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(RESEARCH ARTICLE)

Guided bone regeneration in reconstruction of the jaw and role tissue engineering in dental membrane, a review of literature

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Abstract

Tooth loss can significantly impact the quality of human life, affecting overall well-being, appearance, and nutrition. In advanced dentistry, implant therapy has become a popular option for restoring edentulous regions. Guided Bone Regeneration (GBR) is a bone grafting technique that utilizes a protective barrier membrane to prevent soft tissue penetration. This study aims to review various GBR methods, focusing on topics such as bone resorption in the edentulous jaw, different types of GBR techniques, indications for GBR, and limitations associated with this approach.

Keywords: Guided bone regeneration; Tissue engineering; Dental membrane; Implant; Jaw

1. Introduction

Tooth loss has a profound impact on the quality of human life, including overall well-being, appearance, and nutrition [1]. Implant therapy has gained significant popularity in advanced dentistry for restoring edentulous regions [2]. Optimal implant placement requires sufficient alveolar ridge dimensions, which are crucial for accommodating the dental implant and providing functional and aesthetic outcomes.

After tooth extraction, the typical healing process takes approximately 40 days, starting with clot formation and resulting in a socket filled with bone, surrounded by epithelium and connective tissue [3,4]. Ideally, complete restoration and maintenance of the initial ridge volume after tissue remodelling are desired for successful dental implant integration. However, this often contradicts the actual outcomes. Without additional treatment, crestal bone loss or resorption is inevitable and common, leading to significant dimensional changes in the ridge. These changes include a mean vertical bone loss of 1.5-2 mm and a mean horizontal decrease in ridge width of 40-50% over a period of six to twelve months of healing [5-9]. Most of the dimensional changes occur within the first three months [6] and can persist over an extended period, resulting in an additional 11% decline in volumetric bone loss over five years [10, 11]. Studies have shown that tooth extraction can lead to approximately 40%-60% reduction in bone width and height within 2-3 years [12]. Furthermore, bone resorption is more pronounced in the lateral plane compared to the longitudinal plane, resulting in significant alveolar width resorption [7, 8, 13]. Bone fenestrations or dehiscence during extraction can further contribute to alveolar remodelling, leading to significant buccal depression after healing [14].

To prevent or minimize bone resorption after extraction and maintain ridge integrity, it is recommended to use grafting materials to preserve space in the alveolus during the extraction process. Various ridge preservation materials and techniques have been utilized.

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2. Guided bone regeneration in dentistry

Guided Bone Regeneration (GBR) is a bone grafting technique that involves the use of a protective barrier membrane to prevent soft tissue penetration. While some scholars emphasize that GBR should strictly refer to conditions involving a barrier membrane, the term is generally used to encompass any bone graft method used to address bone abnormalities around an implant. The major uses of GBR include:

2.1. Treatment of bone defects around implants

GBR is commonly employed to address bone defects and deficiencies in the vicinity of dental implants.

2.2. Large defect cases

GBR is particularly useful in cases where significant bone loss or defects are present. It helps to promote bone regeneration and create a favourable environment for successful implant placement.

2.3. Bony wall resorption

GBR is recommended when there is resorption or loss of the bony walls surrounding the implant site. It aids in maintaining the structural integrity and volume of the surrounding bone.

However, it is not necessary to use GBR in every instance of bony dehiscence (a bone defect exposing the implant) surrounding a dental implant. The decision to employ GBR depends on various factors, including the size and type of the remaining bone wall. For example, if implants are immediately placed after tooth extraction and all surrounding bone walls are intact, successful bone healing can be achieved without the use of GBR. In cases of small defects, the potential outcomes may be improved without the need for a bone graft. Minor dehiscence or exposures (<2 mm) on the buccal surface after implantation may not require GBR, especially if the dental implant exhibits stable primary stability.

3. Discussion

In the following discussion, we will delve into important aspects of guided bone regeneration (GBR) in dental implant dentistry. We will explore topics such as bone resorption in the edentulous jaw, various types of GBR methods, indications and uses of GBR techniques, as well as different limitations associated with this approach.

3.1. Bone resorption in edentulous jaw

Bone resorption or loss in the human edentulous jaw is a complex process influenced by various factors such as systemic, nutritional, hormonal, and mechanical factors [17-19]. The replacement of extracted teeth is a common task for clinicians [20]. Numerous studies have investigated the intricate mechanisms underlying this phenomenon.

Roux (1881) proposed that the decline of alveolar bone following tooth loss is a result of disuse atrophy [19]. Glickman (1948) also emphasized that bone integration is part of the body's functional unit, suggesting that the maintenance of bone equilibrium relies on pathological and physiological processes throughout the body [21]. Studies have examined the role of osteocytes and osteoblasts in bone remodelling. Qin et al. (1998) highlighted that mechanical forces on teeth create strains and pressures on both distant and neighbouring regions, leading to a constant state of strain and stress in the mandible [22]. This process is crucial for preserving bone mass. Osteoblasts, responsible for bone formation, release various factors that modulate the response of osteoclasts, multinucleated cells involved in bone resorption. Before initiating bone resorption, non-mineralized osteoid is resorbed via proteases. The outcome of bone resorption in the edentulous jaw is observed as a decrease in both vertical and horizontal measurements of the alveolar bone. This process is persistent, although the precise rate and duration of bone resorption are challenging and variable to determine [23, 24].

3.2. Types of guided bone regeneration

3.2.1. Barrier membrane

Some studies suggest that the use of a membrane has no significant impact on clinical efficacy, as long as the clinician follows bone grafting guidelines. Specifically, Gielkens et al. [25] highlighted that the membranous tissue, also known as the periosteum, can serve as a beneficial barrier membrane with osteogenic properties. The use of a barrier membrane and its positive effects, particularly in reducing bone loss, has been a subject of debate [26]. The decision to

utilize a barrier membrane should be based on the clinical scenario. The study recommends that a barrier membrane is beneficial in cases involving significant bony defects and a larger quantity of bone grafts.

3.2.2. Resorbable vs Non-Resorbable Membrane:

Both non-resorbable and resorbable membranes have their own advantages and disadvantages. However, the type of membrane used does not significantly alter the clinical outcomes as long as the practitioner follows GBR guidelines [26-29]. Resorbable membranes, during their resorption process, may release decomposition matter that can inhibit new bone formation and compromise the mechanical strength as a barrier membrane [30]. Resorbable membranes are not ideal for vertical bone augmentation due to their limited stability and rigidity. Nonetheless, they offer the advantage of preventing infection in cases of wound dehiscence or disruption and maintaining space with the support of grafting material [31, 32]. On the other hand, non-resorbable membranes have excellent space maintenance properties and predictable bone generation, despite an increased risk of infection associated with wound dehiscence or disruption [33, 34].

Various types of non-resorbable and resorbable membranes have been used in dental implantation. Resorbable collagen carrier membranes are commonly utilized, both in non-crosslinking and crosslinking forms, while high-density polytetrafluoroethylene and expanded polytetrafluoroethylene are frequently employed as non-resorbable membranes. Although each product has specific properties, the clinical outcomes are not significantly influenced by the specific type of membrane used [35-37].

3.2.3. Bone graft materials:

Allogeneic graft materials obtained from well-established and reputable tissue banks offer both osteoconductive and osteoinductive properties. However, low-quality allografts have reduced bone regeneration ability and can increase the risk of immune rejection and infection. To achieve successful GBR, bone substitutes with a high content of demineralized bone matrix and good mechanical integrity should be selected, along with proper utilization of the barrier membrane [38-40]. Alloplastic and xenograft bone substitutes only possess osteoconductive characteristics for bone healing and have a slow resorption rate, but they demonstrate excellent volumetric stability and space preservation [41].

3.3. Indications of guided bone regeneration

Guided Bone Regeneration (GBR) has gained scientific support and is suitable for a wide range of indications in various bone augmentation procedures. It has shown effectiveness, particularly in horizontal bone augmentation, where both resorbable and non-resorbable membranes can be used with favourable outcomes. While vertical ridge augmentation has lower predictability, studies have indicated the beneficial impact of non-resorbable e-PTFE membranes in optimizing results. Titanium-reinforced e-PTFE membranes, in combination with different bone-filling materials, have been utilized to enhance vertical bone augmentation. Although non-absorbable membranes have been historically more commonly used for vertical bone defects, recent studies have demonstrated remarkable outcomes with the use of resorbable collagen-derived membranes. Moreover, the integration of rhPDGF-BB or recombinant human platelet-derived growth factor-BB with various bone grafting materials within resorbable membranes has been observed to have a positive effect on soft-tissue healing and improved preservation of regenerated bone, even after 12 months of dental implant loading [42, 43].

3.4. The role of tissue engineering in dental membrane

The field of tissue engineering has shown great promise in the development of dental membranes, which are used to promote the regeneration of damaged or lost tissue in the oral cavity [44]. Dental membranes are thin sheets of material that provide a scaffold for cells to grow on and release growth factors and other signaling molecules that stimulate cell growth and differentiation [45]. Traditional dental membranes are made from synthetic materials such as polytetrafluoroethylene (PTFE) or collagen, but these materials have limitations in terms of their biocompatibility and ability to promote tissue regeneration [44].

Tissue engineering offers a promising alternative to traditional dental membranes by using natural materials that are more biocompatible and can better promote tissue regeneration [44]. One such material is decellularized extracellular matrix (ECM), which is derived from natural tissues such as bone or cartilage. ECM provides a natural scaffold for cells to grow on, as well as a source of growth factors and other signaling molecules that promote tissue regeneration [44].

ECM-based dental membranes have been shown to be effective in promoting the regeneration of bone and other tissues in the oral cavity [44]. Another approach to tissue engineering in dental membrane development is the use of stem cells.

Stem cells are undifferentiated cells that have the ability to differentiate into a variety of different cell types, including bone, cartilage, and other tissues found in the oral cavity [44].

Stem cells can be harvested from a variety of sources, including bone marrow, adipose tissue, and dental pulp. Once harvested, stem cells can be seeded onto a scaffold material and then implanted into the oral cavity to promote tissue regeneration [44]. One of the key benefits of tissue engineering in dental membrane development is the ability to promote the regeneration of tissue that would otherwise be difficult or impossible to regenerate [44].

Tissue engineering approaches, such as the use of ECM or stem cells, offer the potential to regenerate a wider range of tissues in the oral cavity, which could lead to better outcomes for patients [44]. However, there are also challenges to be overcome, including the need to develop materials and techniques that are both effective and safe for use in the oral cavity, as well as cost-effective and scalable [44].

In conclusion, tissue engineering offers a promising approach to dental membrane development that has the potential to revolutionize the way we approach the regeneration of damaged or lost tissue in the oral cavity [44,46]. By using natural materials and techniques such as ECM and stem cells, tissue engineering approaches offer the potential to regenerate a wider range of tissues in the oral cavity and improve outcomes for patients [44]. However, there are also challenges to be overcome, including the need to develop materials and techniques that are both effective and safe for use in the oral cavity, as well as cost-effective and scalable [44]. With continued research and development, tissue engineering has the potential to transform the field of dentistry and improve the lives of millions of people around the world.

3.5. Limitation of guided bone regeneration

However, GBR also has limitations that should be considered when employing this technique. Material exposure post-surgery can lead to changes in fibroblast morphology, limited success in regeneration, and bacterial growth. Preventing membrane collapse to ensure sufficient space for bone regeneration is another challenge. Additionally, the removal of certain membranes such as ePTFE may require an additional surgical procedure [47].

4. Conclusion

In conclusion, GBR is a highly important method used for jaw reconstruction. It involves the use of different barrier membranes and grafting materials to effectively address various bone disorders. However, further studies are needed to optimize regenerative outcomes and enhance patient care.

Compliance with ethical standards

Acknowledgments

AI chat bots (the ChatGPT-3) has been used as a language editing service.

Disclosure of conflict of interest

There is no conflict of interest between the authors.

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