Case Report

Reconstruction of a tibial diaphyseal bone defect using the Masquelet technique. A case report

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A R T I C L E   I N F O

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A B S T R A C T

Segmental bone defects in the lower limb may be treated by distraction osteogenesis, vascularized bone grafts, allografts, metal prostheses or amputation. The induced membrane technique, introduced by Masquelet, consists in induction of a pseudo-synovial membrane by local tissue reaction to a synthetic spacer, followed by application of bone allograft to the resulting cavity.

This article describes the case of a 34-year-old male with severe multiple trauma. The patient's injuries included a Gustillo-Anderson type IIIa open tibial shaft fracture, treated by means of the fix and flap technique. Application of the fix and flap technique resulted in a 7 cm bone defect that was filled using the induced membrane technique.

This case report includes a review of the existing literature and a description of the modifications that have been proposed to the original Masquelet technique, including the use of antibiotic-impregnated cement, extension of the interval between the two surgical stages, and the use of alternative osteosynthesis materials.

Introduction

Small segmental bone defects can be treated by bone grafting and stabilization of the grafting site. However, such a treatment is not indicated when the defect exceeds 4 or 5 cm as resorption and revascularization by creeping substitution often results in a feeble, fracture-prone reconstruction. The gold standard for the management of larger defects is distraction osteogenesis, with more complex techniques such as the use of vascularized bone grafts being used in selected cases [1].

Another valid alternative is the induced membrane (IM) technique developed by Masquelet [2–4]. This is a two-stage procedure where, following induction of a pseudo-synovial membrane through the reaction of local tissue to a cement spacer, filling of the cavity is carried out by application of bone allograft. The membrane constitutes a biological chamber that acts as a barrier to prevent resorption and as a bioreactor, providing a well-vascularized environment filled with growth factors [5–7]. The IM technique is simple, provides satisfactory results, and does not require long-term external fixation. In addition, healing times tend not to depend on the size of the defect [8].

This study describes a case where the IM technique was used successfully to reconstruct a 7 cm-long segmental bone defect. Details are provided of the technical aspects of the procedure and a discussion on the advantages and disadvantages of the technique is included (Table 1).
Case report

The patient was a 34-year-old male with no medical history of interest who was admitted to the emergency department with multiple severe injuries sustained in a motorbike accident. The most serious injuries were located in the left lower limb and included a femoral shaft fracture, a Schatzker type I tibial plateau fracture, and an open Gustilo-Anderson type IIIa tibial shaft fracture [9,10].

Following resuscitation, a damage control surgery was performed [11], which included aggressive debridement and stabilization of all the fractures present by means of external fixators (Hoffmann II; Stryker Corporation, Kalamazoo, USA) (Fig. 1). The week after, definitive treatment of the femoral and tibial plateau fractures was administered by placing an intramedullary nail (T2; Stryker Corporation, Kalamazoo, USA) and by practicing an open reduction and internal fixation (ORIF) procedure (Axsos; Stryker Corporation, Kalamazoo, USA), respectively (Fig. 2). As the poor condition of the soft tissues precluded the use of internal fixation in the tibial shaft fracture, it was decided to keep the external fixator in place.

Three weeks later, a fix and flap procedure [12] was performed in the tibial shaft fracture, aggressively debriding the wound and covering it with a free anterolateral thigh flap [13]. The fracture was stabilized using a straight plate (Stryker Corporation, Kalamazoo, USA) and the cortical defect was filled with Cerament G (Bonesupport Holding AB, Sweden) (Fig. 3). The postoperative course was satisfactory. Hip and knee mobilization exercises were introduced at two weeks but no weightbearing was allowed.

Healing of both the femoral and the tibial plateau fractures progressed uneventfully. However, the tibial shaft fracture failed to heal (Fig. 4). The pseudoarthrosis resulted in breakage of the hardware at 7 months from surgery. As a result, the patient had to be subjected to a revision surgery where the hardware was removed and the first stage of an IM technique was performed on the bone defect [2-4].

The patient was placed in the position required for standard intramedullary nailing and a tourniquet was applied to his thigh, which would only be inflated if complete hemostasis could not be achieved in the surgical field [14]. Following debridement of the area, a 6 cm-long bone defect was uncovered. Once the required samples for laboratory analysis were collected, the defect was filled with VancogenX bone cement (Tecres, Sommacampagna, Italy). The spacer was placed slightly beyond the ends of the bones to ensure that the membrane covered an area larger than that occupied by the defect and to avoid the formation of fibrous tissue at the bone-cement interface [14]. Migration of the membrane was prevented with the help of a Steinmann pin (Fig. 5) and the surrounding tissues were protected from the exothermic reaction resulting from the curing of the cement by irrigation with saline solution [14].

The second surgical stage was carried out at 6 weeks. The patient was infection-free and in a satisfactory clinical condition. As was the case in the first stage, the tourniquet was applied to the thigh but not inflated. The surgical site was approached from the opposite side to the anastomosis of the vascular pedicle. After a careful longitudinal incision of the membrane, the cement spacer was exposed.

Table 1

| Week | Event |
|------|-------|
| 0    | Trauma |
| 0    | Debridement and damage control |
| 1    | Intramedullary nailing |
| 1    | Osteosynthesis to treat the tibial plateau fracture. |
| 1    | External fixation to treat the tibial shaft fracture. |
| 3    | Filling of cortical defect and diaphyseal plate fixation. |
| 5    | Hip and knee mobilization exercises. |
| 35   | Breakage of tibial shaft plate. |
| 35   | First stage of Masquelet procedure. |
| 41   | Second stage of Masquelet procedure |
| 53   | Progressive partial weightbearing |
| 73   | Discharge |

Discussion

Although bone transport is considered the gold standard for the treatment of segmental bone defects in the lower limb, other techniques have been proposed, also associated with satisfactory results. The orthopaedic surgeon must become acquainted with such techniques and be prepared to apply them. These include vascularized bone grafts, allografts, metal prostheses and amputation [1]. Another option is the IM technique, developed by Masquelet in the 1980's [2-4], which involves induction of a pseudo-synovial membrane through local tissue reaction to a synthetic spacer, followed by placement of a bone allograft in the resulting cavity.
Fig. 1. Postoperative X-ray after the initial damage control surgery.
Fig. 2. Internal fixation of the femur and the proximal tibia.
Fig. 3. Stabilization of the tibial shaft fracture by means of a plate.
Fig. 4. X-ray showing clear signs of tibial pseudoarthrosis.
This membrane is key for the success of the technique as it creates a biological chamber that serves a dual purpose. On the one hand, it prevents resorption of the graft, acting as a physical barrier [6]. On the other, it provides a vascularized environment rich in transforming growth factor beta (TGF-β), vascular endothelial growth factors (VEGF) and bone morphogenetic protein 2 (BMP-2) [5].

In the case described in this article, the decision to use the IM technique was based on several reasons. Firstly, there was a risk that the pins of the external fixator used for bone transport could transfix (and therefore damage) the previously implanted muscle flap. Moreover, as the wound had already been covered by the flap, the patient would not benefit from the histogenesis provided by the distraction osteogenesis procedure. Furthermore, the patient had been on treatment for several months already, and a 7 cm bone transport would require another 10 months of external fixation. Finally, the IM technique is simple [14] and has shown satisfactory clinical results, with healing rates (82.5%–100%) comparable to those of bone transport (83%–100%) and vascularized fibular graft placement (88%–100%), with similar complications rates [15].

As regards initial management of the patient, soft tissue coverage was performed later than required. After an immediate radical debridement, the flap should have been applied as soon as the patient was ready to tolerate it, which usually takes one week from injury at most [16]. In our case, this time period was largely exceeded given that the local conditions of the wound were too poor to guarantee viability of the graft. It must be said that the patient did not develop an infection as a result of this delay.

Another aspect to be mentioned is the use of antibiotic-impregnated cement. Although Masquelet did not recommend it on account of the potential negative effects of the antibiotic on the membrane's biological activity [2], animal studies have demonstrated that antibiotics do not undermine the membrane's osteogenic potential [17]. In fact, it seems that the roughness of the filling material exerts a greater influence on the quality of the membrane than the material it is made of [18]. Even if he did not recommend the use of cement, Masquelet himself admitted in an article that most scientific evidence is based on the use of antibiotic- or antifungal-impregnated cement [4].

An important technical consideration has to do with how much time must elapse before the second stage of the procedure, which should only be performed if the patient is infection-free. Otherwise, a new debridement must be performed that includes the removal of the induced membrane and the placement of a new spacer [4]. Fortunately, in our case this was not necessary and the second surgical stage could be performed at 6 weeks. This follows the recommendation of Masquelet and other authors, who consider that the second stage should ideally be performed at 4–8 weeks from the first stage to prevent the membrane from losing its osteogenic properties [2–4]. Other authors, on the other hand, consider that these properties can be preserved for up to 6 months [15]. At any rate, we were able to stay within appropriate safety margins.

Fixation was performed via intramedullary nailing. The absence of active infection and the use of wide spectrum-impregnated cement limited the risk of deep infection, one of the main perils (8%) of this technique [19]. Although Masquelet recognized that
Fig. 6. Second stage of the Masquelet procedure, showing the intramedullary nail and the graft.
Fig. 7. X-ray showing the situation two months after the second stage surgery.
external fixation has the advantage of allowing dynamization of the limb, in our case we were anxious to avoid potential damage to the flap and the discomfort caused by an external fixator. In our case, use of an intramedullary nail demonstrated a favorable risk/benefit profile.

Nonetheless, not all aspects of the IM technique are positive. A metaanalysis on the subject revealed that 18 % of patients require additional surgery, which is associated to an overall failure rate of 10,3 %. Sequelae include pseudoarthrosis (5,9 %), amputation (4 %) and persistent infection (8,9 %) apart from other complications, which may occur in up to 49,6 % of cases [8]. In addition, the incidence of graft donor site problems may be as high as 19 % in cases where the graft is harvested from the iliac crest [7].

In the case described in this study, the IM technique proved to be effective, providing satisfactory functional results and no complications.

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