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Original research

A pilot study: Clinical efficacy of novel polycaprolactone-tricalcium phosphate membrane for guided bone regeneration in rabbit calvarial defect model

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ABSTRACT

In this pilot study, we aim to investigate the clinical efficacy of a novel polycaprolactone-tricalcium phosphate (PCL-TCP) membrane for guided bone regeneration (GBR) in an in vivo model. Eight rabbits, each with two surgically created calvarial defects were reconstructed using a bovine particulate bone substitute, then covered with a mechanical barrier using a PCL-TCP or collagen membrane, or left uncovered without any membrane. The rabbits were sacrificed at 1 and 2 months and the reconstructed defects were harvested for histology and histomorphometry evaluations. Results showed no statistical significance in percentage bone area fraction (BAF%) between the PCL-TCP and collagen membranes at 1 and 2 months. The BAF% of the PCL-TCP membrane group was statistically higher at 2 months compared to 1 month ($p < .05$); the BAF% in the collagen membrane group did not increase significantly from the first to second months ($p > .05$). We postulate that this is attributed to the greater stiffness and slower degradation of PCL-TCP. We conclude that the novel PCL-TCP membrane is as effective as the commercially available collagen membrane as a mechanical barrier for GBR, with good handling characteristics. Future work should explore variations in PCL-TCP composition to further improve its usability and rate of desired degradation.

1. Introduction

Alveolar bone resorption is an inevitable sequelae following the loss of dentition, with a reported mean reduction in alveolar bone width and height of 3.87 mm and 1.67 mm respectively three months after dental extraction [1]. Techniques and materials have been introduced to slow down, limit or reverse the effects of alveolar bone resorption to allow sufficient bone volume for the insertion of dental implants.

One of the most popularly-used alveolar bone grafting techniques is guided bone regeneration (GBR), a term which was coined by Buser in 1990 [2,3]. The technique relies on the success of a bone graft material contained inside the osseous defect, accompanied by the use of a barrier membrane. This isolation process allows time and space for pluripotent undifferentiated mesenchymal cells to differentiate into bone-forming osteoblasts. At the same time, this prevents the ingrowth of surrounding fibroblasts into the bone defect, which will otherwise form fibrous connective tissue that impedes bone formation. The concept has been applied in various clinical situations such as extraction socket augmentation, lateral and vertical ridge augmentation [4,5]. Systematic reviews have reported high survival rates of GBR-treated implants of more than 95% [6,7].

The success of GBR is dependent on multiple factors related to the barrier membranes, such as the barrier permeability for adequate penetration of blood vessels and bone-forming cells as well as the probability of peripheral sealing between the barrier and host bone. Five properties of an ideal barrier membrane have been identified: biocompatibility, space-making, cell-occlusivity, tissue integration and clinical manageability [8].

Barrier membranes used for GBR can be broadly classified into resorbable and non-resorbable membranes. Non-resorbable mem-

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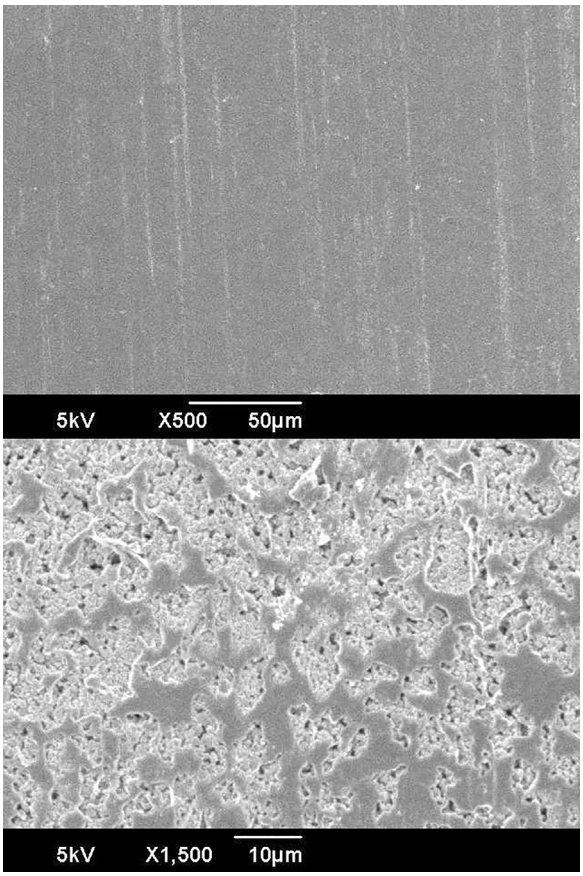

Fig. 1. Scanning Electron Microscope images of PCL-TCP membrane.

branes, such as polytetrafluoroethylene and titanium, allow rigid maintenance of space for osseous regeneration of a bone defect. Although excellent results have been reported with these membranes [7], they are also consistently associated with a high rate of membrane exposure due to the material's rigidity and poor adaptability to the defect edges, hence leading to soft tissue ingrowth and infection [9,10].

To date, resorbable collagen membranes are most commonly used and have shown to exhibit superior results over those of non-resorbable membranes. Zitzmann et al. compared the use of resorbable collagen and non-resorbable polytetrafluoroethylene membranes in 25 split-mouth patients and demonstrated superior bone fill and decreased membrane exposure with the use of the former [11]. Furthermore, collagen membranes offer the advantage of being resorbed by the body, thus eliminating the need for a second surgery to remove the membrane. This reduces the risk of morbidity, tissue damage and also, cost incurred by the patient. However, this material has inherently poor structural integrity [12] and variable degradation rates [13]. It is important to note that the rate at which the membrane resorbs will directly impact on the amount of osseous regeneration [14]. If the membrane resorbs too rapidly, there will be lack of rigidity and support for the defect site. This will expose the defect site to fibrous connective tissue invasion, hence reducing the amount of space available for bone growth.

To achieve more consistent and effective bone regeneration, we propose the use of a synthetic material with tunable properties that can achieve a controlled rate of resorption, mechanical stability for space maintenance as well as bioactivity for inducing bone formation. Bioactive composite materials comprising of a biodegradable polymeric phase and a bioactive ceramic phase that can bond spontaneously to, and integrate with, bone are recent innovations in the field of regenerative medicine. Of particular interest in this study is polycaprolactone tricalcium phosphate (PCL-TCP). This is a non-toxic and biocompatible material, with a slow degradation rate that makes it suitable as a temporary scaffold for regeneration at bony defects. The incorporation of TCP into the polymeric matrix helps promote cell growth and bone formation. Such scaffolds have been used with much success for the regeneration of intra-oral osseous defects [15,16] and have a relative stiffness that permits ease of clinical handling and shaping. These properties are coincident with the ideal properties of a barrier membrane for GBR.

In this pilot study, our aim is to investigate the clinical efficacy of the PCL-TCP membrane for GBR of the dentoalveolar ridge. We hypothesize that the PCL-TCP membrane will serve effectively as a rigid resorbable mechanical barrier in preventing the infiltration of fibrous tissue into the defect site, as well as induce greater bone formation due to its osteoconductive and osteoinductive properties.

2. Materials and methods

2.1. Fabrication of PCL-TCP membranes

The PCL-TCP membranes were fabricated in the laboratory of the contributing authors. Polycaprolactone tricalcium phosphate powders were mixed in proportions of 30:70 and mechanically ground before isothermal press at 80 °C, 0.4 MPa for 15 min. This was followed by convection cooling to room temperature under pressure. The PCL-TCP membrane sheets were produced and fashioned into dimensions of 12 mm × 12 mm to cover each defect completely. Stiffness of this membrane would be higher than 500 MPa. Scanning Electron Microscope images are shown in Fig. 1.

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