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A pilot study: Alternative biomaterials in critical sized bone defect treatment

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ABSTRACT

Background: Critical-sized bone defects are a significant challenge with limited effective reconstructive options. The Masquelet Technique (MT) offers a solution to help restore form and function. Although this technique has produced promising results; a clear mechanism has not been determined. Theories include that the induced membrane has osteogenic potential or the membrane acts as a physical barrier to prevent fibrous tissue ingrowth. We hypothesize the induced membrane acts primarily as a physical barrier and that a synthetic non-biological membrane will allow a comparable amount of bone volume in the defect site.

Methods: Ten New Zealand rabbit forelimbs (n = 10) were divided into three study groups. A critical sized defect of 3.5 cm in the ulna was created. In the control group, a traditional MT was performed (n = 4). The experimental arm varied by replacement of the PMMA with a non-porous (n = 3) or porous (150um) (n = 3) polytetrafluoroethylene (PTFE) membrane filled with allograft. Micro-CT analysis was done to compare bone volume to tissue volume ratios (BV/TV). Defect sections were examined histologically with alkaline phosphatase (ALP), tartrate-resistant acid phosphatase (TRAP) and von kossa (VK) staining.

Results: MicroCT analysis comparing BV/TV between the control and experimental arms showed no difference. BV/TV of the MT was 7.77% ± 2.34 compared to porous 9.12% ± 3.66 and nonporous 9.76% ± 1.57 PTFE membranes (p1 = 0.761, p2 = 0.572, respectively). Histological sections from both samples stained for ALP and TRAP displayed osteoblastic and osteoclastic activity. There was a higher amount of ALP and TRAP positively stained cells near the native bone ends in comparison to the center of the defect, in both sample types.

Conclusion and significance: Replacing the induced membrane from the MT with a synthetic PTFE membrane illustrated that the membrane acts primarily as a functional barrier. Compared to the induced membrane, the PTFE membrane was able to display similar osteointegrative properties. These results allow for future optimization of the technique with the potential to further streamline towards a single stage procedure.

Introduction

Critical sized bone defect healing is one of the most difficult challenges in orthopaedic surgery. It is defined as a bone defect that will not heal without any surgical intervention, or in experimentally studies, it is defined as a defect approximately 2.5 times the diameter of the bone [1–4]. These defects can occur after acute trauma, chronic cases of nonunion, or oncological cases after bone resection [3,5–11]. As these defects arise in a large variety of orthopaedic cases, affecting both pediatric and adult patient populations, it is crucial to search for successful treatment options [5,12–14].

Critical sized bone defect treatment has previously been most completely treated with aggressive modalities [12]. While limb salvage techniques can be clinically successful, they are technically difficult and associated with significant morbidity [12,15–17]. More recently, the Masquelet technique, a potentially simpler alternative treatment – requires less surgical time, less technically demanding, and is associated with lower risk of complications and patient morbidity [15,18–21]. The Masquelet technique is a two-staged surgical procedure with initial systematic debridement of the bone defect and placement of a polymethylmethacrylate

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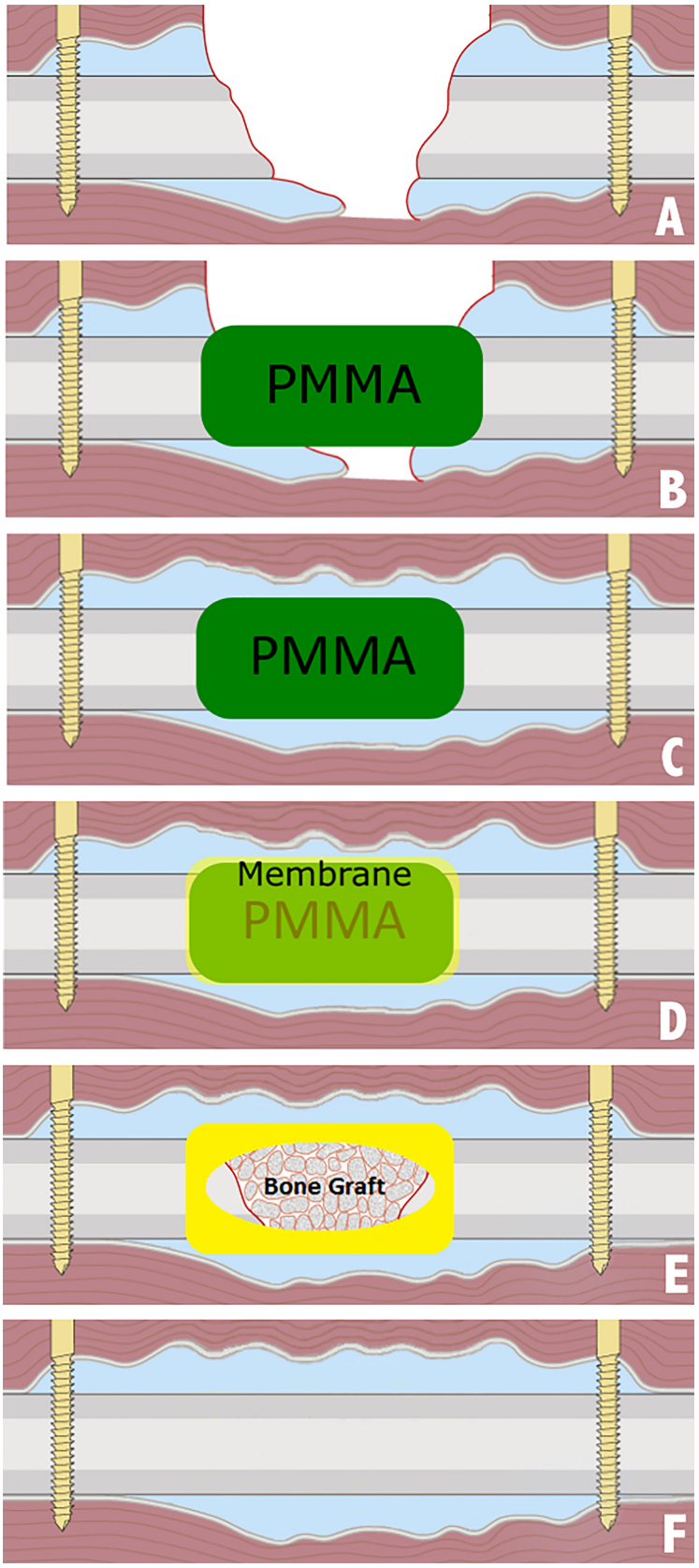

Fig. 1. The Masquelet Technique. Images showcase the step-by-step the two-staged Masquelet Technique. Periosteum is represented by the blue area surrounding the bone. From top to bottom – A) First Surgery: Critical-sized bone defect irrigated and debrided at both bone ends. B) PMMA cement fills the defect, surrounding both proximal and distal bone ends. C) Surrounding soft tissue healing with PMMA in place. D) A membrane forms around the PMMA. E) Second Surgery: Induced membrane exposed, incised, and PMMA removed. Defect site filled with bone graft, membrane sutured closed. F) Defect site showcasing healed bone. Modified from original image, copyright by AO Foundation, Switzerland. Sourced from AO Surgery Reference, www.aosurgery.org. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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