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MEMBRANE BARRIERS FOR GUIDED BONE REGENERATION IN IMPLANT DENTISTRY: CURRENT SCENARIO

Dentistry

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ABSTRACT

Guided bone regeneration (GBR) is a commonly employed method for enhancing alveolar bone. The key to the success of GBR lies in the barrier membrane, which is considered one of the main components. An ideal barrier membrane should exhibit sufficient biological and mechanical characteristics. Barrier membranes can be categorized into two types based on their composition: polymer membranes and non-polymer membranes. Among these, collagen membranes have garnered significant interest due to their remarkable biological properties and favorable outcomes for bone regeneration compared to non-absorbable membranes, even eliminating the need for a second surgical procedure for removal. This review discusses various barrier membranes, highlighting their respective advantages and drawbacks.

KEYWORDS

Dental implants, barrier membrane, absorbable membrane, polytetrafluoroethylene (PTFE)

INTRODUCTION

Missing teeth have long been a challenge in dental history. Dental implants revolutionized treatment possibilities for restoring form, function, and aesthetics. Successful implant placement relies on adequate residual bone, but advanced periodontal disease, trauma or tooth loss often results in insufficient bone and ridge collapse. [1,2]

It was estimated that more than 40% of patients require bone augmentation procedures for optimal implant placement.[3] In such circumstances, reconstructive surgical techniques have been developed to facilitate the creation of adequate bone tissue, thereby allowing for implant placement either concurrently or at a later date.

Guided bone regeneration (GBR) is a standard treatment for alveolar ridge preservation and augmentation. It utilizes barrier membranes to create a separation between soft tissue and bone defects, promoting the proliferation of osteoprogenitor cells and supporting the formation of new bone tissue.

The design of an ideal Guided Bone Regeneration (GBR) membrane should focus on four key properties:
1. Biocompatibility, ensuring it does not harm surrounding tissue or the healing process.
2. Cellular occlusion, preventing non-osteogenic cell invasion into the bone defect.
3. Easy handling, maintaining flexibility while supporting space maintenance.
4. Bioactivation properties, promoting wound healing and integration of tissue.[4] Barrier membranes typically need 4–6 weeks for periodontal tissue regeneration and 16–24 weeks for bone enhancement. [5-6]

History

The application of non-resorbable barrier membranes in guided bone regeneration (GBR) procedures has its origins in the 1980s. [7] The first barrier membrane was initially designed as an occlusive membrane. In 1982, Nyman et al. evaluated a millipore membrane's effectiveness in bone regeneration using periodontal ligament cells in preclinical studies. [8] In 1986, Gottlow et al. implanted polytetrafluoroethylene (PTFE) in 10 patients, and it remains the most commonly used non-absorbable membrane today. [9]

Non-resorbable membranes have two major limitations in clinical use: their stiffness, which can cause soft tissue dehiscences, leading to membrane exposure and potential implant failure. [10,11] The other limitation is that a second surgery is required to remove the membrane that does not dissolve. [12,13]

A new class of absorbable membranes, both synthetic and naturally sourced, has been developed to address the limitations of non-absorbable membranes. Collagen membranes are the most studied and applied due to their excellent biocompatibility and bioactivities, promoting cell adhesion from periodontal ligament and gingival fibroblasts as well as osteoblasts. [14,15]

PTFE membranes

Polytetrafluoroethylene (PTFE), or Teflon®, was discovered in the late 1930s by Dr. Roy J. Plunkett at DuPont in New Jersey. [16]

PTFE serves as the primary material for the most widely used non-absorbable membranes in clinical settings. [7,16] This material is a type of polymer that is long and straight. It is made up of fluorine and carbon, and it has a semi-crystalline structure. [17] PTFE is a type of plastic known as a polyhaloolefin. It also falls under the category of thermoplastics. [18] It is also considered to be very inert. [19]

Different types of PTFE membranes have been developed for various clinical needs: expanded polytetrafluoroethylene (e-PTFE) and high-density polytetrafluoroethylene (d-PTFE). [20-22]

Although both PTFE membranes showed similar clinical outcomes in the treatment of peri-implant vertical bone defects [23], the dense structure of d-PTFE is considered to be effective in preventing bacterial invasion while retaining the potential for oxygen diffusion and small molecule transport. [24] In addition, postoperative removal of the d-PTFE membrane is easier than that of the e-PTFE membrane, which is essential for subsequent recovery and overall healing. [23]

Titanium Meshes and Cages

Titanium meshes have traditionally been used to stabilize bone grafts and maintain bone morphology and volume, but they lack barrier functionality due to their large pore size. [25]

While the sharp edges resulting from the cutting, trimming, or bending of titanium mesh may raise concerns regarding membrane exposure, research indicates that titanium mesh has a considerably lower postoperative exposure rate compared to most barrier membranes. Additionally, it typically does not require immediate removal, as infections following exposure are uncommon. [26,27]

Titanium meshes, often called titanium cages, are made using 3D printing and other technologies. They ensure a perfect fit for bone defects, preventing issues from incorrect placement. [28,29]

Absorbable Barrier Membrane

Depending on their origin, absorbable membranes are usually divided into natural polymers, represented by collagen and synthetic polymers represented by aliphatic polyesters (e.g., poly (lactic acid) (PLA), poly (polyglycolic acid) (PGA), poly (-caprolactone) (PCL)). [30,31] Synthetic polymers are customizable. By changing their chemical structure and preparation, we can control the shape, thickness, strength, porosity, and breakdown of barrier membranes. [32,33] The development of synthetic polymer membranes is a key focus for the next generation of barrier membranes. The development of synthetic polymer membranes is a key focus for the next generation of barrier membranes.

Collagen and chitosan are important natural polymer membranes. Collagen stands out and is widely studied in clinical settings.

Collagen is ideal for GBR procedures due to its properties. It offers a single-step process, promotes early wound stabilization, and has lower exposure rates compared to non-absorbable membranes. Its rapid absorption minimizes the risk of bacterial infection in open environments. [34-36] Collagen is the only animal-derived barrier membrane with low immunogenicity, promoting excellent tissue integration and angiogenesis through adhesion and chemotaxis to fibroblasts and osteoblasts. [37] Collagen membranes adsorb bone and cell-released factors (e.g., TGF-b), aiding in bone regeneration. [38–40]

The primary challenges associated with collagen membranes are their insufficient stiffness and their fast degradation within biological systems. Following implantation, these membranes are susceptible to enzymatic degradation, which is facilitated by various enzymes, including collagenases, bacterial proteases, and enzymes derived from macrophages. This degradation process can compromise the structural integrity and functionality of the membranes, limiting their effectiveness in tissue engineering and regenerative medicine applications. [41,42]

The modification of collagen membranes is a crucial avenue for research and application. Crosslinking presents promising solutions for enhancing the mechanical strength of these membranes.

Various methods—chemical, physical, and enzymatic—have been developed to effectively create crosslinked collagen membranes. However, a higher degree of crosslinking in collagen fibres can lead to increased exposure rates and may influence the foreign body reaction during resorption. The incorporation of bioactive molecules is primarily based on the idea of establishing an optimal microenvironment to promote bone remodelling. Typically, these active molecules undergo two phases of release: an initial explosive phase followed by a prolonged slow-release phase. Their impact on tissue regeneration tends to be concentration-dependent; therefore, further clinical evidence is necessary to determine the optimal loading concentrations.

CONCLUSION

This review collectively outlines the fundamental aspects of barrier membranes for guided bone regeneration (GBR), emphasizing recent advancements in the modification of collagen membranes and their underlying biological mechanisms. The organization and integration of this information are crucial for informing the creation of the next generation of barrier membranes.

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