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Masquelet's Technique for Management of Long Bone Defects: From Experiment to Clinical Application.

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Bone defect, of whatever cause, is clinically challenging to treat. Defects of up to 4.0 cm can be successfully treated with cancellous bone grafting. Large defects require more complex alternatives like, bone transport, vascularized bone grafting, allografts or fibular pro-tibia grafting. There are advantages and disadvantages to these techniques and patient's cooperation is critical for successful outcome. None of these treatment options are reliably successful. The Masquelet's technique is a viable option in the management of large defects. It is based on two principal steps: the formation of induction membrane and cancellous bone grafting. Defects as large as 25 cm can be successfully treated with this technique. The induction membrane is a viable tissue that plays a role in bone formation or incorporation. It has been demonstrated experimentally that the membrane contains elements that are important in bone formation and vascularization of cancellous bone placed inside the induction membrane. Research in still needed on this membrane in human subjects. Clinically the Masque let technique has been shown to be successful. The originator of the technique has the largest series to date plus the longest follow-up. Other clinicians have also shared their experience using the technique. Clinically more cases need to reported and guidelines established.

Introduction

Bone defects may result from a variety of causes. They may be due to trauma, bone infection, congenital defects or extensive excision of malignant tumours. Management of bone defects is very challenging. Small size defects can be easily managed by non-vascularized cancellous bone-grafting. The critical size for non-vascularized bone-grafting is 6.0 - 7.0 cm[1,2]. Larger defects require other options.

Surgical options available for managing large defects are; vascularized bone-grafts, bone transport, non-vascularized grafts, allografts and fibular pro-tibia grafting. Vascularized bone-grafting is technically demanding and require micro vascular surgical skills. The technique is reliable but the donor sites are limited[3]. The advantage is that the bone can be transferred together with soft tissue to cover local soft tissue defect. Bone transport is a well established technique for the management of very large bone defects. The procedure has a very high complication rate: up to 80%. Allografts complication rate is also high; may reach 50%[2].

Masquelet technique is a relative new technique used in the management of large bone defects. It is based on two principles or operative stages:

1. The formation of induction membrane. After bone debridement, the defect is filled with bone cement. The cement is kept for a period of eight weeks. This allows the formation of induction membrane (Figure 1A).
2. Cancellous bone grafting. After a period of eight weeks, the bone cement is gently removed. The defect is filled with cancellous bone graft (Figure 1 B) Defects as large as 25cm can be managed using the Masquelet technique[4].

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The purpose of this review is to review the experimental work on this technique, its clinical application and future direction.

Experimental Work

The first step in this technique is the formation of induction membrane. It forms around the bone cement. The membrane serves a very critical function: protection of cancellous bone graft from the body's immune system. This prevents cancellous bone resorption. This induction membrane has other features that may be important for bone union. Experimental work has indicated that the induction membrane is not inert. It is a living tissue that plays an important role in bone healing or union. Some of research work is discussed in this article.

The first stage in Masquelet's technique is mechanical: the bone cement provides additional support to the limb and maintain the defect. The primary stability is usually provided by an external fixator. Intramedullary device may also be used as a primary stabilizer. The induction membrane is formed at this stage.

The second stage is a biological one[4]. This is the stage that has been studied extensively in a large number of experiments. It has been demonstrated that periosteal flap wrapped around the cancellous bone exerts a protective effect against bone resorption in muscle tissue. The cancellous bone is capable of forming bone even without stress to the bone. But the cancellous bone will resorb if the recipient bed is poorly vascularized[5].

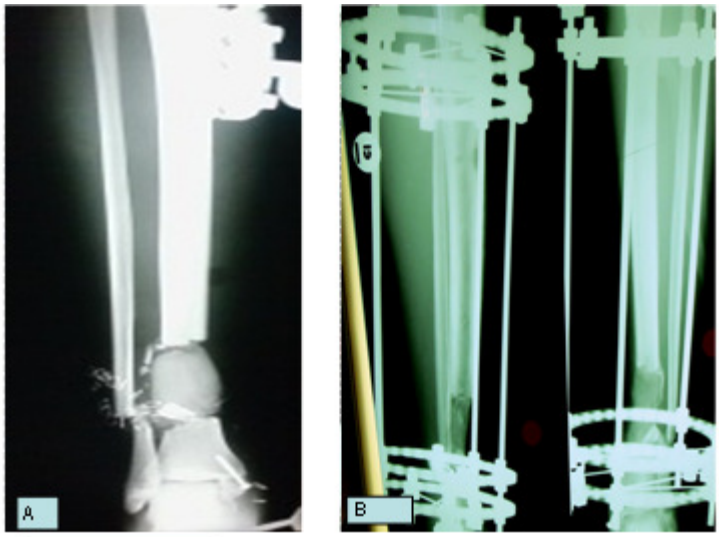

Figure 1.
The Patient with Communited Distal tibia and Fibular Fractures. After Bone Debridement, the Defect was Filled with Bone Cement (A). Radiographs Taken Four Months Later Demonstrate Cancellous Bone Incorporation. (B).

Gerber et al[6] showed in a sheep model that resorbable polylactide membrane also provides protective effect to cancellous bone and allow rapid and stable defect regeneration. They also showed that the structure of the membrane is important to allow growth and stability of the defect. They stated that the ideal pore size is 15 - 50 micrometre and 800 - 900 micrometre perforation or non-perforated[6]. This protective membrane does the following; prevents connective tissue infiltration, plays an important role in osteoconduction and functions as a bone-forming

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chamber[6,7,8]. The induction membrane has been shown to possess growth factors that are important for bone formation. Some of those factors isolated experimentally are: vascular endothelial growth factor (VEGF), transforming growth factor-beta-1 and bone morphogenetic protein -2 (BMP-2)[4,9]. The first two factors appear as early as two weeks. BMP-2 reaches its highest peak in 9 weeks. These factors are known to be important in bone formation, bone metabolism and remodelling[4]. There is a lack of similar studies in human subjects.

Clinical Application

Post traumatic segmental bone defects can have severe negative long-term impact on patients' lives[10]. Managing these defects can be very challenging and is still a debatable issue[11]. Reconstruction is more difficult and functional outcome is usually less satisfactory compared to bony outcome. The Ilizarov technique is the one commonly used to address intermediate and large bone defects. The technique is very demanding and patient's cooperation is critical. There is no single current technique that is reliably successful in the management of large bone defects[12]. The Masquelet technique does offer an alternative and a viable management strategy for large bone defects[13]. The technique was developed in 1986 to address defects larger than 15cm[11]. It was later established that it can successfully address bone defects as large as 25cm. It can be safely used in irradiated or infected areas provided the membrane is formed around the defect to protect and vascularize the bone graft[14].

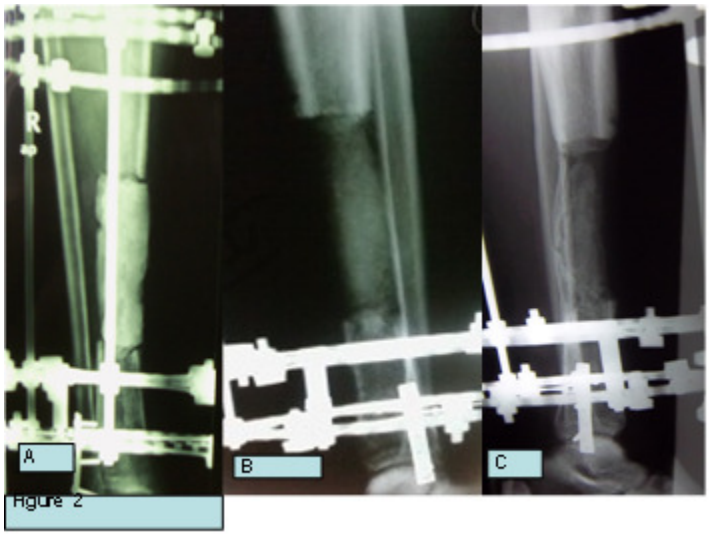

Figure 2. Radiographs of a patient who had Methicillin resistant Staphylococcus aureus (MRSA) infected non- union of the tibia. After bone debridement the defect was filled with vancomycin - impregnated bone cement (A). Infection recurred six months later. The cancellous bone graft was destroyed by infection as demonstrated by progressive bone resorption (B and C).

Most publications about the technique are from Europe, especially France. The originator of the technique has done over 30 cases and has the longest follow-up of up to 14 years[15]. Other publications outside France or Europe consist of few cases and case reports[14,16,17,18,] Some modifications have already surfaced; combination with the Ilizarov technique and/ or intramedullary nail[13,19]. The core concept is retained: the technique needs to have two operative

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stages[21]. There are pertinent clinical questions that clinicians need to ask when applying the technique:

When is the correct time for the patient to bear full weight especially in those where a fixator has been removed? Premature full weight bearing will lead to limb deformity.

What is the risk of infection in patients who had infected non-union and were treated with this technique? Cancellous bone graft infection can lead bone resorption and necessitates revision (Figure 2).

Harvesting large amount of cancellous bone is made easier with the Reamer Irrigation System (RIA) (Synthes[R], South Africa). Up to 90mm^3 of cancellous bone graft can be obtained by this technique.

Conclusion

The Masquelet's technique is a practical alternative in the management of bone defects. It has a relatively low complication rate. It does not 'burn bridges': other complex procedures may be done if the technique fails. Further clinical experience is needed.

Future Direction

Research in humans is needed to clarify the scientific basis of the technique. Clinically the number of publications about the technique is low. We need to know cases that are ideal for this procedure, complications, contra-indications and the results of long term follow-up.

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