ORIGINAL ARTICLE

Masquelet technique to treat long bone defects

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Background: After trauma, tumor removal, or debridement of an infected segment, reconstructing significant segmental bone defect is a challenging issue with considerable long-term morbidity for both morphological and functional outcomes. Large bone abnormalities are extremely difficult to treat since they may not be able to mend on their own and require a lot of bone regeneration. This clinical problem is managed with a two-stage approach that combines delayed bone graft insertion with induced biologic membranes. To create a bioactive membrane, a polymethyl methacrylate spacer is first inserted into the defect. In the second, a membrane containing cancellous autograft is inserted, and through the release of various growth factors, the membrane seems to inhibit graft resorption while encouraging revascularization and the consolidation of newly formed bone. Reconstruction of segmented bone lesions larger than 20 cm has been found to be successful, with excellent clinical results. **Objective:** The study aims to assess the effectiveness of the Masquelet approach in treating post-traumatic segmental bone abnormalities. **Study Design:** This was a prospective study. **Patients and Methods:** Twenty-six patients with segmental bone defect ranging from 4 to 19 cm (average 6.35 cm) were included in this study. The flaws were either post-traumatic or resulted from the removal of the infected segment in cases of infected un-united fractures. Using the induced membrane (Masquelet) approach, all instances were handled. The follow-up time averaged 1 year. **Results:** In 22 patients, union was attained (85%). Based on the system developed by El-Rosasy from Paley *et al.*, 19 patients (75%) attained satisfactory factory-end outcomes. Four patients experienced non-union and reconstruction failure. Three patients (10%) experienced problems related to infection. They were both victims of non-union. **Conclusion:** For the complex issue of considerable bone loss in extremity restoration, delayed bone grafting after initial cement spacer placement offers a viable solution.

KEY WORDS: Masquelet approach, bioactive membrane, segmental bone abnormalities, bone regeneration

INTRODUCTION

Orthopedic surgeons can face difficulties in treating large segmental bone abnormalities. Patients who undergo extended, difficult, and unclear therapy are typically faced with a variety of negative outcomes, ranging from psychological to socioeconomic.[1] The primary causes of bone abnormalities are trauma, the removal of bone cancers, osteomyelitis, and congenital deformity treatment.[2]

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A segmental bone loss >2–2.5 times the diameter of the damaged bone is referred to as a critically-sized defect.[3] Rigid fixation and autologous bone grafting are two treatments for smaller lesions.[4] When the size of the defect is >4 cm, more specialized management is required. Because the bone graft resorbs and the defect persists after a 4–5 cm defect.[5-8] The Ilizarov technique[1,9-13] and vascularized fibular grafting[14-16] are the two widely used methods. Over time, several new cutting-edge methods have emerged. Vascularized fibular autografts have distinct benefits and allow simultaneous soft-tissue coverage.[17] Nonetheless, problems are relatively common. These include infection and stress fracture, which can occur at both donor and recipient sites. The technique also requires specialist microsurgical expertise.[17]

The Ilizarov technique (bone transport and distraction osteogenesis) is a widely used and effective bone regeneration method worldwide. However, it has certain drawbacks, one of which is the prolonged duration of external fixator use required until the newly formed bone in the distracted zone consolidates.[10,18] One clinical consequence that results in functional impairments is the formation of contractures during distraction osteogenesis.[19] Infections at the pin site, discomfort, and non-union at the docking site are additional problems.[13]

In 1986, Masquelet and Begue[5,20,21] reported a technique that combined cancellous autografts and generated membranes. It is a two-phase method. The first involves inserting a polymethyl methacrylate (PMMA) cement spacer into the bone defect, stabilizing the limb, and debridement of the defect.[22] This spacer has a biological purpose by creating an environment that will support the upcoming bone transplant in addition to its mechanical function of inhibiting the ingrowth of fibrous tissue.[22]

This is achieved by causing a foreign body reaction, which forms a pseudoperiosteum 4–6 weeks later.[22] Important growth hormones such as transforming growth factor ß 1, bone morphogenetic protein-2, and vascular endothelial growth factor are secreted by this vascularized membrane.[23] Six to eight weeks later, the spacer is removed in the second stage, all the while maintaining the induced membrane.[22] Morcellized cancellous autologous bone transplant is used to fill the deficiency. The pseudoperiosteum, in turn, prevents this from resorbing and promotes revascularization and corticalization.[22-24]

Study Population

Twenty-six patients with severely large segmental bone defects, with a mean of 6.35 cm and a range of 4–19 cm, were included in this study. Ten (40%) cases of segmental deficiencies occurred after debridement in cases of infected un-united fractures, and 16 (60%) cases of acute traumatic bone loss (all open fractures). Furthermore, two instances that were treated with the Ilizarov approach were eliminated from the study at an early stage, one because the infection persisted after several debridement and the other because the soft-tissue coverage technique failed. The patient's age ranged from 8 to 58 years, with a mean age of (28 ± 11) years. There were eight women (30%) and eight men (70%). Sixteen patients (60%) had damage to the tibia, five (20%) to the femur, and five (20%) to the ulna. The induced membrane (Masquelet) approach was used to treat every case in the orthopedic department of the Rohilkhand Medical College in Bareilly, Uttar Pradesh, from May 2022 to May 2023. The follow-up period was 8–13 months long, with an average of 1 year.

METHODS

El-Rosasy's modified version of the Paley *et al.*,[10] approach was used to evaluate the results. This included assessing the patient's satisfaction, returning to prior work, permanent joint contracture, recurrent infection, residual deformity, remaining leg length disparity, soft-tissue healing, and bony union.[1] Based on these conclusions, the final results were deemed either satisfactory or unsatisfactory.

Surgical Technique

Using a wide resection of all ischemic and necrotic tissue to a well-perfused margin, the area of bone loss was meticulously debrided and irrigated in the first step of the procedure. Any gross debris and non-viable pieces of bone or soft tissue were removed. Fixation was started as soon as an adequate reduction of the fracture was obtained, guaranteeing anatomic length, alignment, and rotation. Ten instances were corrected using constructs made of plates and screws, four with interlocking nail devices, five with Ilizarov frames, and one with intramedullary flexible nails. An external fixator was utilized as a temporary fixation method in instances that were either infected or potentially infected. Later in the second stage, when there was no sign of infection, the definitive fixation was achieved using a plate and screws or an intramedullary nail. Following fixation, the defect was measured and filled using a spacer made of PMMA cement. Eight grams of it were combined with forty grams of vancomycin. To ensure that the spacer was properly sized and shaped, it was then placed as a block during subsequent polymerization processes. It is crucial to use the spacer to completely fill the deficiency, from one end of the bone to the other. After that, the wound was carefully bandaged with a waterproof facial closure applied in layers. Reconstruction or repair was performed when a soft-tissue defect was present [Figures 1 and 2].

If soft-tissue allowed, the second stage treatment was carried out 4–8 weeks after the first, but only if there were no biochemical or clinical signs of persistent infection, as demonstrated by normal erythrocyte sedimentation rate, C-reactive protein, and white blood cell count.

The fracture was approached by making the prior incision, carefully dissecting the area until the bioactive membrane was found, and then making the necessary incisions. After that, the cement spacer was either removed completely or in parts. Before removal, the cement spacer can be longitudinally divided into smaller pieces using an osteotome [Figure 3]. Ensuring complete removal of the cement and avoiding any breaches in the membrane were crucial. With osteotomes or curets, cortical bone ends were refreshed to enhance transplant absorption into native bone. The entire deficiency was then filled with a bone graft [Figure 4], either with or without a bone graft substitute depending on the size of the defect [Figure 5]. After layering wound closure, the biomembrane was sealed with absorbable Vicryl suture.

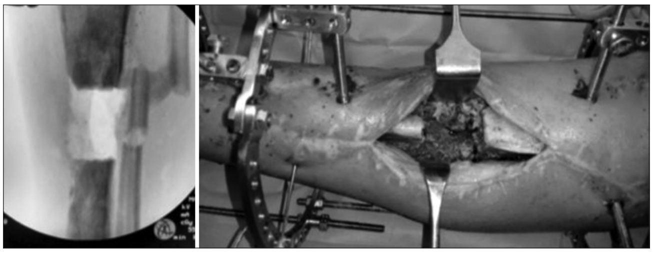

Figure 1: Fluoroscopic imaging conducted during surgery following the removal of the necrotic segment and Intraoperative imaging taken post debridement and excision of the necrotic and infected tissue

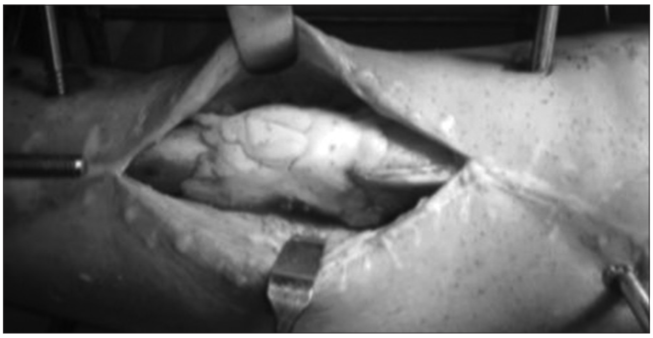

Figure 2: Placement of the spacer as a block covering the bone ends

RESULTS

In 22 patients (85%), union was achieved. In 4 patients (15%), there was non-union. Both upper and lower extremity segmental deficiencies took 2.5–8.5 months (a mean of 4.5 months) to the union from the date of the second stage. Ilizarov treated the patient to rectify the deformity, as just 1 patient (5%) had significant deformity with residual tibia deformity >5°. In 1 patient, there was a notable reduction of more than 2.5 cm. Recurrent infection and non-union were problems for the same patient. In this case, a free vascularized fibular graft was used for management. Three patients (10%) experienced infectious problems and suffered from non-union. One patient had an ipsilateral intercondylar fracture of the humerus, which resulted in elbow stiffness. Another patient experienced tightness in his knees. Regarding the ultimate outcomes, using the approach developed by El-Rosasy from Paley *et al*.,[10] good outcomes occurred in 20 patients (75%), while unsatisfactory outcomes occurred in 6 patients (15%).

DISCUSSION

Reconstruction of large segmental bone loss remains a significant therapeutic challenge in terms of both functional and anatomic outcomes. Conventional bone grafting has its limitations, primarily with regard to uncontrollably high graft resorption. The most attention has been drawn to Ilizarov's bone transport distraction osteogenesis and vascularized fibular graft, two of the most current methods, as dependable solutions for handling such challenging instances. Masquelet did, however, present a revolutionary method in 1986 that was predicated on the idea of an induced membrane. It is a two-step process. The membrane

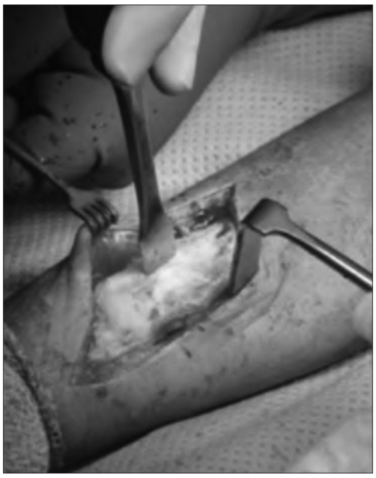

Figure 3: The spacer longitudinally sectioned into pieces with an osteotome

is an example of a foreign body response to the spacer that was initially applied in the void. The spacer is taken out and a bone graft is inserted during the second stage. It appears that the membrane promotes revascularization and consolidation of new bone while inhibiting graft resorption.

Masquelet *et al*.[20] reported in 2000 that in a cohort of 35 patients with bone abnormalities ranging in size from 4 to 25 cm, the union rate was 100%. In their series, 90% of the cases had a bone union, according to Karger *et al*.[25] In addition, Donegan's series of 11 cases showed a 90% union percentage. In a group of 12 patients with segmental bone loss, Apard *et al*.[26] reported a union rate of 92%, whereas Stafford and Norris[27] reported a union rate of 85%. An 85% bone union rate was seen in a group of 20 patients, according to McCall *et al*.[28] However, Morris (2017) found that out of 12 patients with tibial segmental bone abnormalities, only 41% of them had a union rate.[24]

As Regarding the total duration to union, Complete weight-bearing was reported by Apard *et al*.[26] at a mean of 4 months. Ten of the 11 patients with lower extremity segmental bone loss (90%) showed radiographic consolidation of the defect an average of 7.5 months following definitive fixation, according to Donegan *et al*.[29] In the study conducted by Stafford and Norris on lower extremity cases, 70% and 90% of the non-unions were cured at 6 months and a year after surgery, respectively. A mean time to complete weight bearing of 8.5 months was reported by Masquelet *et al*. in 2000 in a series of 35 patients.[20]

The most striking discovery was the lack of correlation between the defect's size and the time to union.

However, it is impossible to draw firm conclusions due to the small number of cases.

The best biomechanical environment for this method of bone fixation has not been studied; instead, each fracture is "bridged" based on the treating surgeon's evaluation of the fracture, the state of the soft tissues, and the existence or absence of infection. The implant's level of stability must also be taken into account:

Table 1: Results evaluation (El-Rosasy version from Paley *et al.*)

Parameter	Satisfactory	Unsatisfactory
Bony union	United	Non united
Residual deformity	Less than 5 degree	More than 5 degree
Residual leg length discrepancy	Less than 2.5 degree	More than 2.5 degree
Recurrent infection	No more infection	Bone and/or soft-tissue infection
Soft tissue healing	No exposed bone	Soft tissue defect remaining
Permanent joint contracture	Less than 5 degree	More than 5 degree
Persistent pain	No or mild pain	Moderate or incapacitating pain
Return to previous work	Yes	Has to change job
Patient satisfaction	Satisfied	Not satisfied

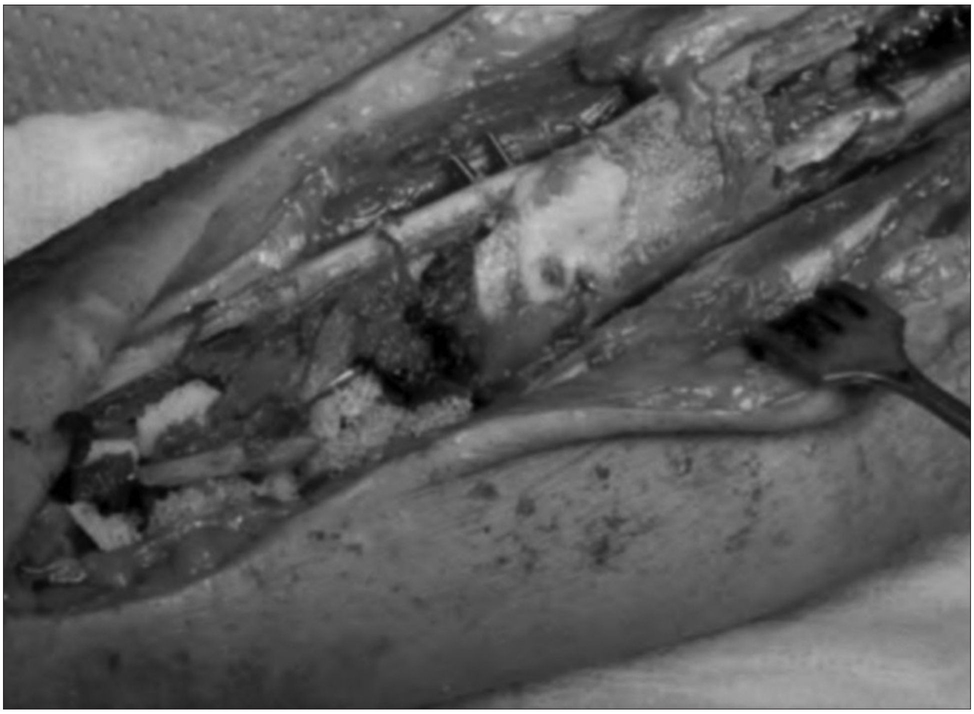

Figure 4: Intraoperative image showing the graft placement, utilizing a cancellous allograft

Stress shielding from extremely stiff fixation may impair the incorporation of the bone graft.[29] On the other hand, excessive micromotion might have a potentially harmful effect by resulting in a weak and poorly vascularized pseudomembrane.[30] An external fixator stabilizes the fracture site in the method Masquelet *et al*.[20] originally described.

Various methods of fracture fixation have been successfully employed in previous studies as well as this one.[24-26]

The mean time interval between the first and second stages in this study was 48 days (35–62), which is similar to most other studies.[22,24,27,29] This information relates to the timing of the second stage. Six to eight weeks have historically separated the first and second phases.[22] However, compared to 2 months old membrane, 1-month-old membrane has stronger osteogenesis-improving capacities, according to a recent study.[31] The implantation of a morselized cancellous autograft taken from the iliac crests was the key component of the method as described by Masquelet and Begue[21] Demineralized allograft is added to the autograft at a ratio of no more than 1:3 if this is insufficient.[21] Depending on the needs in the area, the graft may be strengthened with growth factors, allograft, or other bone substitutes.[22] The majority of the autograft used in this series came from the iliac crest. In six cases, a 1:3 ratio of tricalcium phosphate granules was added to the autograft. In one instance, a canceled allograft was employed.

The femur's medullary canal can be used to harvest massive amounts of bone graft with the reamer-irrigator-aspirator, or RIA, device. It has been demonstrated to have greater concentrations of osteogenic components and important development factors than iliac crest transplant.[27,32,33]

The main complication of this therapy approach is still infection.[26,34] An open fracture's early debridement quality

Figure 5: Intraoperative fluoroscopy taken after the graft placement

has a significant impact on infection and, consequently, the technique's success. It is advised that a senior surgeon perform the procedure. Furthermore, to completely eradicate infection, the support of a qualified bacteriologist and the advice of an infectious diseases specialist cannot be overstated.

Between 0% and 8% of reported cases of bacterial complications result in reconstructive failure. Inadequate debridement is the primary cause of the majority of these failures.[5,26-28] Reconstruction failure happened in one of the five septic problems that Apard *et al*.[26] reported happened after the second stage. In their series of 11 cases, Donegan *et al*.[29] recorded one non-union and one infection, both of which happened in the same patient. Morris *et al*., 2017,[24] however, observed that five out of the 12 patients (or 40%) had infective problems. In two patients (10%) in this series, infection took happened. In both cases, there was a non-union reconstruction failure. Furthermore, a third instance did not advance to the second stage and was eliminated from the study because the infection persisted after numerous debridement. During the operation, it was observed that the membrane was poorly formed.

There is ongoing discussion on the use of antibiotics in cement spacers. According to Apard *et al*.,[26] they might conceal the impact of inadequate debridement by reducing but not eliminating any subsequent infection. To prevent the masking effect, Masquelet *et al*.[20] advise utilizing a spacer free of antibiotics and an oral antibiotic treatment for a week. The benefit of this treatment plan is that infection can be detected early on, preventing bone graft loss, as opposed to after the procedure's second stage.

On the other hand, the orthopedic literature has long recognized the benefits of using antibiotic-impregnated cement. When combined with sufficient debridement, this method can reduce infection rates during the intervals between stages of the treatment.[35] The technique has the benefit of being straightforward and not requiring specialized knowledge, but technical execution still needs to be done with care. On the other hand, sometimes sophisticated soft-tissue covering techniques are required. For the earliest possible planning of soft-tissue covering, having an orthoplastic team on hand is very crucial.

CONCLUSION

The induced membrane approach is a dependable treatment option for segmental bone loss following trauma. It is regarded as a proven bone-rebuilding technique for handling such difficult cases. There is a vast experimental field to be explored using the concept of induced membrane.

To ascertain the ideal time for the second stage, more research is required to assess osteoinductive elements and the timing of their release. The ideal chemical makeup of the spacer is another dubious matter. Furthermore, more research is necessary to identify the optimal graft material type in terms of clinical and radiological results before filling the vacuum.

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