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Masquelet technique for treatment of post-traumatic bone defects

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Abstract

Background: Segmental bone defects from traumatic injuries are complicated problems with significant long term morbidity. Historically, amputation was the preferred treatment although, limb salvage by Ilizarov technique, vascularized fibular graft, and acute limb shortening were also used. The treatment regimes were long, burdensome and patient unfriendly involving multiple procedures and complications. Masquelet described the technique of antibiotic cement spacer following debridement for an induced bio-membrane, with subsequent bone-grafting within this space. However, similar results were not reported at multiple centers due to damage to the biomembrane while removal of the cement. Hence, the present study describes the technique of cementation and cement retrieval in order to prevent the damage of the bio-membrane.

Objective: To study the outcome of the role of Masquelet technique in the management of post-traumatic (long) bone defects following trauma presenting at our center.

Method: 15 patients with mean bone defect of 7.2 cm after debridement were operated with the modified Masquelet technique.

Results: Union was obtained in all of the cases; the average time for bony union was 8 months since first presentation with mean follow up of 2.5 years.

Conclusion: The technique of delayed bone grafting with definitive fixation after initial debridement and placement of a cement spacer provides excellent results for patients with large posttraumatic bone segment loss.

Keywords: Masquelet technique, post-traumatic bone defect, ORIF, fixation

Introduction

Reconstruction of the extensive traumatic bone defects of the long bones is still a major therapeutic challenge faced by orthopaedics surgeons both in view of anatomical and functional results [1]. Bone defects of upto 4.0 cm can be successfully treated with cancellous bone grafts [2]. Larger defects may cause complicated problems with significant long-term morbidity like pseudoarthrosis, limb length discrepancy and deformities [3]. Earlier, amputation was the preferred treatment due to the difficulty in managing large segmental long bone defects. Limb salvage has been developed over the last half century. Massive cancellous bone graft used as a mainstay of treatment during World War II [4]. Later on other surgical options like bone transport through distraction osteogenesis by Ilizarov technique, vascularized fibular grafts, non-vascularized grafts, fibular pro-tibia grafting, allograft and acute limb shortening used to address defects of various lengths. However, vascularized fibular grafting is technically demanding and requires microvascular surgical skills. The technique is reliable but the donor sites are limited. The advantage is that the bone can be transferred together with soft tissue to cover local soft tissue defect. Bone transport is a well-established technique for the management of very large bone defects but with a high complication rate; up to 80%. Complication rate of allograft is also very high which may reach up to 50% [5]. Traditional bone graft techniques are limited by uncontrollable graft resorption, even when the recipient site is well vascularized [6]. The Induced membrane technique for the surgical reconstruction of massive bone defects proposed by A. C. Masquelet in 1986 has rarely been studied or evaluated in the literature till recently [7].

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The Masquelet technique is a relatively new innovation involving the induction of a fibrous pseudo membrane around the bone defects site as a result of the body's foreign reaction to the presence of polymethylmethacrylate (PMMA) spacer [8]. The purpose of the present study was to evaluate the results of the induced membrane technique in the management of bone defects resulting from trauma, debridement of infected nonunion.

Material and Methods

Between 20014 and 2017, all patients admitted in department of Orthopedics at Indian Spinal Injuries Centre, with post-traumatic bone defects, infected nonunion and gap nonunion and managed by Masquelet technique (Table 1) were recruited.

Table 1: List of Patients recruited in the study

Sr. no	Age /sex	Type of Injury	Fracture Type	Soft Tissue condition	Indication	Bone Defects (cm)	Spacer	Definite Fixation	Current Status	Duration of Cementation (Days)
1	60/M	Fracture Proximal Femur	Closed	Wound Contaminated	Post Operative Wound Infection	8.3 cm	vancomycin	Plate And screws	Bone Grafting And Healed	48 days
2	60/M	Fracture Proximal Tibia	Open Gustilo II	Minimal Contamination	Bone Loss	7.6 cm	Gentamycin	Plate and Screws	Bone Grafting And Healed	55 Days
3	32/M	Fracture Tibia Shaft	Open Gustilo IIIB	No Contamination	Bone Loss	7.7 cm	Gentamycin	Intramedullary Nail	Bone Graft And Healed	35 Days
4	65/F	Fracture Distal Tibia	Open Gustilo IIIB	Gross Contamination	Soft Tissue Viable With Bone Loss	7.3 cm	Vancomycin + Gentamycin	Plate And Screws	Bone Graft And Healed	49 Days
5	48/M	Fracture Distal Femur	Open Gustilo IIIA	No Contamination	Bone Loss	8.4 cm	Vancomycin	Plate And Screws	Bone Graft And Healed	47 Days
6	44/M	Fracture Distal Tibia	Open Gustilo IIIB	No Contamination	Bone Loss	7.9 cm	Vancomycin	Intramedullary nail	Bone Graft And Healed	39 Days
7	24/M	Fracture distal femur	Open Gustilo II	Contaminated	Bone Loss	9.4 cm	Gentamycin	Plate and Screws	Bone Grafting And Healed	32 days
8	57/F	Fracture Shaft Femur	Closed With Discharging Sinus	Contaminated	Non Union With non Viable Bone	13 cm	Vancomycin	Plate And Screws	Bone Grafting And Healed	59 Days
9	36/M	Fracture Proximal Tibia	Open Gustilo IIIB	No Contamination	Bone Loss	6.7 cm	Vancomycin	Plate and Screws	Bone Grafting and Healed	33 days
10	20/M	Fracture distal Femur	Open Gustilo IIIA	Minimal Contamination	Bone Loss	8.7 cm	Vancomycin	Plate and Screws	Bone Grafting and Healed	42 days
11	39/M	Fracture Tibia Shaft	Open Gustilo IIIA	No Contamination	Bone Loss	8.8 cm	Gentamycin	Plate and screws	Bone grafting/ Healed	58 days
12	42/M	Fracture Proximal Tibia	Open Gustilo II	Minimal Contamination	Bone Loss	8.4 cm	Gentamycin	Plate and screws	Bone grafting/ Healed	44 days
13	18/M	Fracture Tibia Shaft	Open Gustilo II	No Contamination	Bone Loss	7.8cm	Vancomycin	Plate and screws	Bone Grafting/ Healed	39 days
14	55/M	Fracture Distal Tibia	Open Gustilo II	No Contamination	Bone Loss	7.4 cm	Vancomycin	Plate and screws	Bone Grafting/ Healed	44 Days
15	34/M	Fracture distal tibia	Open Gustilo IIIC	Minimal contaminated	Bone loss	8.2 cm	vancomycin	Plate and screw	Bone grafting/ Healed	48 days

The patients were evaluated for injury type, location, soft tissue condition, length of bone defect, antibiotic used, and duration of cementation. Moreover, the type of fixation, presence of infection, and current state of all patients were

recorded.

Surgical Technique First Stage



Image 1



Image 2

During the first stage, the operative extremity was prepared and draped in the usual sterile fashion after a thorough wash (Image 1). The area of bone loss was carefully debrided and irrigated. Debris and nonviable tissues were removed. Careful dissection was then performed down to the fracture site and the fracture ends were identified and debrided again (Image 2).

Based on preoperative radiological evaluation (figure 1), the length, alignment, and rotation of the injured limb were obtained. Method of fixation depended on the fracture type and location but in our study, we didn't used external fixator after primary debridement.



Fig 1: AP (a) and lateral (b) radiographs of an open fracture right distal femur Gustilo Type IIIA at admission

* (It was initially debrided, and stabilized primarily by internal fixation, leaving a large defect over right distal femur)

Once acceptable reduction was achieved (ensuring anatomic length, alignment, and rotation), fixation was undertaken (figure 2). Once fixation had been achieved, attention was then turned to the bone defect. The defect was measured and filled with a polymethylmethacrylate (PMMA) bone cement

spacer. We preferred to use 2 g vancomycin or gentamycin per 40 g of cement prepared (figure 2).

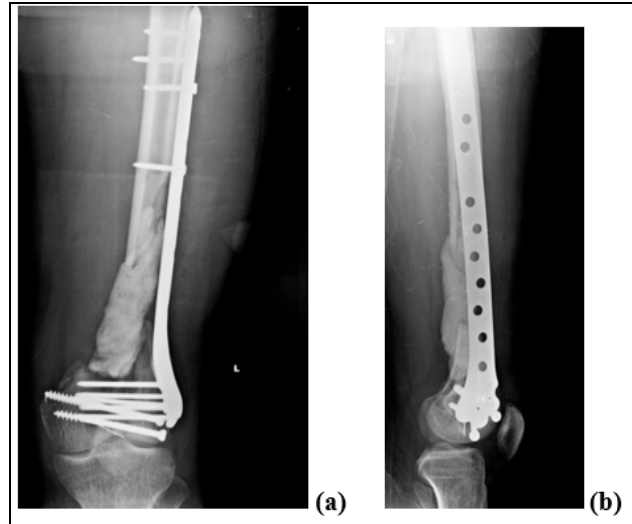


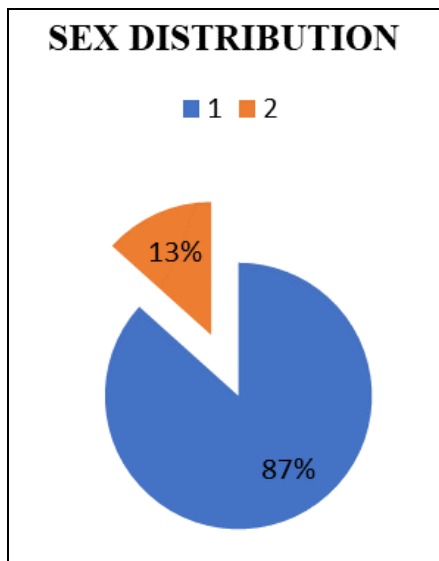
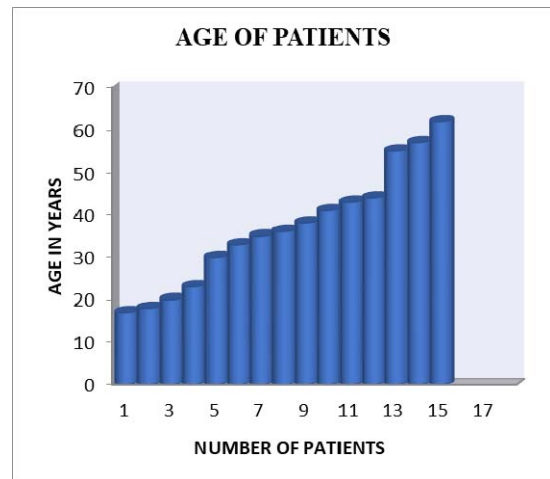
Fig 2: AP (a) and lateral (b) radiographs showing internal fixation with screws and plate and placement of antibiotic cement spacer in the defect after the wound had been adequately debrided.

Second Stage

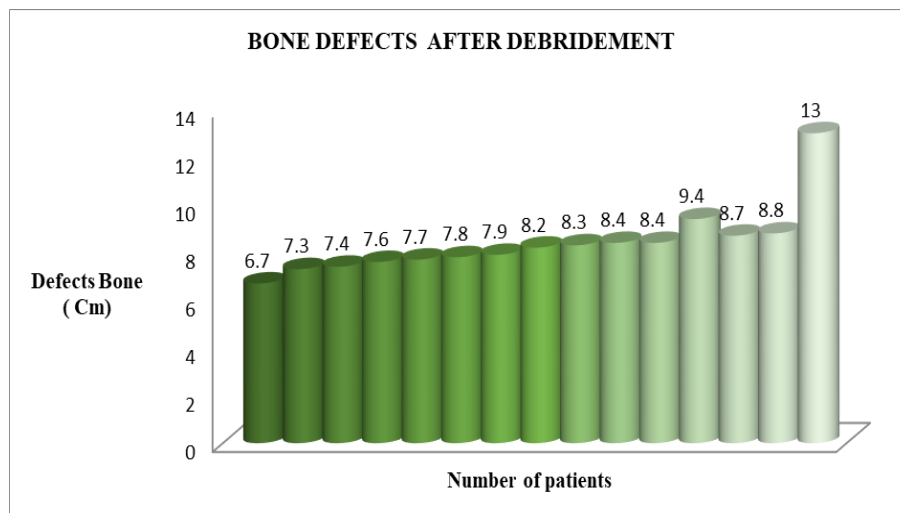
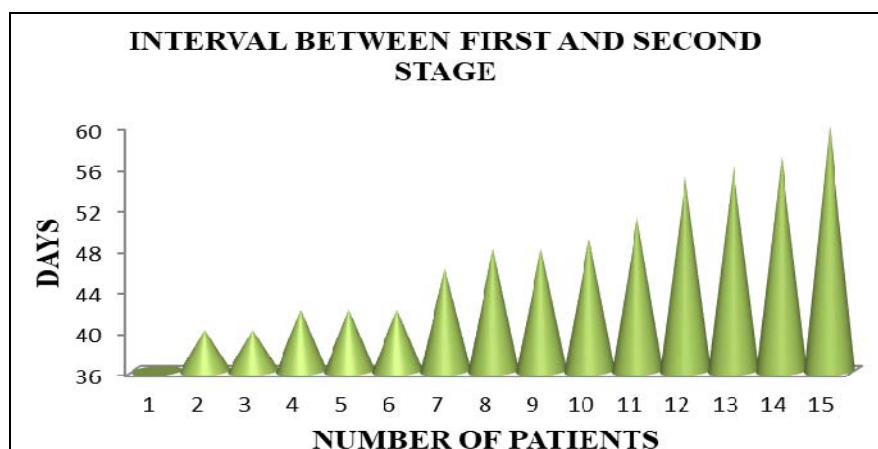
The second stage of bone grafting was performed 6–12 weeks after the first surgery. The bone graft was harvested from the iliac crest in majority of cases but sometimes bone graft also needed to be harvested from proximal tibia, distal femur including iliac crest in case of large defects. The fracture was approached through the previous incision and careful dissection was performed down to the defect. The biomembrane encapsulating the cement spacer was carefully incised. Once exposed, the cement spacer was removed gently taking care of the induced bio-membrane (Image3). Once the cement spacer was removed, the biomembrane capsule was irrigated to remove any residual debris. With the defect being open, bone graft was placed to fill the entire defect (Figure 3). The defect should be completely filled but not overstuff. Once the defect was filled, the biomembrane was closed with absorbable suture.



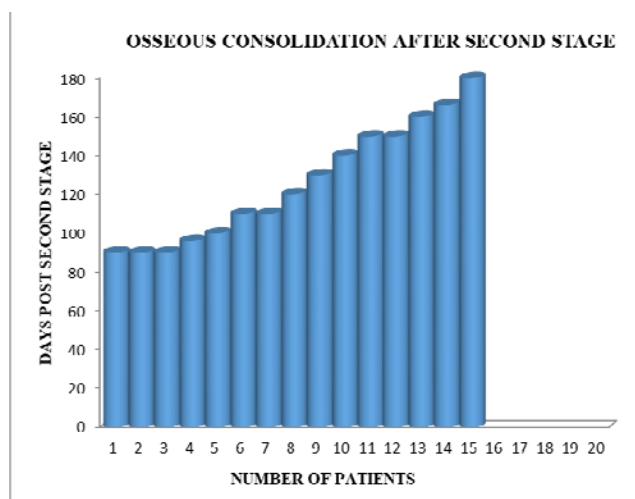
Fig 3: AP (a) and lateral (b) images showing the cement spacer being removed and the defect filled with cancellous autograft harvested from iliac crest with further augmentation with a medial plate.

Results**Graph 1:** Sex distribution of the patients**Graph 2:** Age wise distribution of patients

A total of 15 consecutive patients were identified within the time period. The series included 13 men and 2 women (Graph 1), with a mean age of 42 (18–65) (Graph 2). The bone defects were located at tibia (11 cases) and the femur (4 cases). Two cases were closed fracture but complicated with infection or nonunion or severe comminution with non viability. The other thirteen cases were open fractures with bone loss (Gustilo Classification Type II or III)

**Graph 3:** Length of bone defects after initial debridement**Graph 4:** Interval between first and second stage in days

The length of bone defect ranged from 6.7 cm to 13 cm with a mean defect of 8.37 cm (Graph 3). The antibiotics used for cement spacer were either gentamycin or vancomycin. The mean interval between the first-stage and second-stage surgeries was 44.8 days (32–59) (Graph 4). 13 affected limbs were fixed with screw and plate construct while two were fixed with intramedullary nailing.



Graph 5: Osseous radiological consolidation after second stage

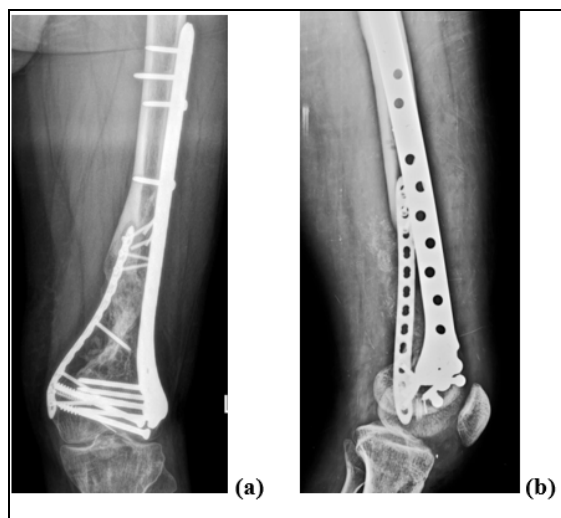


Fig 4: AP (a) and lateral (b) radiographs taken 6 months later showing osseous consolidation

All patients demonstrated radiographic consolidation in a mean time of 115.4 days (range 90–180) over the defect after second stage of surgery (Figure 4) (Graph 5). No complication was reported in the series.

Discussion

The reconstruction of large segmental bone defects is often a major challenge for orthopaedic surgeons [9, 12]. Masquelet *et al.* [10, 11] described a procedure for treatment of these large segmental bone defects by combining the concept of induced pseudo membrane and cancellous autograft. After initial debridement and primary fixation of these defects along with cement spacer bone grafting is often delayed to allow soft tissue healing, decrease the risk of infection, and prevent graft resorption [9, 12]. Antibiotic impregnated cement beads or spacers often used in these defects help in local antibiotic

administration to the surrounding soft tissue bed. In addition, the advantages of inserting such a spacer include maintaining a well-defined void to allow for later placement of graft, providing structural support, offloading the implant, and inducing the formation of a biomembrane [12]. Masquelet and Begue in their study proposed that this membrane prevents graft resorption and improves vascularity and corticalisation. It has been described that, after the initial placement of the antibiotic impregnated spacer, an interval of 4 to 6 weeks is needed for development and maturation of a biologically active membrane that is suitable for grafting. The spacer also maintains the defect and inhibits fibrous ingrowth [11].

As per the recent studies it has been found that this induced membrane can be 0.5 to 1 mm thick [13] and has been described as both hyper-vascular and impermeable [14]. Viateau *et al.* [15] studied this technique in an ovine model and found that radiographic, CT, and histologic examinations at 6 months after the 2nd surgery revealed non-union in ungrafted defects whereas grafted defects showed bone healing. He concluded that this PMMA induced membrane may help confine bone morphogenetic proteins, stem cells or other osteogenic properties inside the defects which with the help of morcellized bone grafts can be osteoinductive for the formation of new bones.

Aho *et al.* [16] studied the mechanism of action of induced membranes on defects healing in fourteen patients and collected biopsy samples of foreign body-induced membranes from each patient at different time points during scheduled surgical procedure. This PMMA induced membrane was co-grown with mesenchymal stromal cells and differentiation to osteoblastic line was assessed by measuring specific alkaline phosphatase activity, PINP, and Ca^{2+} concentration. Vascular endothelial growth factor (VEGF), interleukin-6, and type 1 collagen expression was assessed by quantitative reverse transcription PCR. They found that the vascularization was highest in one month old samples and decreased to 60% in three month old samples. He also found that one month old samples had the highest expressions of VEGF, IL-6, and Col-1 which decreased to $\leq 40\%$ in two month old sample. PINP production and Ca^{2+} deposition in one month old samples was twice higher than two month old samples. He concluded that optimal time for performing second-stage surgery may be within a month and half after implantation of foreign material. In our series, the mean interval between the first and second surgeries is 44.8 days, which is comparable to other studies.

Pelissier *et al.* [17] evaluated the vascularity of the pseudo synovial membrane induced in rabbits. He carried out histological studies to assess vascularization at two, four and eight weeks following implantation. Qualitative and quantitative immunochemistry revealed production of VEGF, $tgf\ \beta 1$, and BMP-2 which was maximum at for weeks post implantation which could stimulate bone regeneration. Biau *et al.* [18] described the management of a 16.4 cm defect in the femur of a 12-year-old child who had been diagnosed with Ewing's sarcoma and required resection of a large segment of his femur. This segmental defect was stabilized with an intramedullary nail and PMMA antibiotic spacer followed by adjuvant chemotherapy for seven months. Second stage was performed after seven months and subsequent successive plain radiographs showed rapid integration of the autograft to the host bone with bone union and cortical reconstitution. He concluded that the principles of the induced membrane reconstruction seems applicable to intercalary segmental reconstruction after bone tumor resection in children.

However, Accadbled *et al.* [19] reported their 3-case study showing that reconstruction of the femur seems to be specifically associated with a risk of graft resorption. N. T. O'Mally *et al.* [20] reported a case using a cage and nail construct, resulting in successful eradication of methicillin-resistant staphylococcus aureus infection and reconstitution of a 17 cm diaphyseal defect in the tibia. Huffman *et al.* [21] reported use of this technique in a significant area of bone loss in the midfoot of a patient who had sustained multiple gunshot injuries. Stabilization of the bone was done with an external fixator. Apard *et al.* [22] reported a series of 12 patients who presented with 6 cm segmental defects in the tibia, all of whom were initially fixed with an intramedullary nail and PMMA cement spacer. They reported union following the second-stage procedure in 11 of 12 patients at an average of 4 months. Although no study has confirmed the optimal biomechanical environment for this technique; rather each fracture is "bridged" according to the treating surgeon's assessment of the fracture. Too rigid construct may have a potential effect of stress shielding near the construct, which may cause reduction of the bone graft near implants. This does not preclude bony union but may increase time to osseous consolidation and affect the radiographic appearance of the defect. Masquelet and Begue [11] relied on the placement of morselized cancellous autograft harvested from the iliac crests within the biomembrane lined defect. If this amount is not sufficient, demineralized allograft is added to the autograft in a ratio that does not exceed 1:3 [11]. In our study, we used autograft harvested mainly from iliac crest, without any allograft. Biau *et al.* [18] used both iliac crest corticocancellous autograft and a medial tibial cortical strut autograft to fill their large defect. Use of cancellous autograft from the femoral canal has also been described, and evidence exists to show that levels of many growth factors (fibroblast growth factor- α , platelet derived growth factor, insulin-like growth factor 1, TGF-1, and BMP-2) in femoral cancellous bone are present in higher concentrations than they are in iliac crest and platelet preparations [23]. Masquelet technique was used in our series to treat post traumatic bone defects successfully. Further research and clinical studies are required to elaborate the grafting components necessary to optimize union in these patients.

Conclusion

The technique of delayed bone grafting after initial placement of a cement spacer provides a reasonable alternative for the challenging problem of significant bone loss in extremity reconstruction. This technique can be used in either an acute or delayed fashion with equally promising results. The bioactivity of the pseudo-membrane created by filling large bony defects with cement leads to a favourable environment for bone formation and osseous consolidation of a large void. As this technique becomes more widely applied, the answer to which graft substances to place in the void may become clearer. Increasing clinical evidence will also help support the use of this technique in treating segmental bone loss.

Conflict of Interests

The authors declare that they have no conflict of interests, any grant, or financial profit related to this clinical study. This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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