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Major approaches to dental implants in the biological environment of bone regeneration: a systematic review

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Abstract

Introduction: The presence of sufficient bone volume, both in width and height, is crucial for adequate implant placement and osseointegration, allowing stability of the peri-implant hard and soft tissues. Several bone augmentation techniques can be performed to preserve or reconstruct a resorbed alveolar ridge or pneumatized maxillary sinus. Bone remodeling of the ridge and buccal bone will still occur after tooth removal. **Objective:** It was to develop a systematic review to present the main approaches to dental implants in the biological environment of bone regeneration. **Methods:** The present study was followed by a systematic review model (PRISMA). The search strategy was performed in the PubMed, Cochrane Library, Web of Science Scopus, and Google Scholar databases. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** A total of 123 articles were found involving implantology and biomaterials. A total of 48 articles were fully evaluated and 34 were included in the systematic review. A total of 26 studies were excluded because they did not meet the GRADE criteria, and 22 studies were excluded because they had a high risk of bias. The symmetric funnel plot does not suggest a risk of bias between the small sample size studies. It was concluded that the search for a solution for large bone defects guided studies toward tissue regeneration therapy or bone regeneration. These studies can promote the use of fillers and epithelial barriers that assist in treatment as adjuvants to bone grafting techniques. Understanding host biological niche processes of signaling for neovascularization and bone regeneration and filling is necessary for subsequent dental success. Furthermore, implants placed in tobacco users, as well as in enlarged maxillary sinuses, simultaneously or in stages, and enlarged ridges lead to higher rates of implant failure.

Keywords: Bone regeneration. Bone augmentation techniques. Biological environment. Dental implants.

Introduction

The presence of sufficient bone volume, both in width and height, is crucial for adequate implant placement and osseointegration, allowing stability of the peri-implant hard and soft tissues [1]. Insufficient bone volume can lead to soft tissue compromise and aesthetically unpleasant results. The lack of bone volume is generally associated with reabsorption of the alveolar ridge and/or pneumatization of the maxillary sinus. Thus, bone augmentation procedures may be necessary to allow for optimal implant placement that will lead to long-term functional and aesthetic results. Bone regeneration procedures can be performed simultaneously with implant placement or separately [2,3].

In this sense, several bone augmentation techniques can be performed to preserve or reconstruct a resorbed alveolar ridge or a pneumatized maxillary sinus. Bone remodeling of the ridge and buccal bone will still occur after tooth removal. Ridge augmentation after tooth extraction is often performed following the principles of guided bone regeneration, which includes the use of bone graft materials and barrier membranes. Atrophic alveolar ridges can be reconstructed by a ridge-splitting procedure or distraction osteogenic techniques [2,3].

In this regard, maxillary sinus floor augmentation techniques have been developed to reconstruct pneumatized maxillary sinuses using graft materials. Elevation of the sinus membrane can be performed either through the lateral window or through the crest. Regarding graft materials, autogenous bone grafts, allogeneic and xenogeneic bones, or synthetic materials are generally applied [3].

In the bone engineering scenario and the molecular and cellular constituents, when a dental element is lost in the posterior region of the maxilla, there is natural reabsorption of the alveolar process and, at the same time, pneumatization of the maxillary sinus will occur [4]. It will increase its volume toward the place where the roots existed and this will often make it difficult or impossible to restore implants at the site [5-7]. For this reason, the maxillary sinus floor elevation procedure should be performed, or short implants when possible [8-10].

In this sense, when grafting procedures are needed, the focus is often on the type of biomaterial to be used and the success and predictability of results do not depend solely on the biomaterial. It is also necessary to consider the type of defect to be treated, and its morphology [5]. The morphology will have an impact mainly because the defects have different vascularization capacities, different osteogenic cell recruitment capacities, and different graft natural stabilization capacities, therefore, the characteristics of the biomaterials that we should use, but also the characteristics, must be considered bed and bone defect for treatment [11,12].

Furthermore, platelet concentrates have been proposed as regenerative materials in tissue regeneration procedures. Among the platelet concentrates proposed in the literature, there are PRP (platelet-rich plasma) and PRF (plasma-rich-fibrin) which act as autogenous platelet aggregates with osteoinductive properties. These biomaterials, due to their low morbidity and possible regenerative potential, have been indicated for use in combination with other biomaterials or even alone [13-15].

Also, the most used xenograft in guided bone regeneration procedures is deproteinized bovine bone mineral, commercially known as Bio-Oss®, it is the most researched product in regenerative dentistry worldwide. It is a bone of bovine origin processed to produce natural bone minerals without organic elements [16]. The excellent osteoconductive properties of Bio-Oss® lead to predictable and efficient bone regeneration, Bio-Oss® particles become an integral part of the newly formed bone structure and conserve its volume in the long term [16,17].

Given this, the present study developed a systematic review to present the main approaches to dental implants in the biological environment of bone regeneration.

Methods

Study Design

The rules of the Systematic Review-PRISMA Platform (Transparent reporting of systematic reviews and meta-analysis- www.prisma-statement.org/) were followed.

Data sources and research strategy

The search strategies for this systematic review were based on the keywords (MeSH Terms): *"Bone regeneration. Bone augmentation techniques. Biological environment. Dental implants".* The research was carried out in June to August 2023 and developed based on Scopus, PubMed, Science Direct, Scielo, and Google Scholar. Also, a combination of the keywords with the booleans "OR", "AND", and the operator "NOT" were used to target the scientific articles of interest.

Study Quality and Bias Risk

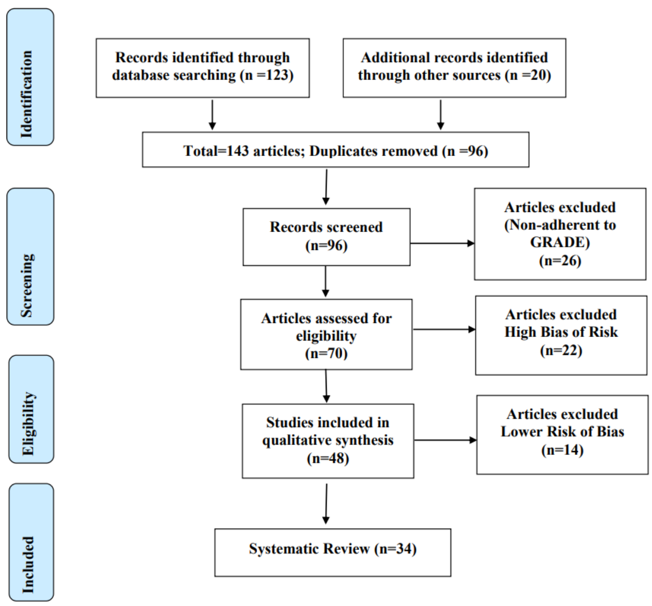
The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument.

Results and Discussion

Summary of Findings

A total of 132 articles were found involving implantology and biomaterials. Initially, the duplication of articles was excluded. After this process, the abstracts were evaluated and a new exclusion was performed, removing the articles that did not include bone regeneration using Biomaterials and/or fibrin-rich plasma. A total of 48 articles were fully evaluated and 34 were included in the systematic review. A total of 26 studies were excluded because they did not meet the GRADE criteria, and 22 studies were excluded because they had a high risk of bias (**Figure 1**).

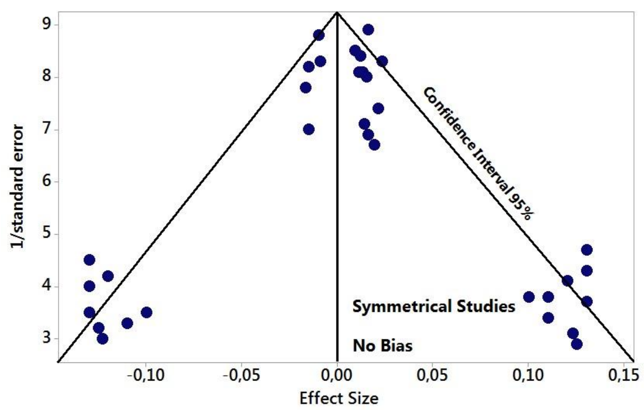
Figure 1. Study Eligibility (Systematic Review).



Source: Own Authorship.

Figure 2 presents the results of the risk of bias in the studies using the Funnel Plot, through the calculation of the Effect Size (Cohen's Test). The sample size was determined indirectly by the inverse of the standard error. The number of studies evaluated was n=34. The graph showed symmetric behavior, not suggesting a significant risk of bias in studies with small sample sizes, which are shown at the bottom of the graph.

Figure 2. The symmetric funnel plot does not suggest a risk of bias between the small sample size studies that are shown at the bottom of the graph.



Source: Own Authorship.

Major Outcomes

After evaluating the results in the literature, it was observed that bone quality, volume, height, and width play a fundamental role in the stability, success, and survival of dental implants. The lack of adequate bone can be overcome with various bone grafting procedures. It depends on many factors, including the amount of bone needed, the implant placement site, patient preferences, and clinical factors. The type of bone graft material and the procedure performed may vary. Supplemental bone can come from a variety of sources, including autogenous, allogeneic, and xenograft bone. Depending on the origin of the bone, it will have different properties in aiding bone formation, in addition to being presented in different formulations, such as bone particles or bone blocks [3].

In this regard, a study retrospectively evaluated the failure rate of implants placed in augmented and non-augmented sites and investigated whether implant timing and bony placement are associated with the risk of implant failure in a university setting. Data from 553 implants were analyzed in the study. More than half of the implants were placed in the maxilla (56.8%) and posterior regions (74.3%). The overall survival rate was 96.9%. Maxillary sinus augmentation was performed in 19.5% of cases, while in 12.1% of treatments included, an implant was placed simultaneously. Staggered and simultaneous ridge enlargement occurred in 45.2% and 18.8% of cases, respectively. Implants placed in an area after (p=0.018) or simultaneously (p=0.025) with sinus augmentation showed significantly reduced survival. Cox regression analysis showed that smoking and simultaneous ridge augmentation and implant placement increased failure rates. Therefore, implants placed in tobacco users as well as in enlarged maxillary sinuses, simultaneously or in stages, and in enlarged ridges lead to higher implant failure rates [18].

The dental implant combines technology and science in physics, biomechanics, and surface chemistry from the macroscale to the nanoscale. In recent decades, biomaterials in implant therapy have promoted bone response and biomechanical capability, which is long-term from surgical equipment to final prosthetic restoration. Biomaterials play a crucial role in the rehabilitation of damaged tooth structures and in providing acceptable results correlated with clinical performance. There are some challenges in implantation such as bleeding, mobility, peri-implant infections, and the solution associated with modern strategies that refer to biomaterials. Biomaterials must be biodegradable and biocompatible. Furthermore, biomaterials have important roles in prosthetic conditions, such as dental pulp regeneration, the healing process, and antibacterial and anti-inflammatory effects [19].

Normal bone formation and tissue repair involve coordinated interaction between bone-forming cells and biological signals. The main force in this process is the osteoblasts and their precursors [20,21]. Osteoblasts can produce new bones along with biomaterials and can initiate the release of biological signals that guide bone formation and remodeling [22].

These biological signals attract bone-forming cells to the recipient site. Growth factors and other proteins are some biological signs that may be involved in bone neoformation and tissue remodeling. Furthermore, through chemotaxis, there is a migration of bone-forming cells to the application area, as the stimulation of cell migration occurs in response to chemical stimuli [23].

In this sense, monocytes, macrophages, and endothelial cells contribute to bone remodeling, either through contact with osteogenic cells or through the release of soluble factors such as cytokines and GF [23]. In the skeletal system, TNF-α stimulates bone and cartilage resorption and inhibits collagen and proteoglycan synthesis. IL-1 induces the expression of a wide variety of cytokines. LIF and IL-6 are two of these molecules that are known to stimulate the differentiation of mesenchymal progenitor cells into the osteoblastic lineage, they are also potent anti-apoptotic agents for osteoblasts. In bone, the main sources of IL-6 are osteoblasts and not osteoclasts. Prostaglandin E2 (PGE2) is also directly related to the expression of the cytokine IL-6 [24,25].

In this aspect, for the success of the dental implant practice, osseointegration is essential. However, it is a complex process with many factors interfering in the formation and maintenance of bone tissue around the implant, such as topography and surface roughness, biocompatibility, and loading conditions. In addition, a healthy, compatible host bone layer that allows for primary stability is needed [26-29].

Dental implants are being used more and more due to their high success rates. However, a large number of patients do not have sufficient minimum bone conditions for the installation of implants, therefore, previous bone reconstructive surgery is necessary. Dentists must master the knowledge of the healing process of post-extraction alveoli, to provide correct planning of cases [30,31].

In this sense, after extraction, the repair process occurs in the inner region of the alveolus, together with the formation of a clot rich in cells and growth factors, promoting neoformation, bone remodeling, and soft tissue epithelialization. During this process, the alveolar ridge undergoes relevant changes, both in height and thickness, which influence the possibility of installing the implants. Thus, the optimized processes of implantology and biomaterials allow the installation of implants in areas of thin bone thickness, width, and height, with simpler surgeries and greater success rate and patient comfort [32].

The lack of bone in the alveolar crests has been a major problem in the functional aesthetic recovery of patients who have suffered dentoalveolar trauma, traumatic tooth extractions, congenital tooth loss, and maxillary and mandibular pathologies. To fill large bone defects, the development of bone regeneration improves the epithelial barriers for the bone graft, favoring greater predictability in alveolar and peri-implant reconstructions and presenting a good prognosis [33]. In this sense, filling biomaterials can be fibrin-rich plasma (PRF), Bio-Oss®, hydroxyapatite, lyophilized and ground demineralized bone marrow, and autogenous bone, which is considered the gold standard, among others [26].

Thus, PRF as an autologous biomaterial for use in oral and maxillofacial surgery has the majority of leukocytes, platelets, and growth factors, forming a fibrin matrix, with a three-dimensional architecture [34]. The Bio-Oss® (Geistlich) biomaterial, as it is biodegradable, biocompatible, non-toxic, and has low immunogenicity and bio stimulators, can act in the regeneration of bone tissue, as it establishes, with adenomatous mesenchymal stem cells, the appropriate biological niche for bone growth and, thus, allowing the dental implant as effectively as possible [17].

Based on this, two important studies reported results on the combined use of Bio-Oss® and PRF. Thus, the first study investigated clinically and histologically the potential of PRF as a graft material in pre-implant reconstructive surgeries for severe maxillary atrophy after sinus lift procedures in 106-120-180 days, to determine whether the use of PRF can accelerate the bone regeneration process, which is essential to promote implant stability. This study also includes a control group, in which only deproteinized bovine bone (Bio-Oss®) was used as reconstructive material. As a result, the use of PRF optimized bone formation [16].

The second study compared the use of Bio-Oss® mixed with PRF and Bio-Oss® with Tisseel® to improve bone regeneration. After elevating the sinus membrane in both maxillary sinus cavities, an implant was placed in the sinus cavity. In one of the sinus cavities, the PRF/Bio-Oss® composite was grafted and the Tisseel®/Bio-Oss® composite was grafted in the other sinus cavity. After a 6-month healing period, bone formation at the graft sites and bone-implant contact were assessed. The mean rate of osseointegration was 43.5 ± 12.4% and the rate of new bone formation was 41.8 ± 5.9% at the PRF/Bio-Oss® composite sites. In the composite sites, Tisseel® / Bio-Oss® was 30.7 ± 7.9% and 31.3 ± 6.4%. There were statistically significant differences between groups. The findings of this study suggested that when PRF is used as an adjuvant to Bio-Oss® particles for bone augmentation in the maxillary sinus, bone formation at the graft sites is significantly greater than when Tisseel® is used [17].

Conclusion

It was concluded that the search for a solution for large bone defects guided studies toward tissue regeneration therapy or bone regeneration. These studies can promote the use of fillers and epithelial barriers that assist in treatment as adjuvants to bone grafting techniques. Understanding host biological niche processes of signaling for neovascularization and bone regeneration and filling is necessary for subsequent dental success. Furthermore, implants placed in tobacco users, as well as in enlarged maxillary sinuses, simultaneously or in stages, and enlarged ridges lead to higher rates of implant failure.

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Conflict of interest
The authors declare no conflict of interest.

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