phase resolves and a high concentration of osteoprogenitor cells, vascular endothelial growth factor, bone morphogenic protein-2 and transforming growth factor beta-1 are present [1,2,11-13]. Timing of the second procedure is often dictated on soft tissue healing, but it is important to note that performing the second stage of the procedure earlier than 6 weeks fails to yield a robust membrane capable of reliable osteogenesis and longer than 8 weeks may lower growth factor concentrations. This technique has excellent reported outcomes, with union rates between 80-93% and an average time to consolidation of 1.24 months per centimeter of defect [1,11,12].

One critique of this case is the formation of the cement spacer itself. The membrane formation for this patient may have been strengthened by shaping the cement spacer so that it engulfed at least 1 cm of the two ends of the bone juxtaposing the defect. This would have encouraged membrane production away from the defect itself in a manner similar to a joint capsule which has been shown to improve outcomes [3]. It would also have been beneficial to exclusively use autograft however due to the size of the defect allograft was a necessary supplement to adequately fill the defect. Further research in this area of segmental bone defect management should focus on characterizing the membrane itself in different host populations as well as evaluation and large cohort studies.

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References


