

First Ray Reconstruction Using the Masquelet Technique: A Case Series

Rona W. Law, DPM¹, John M. Thompson, DPM¹, Nathaniel L.P. Preston, DPM, AACFAS², Randall C. Thomas Jr., DPM, FACFAS³

1. Resident Physician, Grant Medical Center, Columbus, OH ; 2. Lieutenant, United States Naval Hospital Okinawa, Japan 3. Associate Residency Director, Grant Medical Center, Columbus, OH; Clintonville & Dublin Foot and Ankle Group, Columbus, OH, USA

INTRODUCTION & PURPOSE

Reconstruction of significant bone defects of the first ray, whether from trauma, infection, or neoplastic processes, can pose a challenge to the foot and ankle surgeon.

Masquelet and colleagues described autologous bone grafting within induced granulation tissue membranes for management of extensive bone loss^{1,2,3}. The use of induced membrane (IM) assisted massive autograft for segmental bony defects was successfully managed in defects ≤ 25 cm with associated severe soft-tissue injury^{1,2,3}. This 2-stage technique, based on a foreign body reaction triggered by the presence of a PMMA spacer, is a viable option in both aseptic and septic conditions with substantial bone loss.

In the first stage, a thorough debridement of devitalized tissue is performed, the segmental bone defect is bridged by a tubularized construct of polymethylmethacrylate (PMMA). The bone is stabilized by orthopedic hardware; typically, with external fixation. Key tips to achieve optimal success during the first stage include completely eradicating infection by impregnating the PMMA cement spacer with antibiotics and employing appropriate soft tissue reconstruction techniques to achieve healthy and well perfused soft tissue envelope to the defect region.

In the second stage, performed 6- 8 weeks later, the cement spacer is removed. A thin fibrous membrane, with peak expression of growth factors within 4-6 weeks, forms around the PMMA cement spacer. While preserving the induced membrane, the contained void is filled with cancellous or cortico-cancellous autograft bone. Careful handling of the IM is paramount and should be sutured without tension upon implantation of the autograft. Robust fixation in a clinically and biomechanically stable position in this stage will decrease failure outcomes. One of the strengths of this technique is its simplicity, as it does not require special implant resources^{4,5,6,7,8}.

We report a case series of patients who underwent first metatarsophalangeal joint (MPJ) salvage or hallux interphalangeal joint (HIPJ) via the Masquelet technique¹. To date, there have been no case series reporting the success of first MPJ utilizing this two-stage autologous grafting technique.

METHODS

A total of seven patients of the surgeon senior author RCT who underwent a 2-staged Masquelet procedure of the first ray, either first MPJ or HIPJ, between 2015-2019, were retrospectively reviewed. Inclusion criteria involved a minimum of 12 months of follow up, with an associated first MPJ resection or HIPJ resection. All patients underwent subsequent antibiotic cement application, external fixator application and definitive fixation with spanning autograft or allograft as described by Masquelet³. Clinical data including indication for initial procedure, pre-operative and intraoperative cultures, antibiotic cement composition, duration of cementation, time until osseous union, incorporated graft type, time to weight bear, and complications were recorded (Table 1). Synapse PACS system (Fujifilm Medical Systems, USA) was utilized to analyze the radiographic length of bone defect after osseous resection.

RESULTS

Five (four females, one male) out of seven patients met inclusion criteria. All included patients had a minimum follow up of 18 months.



Fig. 1: Patient 1

Fig. 2: Patient 2

Fig. 3: Patient 3

Fig. 4: Patient 4

Figures 1-4. AP Radiographs of patients 1 through 4 demonstrating cement spacer application prior to secondary, definitive fixation of the first MPJ or HIPJ at approximately 6 to 8 weeks.

RESULTS

Patient	1	2	3	4	5
Age (at time of initial sx)	55	61	44	52	56
Gender	M	F	F	F	F
Comorbidities	DM2, peripheral neuropathy, CKD	None	DM2, peripheral neuropathy	DM2, peripheral neuropathy	HTN
Indication	1st Metatarsal acute OM	Nonunion, 1st Metatarsal chronic OM	Hallux OM (HIPJ)	1st Metatarsal acute OM	Hallux OM (HIPJ)
Laterality	R	L	L	L	L
Length of follow up (months)	18	25	38	33	21
Preop Culture	No Growth	Staph Epidermidis	Methicillin sensitive staph aureus	Methicillin sensitive staph aureus	Methicillin sensitive staph aureus
Cement Antibiotic Regimen	Gentamicin & Tobramycin	Tobramycin	Vancomycin & Tobramycin	Vancomycin & Gentamicin	Vancomycin & Gentamicin
Bone Defect (AP View) (cm)	2.64	1.52	1.00	3.10	0.80
Initial Stage Fixation	1st MTPJ Monorail External Fixator	1st MTPJ Monorail External Fixator	Unilateral External Fixator	1st MTPJ Monorail External Fixator	Unilateral External Fixator
Time in Weeks between Surgeries	8	7	7	6	6
Cement Spacer	PMMA	PMMA	Palacos Cement	Palacos Cement	Palacos Cement
Duration of Cementation (weeks)	7	7	7	6	5
Time until Osseous Union (weeks)	12	7	12	10	7
Time to Weightbear (weeks)	12	6	8	7	4
Definitive Fixation Type	Revisional graft spanning locking plate with 3.5mm screws	Revisional graft spanning locking plate with 3.5mm screws	Headless cannulated partially threaded 3.0mm screws	Revisional graft spanning locking plate with 3.5mm screws	4.0mm Partially threaded cortical Screw
Graft Type	Ipsilateral Calcaneal corticocancellous Autograft with Spanning disc allograft	Ipsilateral Calcaneal corticocancellous Autograft with Spanning disc allograft	Ipsilateral Calcaneal corticocancellous Autograft, Ipsilateral Calcaneal BMA	Iliac Crest Tricortical Bone Allograft; beta-tricalcium Phosphate/recombinant human-PDGF (3mL), Ipsilateral Calcaneal BMA	Ipsilateral Calcaneal corticocancellous Autograft
Complications	None	None	Superficial Cellulitis treated with PO antibiotics	None	None
Comments	Healed without complications and pain free	Allergy to Vancomycin	Patient ended up with a hallux amputation 28 months status post initial surgery	Pain on L hallux site: Possible nonunion pain healed w bone stimulator and repeat Computed tomographic scans	Eventual return to OR for hardware removal. Patient was asymptomatic thereafter.

Table 1. Data series of 5 included patients

The mean age of all included patients was 53.6 years [44-61]. Three patients had diabetic peripheral neuropathy, one patient had concomitant chronic kidney disease, and one patient had essential hypertension. The average length of follow up was 27 months, while the average time between initial and secondary surgeries was 6.8 weeks. The mean duration of cementation was 6.4 weeks and mean time to osseous union was 9.6 weeks [7-12]. The mean time to weight bear was 7.4 weeks [4-12]. Either polymethylmethacrylate (PMMA) or Palacos® Cement was used in conjunction with the listed antibiotic regimen (Table 1). The average bone defect length on the AP radiographic view was 1.8cm (Figs 1-4). Antibiotic regimen was dependent on patients' allergy profile and previous bone culture results. Pathology reports from all patient were negative prior to the secondary procedure. All patients received either calcaneal autograft or a tricortical iliac crest allograft. Definitive fixation varied between screws versus a locking plate and screws.

ANALYSIS & DISCUSSION

We report a cohort of five patients who underwent a two-staged technique first described by Masquelet. All patients achieved osseous union by 12 weeks. We consider this a 100% success rate given the eradication of infection prior to the secondary definitive fixation and eventual return to full weightbearing. Although patient number 3 eventually ended up with a hallux amputation, this infection occurred 28 months after the initial HIPJ resection and 16 months after osseous union. Patient 4 returned to the operating room for hardware removal at 14 months.

In recent studies, osseous union was achieved in 90-91% of reviewed cases treated with the Masquelet technique with an average time to union of 8.5-14.9 months^{5,6}.

The largest single center case series of 43 patients undergoing repair of long bone defects using this technique has highlighted the importance of the "diamond concept" for successful grafting¹⁰. This concept expounds on the predication that optimal outcomes of bone repair response depends on mechanical stability, presence of adequate cellular populations, inductive stimulating proteins, osteoconductive matrix, and host vascularity.

Recently, Ono et al. reported two cases of successfully staged arthrodesis for osteomyelitis of the finger with articular destruction utilizing the Masquelet technique¹⁰. Kargera et al. reported that full weight-bearing was possible in legs a mean 17.4 months after treatment of the bone defect, and 23.7 months after the initial trauma⁶. 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 defect⁶.

Recently, it has been suggested that the potential modification of the 2-stage procedure to 1 stage by using degradable spacers (calcium sulfate or polyvinyl alcohol sponge). The evidence about this concept remains minimal and contradictory at present⁹.

Instead of undergoing complete resectional arthroplasty of the first MPJ or HIPJ and sacrificing digital length and plantigrade first ray, re-establishing a functional forefoot parabola permits biomechanical stability for appropriate propulsion. In patients that fit the criteria of compliance and minimal comorbidities, the Masquelet technique should be considered as a salvage procedure. This procedure remains a powerful one in the armamentarium of the podiatric surgeon. Limitations of this study include its retrospective nature, and low number of subjects. Studies comparing cement spacer type and antibiotic regimen merit further investigation.

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