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Reconstruction of septic diaphyseal bone defects with the induced membrane technique

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KEYWORDS

bone defects
septic diaphyseal defects
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induced membrane technique

ABSTRACT

Septic segmental bone voids of the diaphysis are difficult to manage. The induced membrane technique by Masquelet has been successfully used to reconstruct segmental defects more than 20cm.
Our article describes a series of 13 cases with extensive posttraumatic bone loss of the metatarsal, tibial, femoral and radial bones after septic injuries followed by multiple surgical interventions. Antibiotic-impregnated polymethyl methacrylate (PMMA) cement spacers were implanted after successful eradication of bacterial infections of soft tissue and bones. After a mean of 9.8 weeks, body-induced membranes were established and the cements spacers removed. To fill up the bone void, cancellous bone autografts were implanted into the membranes.
The follow-up examination after 24 months revealed bony union in all cases and favorable functional results.
The induced membrane technique has shown to be effective in treating bone defects of upper and lower extremity bone defects.

Introduction

Treatment of diaphyseal bone defects after extensive trauma still is a therapeutic challenge. Surgical eradication after contaminated open fractures or septic osteosynthesis regularly mandates implant removal and wide excision of the affected bone mass, that leads to large gaps and soft tissue damage [1].

Multiple methods are described to treat large bone gaps, including microsurgical reconstruction with vascularized bone grafts and flap coverage, bone transport with external fixators and megaprosthesis [2-10]. Using internal fixation methods as intramedullary nails or plates to stabilize bone gaps after septic conditions increases the risk for complications [11,12] Recurrent infections after internal fixation may lead to even larger defects [13]. A two-staged approach using the induced membrane technique by Masquelet has been developed to treat long diaphyseal defects by stabilizing the bone with external fixation, filling the void with a tubular polymethyl methacrylate (PMMA) cement spacer to activate formation of a pseudosynovial membrane and replacing the spacer after three months with extensive fresh autologous cancellous bone grafts [14]. Initially, tibial diaphyseal defects were treated; later, tubular bone defects of the metatarsus, femur, humerus and forearm were stabilized successfully [15-20]. Recent in-vivo analysis of the membrane showed high degree of vascularization, production of osteoinductive factors (BMP-2) and growth factors (VEGF, TGFß1) [21,22]. The osteoinductive potency of this technique can achieve bone formation to fill voids of up to 25cm [23,24].

Common indications for the application of the induced membrane technique are mainly aseptic, posttraumatic bone voids [14]. Also congenital pseudarthrosis of the tibia had been successfully treated [25]. Only few data exist on septic conditions, where bacterial inflammation, multiple surgery and soft tissue damage is the chief cause of bony non-unions [26-28].

Reluctance to use this technique may be explained by a possible risk of recurrent infections when using inert spacer materials and autologous cancellous bone [29]. The concept of using external fixation and cement spacers containing specific antibiotics to help eradication and prevent relapse of septic conditions may be suitable in patients with large bone gaps after osteitis [30].

The aim of this study was to present radiographic and functional results of patients treated with the two-staged induced membrane technique after using antibiotic-impregnated bone cement to fill the osseous void in diaphyseal defects.

Materials and Methods

Between 2010 and 2014, 13 patients from two institutions with septic diaphyseal bone defects were treated with the two-staged

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induced membrane technique. 8 cases suffered from open fractures. The patients chosen for this study can be classified as A2 or B2 with defect sizes over 5cm and quiescent/non-draining or active/draining osteitis according to Jain et al. [31]. All patients underwent a rigorous eradication treatment with i.v. antibiotics, multiple surgical interventions, including soft tissue debridement, removal of infected bone and stabilization with external fixators (Table 1). A mean of 4.7 operations were undertaken prior launching the induced membrane technique. The presented treatment protocol was similar to previously published protocols [27].

All but one patient were males, with a mean age of 41.4 years (range 16 – 69 years). The mean defect size was 8.08cm (range 5.5 – 14.5cm), the location of the defect zone and the microbiological findings are presented on Table 1.

External fixators were kept in place to stabilize the affected bones. After negative microbiological findings, the decision was made to fill the bone void with PMMA cement spacers (Biomet, Haereus), which were antibiotic-impregnated with Gentamycin or self-made with Gentamycin and Vancomycin (max. 10% of volume). The spacers were formed as cylinders with sleeves at the end to embed the tubular fragments of the bone.

After 9.8 weeks (range 8 to 14 weeks), the spacers were explanted and fresh autologous cancellous bone grafts were implanted from the iliac crest. In three cases, adjunct BMP-7 (Eptotermin alfa, 3.5mg, Osigraft®, Olympus Biotech Int., Dublin, Ireland) was added to the bone grafts. External fixators were kept in place, except in those cases (n = 5), where pin tract infections were present or other complications were noted. In all these cases, the external fixator was removed and internal osteosynthesis (intramedullary nail, plates) were applied.

The follow-up examinations were carried out at a 2-week interval during the first stage of the treatment with the bone cement. Subsequently, every 6-weeks intervals and until bony union was established. Parameters assessed were mainly radiological features of evolution of bony union. Bony union was defined as three-sided cortical bridging on two perpendicular X-rays of the fracture zone. Clinical union was defined as full weight bearing with a visual analogue score (VAS) for pain less then 2 (VAS = 0-10; 0= no pain, 10= severe pain). At the final follow up the range of motion of the joints above and below the affected extremity were evaluated by means of range of motion. The opposite limb site was used as a control.

The mean follow-up interval was 13 months (range 9 to 24 months). Descriptive statistics were carried out in a retrospective study design.

Table 1
MRSA: Methicillin-resistant Staph. aureus., CNS: Coagulase-neg. Staph. epidermidis.

	number of cases
localization	
• tibia	5
• femur	3
• fibula	2
• radius	1
• metatarsus	2
microbiol.	
• Staph. aureus	4
• MRSA	3
• Enteroc. faecalis	3
• Enterobact. cloacae	1
• CNS	2
defect size	
• 5 - 7cm	6
• 7 - 10cm	5
• > 10cm	2
osteitis	
• draining	4
• non-draining	9

Results

During the first interval of the treatment, we did not identify any complications at the bone void, the soft tissue and the pin tracks of the external fixators. The leukocytes count, the C-reactive protein levels and the erythrocyte sedimentation rate were normal and did not show any recurrence of infection. The clinical parameters were the absence of infections, such as discharge, red and warm skin, swelling and pain.

During the second interval of treatment, after explantation of the cement spacer and the implantation of bone grafts, we found five complications. In two cases, pin track infections of the external fixators were observed, in one case, we noted deviations of the long axes of the bones mandating re-operations in all cases. Internal fixation with plates and intramedullary nails were applied (Fig. 1 and 2). We decided to change to internal fixation methods, depending on the localization and the stability. No signs of recurrent infections were found during the last follow-up examinations.

In all cases of the lower extremities we found a gentle osteopenia of the extremity, because of the non-weight bearing of the affected extremity until bony union.

Radiographic Results

Radiographic confirmation of bony union was found after 18.92 weeks (range 12 – 24 weeks). The re-modelling of the defect was less in cases with very large defects. No ossification in the soft tissue were detected. Of interest, we did not observe any deformity of the adjacent joint axes after bony union.

Functional Results

The adjacent joints were handicapped in the function in two cases. In the first case we reconstruct a very large defect of the

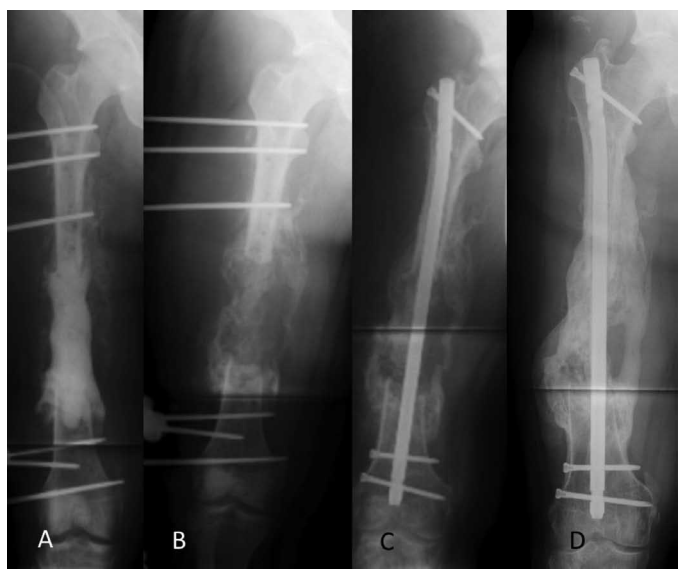

Fig. 1. Bone void of 14.5cm after traumatic osteitis with MRSA of the femoral diaphysis, (A) Implantation of the tubular PMMA-cement spacer (B) removal of the spacer and implantation of bone graft after 8 weeks, (C) intramedullary nail implantation after 8 weeks. (D) Bony union after 24 months.