Staged bone grafting using the induced membrane technique in the management of infected nonunion of long bones

Mohamed Nabil

Department of Orthopedic, Faculty of Medicine, Suez Canal University, Ismailia Governorate, Egypt

Correspondence to Mohamed Nabil, MD, PhD, Faculty of Medicine, Suez Canal University, Ismailia Governorate, Egypt.
Tel: +20 100 979 7107;
e-mail: nabilhassona@yahoo.com

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Introduction
The treatment of bone defect is a demanding matter especially in the presence of infected nonunion. The technique of bone grafting within induced membranes offers a feasible option with nominal complications.
Patients and methods
In the time period from September 2010 until October 2012, patients who came to the orthopedic emergency in Suez Canal University Hospitals with posttraumatic bone defects and infected nonunion were involved in the study. We used the induced membrane technique and Ilizarov external fixation in all included patients.
Results
A total of 11 consecutive patients were identified within the time period. The length of bone defect ranged from 2 to 7 cm. All patients demonstrated radiographic evidence of union over the defect after treatment with a mean duration of 88.4 days (84–96 days) from the bone grafting surgery till the appearance of radiographic consolidation. No complication was encountered in this series.
Conclusion
Masquelet technique is effective in the treatment of cases of infected nonunion of long bones.

Keywords:
induced membrane technique, infected nonunion, segmental bone loss

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Introduction

Wide-ranging bone defect of limbs is a gigantic difficulty faced by orthopedic surgeons and reconstruction is always mandatory for acceptable anatomical and functional outcomes [1]. It may occur after a diversity of causes such as bone infections, trauma, congenital defects, or extensive excision of malignant tumors. In the past, the complexity in dealing with segmental long bone defects usually ended with amputations [2].

The treatment of bone defect is a demanding matter especially in the presence of infected nonunion. Small defects could be managed with nonvascularized cancellous bone grafts, which have critical limits of maximum 6.0–7.0 cm length [2,3]. Limb saving surgery has progressed over the last 50 years. During World War II, substantial cancellous bone autograft has been the basis of management [4,5]. Nonvascularized grafts could not be well thought-out as a dependable choice for larger bone defects. Vascularized bone grafts, bone transport, allografts, and fibular protibia grafting are other accessible choices for treatment. Vascularized bone grafting has its own difficulty and demands microvascular surgical skills [6]. The French technique of bone grafting within induced membranes, or else known as the Masquelet technique, offers a feasible option with nominal complications [7,8].

Patients and methods

In the time period from September 2010 until October 2012, patients who came to the orthopedic emergency in Suez Canal University Hospitals with posttraumatic bone defects and infected nonunion were involved in the study. The study was approved by the institutional ethics committee in the Orthopedic department, Faculty of medicine, Suez Canal University, Ismailia, Egypt. A precise evaluation of every patient was done for the type of trauma, site, and condition of soft tissue. The method of bone fixation and occurrence of infection were registered. A formal consent was obtained from every patient to do this technique.

A total of 11 consecutive patients were identified within the time period. The series included nine males and two females, having a mean age of 37 years (22–53 years). The bone defects were located at the tibia (six cases) and the femur (five cases). Six

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Figure 1

Infected nonunion with segmental bone loss of 5 cm at the distal third of the femur fixed with Ilizarov external fixator.

cases had closed fractures of the midshaft of the tibia fixed with interlocking nail but complicated with infected nonunion, while the remaining five cases had open fractures of the shaft of the femur with segmental bone defect (Gustilo Type IIIA) treated with Ilizarov external fixation and also complicated with infected nonunion.

Surgical technique

The limb was draped in the ordinary method. Careful debridement, washing, and dissection were done as well exposing the fracture site and the fracture ends were cut and freshened. The length, alignment, and rotation of the injured limb were restored. Ilizarov external fixator was used as the standard method of fixation in all cases (Fig. 1). After fixation had been accomplished, the segmental bone defect was dealt with. The defective segment was measured and filled with polymethylmethacrylate cement spacer. The length of bone defect ranged from 2 to 7 cm with a mean of 5.08 cm. A measure of 2 g of vancomycin was added to 40 g of cement and mixed together (Fig. 2).

Figure 2

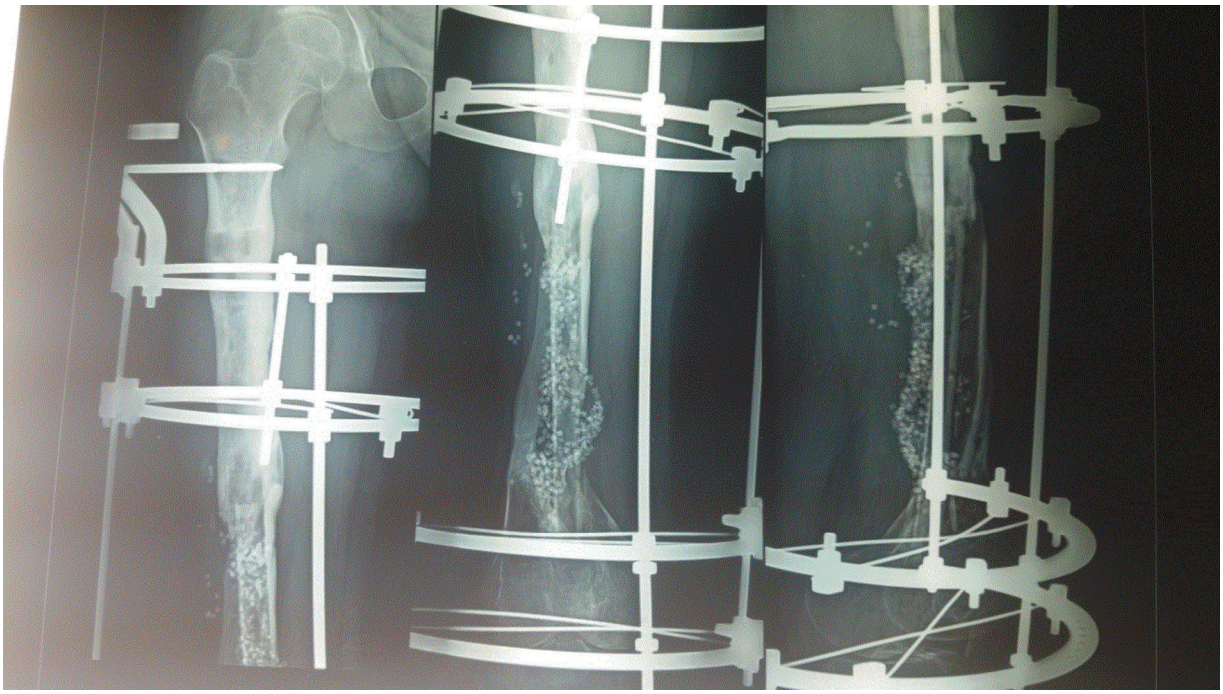
Insertion of cement spacer mixed with 2 g of vancomycin inside the defect.

Then closure was done in layers in the usual manner. The mean duration elapsed between the surgery of Ilizarov external fixation with application of cement spacer and second surgery of bone grafting (duration of cementation) was 43.72 days (35–56 days). In the second stage surgery, we used the fibular bone graft in two cases and the cancellous bone harvested from the iliac crest together with bone granules in nine cases. Cancellous bone graft was mixed with the bone graft substitute with a variable amount according to the size of defect. Incision was done on the previous one and dissection until reaching the defect. The biomembrane was opened. Then, the cement spacer was extracted. Then, the biomembrane was irrigated to get rid of any residual debris. Then, a mixture of cancellous bone graft and artificial bone granules was put into the defect so as to fill it (Fig. 3). Then, the biomembrane was sutured tightly with no. 1 Vicryl and then continue closure in layers in the usual manner.

Results

All affected limbs were fixed with Ilizarov external fixation. All patients demonstrated radiographic evidence of union over the defect after treatment with a mean duration of 124 days (98–152 days) from the bone

Figure 3



Insertion of fibular bone graft together with corticocancellous graft harvested from the iliac crest and artificial bone granules after removal of the cement spacer.

grafting surgery till the appearance of radiographic consolidation (Fig. 4). Full weight bearing was achieved in all cases after a time range from 8 to 12 months with a mean of 9.45 months. At the final follow-up, seven patients were walking normally while four patients used a cane during walking.

Complications

Two cases had malalignment in the form of varus deformity at the final follow-up after 2 years. Leg length discrepancy ranged from 2 to 14 mm with a mean of 7.18 mm at the final follow-up (Table 1).

Discussion

Management of infected nonunion with segmental bone loss is still a challenging issue in orthopedic surgery. Masquelet *et al.* [9] described a technique taking the advantage of the biomembranes and cancellous bone autografts. Cancellous bone grafting of the defects is often postponed after initial fixation to lower the potential of infection, allow soft tissue healing, and to prevent graft resorption [10]. In open fractures, cement beads or spacers containing antibiotic are usually used for local antibiotic infiltration to the soft tissue. As well, the benefits of using such a spacer include obtaining a distinct empty space to permit later placement of cancellous bone graft, giving mechanical support, and enhancing the creation of a biomembrane.

Figure 4

Removal of Ilizarov and application of walking high above the knee cast with signs of consolidation at the graft site.

Table 1 Variables measured during the study

Cases	Site	Defect size (cm)	Duration of cement spacer (day)	Graft used	Duration from grafting till union (days)	Malalignment	Length discrepancy (mm)	Full weight bearing (months)	Final follow up (2 years)
1	Femur	5.4	56	Fibular	136	No	2	8	Normal
2	Femur	4.3	35	Iliac	124	Yes	5	9	Use cane
3	Tibia	4.7	44	Iliac	98	No	4	11	Normal
4	Femur	6.6	42	Fibular	112	No	3	8	Normal
5	Tibia	2	37	Iliac	104	No	9	10	Normal
6	Tibia	3.6	48	Iliac	125	Yes	6	9	Use cane
7	Tibia	6.2	46	Iliac	116	No	3	12	Normal
8	Femur	7	38	Iliac	152	No	12	10	Use cane
9	Femur	5.8	41	Iliac	143	No	14	8	Use cane
10	Tibia	4.6	42	Iliac	121	No	10	9	Normal
11	Femur	5.7	52	Iliac	133	No	11	10	Normal

It was suggested that the new biomembrane keeps the graft from resorption and improves blood supply and cortical bone formation. It was also suggested that after the primary application of the spacer containing antibiotic, a duration of 4–5 weeks interval is necessary for the formation and maturation of a biomembrane that is appropriate for grafting. The cement spacer also keeps the space and prevents fibrous tissue ingrowth [11]. Recent studies have shown that this biological membrane could be 0.5–1 mm thick [12] and it was suggested as being both hypervascular and watertight [8]. The function of induced biomembrane in bone healing was studied by many authors [13]. They suggested that the 4-week-old membrane has increased osteogenic function compared with the 8-week-old membrane; they concluded that the most favorable time for doing bone grafting surgery may be within 4 weeks after application of cement spacer [13]. In the current study, the mean time interval between the stage of cement spacer placement and the stage of bone graft placement is 43.72 days, which is comparable to other studies. Pelissier *et al.* [8] suggested that the induced membranes secrete vascular and osteoinductive growth factors and could encourage bone regeneration. Apard *et al.* [14] had a series of 12 patients who had 6 cm segmental bone loss in the tibia, all of whom were primarily fixed with an intramedullary nail. They reported healing following the bone grafting procedure in 11 out of 12 patients at an average of 16 weeks [14]. No study has concluded the most advantageous method of fixation for such a technique; fairly each fracture is fixed according to the treating surgeon's preference. In this series, Ilizarov external fixator was used as the sole method of fixation for all cases. A probable effect of a fixation that is very rigid may be stress shielding close to the implant, which decreases incorporation of the bone graft at that area. This may not prohibit bony union but may add to the time that is required for osseous consolidation and influence the radiographic picture of the defect. The procedure as described by Masquelet and Begue [11] suggested putting cancellous bone autograft taken from the iliac crest inside the biomembrane lining the defect. If the amount is not enough, demineralized allograft is further mixed to the autograft in a ratio of 1 : 3 [5].

In the current study, autograft is taken mainly from the iliac crest, and fibular graft (used in two cases) with added artificial bone granules when needed was used. Biau *et al.* [15] harvested iliac crest corticocancellous autograft together with a medial tibial cortical autograft to fill the defect.

Conclusion

In this series, Masquelet technique was used to treat posttraumatic infected nonunion successfully. Further studies will hopefully explain the grafting components required to obtain excellent healing in these patients.

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Conflicts of interest

There are no conflicts of interest.

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