ORIGINAL ARTICLE

Management of tibial non-unions with Masquelet technique after failed previous treatment options for Grade III open fractures

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ABSTRACT

BACKGROUND: Non-union is a serious complication of open tibial fractures. This case series investigates the efficiency of the induced membrane technique in patients with tibial exposed non-union.

METHODS: Eleven consecutive male patients with non-union after an open tibia fracture were enrolled into the study. The mean age of the patients was 40.7 (25–63). Induced membrane technique described by Masquelet was performed. Operative treatment with a temporary polymethylmethacrylate cement spacer to induce membrane formation followed by spacer removal and bone grafting at 7.35 (6–10) weeks were performed. Time to union, time to full weight-bearing, and any complications were evaluated.

RESULTS: The average follow-up period of patients was 24.6 (13–40) months after the second stage. The mean length of bone defects after radical debridement was 51 mm (25–98). Fracture healing was observed in 9 patients (81%). The mean time needed to obtain bony union healing was 8.1 (8–12) weeks after second stage of surgery. Patients were allowed to full weight bearing as tolerated at 12 weeks. Two patients were failed to obtain bony union and infection control. One patient had below knee amputation due to persistant infection. Vascularized bone graft was performed for other patient due to the inability to obtain bone union.

CONCLUSION: The induced membrane technique is a reliable and reproducible treatment modality for tibial non-unions after failed open fracture treatment. However, it is unpredictable to obtain bony union and control of infection in initial infected non-unions with a large bone defect.

Keywords: Induced membrane; Masquelet technique; non-union; open fracture.

INTRODUCTION

Non-union is a devastating complication of a fracture which may lead to substantial patient morbidity. The management is still challenging despite advances in surgical techniques with regard of anatomical and functional results.[1,2] Treatment of tibial non-unions following surgical interventions for Grade III open fracture continue to be one of the greatest challenges in orthopedic surgery due to high risk of associated infection, the limited soft tissue, inadequate vascularity, and presence of significant bone loss or avascular bone segments.[3,4] Conventionally, different management options for the tibial non-unions with established bone defects exist. The most common and widely accepted procedures are intercalary bone transport using distraction osteogenesis, vascularized bone transfer, and massive cancellous allografts. Bone autograft is not advocated when the defect is over 5 cm. However, these techniques are associated with long healing periods and a relatively high complication rate.[4–6]

Cite this article as: Özpolat N, Tunçez M, Reisoğlu A, Akan İ, Kazimoğlu C. Management of tibial non-unions with Masquelet technique after failed previous treatment options for Grade III open fractures. Ulus Travma Acil Cerrahi Derg 2022;28:1180-1185.

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Ulus Travma Acil Cerrahi Derg 2022;28(8):1180-1185 DOI: 10.14744/tjtes.2021.36768 Submitted: 16.12.2020 Accepted: 24.04.2021

The concept of the induced membrane introduced by Masquelet is an alternative and relatively new surgical treatment modality in the management of large bone defects in the acute open fractures with significant bone loss and after tumor resections. Besides, it can also be used in the treatment of complex pseudoarthrosis even in non-unions secondary to chronic infections.[4,7–10] The induced membrane provides an envelope that protects and revascularize the bone graft, it promotes the vascularization and the corticalization of the cancellous bone while preventing resorption of the cancellous bone.

The induced membrane concept is presented by Masquelet as a technically less demanding and more predictable treatment modality compared to other conventional treatment options in the treatment of complex non-unions. This study presents a homogenous group of patients with established tibial non-union after Grade III open fracture treated by Masquelet technique. The aim of the present study was to analyze the results of this series and discuss the implications of this new treatment concept in established complex tibial non-unions.

MATERIALS AND METHODS

We retrospectively reviewed the clinical and radiological results in 11 consecutive patients treated by Masquelet technique for nonunion of the tibia between 2016 and 2019. All Masquelet procedures were performed by a single surgeon (CK) with a special interest in this technique. The Institutional Review Board at our institution approved the study and informed consent was obtained from all patients. The patients included 11 men with a median age of 40.7 (range 25–63) years. All patients had a sustained tibial pseudoarthrosis where seven had also associated infection at the fracture site. All patients had sustained Grade III open fractures and had failed operations before the treatment with induced membrane technique.

The diagnosis of tibia nonunion was defined according to the following protocol: Non-completely healing within 9 months of injury and that had not shown progression towards healing over the past 3 consecutive months after the initial osteosynthesis; and instability at the fracture site confirmed by stress radiography.

Pre-operative X-ray, computed tomography (CT), and occasional magnetic resonance imaging scans were routinely performed to evaluate the scope of infection and length of the bone defect.

Reconstruction was performed by the two-stage induced membrane technique in all patients described by Masquelet et al.[4,9,10] Initially, the avascular bone was resected to the level of viable bone. Thereafter, bone fixation was performed with an intramedullary nail or a locking plate depending on the location of the fracture or stability of the previous implant. Rigid internal fixation materials in two patients were left *in situ* (Figs. 1 and 2). After meticulous debridement and fracture stabilization, a PMMA (polymethylmethacrylate) cement spacer that envelopes the bone ends was prepared into the defect as described by Masquelet.[4,7] During the second

Figure 1. Pre-operative anteroposterior **(a)** lateral **(b)** radiographs and **(c)** coronal and **(d)** sagittal computed tomography at before the first-stage procedure in a patient with non-union at 10 months after plate fixation. Anteroposterior **(e)** and lateral radiographs **(f)** and computed tomography at 12 months after the second stage of the induced membrane procedure in the same patient.

operation, the membrane is incised in the axis of the bone and the cement removed making sure not to disturb it (Fig. 3). Initially, the cement was fragmented using a drill and osteotome. After extraction of cement pieces, saline irrigation was carried out for the removal of cement debris. The medullary canal was opened and the bone ends were revitalized. The bone defect was completely filled with autologous bone graft in one patient. Cancellous allograft combined with autologous bone graft was used in ten patients where the defect was too large to be filled by autologous graft alone and the membrane was then closed with absorbable 2–0 vicryl sutures. We harvested as much as possible autologous cancellous bone graft from the iliac crests to reduce the fracture

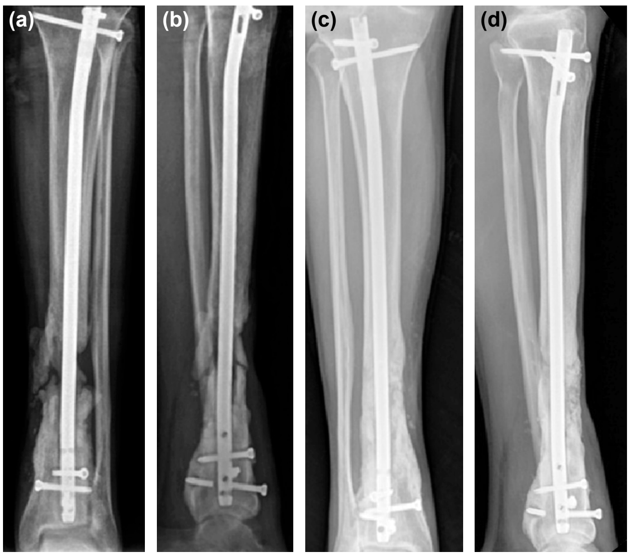

Figure 2. Pre-operative anteroposterior **(a)** and lateral **(b)** radiographs at before the first-stage procedure in a patient with non-union at 20 months after intramedullary nailing. Anteroposterior and **(c)** lateral radiographs **(d)** at 18 months after the second stage of the induced membrane procedure on previous implant in the same patient.

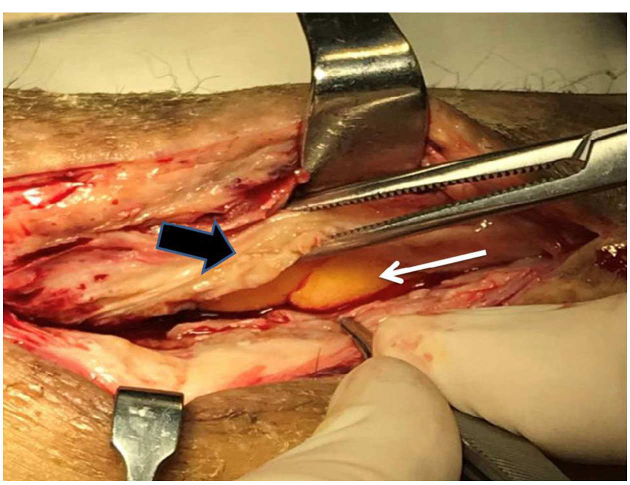

Figure 3. Tibial midshaft bone defect was treated with induced membrane technique in a patient. Black arrow revealing the induced membrane during the second stage of the operation and white arrow revealing the bone defect filled with cement.

consolidation time. Multiple tissue biopsy specimens were sent for culture during both stage of the procedure.

For infected non-unions at the first stage, the sinus, dead bone, and necrotic tissue were removed and sampled to identify the bacteria. Bone defects were filled with antibiotic PMMA cement (2 g vancomycin-loaded bone cement). Evidence of infection recurrence or eradication was made post-operative clinical and laboratory conformation regularly at follow-ups. Systemic antibiotic treatment was given at the time of wound coverage and adjusted according to the antibiogram confirmed. The duration of systemic antibiotic therapy was 2–4 weeks and the patients were given further oral antibiotics for additional 2 weeks after cessation of systemic therapy after infectious disease consultation. Seven patients had bacterial cultures containing four strains in these series. The microorganisms produced from these patients were *Staphylococcus aureus* in five patients, *Pseudomonas aeruginosa* in one patient, and *Enterobacter cloacae* in one patient. No drug resistance bacteria were noted. Three patients with staphylococcal infections received 3 weeks of intravenous vancomycin and two patients received 3 weeks of intravenous teicoplanin followed by intravenous 3-weeks of linezolid treatment. Five patients with staphylococcal infections also received combined oral fusidic acid and ciprofloxacin for 2 weeks. Two patients with Gram-negative infections received 2–4 weeks of intravenous ceftazidime plus levofloxacin, followed by 2 weeks of oral ciprofloxacin.

Sedimentation (ESR) and C-reactive protein (CRP) level was determined at regularly and 5 days after cessation of antibiotic treatment. Patients proceeded with the second-stage reconstruction until routine blood investigations indicated normalization of C-reactive protein and erythrocyte sedimentation rate. After confirmation of normalization of laboratory values, we perform the second stage of the procedure including removal of bone cement and grafting. There was no need for additional debridement before performing the second stage due to subsequent elevation of laboratory values in these series.

Full weight bearing as tolerated was initiated at 12-week follow-up. Clinical and radiological assessment of patients was reviewed regarding defect size, presence of infection, spacer-time, time to full weight bearing, time to consolidation, necessity of reconstructive soft-tissue procedures, and complications (Table 1). The bone defect was considered to have healed when radiography revealed that there was uniform consolidation of the graft without translucent lines in the segment or the graft-host interface and corticalization in three out of four cortices, and when there was no pain on weight bearing.

RESULTS

The patients had undergone an average of 2.8 surgical procedures (range, 1–6) before the induced membrane technique.

Table 1. Patient demographics and clinical details of fractures

Patients, n	11
Male	11
Female	None
Mean age in years (range, SD)	40.7 (25–63, 12.1)
Etiology of the fracture	
Vehice accident	6
Gunshot inury	5
Location of fractures	
Proximal tibia	1
Tibial diaphysis	6
Distal tibia	4
Gustilo-Anderson; grade, n (%)	IIIA: 6; IIIB: 5
Fixation method, n (%)	
Tibial intramedullary nail	9
Plate	2
Pervious surgeries	2.8 (1–6)
Soft tissue reconstruction	
Free flab	3
Transposition flab	4

N: Number; SD: Standard deviation.

A mean of 44.8 months (range, 18–100 months) elapsed from the prior surgery to enrollment at our facility. Nine patients were treated at outside institutions before presentation to our institution. Two fractures were treated with a locking plate, whereas nine were treated with a tibial intramedullary nail. The mean follow-up period was 24.6 months (R: 13–40, SD: 7.8). The mean time interval between the first and second stages was 7.35 weeks (R: 6–10, SD: 1.2). The average length of the bony defect after debridement was 51 mm (R: 25–98, SD: 2.4).

Demographic and clinical details of the patients are shown in Table 1. Nine fractures out of 11 progressed to union at an average of 8.1 weeks (R: 8-12, SD: 1.6) in this series. Repeated debridement and cementing were needed in one patient to control infection. One patient had 3 times reoperation including repeated cementing and bone grafting procedures due to persistent infection and failed to obtain bony union. Eventually, below knee amputation was performed for the control of infection. One patient revealed repeated infection and bone (graft) resorption at the defect site at 18-month follow-up after a trauma. Vascularized bone graft was performed for this patient recently. Seven patients out of 11 needed flap surgery for soft-tissue coverage. Four patients received flap surgery during the first stage and three patients needed flap surgery after the second stage of induced membrane technique.

Overall, we encountered technique failure in two case. Failure was defined as recurrence of infection or absent bony union. No implant failure was noted.

DISCUSSION

Despite the technique of induced membrane was originally described using external fixation for bone stabilization, there is a trend in using nails and plates in the current literature.[11–13] In our experience, rigid fixation of the bone initially with a plate or preferably with an intramedullary tibial nail could be done at the first stage of the induced membrane technique. The bone defect is filled with bone cement and axial stabilization is obtained at the first stage permitting immediate patient mobility postoperatively.

Wang et al.[13] reported that induced membrane technique is an effective method in the treatment of extremity osteomyelitis with a total recurrence rate 12.26%. The authors reported slightly increased recurrence rate in patients with internal fixation at the first stage as 15.65%. Our results are well correlated with Wang et al. Only one patient out of seven infected non-unions treated with intramedullary nailing at the first stage revealed persistent infection in this series. Intramedullary nail also reduces the volume of graft needed at the second stage and does not seem to affect the consolidation process adversely. Besides, we think that it is feasible not to change the stable implant in atrophic non-unions where skeletal stabilization was previously performed with a nail or a plate. Induced membrane technique can be done on a stable previous implant which reduces the operation time and possible complications significantly unless the presence of an ongoing infection.

Masquelet et al.[4,9] stated that bone grafting should only be done when the healing of the infection and the perfect healing of the soft tissues, notably when a flap was required. Usually, the suggested time between the two stages ranges from 6–10 weeks. We agree with that soft-tissue reconstruction (flap surgery) should be done at the first stage of induced membrane technique. Thereafter, bone grafting can safely be done at the second stage without damaging the flap. However, we had three patients with compromised soft tissue after bone grafting procedures. Flap surgery was successfully performed after debridement and soft-tissue reconstruction obtained without violating the excising membrane and causing any adverse effect in the healing process of the fracture. One of the most important challenges in this series was the necessity of additional operations for soft-tissue reconstruction. Seven patients received flap surgery for soft-tissue coverage indicating the complexity of treating these patients. Morris et al.[14] reported mixed results in their series presenting worse results for the patients initially treated in smaller hospitals. Overall, induced membrane procedures are laborious on tibia compared to other long bones and have the disadvantage of facing many complications regarding the infection control, obtaining bony union, and also soft-tissue coverage.[15]

All patients underwent second stage surgery before 10 weeks in our series. We also observed clinical and laboratory control of infection before bone grafting surgery. Out of seven infected non-unions five healed without infection recurrence. Below knee amputation was needed to control persistent infection for one patient after repeated induced membrane procedures. The bony defects preoperatively were comparatively large and over 8 cm in these two patients. Larger bone defects needed to be filled mostly with commercially bone graft materials because of the limited amount of autograft obtained. This might have played an important role in failure of these cases.

Masquelet et al.[4,9] suggest to put drainage inside the membrane to prevent partial loss of graft due to hematoma obliging a surgical drainage. We did not use suction drainage in any patients and we do not think that it is mandatory. The authors also suggested that recovery of weight bearing should be progressive and is acquired within 6–7 months after the grafting procedure. However, we initiated weight bearing partially at post-operative 8 weeks and allow full weight bearing as tolerated with crutches at 3 months in our series. We did not observed pain at the fracture site in any patient at 3-month follow-up after weight bearing. Our results are well correlated with Morwood et al.[12] The authors reported 2.3 versus 3.9 months for full weight bearing time when using an intramedullary nail for stabilization as compared to a plate fixation.

We think that clinical consolidation occurs before radiological consolidation in these patients. We may speculate that partial weight-bearing with crutches after 2 months and full weight bearing as tolerated at 3-month follow-up does not interfere with bone consolidation.

This study is a retrospective case series with a relatively few patients presenting our clinical experience. We acknowledged this limitation as larger prospective studies are needed for meaningful conclusion being drawn. On the other hand, the key strength of this study is the inclusion of a homogeneous population with Grade III open tibial fractures who all underwent definitive reconstruction by Masquelet technique after failed surgical interventions.

Conclusion

This present series demonstrates that Masquelet technique led to satisfactory bone healing in the treatment of complex tibial non-unions after failed surgeries for Grade III open fractures. One advantage of the Masquelet technique is that it does not preclude other techniques that should it fail (burning the bridges). The procedure can also be done on previous stable implants. Repeated debridement and reoperation with Masquelet technique are also an option when infection reoccurs.

Ethics Committee Approval: This study was approved by the İzmir Kâtip Çelebi University Faculty of Medicine Non-Interventional Research Ethics Committee (Date: 06.02.2019, Decision No: 43).

Peer-review: Internally peer-reviewed.

Authorship Contributions: Concept: C.K.; Design: C.K.; Supervision: C.K.; Resource: N.Ö., A.R.; Data: N.Ö., A.R.; Analysis: N.Ö., M.T., A.R., C.K.; Literature search: N.Ö., M.T., A.R., C.K.; Writing: M.T., İ.A., C.K.; Critical revision: M.T., İ.A., C.K.

Conflict of Interest: None declared.

Financial Disclosure: The authors declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Tip III açık tibia kırıklarında başarısız cerrahi girişimler sonrası gelişen kaynamamalarının Masquelet tekniği ile tedavisi

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AMAÇ: Açık tibia kırıkları sonrası izlenen kaynamama çok ciddi bir komplikasyondur. Bu çalışmada açık tibia kırığı sonrası kaynamama gelişen hastaların tedavisinde uygulanan indükte membran tekniğinin etkinliği incelenmiştir.

GEREÇ VE YÖNTEM: Açık tibia kırığı sonrası kaynamama izlenen on bir erkek hasta çalışmaya alındı. Hastaların ortalama yaşı 40.7 (25–63) idi. Tüm hastalara Masquelet tarafından tanımlanan indükte membran tekniği ile kemik rekonstrüksiyonu uygulandı. Ameliyatta öncelikle kemik defektler polimetilmetakrilat çimento spacer ile dolduruldu. Ameliyat sonrası ortalama 7.3 (6–10) haftada spacer çıkarılarak kemik graftleme uygulandı. Kaynama zamanı, tam yük verme zamanı ve oluşan komplikasyonlar değerlendirildi.

BULGULAR: Hastaların ortalama takip süresi ikinci aşamadan sonra 24.6 (13–40) aydı. Radikal debridman sonrası kemik defektlerinin ortalama uzunluğu 51 mm (25–98) idi. Dokuz hastada (%81) kırık iyileşmesi görüldü. Cerrahinin ikinci aşamasından sonra kemik kaynamasının iyileşmesi için gereken ortalama süre 8.1 (8–12) hafta idi. Hastaların, 12 haftada tolere edebildiği şekilde tam yük vermesine izin verildi. İki hastada kemik kaynaması ve enfeksiyon kontrolü sağlanamadı. İnatçı enfeksiyon nedeniyle bir hastada diz altı amputasyon uygulandı. Diğer hastada ise kemik kaynamaması nedeniyle vaskülarize kemik grefti yapıldı.

TARTIŞMA: İndüklenmiş membran tekniği, başarısız açık kırık tedavisi sonrası oluşan tibial kaynamamalarının tedavisinde güvenilir ve tekrarlanabilir bir tedavi yöntemidir. Buna rağmen büyük kemik defekti olan enfektif kaynamamış kemik kırıklarında kaynama ve enfeksiyon kontrolü öngörülemeyebilir.

Anahtar sözcükler: Açık kırık; indükte membran; kaynamama; Masquelet tekniği.

Ulus Travma Acil Cerrahi Derg 2022;28(8):1180-1185 doi: 10.14744/tjtes.2021.36768