International Journal of Orthopaedics Sciences

ISSN: 2395-1958
IJOS 2016; 2(4): 298-301

www.orthopaper.com
Received: 17-08-2016
Accepted: 18-09-2016

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Induced membrane technique for treatment of acute post-traumatic femoral bone loss

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DOI: http://dx.doi.org/10.22271/ortho.2016.v2.i4e.47

Abstract
Background: The segmental bone loss resulted from osteomyelitis or after high energy trauma is one of the great challenges facing trauma surgeons.
Patients and methods: twenty four patients 20 males and 4 female with large bone defect resulted after posttraumatic bone loss with potentially infected wound were treated by the two-stage induced membrane technique. The patients included in this study had bone defect of mean (6 cm) – (range 4-8 cm) due to acute bone loss. The mean age of the patients was 24 years ranged from (14 to 36). Clinically, the patients were examined for wound problem, pin tract infection (PTI). Radiologically, the assessment of bone growth and consolidation on serial x-rays. The mean time for removal of external fixator was 12 weeks (range: 9 -16 weeks) after complete healing of the bone graft. Long leg cast was done after removal of external fixator for 6-10 weeks to protect the bone from refracture.
Results: The mean follow up period was 24 months (range 18-36 months). There was significant relation between the size of the defect and the time of healing as the bigger the defect, the longer the time needed for healing. The average external fixation index in this study is 1.8 (range: 1.5 to 2 months/cm). Radiologically, there was angular deformity of 10°-15° in healed cases. The lost range of knee flexion ranged from 20–30° when compared to the other side. There was no loss of hip range of motion in all patients.
Conclusion: The induced membrane technique is a simple and valid technique for the reconstruction of posttraumatic bone defects after debridement of bone fragments and lost bone.

Keywords: Induced membrane, post-traumatic, acute, bone loss

1. Introduction
The segmental bone loss resulted from osteomyelitis after high energy trauma is one of the great challenges facing trauma surgeons. After removal of sequestrum and biofilm on metal fixation, many surgical techniques were recorded in the literatures like distraction histogenesis, vascularized or pedicled vascularized fibular graft [1-6]. The technique described by Masquelet *et al* [7, 8] for reconstruction of large bone defects resulted after debridement. They reported good results of two stage technique starting by insertion of bone cement used as spacer which induce the formation of a tissue membrane circulating the bone cement. Another stage of cement removal with bone graft impaction inside the induced membrane tube.

In a study conducted by Fleiter *et al* [9] they used gentamicin-impregnated bone substitute for treatment of osteomyelitis, and reported decrease in infection in 80% of patients. By analysis of the membrane it was found to be impermeable and can contain the bone graft. Added to this, the membrane is hypervascular and biologically active secreting growth factors acting as osteoinductive and help new bone formation [10]. This technique has good results when used in the management of bone defects resulted from trauma and after resection of bone tumors [7, 10-12]. This prospective study was conducted for the evaluation of induced membrane technique for treatment of 24 patients with acute bone loss in contaminated open fractures.

2. Materials and Methods
Through the period from May 2012 to November 2015, twenty four patients 20 males and 4 female with large bone defect resulted after posttraumatic bone loss with potentially infected wound were treated by the two-stage induced membrane technique. The patients Included in this study had bone defect of mean (6 cm) – (range 4-8 cm) due to acute bone loss. The mean age of the patients was 24 years ranged from (14 to 36).

The diagnosis of open fractures was femoral fractures in all patients (20 diaphyseal and 4 metaphyseal fractures). According to Gustilo Anderson classification there were 20 patients with type 3A and 4 patients with type 3B. In 20 patients Limb Reconstruction System (LRS) (Figure 1) was used and Ilizarov external fixator in 4 patients (Figure 2).

In the first stage, debridement and excision of potentially contaminated and necrotic bones were excised down to a healthy surface. After radical debridement, the defects ranged from 4 cm to 11 cm with a mean of 7 cm. The resultant defects were filled with bone cement handmade circular spacer. The cement was applied in its doughy stage and it was not allowed to go inside the medulla to facilitate its removal later on, but it was allowed to cover the outer surface of bone ends for about half cm on each side. The skin and soft tissues were then closed over the cement spacer. The bone cement was left in place for an average of 2 months (range: 1.5 – 3 months) to insure the formation of the biological membrane around the cement. Intravenous antibiotics of third generation cephalosporin were given for 2 weeks at least followed by 2 weeks oral antibiotics.

The second stage surgery was done when normal laboratory investigations of (ESR) erythrocyte sedimentation rate, (CRP) C-reactive protein and (WBC) white blood cell count. The second stage was performed in a mean time of 2 months (range: 1.5-3 months) by removal of the cement spacer and taking open biopsy from the around tissues for culture and sensitivity. Refreshment of bone ends, opening the medullary canal on each side of the gap were done. The bone graft was taken from the iliac crest according to the size of the gap. The graft was taken in the form of small longitudinal chips and inserted to the defect. The membrane tube was then closed over the graft.

In eight cases the frames were adjusted to increase the stability of fixation after grafting of the defect and to correct any angular or rotational deformities in the bone. Intravenous prophylactic antibiotics were given 12 hours before operation, intraoperative, and for 2 weeks postoperative according to the results of cultures.

The patients were discharged from the hospital after an average of 8 days postoperative. Follow up visits weekly for the first month, monthly after that until time of removal of the frame. Clinically, the patients were examined for wound problem, pin tract infection (PTI). Radiologically, the assessment of bone growth and consolidation on serial x-rays. The mean time for removal of external fixator was 12 weeks (range: 9 -16 weeks) after complete healing of the bone graft. Long leg cast was done after removal of external fixator for 6-10 weeks to protect the bone from refracture.

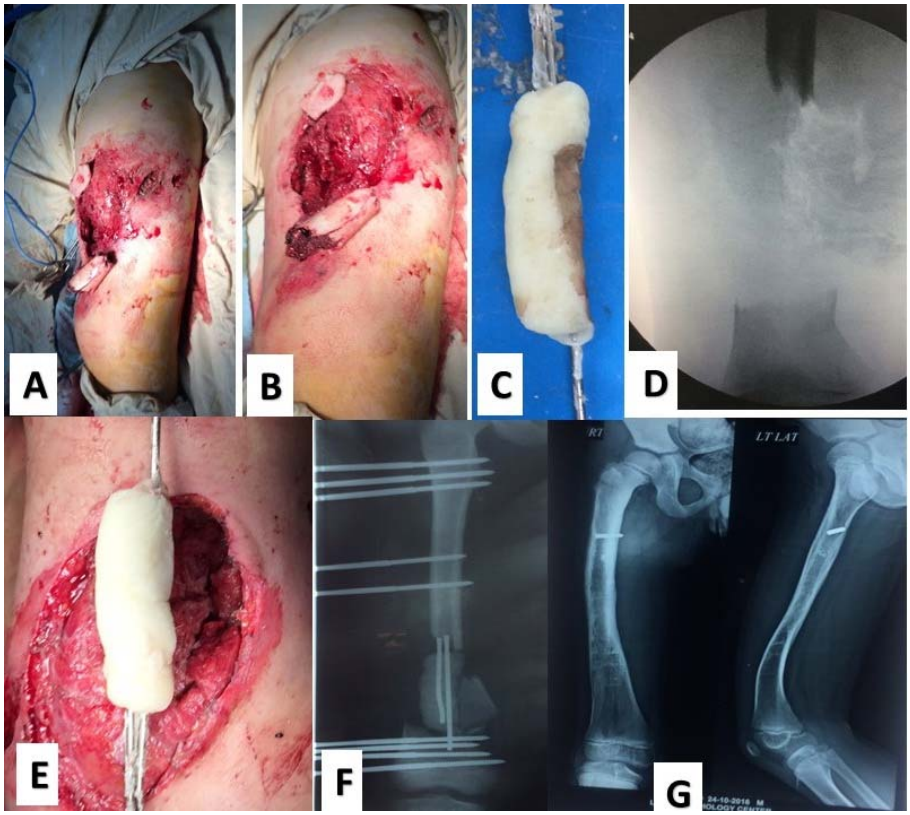

Fig 1: fourteen years old boy with Gastello type 3b open fracture femur with bone exposed and potentially infected: A & B) preoperative photo showing the trauma of the patient and exposed bone; C) intraoperative photo showing the bone cement spacer; D) intraoperative radiology after external fixation; E) intraoperative measuring of the defect and assembly of the spacer; F) postoperative x-ray; G) x-ray 30 months postoperative with bone union.

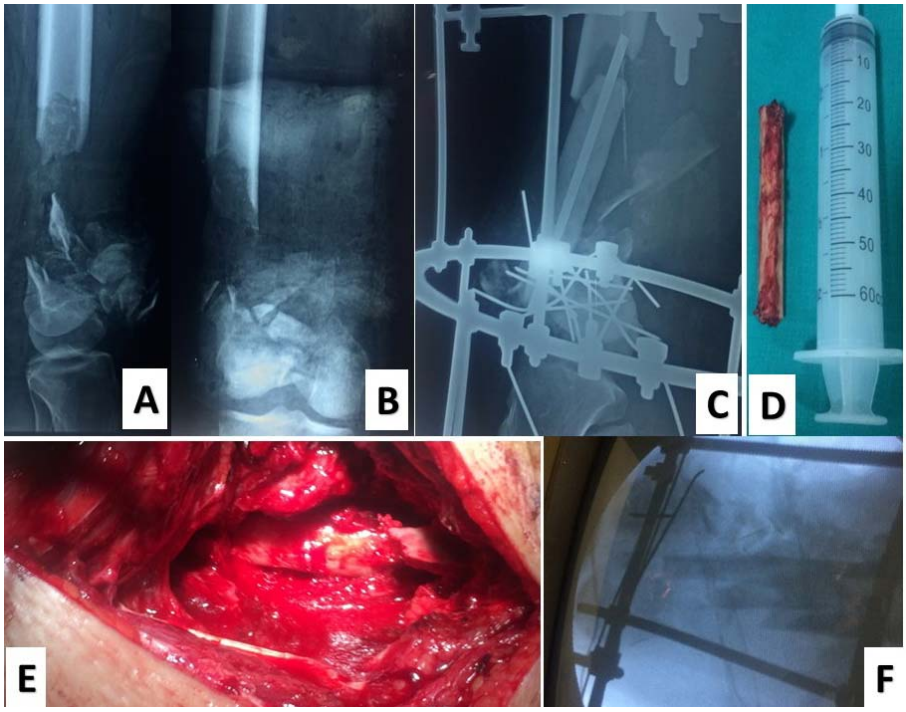

Fig 2: male patient 32 years old with Gastello type 3b supracondylar intercondylar fracture femur with bone loss: A & B) preoperative x-ray; C) postoperative x-ray with external fixation and cement spacer; D) second operation with novascularized fibular graft 8 cm long; E) intraoperative photo during insertion of fibular graft; F) x-ray after fibular graft insertion.

3. Results

The mean follow up period was 24 months (range 18-36 months). Positive tissue cultures found in 4 cases of 24 during the second stage. The mean time of graft healing and consolidation was 10 months after the second stage of surgery (range 8-14 months). There was significant relation between the size of the defect and the time of healing as the bigger the defect, the longer the time needed for healing. The average external fixation index in this study is 1.8 (range: 1.5 to 2 months/cm) (p: 0.005). This index referred as the time of external fixation in months from the first stage of surgery needed for each cm of the defect to heal.

The average time to begin full weight bearing in the frame was 7 weeks (range: 5-10 weeks). In four cases, second stage grafting with novascularized fibula with added cancellous bone graft from the other iliac crest needed due to lake of graft maturation. There were residual shortening in 6 cases with a mean of 2. 5 cm range: 1.5-3 cm). Radiologically, there was angular deformity of 10°-15° in healed cases. The lost range of knee flexion ranged from 20–30° when compared to the other side. There was no loss of hip range of motion in all patients.

The complications in this study were found in 11 cases (45.8%) and all were managed during the course of treatment without affection of the final outcome. Pin tract infection in 6 cases and were treated by repeated dressing and intravenous antibiotics. In four cases, failure of graft maturation and treated by second stage grafting and novascularized fibula. In one case donor site morbidity as extensor hallucis longus tendon laceration during harvesting the fibular bone graft.

4. Discussion

Orthopedic surgeons find a true challenge in the surgical reconstruction of large bone defects. Autogenous bone graft is the main source for management of segmental skeletal defects. The risk of graft rejection and donor site morbidity as pain and infection are the main problems of autogenous bone graft [3]. Distraction osteogenesis for treatment of bone defects was developed from fifties. Many complications have been recorded such as joint stiffness, pin tract infection, chronic edema, nonunion, and refractures after removal of the frame [13-16]. With the advances in microvascular technology, the vascularized bone graft have been utilized for reconstruction of large bone defects, but this procedure has major complications, technically demanding, and time consuming [5]. Masquelet *et al* [7, 8] have described a relatively new technique as the induced membrane technique for reconstruction of large bone defects with good results.

The induced membrane creates a biological chamber to safeguard against graft resorption and acts as an osteoinductive factor that provides a source of stem cells and vascular cells that support revascularization and bone consolidation [17, 18]. In this study, the induced membrane technique was used to reconstruct segmental skeletal defects resulting from acute posttraumatic bone loss in potentially infected wounds. LRS external fixator was used to stabilize the bone segments in diaphyseal defects, and ilizarov external fixator for metaphyseal bone defects.

After thorough debridement in the first stage of surgery and 2 weeks intravenous antibiotics followed by 2 weeks oral antibiotics were sufficient to prevent infection in all patients. The timing of the second stage of surgery is a controversy in literatures. In this study, the second stage was performed in a mean time of 2 months (range: 1.5-3 months). Aho *et al* [18] reported in their recent study that 1 month from implantation of the cement spacer is the optimum time for membrane to become well-formed and reaches its top biological activity. The bone graft taken from the iliac crest was sufficient to fill the defects in all patients. Other authors recommended allograft or synthetic bone graft in big defects [3].

Chotel *et al* [12] used the same technique for the treatment of large bone defects due to tumor resection and reported that the mean time for bone union was 4.8 months. In this study, the mean time of graft consolidation was 10 months after the second stage of surgery (range 8-14 months). The average external

fixation index in distraction osteogenesis technique reported to be less than 1.5 months/cm in the literatures [7, 11, 12]. The average external fixation index in this study is 1.8 (range: 1.5 to 2 months/cm). The advantages of induced membrane technique over the distraction osteogenesis include that the frame is used just to stabilize the bone segment without the disadvantages of distraction on soft tissue and nearby joins causing pain and stiffness. The rule of the patient and relatives in induced membrane is not a factor as turning of the nuts which require special compliance. Also, using a simple frame instead of the complex one needed for bone transport.

In this study, complications were found in 11 cases (45.8%) and all were managed during the course of treatment without affection of the final outcome. There was pin tract infection in 6 cases, failure of graft maturation in four cases treated by second stage grafting and novascularized fibula. Extensor hallucis longus tendon laceration in one case during harvesting the fibular graft. The rate of union in this study was 83% (20 out of 24). Four cases with failure of graft maturation were treated by second stage grafting and novascularized fibula which is comparable to other studies.

5. Conclusion

The induced membrane technique is a simple and valid technique for the reconstruction of posttraumatic bone defects after debridement of bone fragments and lost bone. The technique may take more time than distraction osteogenesis but still has the advantages of low pain and stiffness of the joints due to distraction.

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