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Journal of Prosthodontic Research 57 (2013) 3–14

Journal of Prosthodontic Research

www.elsevier.com/locate/jpor

Review

Current barrier membranes: Titanium mesh and other membranes for guided bone regeneration in dental applications

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Received 27 November 2012; accepted 18 December 2012
Available online 21 January 2013

Abstract

Research on guided bone regeneration (GBR) is still ongoing, with evidence mainly from preclinical studies. Various current barrier membranes should fulfill the main design criteria for GBR, such as biocompatibility, occlusivity, spaciousness, clinical manageability and the appropriate integration with the surrounding tissue. These GBR characteristics are required to provide the maximum membrane function and mechanical support to the tissue during bone formation. In this review, various commercially available, resorbable and non-resorbable membranes with different characteristics are discussed and summarized for their usefulness in preclinical studies. Membranes offer promising solutions in animal models; however, an ideal membrane has not been established yet for clinical applications. Every membrane type presents both advantages and disadvantages. Titanium mesh membranes offer superb mechanical properties for GBR treatment and its current efficacy in trials will be a focus in this review. A thorough understanding of the benefits and limitations inherent to various materials in specific clinical applications will be of great value and aid in the selection of an optimal membrane for GBR.

Keywords: Titanium mesh; Guided bone regeneration; Resorbable; Non resorbable; Membrane

Contents

Abbreviations: GBR, guided bone regeneration; GTR, guided tissue regeneration; Ti, titanium; e-PTFE, expanded polytetrafluoroethylene; d-PTFE, dense polytetrafluoroethylene; Max, maxilla; Mand, mandibular; CTM, configured titanium mesh; M-TAM, micro titanium augmentation material; GT, Gore-Tex®; GTRM, Gore-Tex® regenerative membrane; GTAM, Gore-Tex® augmentation material; RIF, rigid internal fixation; MI, microporous membrane; MIP, microporous laser-perforated membrane; BG, bone grafts; MAR, mineral apposition rate; PRP, protein rich plasma; DBM, demineralized bone matrix; w, weeks; m, months; y, years; Ant, anterior; Post, posterior; ND, no data.

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1883-1958/$ – see front matter
http://dx.doi.org/10.1016/j.jpor.2012.12.001

1. Introduction

Adequate bone volume is an important prerequisite for a predictable, long-term prognosis in implant dentistry. However, some patients present with insufficient horizontal or vertical bone, which frequently precludes the successful outcome of an ideal implant placement (Fig. 1). Various methods have been developed to increase bone volume and augment new tissue growth: (1) Distraction osteogenesis, which describes the surgical induction of a fracture and the subsequent gradual separation of the two bone ends to create spontaneous bone regeneration between the two fragments [1]; (2) Osteoinduction, which employs appropriate growth factors and/or stem/osteoprogenitor cells to encourage new bone formation [2–4]; (3) Osteoconduction, in which a grafting material serves as a scaffold for new bone formation [5]; and (4) Guided bone regeneration (GBR), which provides spaces using barrier membranes that are to be subsequently filled with new bone [6,7].

Most biochemical osteoinductive approaches still have an extremely limited clinical application, such as the use of bone morphogenetic proteins (BMPs) [8]. In addition, in certain locations, such as in the jaw, distraction osteogenesis is still in its development phase and often leaves undesirable tissue scarring [9]. This leaves GBR and the use of bone grafting materials or combinations of these methods as the only ones commonly applied in clinical practice. GBR is reported as providing the best and the most predictable results when employed to fill peri-implant bone defects with new bone [6,7,10]. Furthermore, GBR improves the predictability of bone augmentation and provides long-term stability to the newly augmented site [11,12].

2. Principles of guided bone regeneration

The underlying concept of GBR was first introduced more than 50 years ago, when cellulose acetate filters were experimentally used for the regeneration of nerves and tendons [13]. Subsequently, cellulose acetate (Millipore™ membrane filter) enhanced osseous healing of rib, radial bone and femoral bone defects [14]. Later, a series of animal studies provided evidence to show that GBR can predictably facilitate bone regeneration in critical-sized osseous defects [15–20], as well as the healing of bone defects around dental implants by augmenting the height and the width of atrophic alveolar ridges prior to implant insertion [21–26].

The basic principle of GBR (Fig. 2) involves the placement of mechanical barriers to protect blood clots and to isolate the bone defect from the surrounding connective tissue, thus providing bone-forming cells with access to a secluded space intended for bone regeneration [27]. According to this principle, the use of a barrier membrane is advantageous to facilitate augmentation of alveolar ridge defects, induce bone regeneration, improve bone-grafting results, and treat failing implants [28].

3. Design criteria for GBR membrane

In addition to the surgical technique used, there are many factors that contribute to a successful GBR outcome, including barrier occlusion and stability, the size of the barrier perforations, peripheral sealing between the barrier and the host bone, an adequate blood supply, and access to bone-forming cells [29–35]. Moreover, in the last few years, several membrane designs have been studied that not only enhance new bone formation, but also stabilize the bone graft below the membrane and minimize the risk of collapse and/or soft tissue ingrowth (Table 1) [19,25,31,32,36–48].

For use as a medical device, barrier membranes must fulfill five main design criteria, as described by Scantlebury [49]: biocompatibility, space-making, cell-occlusiveness, tissue integration and clinical manageability.

3.1. Biocompatibility

The membrane must provide an acceptable level of biocompatibility. The interaction between the material and tissue should not adversely affect the surrounding tissue, the intended healing result, or the overall safety of the patient.

3.2. Create a space for ingrowth

The membrane should have an adequate stiffness to create and maintain a suitable space for the intended osseous regeneration. This quality is predominantly related to the membrane thickness. In addition, a membrane should provide an optimal space that can be maintained for tissue ingrowth but also still provide adequate support to the tissue, even in large defects. The material should also be appropriately malleable to provide the specific geometry required for functional reconstruction, but be sufficiently stiff to withstand the pressures exerted by external forces, such as mastication in jaw reconstructions [50]. If the membrane were to collapse into the defect space, the volume for regeneration is reduced and an optimal clinical outcome would not be achieved.

3.3. Occlusivity

An optimal barrier should be sufficiently occlusive to avoid fibrous tissue formation, which may prevent or delay bone formation. Occlusivity is therefore closely linked to membrane porosity; this factor has a major influence on the potential for cell invasion [46]. Indeed, barrier occlusivity of a membrane