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Review Article

Comparison of Xenograft and Alloplast Bone Grafts for Infrabony Bone Defect: Literature Review

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Abstract: Restoring supporting tissues to a healthy state is a critical area that provides much more appealing than prevention, initial therapy, and corrective procedure. Infrabony defects can be found in the interalveolar and marginal bone caused by periodontal disease as a result of local factors. Various surgical therapies, such as bone grafts, are available for treating infrabony defects. However, several factors must be considered while deciding on the optimal bone graft materials. This article compares the effectiveness of Xenograft and Alloplast bone graft in infrabony defect therapy. The allograft presented a significantly higher amount of newly formed bone than the xenograft. There were no differences in the percentage of newly formed bone between the allograft and the alloplastic graft and between the alloplastic graft and the xenograft. Between the three types of grafts, there were no discernible changes in the percentage of remaining particles. All bone substitute materials have shown favorable properties for bone regeneration treatments. Local factors such as oral hygiene and controlled chronic disease are the main point of successful bone graft therapy. The present study concludes that Alloplast and Xenograft have equal potential in infrabony bone defect therapy.

Keywords: infrabony bone defect, xenograft, alloplast bone graft

1. INTRODUCTION

Modern periodontics aim to keep teeth and their supporting structures healthy. Most periodontal practices focus on early therapy, disease prevention, and corrective surgery to remove severe periodontal pockets [1]. The crucial area that offers a lot more appealing and desirable outcome for the patients is returning supporting tissues to a healthy state. Current periodontal therapy focuses on infection control and regeneration of lost supporting structures [2].

The process of periodontal regeneration involves repairing the periodontal ligament, bone, and other supporting tissues of the teeth to their previous healthy state. The key to tissue regeneration is to initiate a chain of healing events that, when coordinated, can form integrated tissue. A substantial improvement in treating severe periodontal disease and avoiding tooth loss is the regeneration of supporting tooth structures [3].

Periodontal disease is a chronic inflammatory condition that affects periodontal tissues (including the bone, cementum, gingiva, and periodontal ligament), leading to periodontal attachment loss. It is well known that periodontal disease may lead to the formation of bone defects. Periodontal bone defects are classified by osseous resorption tendencies [4].

Infrabony defects can be found in the interalveolar and marginal bone. Defects of infrabony are considered when an apical position of the pocket base is to the alveolar bone crest. Infrabony defects

are a result of progressive periodontitis because of local factors (e.g.), plaque accumulation, food debridement, tooth position, occlusal trauma) [5].

Various surgical therapies are available for treating infrabony defects, from open-flap procedures associated with guided tissue regeneration to autologous or synthetic bone grafts [6]. Bone grafts remain among the most widely used therapeutic strategies for correcting periodontal osseous defects. Various graft materials have been applied and evaluated clinically, including autografts, allografts, xenografts, and synthetic/semi-synthetic materials [7].

Bone graft is a living tissue that promotes bone healing, transplanted into a bony defect alone or in combination with other materials [7]. A bone substitute is a natural or synthetic material, often containing only a mineralized bone matrix with no viable cells, that can achieve the same purpose [8]-[9]. Bone grafts and substitutes have been used in medicine for centuries, with the first recorded use of bone grafts in 1682, when a cranial defect was successfully restored using a cranial bone graft from a deceased dog. In recent years, there has been a more significant market push to use newer bone grafting materials, such as bone substitute products, despite the lack of evidence-based research for indications and safety [7].

There are several factors to consider when selecting bone graft materials for treating infrabony defects, such as biocompatibility, recovery phase, product availability, supporting instruments, operator abilities, and the patient's socioeconomic. However, both components don't originate from self-donors, so the osteoconductivity factor must be highly considered. This review will discuss or compare the pros and drawbacks of several bone grafts, aiming to guide operators in deciding the proper bone grafts to utilize in treating infrabony defects.

2. LITERATURE REVIEW

2.1. Infrabony Bone Defect

Classically, periodontal defects have been differentiated based on bone resorption patterns into "supra osseous" ("suprabony") and infraosseous" ("infrabony"). These authors defined suprabony defects as those where the pocket base is coronal to the alveolar crest. On the other hand, infrabony defects are those with an apical location of the base of the pocket relative to the bone crest. Goldman and Cohen then classified infrabony defects according to the area and the number of osseous walls remaining around the pocket. It has been suggested that the term "intrabony" means "within or inside the bone," while "infrabony" means "below the crest of bone" [8].

A variety of factors have been associated with the formation of intrabony defects: among these, trauma from occlusion and food impaction. Anatomic factors such as plaque-retaining local elements and the distance between adjacent root surfaces have also been proposed to play a role [10]. The latter argument is based on the observation that proximity between neighboring roots results in the involvement of the whole interdental septum in the inflammatory, resorptive process, which, in turn, results in the destruction of the entire interdental alveolar bone and precludes the formation of an infrabony defect [11].

Diagnosing the presence and the morphology of infrabony defects represents a major clinical challenge. It is primarily performed by combining clinical information derived from the evaluation of the attachment level with information derived from diagnostic-quality parallel technique intraoral radiographs. A precise knowledge of root anatomy and its variations is also an essential component

for the diagnosis of infrabony defects, and interradicular defects in particular. Diagnostic-quality radiographs provide additional information on the morphology of the alveolar bone resorption [6].

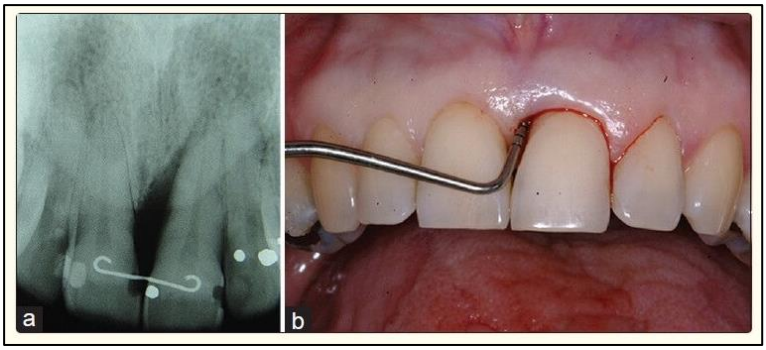

Figure 1. (a) Radiographic of infrabony defect, (b) Probing on defect [12]

2.2. Bone Substitutes

The main function of bone grafts is to provide mechanical support and stimulate osteo-regeneration, with the ultimate goal of bone replacement. The four fundamental biological properties of osseointegration, osteogenesis, osteoconduction, and osteoinduction, are paramount in performing this role effectively. The ability of grafting material to chemically bond to the surface of the bone in the absence of an intervening fibrous tissue layer is called osseointegration. Osteogenesis refers to the formation of new bone via osteoblasts or progenitor cells present within the grafting material, and osteoconduction refers to the ability of a bone grafting material to generate a bioactive scaffold on which host cells can grow. This structure enables vessels, osteoblasts, and host progenitor cells to migrate into the interconnected osteomatrix. Osteoinduction is the recruitment of host stem cells into the grafting site, where local proteins and other factors induce the differentiation of stem cells into osteoblasts [12].

Multiple growth factors influence this process, including platelet-derived growth factors (PDGFs), fibroblast growth factors (FGFs), and transforming growth factors-β (TGFs-β). These four fundamental properties enable new bone formation, which occurs parallel to direct osseous interconnection [7,13]. Amongst the material used in bone grafting, an autogenous graft is considered the gold standard for reconstructions because it has properties such as osteoinduction, osteoconduction, and osteogenesis. Despite that, a donor site is necessary to increase surgical morbidity and limited bone volume. For that reason, bone replacements are being developed and researched. Among these, an organic bovine bone matrix is widely used for its many years of research and known osteoconductive potential [14].

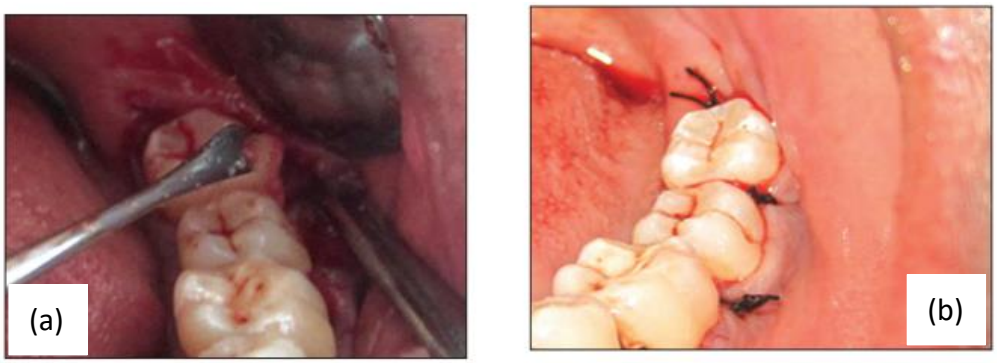

Figure 2. (a) Bone graft placed [13], (b) Sutured post-operative [13]

2.3. Xenograft

A xenograft is a tissue transferred between genetically dissimilar members of different species. It is osteoconductive, biocompatible, and structurally similar to human bone. Two sources of xenografts are used for bone replacement in periodontics: bovine bone and natural coral [15].

The most common source of xenograft materials in the dental field is deproteinized bovine bone, commercially available as *BioOss*™. Bovine bone is treated with a stepwise annealing process followed by chemical treatment with NaOH to produce porous hydroxyapatite (HA) material containing only the inorganic components of bovine bone. The resulting porous structure highly resembles human bone and can provide good mechanical support and stimulate bone healing through osteoconduction. The porous structure exhibits a vast surface area and promotes the growth of new blood vessels via angiogenesis which enhances bone growth [16].

Other commercially available products based on bovine bone, such as OsteoGrafTM and CeraboneTM, are also available. Both of these products are high-temperature treated, thus eliminating all organic components, resulting in a product with low immunogenicity. Like *BioOss™*, these products exhibit very similar structural and biochemical properties to human bone and can act as effective osteoconductive grafting materials [17].

2.3.1. Bovine-derived Bone Replacement Graft

Commercially available bovine bone is processed to yield natural bone minerals minus the organic component. A purported advantage of this product as a bone substitute is that it is natural because it can provide structural components similar to human bone, improving its osteoconductive capability compared to synthetically derived minerals [18].

Inorganic bovine bone is a hydroxyapatite (HA) skeleton, which retains a highly porous structure similar to cancellous bone (Jarcho, 1981) after chemical or low-heat extraction of the organic component. Historically, bovine xenografts have failed due to rejection, probably because earlier materials used chemical detergent extraction that left residual protein, producing adverse reactions and clinically unacceptable results [19]. Currently, available bovine-derived hydroxyapatite is deproteinated but retains its natural microporous structure and supports cell-mediated resorption (Jarcho, 1981; Nasr *et al*., 1999), which becomes necessary if the product is to be replaced with new bone. Two products are currently available: Osteograf/N and Bio-Oss®. Both have been reported to have good tissue acceptance with natural osteotrophic properties. Histologically, no fibrous tissue or space between hydroxyapatite and newly formed bone was found [20].

Because of their porosity, bovine-derived HA bone substitutes increase the available surface area that can act as an osteoconductive scaffold. This HA mineral content is comparable to the bone, allowing it to become well vascularized and integrate with new host bone. A statistically significant gain of clinical attachment and reduction in probing depth was demonstrated when bovine bone was compared to a non-graft control for treating human vertical osseous defects [21].PepGen P-15™ is bovine-derived hydroxyapatite containing P-15, a synthetic short chain peptide of the 15 amino acid sequence of type I collagen uniquely involved in the binding of cells, mainly fibroblasts and osteoblasts. The combination of P-15 with bovine bone has been shown *in vitro* to enhance the attachment of cells and to promote the attachment of periodontal ligament fibroblasts to bovine bone [22].

2.3.2. Coralline Calcium Carbonate

Bicoral (Inoteb, Saint Gonnery, France) is calcium carbonate obtained from natural coral and is composed primarily of aragonite (> 98% calcium carbonate). It is biocompatible and resorbable with a pore size of 100 to 200 μm, similar to the porosity of spongy bone. Its porosity provides a large surface area for resorption and replacement by bone. It does not require surface transformation into a carbonate phase, as do other bone substitutes, to initiate bone formation; hence, it should more rapidly create the bone formation. It has a high osteoconductivity potential because no fibrous encapsulation has been reported. When compared to other bone substitutes, coralline calcium carbonate produces comparable results. Significant gains in clinical attachment level, reduction of probing depth, and defect fill have been reported [21].

2.4. Alloplast Bone Graft

Alloplastic bone grafts consist of materials that are synthetic, inorganic, biocompatible, and/or bioactive bone graft substitutes, which are claimed to promote bone healing through osteoconduction. Alloplasts are usually conductive with bone without any induction of bone and osteogenic capacity on their own and have been used frequently for periodontal regeneration. Alloplastic materials are plaster of Paris, polymers, calcium carbonate, and ceramics [23].

2.4.1. Hydroxyapatite

Hydroxyapatite, $Ca_{10}(PO_4)6\ (OH)_2$, is the primary mineral component of bone. Synthetic hydroxyapatites have been marketed in various forms, primarily as porous, non-resorbable, dense, or solid, and porous, resorbable, non-ceramic forms. Processing the basic calcium phosphate mixture dictates which listed properties it will possess [23]. Hydroxyapatite resorbability is determined by the temperature at which it is processed. Resorbability is desired if the host bone eventually replaces the graft [24].

2.4.2. Tricalcium Phosphate

Tricalcium phosphate is a porous form of calcium phosphate: the most commonly used form is β-tricalcium phosphate. The beta refers to the particular orientation of the tricalcium phosphate crystal. β-tricalcium phosphate was one of the earliest calcium phosphate compounds to be applied as a bone graft substitute. With this material, it is possible to induce osteoconduction of bone into the defect, followed by the resorption of the β-tricalcium phosphate scaffold so that no biomaterial is permanently left within the reconstruction site. Unfortunately, the replacement of β-tricalcium phosphate by bone does not occur in a 1:1 ratio; less bone volume is produced compared to the importance of tricalcium phosphate absorbed. This bone volume also varies according to the site application and local conditions within the defect [25].

2.4.3. Calcium Sulfate (Plaster of Paris)

Calcium sulfate has a 100-year history in orthopedic literature as a safe bone substitute. It resorbs within 33 days. This material was a bioabsorbable barrier for guided tissue regeneration in periodontal defects. Additionally, calcium sulfate dissolution creates an acidic milieu (pH = 5.6) that may help restrict bacterial activity in the impacted area. Beta and alpha forms are the two primary forms of calcium sulfate hemihydrate that may be manufactured. Crystals with erratic shapes make up beta-hemihydrate. Alpha-hemihydrate contains smooth, uniform, acicular-shaped, denser

particles while being moderately soft, highly porous, and having a quick setting time. Low porosity, prolonged setting time, and better compressive and tensile strengths after setting are its main advantages [26].

2.4.4. Bioactive Glass

Bioactive glass is a complex, solid, transparent material composed of sodium oxide, calcium oxide, phosphorus pentoxide, and silicon dioxide, with silicate as the primary component [27]. The mechanism that allows the bone to bond with bioactive glass is exciting and complex [18].

Alloplastic bone substitutes can support osteoconduction; their regenerative abilities might generally be weak. Multiple observational studies have provided consistent histological evidence that autogenous and demineralized allogeneic bone grafts support the formation of new attachments. Limited data also suggest that xenogenic bone grafts can help the appearance of a new attachment apparatus. In contrast, nearly all available data indicate alloplastic grafts support periodontal repair rather than regeneration [25]. Previous studies have shown that particles of alloplastic bone substitutes could be encapsulated by connective tissue during periodontal regeneration [27]. Recent studies have shown that alloplastic bone graft substitutes composed of a BCP 90:10 ratio of β-TCP and HA can potentially induce ectopic bone formation similar to demineralized freeze-dried bone allograft [28].

3. RESULTS AND DISCUSSIONS

Periodontitis is an inflammatory disease characterized by the destruction of alveolar bone, root cementum, periodontal ligament, and gingiva in response to insults elicited by microbial accumulations on tooth surfaces. These responses tend to result in various intraosseous defects of various architectures. Periodontal therapy is performed to gain access to the diseased sites, reduce pocket depth, arrest further disease progression, and restore the periodontal tissues lost due to the disease process. The ultimate aim is to achieve periodontal regeneration via new attachment formation. Regeneration has been defined as the reproduction or reconstitution of the lost or injured part to restore the architecture and function of the periodontium [14].

Bone graft is the appropriate action to increase the height of the alveolar ridge, jaw bone remodeling, microvascular free tissue transfer, and alveolar crest re-formation. Generally, the bone graft is divided into four categories, namely autografts / autogenous, bone tissue derived from the same individual, allografts, bone tissue from different individuals, heterografts, bone tissue of other species (animals), alloplastic grafts, bone tissue using synthetic bone such as hydroxylapatite, phosphoric calcium ceramics, and oily calcium hydroxide in cream form. Therefore, bone allografts harvested from another human cadaver have been the most common alternative. Freeze or fresh-frozen bone, freeze-dried bone allograft (FDBA), and demineralized freeze-dried bone allograft (DFDBA) have all been utilized successfully to regenerate intrabony/furcation defects. Similarly, while certain countries do not allow allografts, xenografts derived from various animal sources have also been widely used. Lastly, alloplastic is synthetically developed bone replacement grafts fabricated from different laboratory materials, including hydroxyapatite and beta trial-calcium phosphate [14,29].

Research by Djais proved that his review of compare the result of treatment using platelet-rich fibrin and bone graft in intrabody defect cases showed decreased probing depth (PD), clinical

attachment loss (CAL), intrabody defect (IBD) or radiograph defect depth (RDD) after nine months follow up [14].

According to research by Alghamdi, the review indicates that reconstructive procedures using xenografts and alloplastic support comparable clinical outcomes to other bone grafting materials. It should be considered, however, that similar improvements in clinical parameters do not necessarily imply similar wound-healing processes on a histological level. The effect of graft biomaterials on forming a new attachment apparatus, including bone, cementum, and periodontal ligament, rather than periodontal repair, is still debatable. The addition of autografts or growth factors to xenografts and alloplasts seems to enhance the regenerative potential of these materials [15].

According to research by Reynolds for the treatment of intrabony defects, the results of the meta-analysis showed that bone grafts increase the bone level, reduce crestal bone loss, increase clinical attachment level, and reduce probing depth compared to open flflap debridement (OFD) procedures; No differences in clinical outcome measures emerge between particulate bone allograft and calcium phosphate (hydroxyapatite) ceramic grafts [21].

According to research by Mahajan that evaluates periodontal bone regeneration in intrabony defects using osteostimulative oleaginous calcium hydroxide suspension Osteora® (Metacura, Germany) in combination with osteoconductive bone graft Ossififi™ showed that Osteora® could be used as an adjunct to osteoconductive bone grafts, as an osteostimulating agent in the treatment of periodontal intrabony defects [26].

This synthetic was compared with xenografts, autografts, and allografts; all were investigated for their abilities to form ectopic bone in rat muscle. The same working group found that the synthetic BCP consistently developed ectopic bone in the calf muscles of beagle dogs within eight weeks after engraftment. This in vivo ectopic bone model demonstrated that while xenografts were not osteoinductive and autogenous bone grafts were resorbed quickly in vivo, ectopic bone formation was reported in demineralized freeze-dried bone allograft and synthetic BCP grafts. The results from this study indicate that synthetic bone grafts serve as a 3D scaffold and can promote osteoinduction [16].

Because the ideal forms and resorption rates of alloplastic bone substitutes differ among patients and clinical situations, dental clinicians should carefully consider the compositions, porosities, and properties of the available products. A sufficient understanding of the properties of alloplastic bone graft products aids in their appropriate selection. Moreover, further studies concerning alloplastic materials are expected to enhance osteoconduction in cell migration and angiogenesis, creating a suitable space without inhibition of wound healing while maintaining stable blood clot formation and a proper resorption rate [16]. Serrano Méndez et al. assessed allografts and xenografts used for alveolar ridge preservation. They concluded that both grafting materials are ideal for preserving the alveolar ridge [30].

4. CONCLUSION

Current bone graft and substitute materials primarily serve as a structural framework for osteo-regenerative processes that only satisfy the osteo conductivity criteria. Potential issues relating to graft vs. host responses for all current non-autograft-derived materials persist. However, as the research in the field of tissue engineering progresses, there have been many new developments, such as diverse ceramic and polymeric-based bone substitutes integrated with growth factors or modified

with living osteogenic progenitor cells. Our understanding of these materials and the growth factors at the molecular level is growing, which allows us to control better and modify their structure, understand their surface properties, and tune their interaction with other materials or physiological environments. This progress will eventually allow us to design and develop more effective dental bone substitutes.

Nevertheless, the cost of these bone substitutes is another aspect. Clinicians should consider the higher costs of these new technologies compared to the benefit of existing osteoconductive-only implants. Due to continual technological advancements in this field, synthetic bone substitutes have gradually replaced natural bone grafts. The development of hybrid grafts, which utilize growth factors and living osteogenic cells capable of inducing bone regeneration, presents the future of dental bone grafting and dental implants. Good examples include bone substitutes that can release bone morphogenic proteins or platelet-derived growth factors in a controlled manner. Despite the progress highlighted in this review article, more work is needed to develop dental biomaterials that have a porous structure, mechanically stability, controlled degradation, and remodeling ability comparable with the new bone formation rate.

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