ORIGINAL ARTICLE

Management of Infected Nonunion of the Forearm by the Masquelet Technique

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Abstract

Purpose: Infected nonunion of the forearm bones is a challenge for the orthopedic surgeon on several fronts. The forearm itself is unique as the difficulties include the relation between restoration of shaft length with the anatomy and long-term functional outcome of adjacent joints, and the risk of elbow and wrist stiffness related to prolonged immobilization. The problem of infection is complex due to the presence of bone necrosis, segmental bone loss, sinus tract formation, fracture instability, and scar adhesion of the soft tissues. The ideal management method for these situations is still debated.

Materials and methods: We used the two-stage-induced membrane technique devised by Alain Masquelet for the management of these infected nonunion of 12 forearm bones.

Results: All 12 bones united uneventfully. The bones united in a period ranging from 6 to 12 months with a mean of 7.8 months.

Conclusion: Our results show that this technique addresses several of the challenges pertinent to the forearm nonunion simultaneously and results are uniformly predictable.

Keywords: Bone grafting, Infected nonunion, Masquelet technique.

Strategies in Trauma and Limb Reconstruction (2019): 10.5005/jp-journals-10080-1411

Introduction

The surgical treatment of diaphyseal forearm fracture nonunions remains a therapeutic challenge for orthopedic trauma surgeons. Key to success in the management of these demanding conditions is to develop a comprehensive treatment concept which considers the forearm and its adjacent joints, the elbow, and wrist, as a complex functional unit.[1,2] Nonunions of the radius and ulna shaft cause a severe anatomic and functional impairment, related to disturbance of the interosseous membrane and dysfunction of the adjacent joints, elbow, and wrist.[3–6] Infection complicates the nonunion significantly. Infected nonunion of the forearm is relatively uncommon. The problem is complex due to the presence of bone necrosis, segmental bone loss, sinus tract formation, fracture instability, and scar adhesion of the soft tissues.[7,8]

There have been extensive developments in the reconstruction of defects including (1) distraction osteogenesis, (2) structural auto/allografts, (3) titanium cages and cancellous autograft, (4) polymeric membranes, and (5) free microvascular fibula transplant.

French surgeon Alain-Charles Masquelet developed the Masquelet technique which involves a staged procedure in which a temporary skeletal stabilization is paired with implantation of an antibiotic spacer and left in place for 6–8 weeks, during which time, a "pseudomembrane" forms around the cement spacer. Addition of antibiotics, theoretically, increases the chance of eradication of infection. During the second stage of the procedure, the pseudomembrane is incised, the antibiotic spacer removed, and the bone graft is placed.[9–11]

We used the Masquelet technique in 12 infected forearm nonunions where the defects post-debridement ranged from 3.5 to 7 cm. This paper presents the results and complications of these 12 cases.

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How to cite this article: Dhar SA, Dar TA, Mir NA. Management of Infected Nonunion of the Forearm by the Masquelet Technique. Strategies Trauma Limb Reconstr 2019;14(1):1–5.

Source of support: Nil

Conflict of interest: None

Materials and Methods

Surgical Technique

The infected area was exposed and the hardware removed. The dead and devitalized bone was debrided until bleeding bone with punctate bleeding was exposed Paprika sign. All bone ends were made transverse. The unhealthy soft tissue was removed along with sinus tracts. The defect was stabilized by a plate and screws. The initial five cases were stabilized by conventional dynamic compression plates while we used locking plates in the last seven cases. We attempted to get a six cortex purchase on both sides of the fracture in all cases but had to compromise in three cases where the distal fixation was restricted to four cortices due to the short remaining length of the bony fragment. This was the main reason that we shifted to locking plates in the latter half of the series. In cases with any kind of doubt about the clearance of the infection, we repeated Gram staining during the procedure to ensure proper debridement. The antibiotic cement molded in the shape of the defect was placed in the gap with some degree of wrap over the debrided bone ends. The wound was carefully closed over the cement and the plate (Figs 1 to 4).

Fig. 1: Debridement with plating. Cement has been placed in the defect. The Masquelet membrane after cement removal

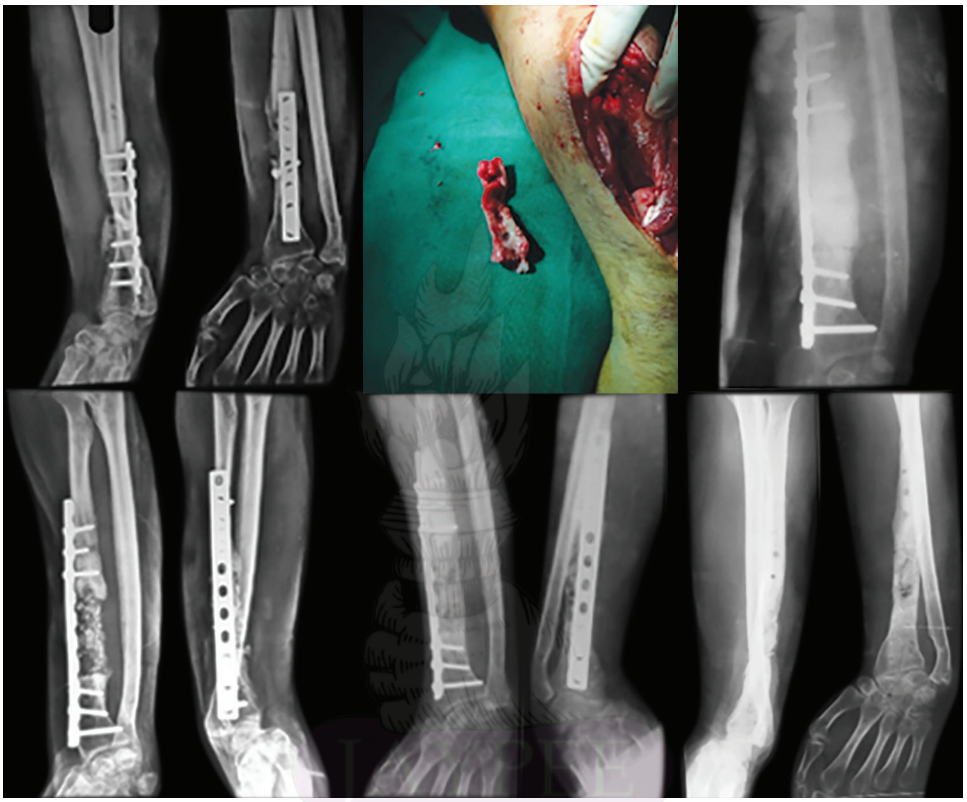

Fig. 2: Infected nonunion of the radius. The plate was removed and the sequestrated fragment was removed. Cement placed in the defect. Initial postoperative radiograph followed by union. Hardware was removed at 2 years follow-up. The patient did not agree to a procedure for the distal radioulnar joint as his hand function was good

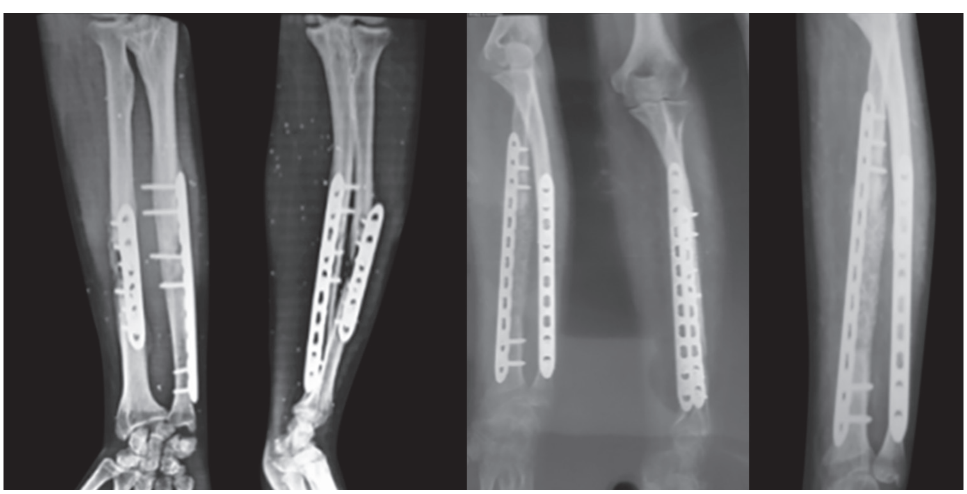

Fig. 3: Infected nonunion of the radius. The radiograph of the postoperative phase after the second stage bone grafting. Union at 6 months

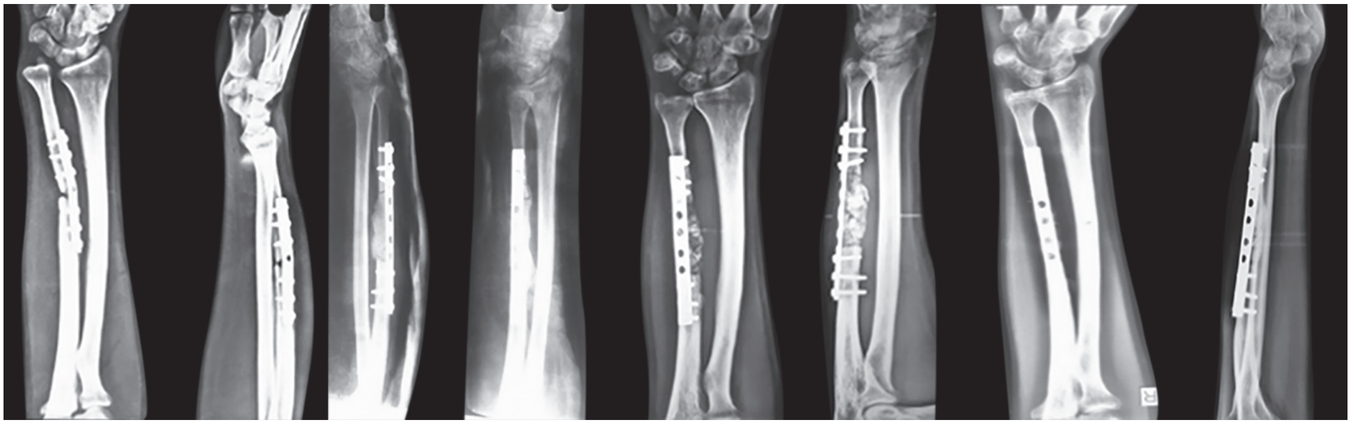

Fig. 4: Infected nonunion of the ulna. Cement placement with fixation. Grafting followed by union at 1 year follow-up

Six weeks after the first procedure, the cement spacer was removed and the ends of the bone were debrided and decorticated. The cement membrane was carefully preserved elsewhere. The graft obtained from the iliac crest was morsellized and placed in the gap. The soft tissue was carefully closed over the graft and the biological membrane creating a closed biological chamber.

Postoperatively, we put all patients on antibiotics based on the culture report, which was changed if the intraoperative material that had been sent for culture grew something else. The antibiotic was continued for 6 weeks.

The patient was placed in a splint for 6 weeks with a careful range of motion being instituted after 2 weeks. Radiological follow-up was done 2 monthly for 6 months and thereafter on a monthly basis.

Results

Twelve cases were taken up for study. There were 11 males and 1 female. The average age of the patients ranged from 19 to 56 with an average of 37.91 years. The right forearm was involved in seven cases and the left one in five cases. The duration of the infected nonunion ranged from 6 to 18 months with an average of 10.25 months. The culture was obtained from the tissue around the nonunion site in all cases by ultrasound-guided aspiration. The culture grew *Staphylococcus aureus* in six cases, *Escherichia coli* in four cases, *Klebsiella* in one case, and one case showed a mixed growth. According to the sensitivity report, vancomycin was used with the cement in seven cases and tobramycin in five cases. In all the cases, the hardware was removed during the first stage and extensive debridement was done. All cases were fixed at the time of debridement with plates. The defect created ranged from 3.5 to 7 cm with a mean defect of 5 cm. The range of motion improved in all the cases with the wrist flexion ranging from 40° to 60° and the wrist extension ranging from 45° to 60° at the final follow-up. The range of pronation ranged from 50° to 85° and the pronation from 60° to 85°.

All patients went on to uneventful union. As there are no clearly defined parameters of union in the Masquelet method, we defined union as a stage when two radiologists and two orthopedic surgeons (apart from the operating surgeon) agreed on the radiograph having reached a stage of union. The bones united in a period ranging from 6 to 12 months with a mean of 7.8 months. At present, the follow-up of our first case is more than 4 years and none of the cases has a follow-up of less than 1 year (Table 1).

Discussion

Forearm nonunions are uncommon but severely disabling and challenging to treat.[12] Treatment of diaphyseal forearm nonunions differs from that of other type of diaphyseal nonunions because of the intimate relationship between the radius and the ulna and their reciprocal movement. Other limiting aspects of this particular anatomic location include the relation between restoration of shaft length with the anatomy and long-term functional outcome of adjacent joints, and the risk of elbow and wrist stiffness related to prolonged immobilization. The reported outcomes are moderate at best.[13]

Motor vehicle trauma and injuries sustained in various conflicts are increasing. A high proportion of these injuries will be associated with environmental foreign body and bacterial contamination. Consequently, the management of these injuries is difficult and is still an evolving science.

Nonunion in the presence of infection complicates the management in several ways. The presence of bone necrosis and sequestrae, segmental bone loss, sinus tract formation, fracture instability, soft tissue compromise, and scar adhesion of the soft tissues make management even more difficult.[8]

The prerequisite for the management of any infected nonunion is debridement and excision of infected tissues. This has to be combined with prior restoration of a vascular soft tissue envelope.[12,14–16]

Intramedullary nailing has been recommended as a treatment method for nonunion despite 7% nonunion rates reported for primary nailing.[17] Weiland has recommended the use of vascularized autografts for the management of bone defects.[18] Autologous fibular grafting is technically demanding and has potential donor site morbidity, but has a high rate of success.[19] Jupiter reported 11% of the development of nonunion of the graft to the host site following compression plating and grafting with iliac crest autograft.[20] We have used the ilizarov method with success rates in the forearm being lower than other long bone areas.[21]

Traditional bone graft techniques are limited by uncontrollable graft resorption, even when the recipient site is well vascularized.[22] Masquelet technique uses antibiotic-impregnated cement beads or spacers for local antibiotic administration to the 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. Masquelet and Begue

Table 1: The clinical parameters of the patients

S no	*Age/sex*	*Side/bone*	*Culture*	*Duration (minute)*	*Defect created (cm)*	*Antibiotic used*	*ROM Flex/ext [wrist]*	*ROM Sup/pron*	*Union (m)*
1	28/M	R/radius	Staph.	6	4	Vancomycin	45–0–50	45–0–80	6
2	36/M	R/radius	Staph.	8	6	Vancomycin	40–0–60	80–0–80	8
3	37/M	L/ulna	Staph.	12	5.5	Vancomycin	50–0–55	75–0–80	8
4	19/M	R/ulna	*E. coli*	14	6	Tobramycin	60–0–60	80–0–70	12
5	38/F	L/ulna	*E. coli*	6	4	Tobramycin	60–0–60	60–0–50	6
6	63/M	R/radius	Staph.	7	3.5	Vancomycin	50–0–55	70–0–65	6
7	42/M	L/radius	Klebs.	18	6	Tobramycin	50–0–55	75–0–70	9
8	23/M	L/ulna	Mixed	7	6	Vancomycin	60–0–60	80–0–80	9
9	31/M	R/ulna	Staph.	18	7	Vancomycin	55–0–55	75–0–75	12
10	54/M	R/radius	*E. coli*	9	4	Tobramycin	45–0–45	60–0–60	6
11	56/M	R/ulna	Staph	6	4.5	Vancomycin	50–0–45	55–0–70	6
12	28/M	L/ulna	*E. coli*	12	5	Tobramycin	60–0–60	80–0–85	6

proposed that this membrane prevents graft resorption and improves vascularity and corticalization.[10]

It has been described that, after the initial placement of the antibiotic-impregnated spacer, an interval of 4–5 weeks is needed for the development and maturation of a biologically active membrane that is suitable for grafting. The spacer also maintains the defect and inhibits fibrous ingrowth.[11]

The spacer results in a pseudomembrane, which has been shown, in rabbits, to secrete vascular endothelial growth factor (VEGF), transforming growth factor-B (TGF-B), and BMP-2. This stimulates bone formation.[23]

After debridement, all our cases had a critical-sized defect. A critical-sized defect is defined as the smallest bony defect that does not heal spontaneously and is generally defined as 6 cm. However, it is more logically defined in the context of the bone, with a critical-sized defect defined by multiplying the shaft diameter by 2.0–2.5.[24]

The preferred type of fixation in most cases of pseudoarthrosis is the external fixator. However, this type of fixation does not always provide rigid enough fixation throughout the process of healing and fixation of the radius proximally is an issue as the posterior interosseous nerve is likely to get damaged. Therefore, we used a plate to stabilize the defect and found the results to be good without any persistent and recurrent infection at the time of final follow-up. The use of a tibial nail from the beginning, along with the Masquelet procedure, has been reported.[25]

The graft material used in such cases is of several types. Recently, the reamer irrigator and the aspirator have been used to harvest graft from the femur. However, this graft is dense and can cause irregular union. Currently, the gold standard for graft material is the cancellous graft obtained from the iliac crest.[10,26,27] This graft provides osteoinductive, osteoconductive, and osteogenic properties.[28] However, the large volumes of graft material required to fill critical-sized segmental defects lead to an increase in the incidence of comorbidities associated with the harvesting of large amounts of autograft, its exclusive use in these scenarios can often outweigh the benefits. Materials used to help decrease the reliance on autograft are mostly osteoconductive, they can, however, be combined with proteins such as bone morphogenic proteins (BMPs).[29,30] Complications have been reported with the addition of inductive proteins into graft materials including the need for supraphysiologic concentrations, ossification in adjacent unwanted sites, the inability to control their timing of release, and a potential risk of cancer.[31] Luo et al. studied the Masquelet technique in seven cases and reported a 100% union rate. They mentioned that the technique was essentially meant for the lower limb, but produced excellent results in the upper limb too.

In all our cases, we found that we could obtain enough graft from a single iliac crest to fill the defects which ranged from 3.5 to 7 cm. This is easily achieved in the forearm than in other long bones due to the difference in the mass of the bones.

Conclusion

Infected nonunion of the forearm bones is a difficult problem and the treatment options continue to evolve. The Masquelet procedure is an effective procedure for such situations. On the basis of our findings, we would suggest that it should be the frontline procedure for the management of the infected nonunion of the forearm bones.

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