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Review Article

Types and tissue sources of bone grafts in dental implants

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ABSTRACT

Using bone grafts has been described in the literature for multiple decades and has been applied within the different medical fields. Furthermore, in the field of dentistry, evidence shows that these approaches have been widely used for different purposes, including the management of craniofacial defects and dental implantology. However, it should be noted that many disadvantages have been reported for the different tissue sources of bone grafting in dental implants despite the wide acceptance of the outcomes and favorable prognosis with these materials. Therefore, many efforts were conducted to innovate further approaches with reduced disadvantages and favorable outcomes. Our present study discusses the types and tissue sources of bone grafts in the settings of dental implants. This can provide dentists with better information and enhanced knowledge levels about the tissue sources of dental implants, which should help them decide the most appropriate source with the least adverse events. Different tissue sources were reported in the literature, including materials that are no longer used for their disadvantages and associated complications. Among the proposed materials, biomimetics has been reported with favorable outcomes and reduced adverse events, and using combinations of these materials can furtherly enhance the prognosis. Further research is needed to innovate additional modalities that can overcome the currently reported limitations.

Keywords: Dental implant, Bone graft, Allograt, Autograft, Xenograft, Biomemetics

INTRODUCTION

Using bone grafts has been described in the literature for multiple decades and has been applied within the different medical fields.[1] Furthermore, in the field of dentistry, evidence shows that these approaches have been widely used for different purposes, including the management of craniofacial defects and dental implantology. Oral cancer, congenital malformations, infectious diseases, cranioplasty, surgical excision, periodontal diseases, and trauma can attribute to the development of craniofacial deformities that require management with bone grafting.[2]

Adequate alveolar bone dimensions are essential to perform successful dental implant procedures.[3] Estimates indicate the use of bone grafts has recently been increasing, and reports show that bone grafts are involved in up to 50% of dental implant procedures.[4] However, it should be noted that many disadvantages have been reported for the different tissue sources of bone grafting in dental implants despite the wide acceptance of the outcomes and favorable prognosis with these materials. Therefore, many efforts were conducted to innovate further approaches with reduced disadvantages and favorable outcomes. The present study aims at providing evidence regarding the types and tissue sources of bone grafts for dental implant procedures.

LITERATURE REVIEW

This literature review is based on an extensive literature search in Medline, Cochrane, and EMBASE databases which was performed on 4th October 2021 using the medical subject headings (MeSH) or a combination of all possible related terms, accprding to the database. To avoid missing poetential studies, a further manual search for papers was done through Google Scholar, while the reference lists of the initially included papers. Studies discussing bone grafts for dental implant procedures were screened for useful information, with no limitations posed on date, language, age of participants, or publication type.

DISCUSSION

Based on data from the different investigations in the literature, bone grafts for dental implants can be broadly divided into four categories, including allograft, autograft, xenograft, and synthetic bone substitutes. Each of these types will be discussed in the following paragraphs providing more evidence about the tissue sources used for each procedure, and elaborating on the advantages and disadvantages of each procedure.

In allograft, the tissue sources are obtained from humans, and it should be noted that the donor individual is not the patient that is indicated to receive the dental implant. Furthermore, evidence shows that the obtained tissue sources are usually from cadavers that allow using their bone after death to benefit patients that require these resources.[2] Various sizes and shapes can be provided for this procedure, and it has been demonstrated that they can either be cortico-cancellous, cancellous, or cortical. Three main types of tissue sources have been provided for allograft procedures.[5] The first type of fresh-frozen or fresh bone is acellular graft that is frozen at 80ºC. Consequently, it can be protected from demineralization, lyophilization, irradiation, and degradation by enzymes. As a result of the presence of bone morphogenetic protein, it has been shown that these sources have specific characteristics, being osteoconductive and osteoinductive. Nevertheless, this type of allograft is no longer used because of the severely associated immune response and the high transmission rate of the different diseases. The second type is mineralized freeze-dried bone allografts (FDBA) which have an osteoconductive characteristic only with no other properties.[2,6] It can be obtained by freezing and dehydration with no demineralization to prevent or reduce the associated antigenicity events and related complications. The third type of allograft is the demineralized FDBA (DFDBA), which undergoes the previous process that was reported with FDBA. However, an additional step of removing the inorganic part of the allograft and only leaving the organic part which contains bone morphogenetic protein. In some cases, it has been shown that deactivation of proteins that are usually present in the healthy tissue, and adequate sterilization is usually required before conducting allograft for bone repair. The presence of abundant amounts of proteins and growth factors, in addition to other bioactive materials within the extracellular matrix of the bone tissue, allows for successful bone healing events secondary to osteoinduction. In many cases, demineralization is usually used to remove the desired minerals and proteins from the tissues, using demineralizing agents as hydrochloric acid. Following this, degradation of the bone minerals and proteins occurs, and the osteoinductive materials are preserved in a demineralized bone matrix state. Many advantages have been proposed for allograft techniques in dental implants. These include the absent need to perform an additional donor-site surgery, predictable findings and favorable outcomes, and the wide availability of these modalities in adequate quantities of different sizes and shapes. However, it should be noted that the rate of disease transmission cannot be excluded in the best cases and the risk of transmission of infectious diseases from the donor to the recipient is still present. Therefore, adequate testing for treponema serological markers, hepatitis B and C viruses, and HIV should be performed before implantation process takes place. Furthermore, it has been reported that compared to autograft materials, allografts are usually associated with less revascularization, increased immunogenic response, and a high resorption rate. The characteristics of these modalities usually widely differ because of the absence of standardization between the demographic characteristics of the donors and the recipients.[7]

Reconstruction of osseous defects was first approached in 1923 by Hegedus using bone grafts.[8] The approach was furtherly reported and performed in 1965 by Nabers and O'Leary.[9] due to their osteogenic properties, it has been indicated that autografts are considered the gold standard modalities in the field when compared to other modalities. Accordingly, they can be used to preserve viable tissues from the donor to the recipient site, in addition to having different osteoinductive characteristics which enables them to influence mesenchymal stem cell differentiation into osteoblasts as a result of the wide availability of growth factors in their matrix.[10,11] These modalities are obtained from the body of the same individual and different bone sources were reported, including removed bone for ostectomy or osteoplasty, coronoid process (anterior mandibular ramus), mandibular symphysis, and iliac crest. Graft rejection using autogenous bone grafting is of minimal risk compared to other modalities, and therefore, the use of these modalities is recommended in cases of block grafting.[12] However, it should be noted that an additional surgery site is required which might be the main disadvantage for this approach, which might furtherly lead to the development of complications and postoperative pain. Bone swaging, cancellous bone marrow transplant, bone blend, and osseous coagulum are the different types that were reported for autograft.[13,14]

Xenografts are obtained from different species other than humans and have been reported with acceptable osteoconductive properties and limited resorption. However, many disadvantages were reported for these modalities, including the potential to transmit the different diseases, in addition to mutagenicity.[15] Besides, there is a risk that the characteristics of these modalities might be influenced during the process of preparation. There are two main types of xenografts that have been reported in the settings of dental implants. These include demineralized bovine bone grafts and coral-derived bone substitutes. The former has been described as the first of its kind to be applied in humans and is widely available. No immune response has been reported with these modalities because they are lyophilized and deproteinized, in addition to having good osteoconductive features.[16] However, evidence shows that there is slow or poor absorption of the granules on these materials. Further reduction of the absorptive capabilities of the modality has also been reported as a result of being processed at high temperatures to reduce the intensity of disease transmission and allergic, and immune reactions. Improving bone formation for fixing jaw defects was effectively approached using coral-derived bone substitutes as a result of their osteoconductive properties and the abundance of growth factors. Fast resorption rate, adequate blood supply, and reduced mechanical strength were reported with the modality. Different studies have reported favorable outcomes of using these approaches in settings of dentoalveolar reconstruction.[17-19]

As a result of the increased risk of graft rejection and disease transmission that were reported with the previous modalities, researchers exerted serious efforts to introduce efficacious biomimetic materials that can be effectively used with minimal risk of developing adverse events. These materials are characterized by the absence of osteogenic and osteoinductive properties but have osteoconductive features. They increase cell adhesions and proliferation, in addition to supporting cellular growth. Different modalities were reported in the literature and validated by many investigations and will be discussed here. For instance, a mineral to organic matrix ratio that is similar to the naturally occurring in human cells has been observed for Flexible hydrogel-hydroxyapatite. Accordingly, it has been reported that artificial bone can be obtained from these materials, which are biologically active with favorable clinical outcomes. Moreover, to increase their biological activities, it has been demonstrated that they are usually combined with different growth factors and bone materials. Improved osteoblast proliferation and high bone mineral density can be obtained by the presence of certain elements, like strontium in combination with these materials.[2,20,21] Calcium phosphates, including hydroxyapatite and tricalcium phosphate, have been reported as efficacious modalities that can be used in the settings of dental implants and can be furtherly classified into cement and ceramics. The composition of these modalities has been shown to enhance vascularization, bone resorption, and phagocytosis. Tricalcium phosphates were found to be resistant to compressive loads. Nevertheless, they are usually weak under shear and tension and are brittle. They are also less mechanically stable and quickly resorb more significantly than hydroxyapatite.[22-24]

The main advantage of hydroxyapatite is its excellent biocompatibility with the human body, which enables it to be used for different grafting approaches. It has been demonstrated that they have a risk of fracture on shock loading and are brittle. Nonetheless, they have a low resorption rate and are osteoconductive. Enhanced resorption rate and good mechanical properties could be obtained by mixing hydroxyapatite with tricalcium phosphates resulting in the formation of biphasic calcium phosphates. In another context, Paris gypsum or calcium sulfate was also reported since 1892 to be used in the field of bone grafting.[25] It has been primarily used to fill the tubular cavities of the long bones. It can be found either as granules or cement, both of which were reported with many characteristics, including osteoconductivity, carrier material abilities, tolerability, bioactivity, and biocompatibility. Moreover, these modalities were also reported to have reduced costs and can be easily handled. The rate of bone formation with these materials has been reported to be slower than the rate of resorption. It has been widely used in the settings of dental implants, including tooth extraction, dentoalveolar, and periodontal defects.[26,27]

Compared to calcium phosphates, bioactive glass has been shown to have better strength abilities when used in the settings of bone grafting. It is mainly composed of active silicate-based glass , and it acts by forming a solid bond between the host bone and glass using hydroxyapatite crystals, which is usually termed bioactivity. According to the components of which bioactive glass is composed, the rate of resorption varies. Some of the components include phosphorus, silicon dioxide, calcium oxide, and sodium oxide, which significantly determine the strength and resorption rate of the modality. Polymeric substitutes for hard tissue replacement were also validated among the different investigations.[28] Polymethyl methacrylate was reported to be the most important compound in this context for bone grafting and augmentation. These materials are characterized by their impressive strength and elasticity similar to the cortical bone, and their favorable biocompatibility and osteoconductive characteristics, which makes them good candidates for bone grafting in dental implantation procedures. However, it should be observed that some adverse events might develop during the polymerization process due to the influence of high temperatures. For instance, between bone-cement interfaces, a membrane might formulate, in addition to inducing damage to the corresponding circulation, and developing thermal bone necrosis.[29,30]

CONCLUSION

Different tissue sources were reported in the literature, including materials that are no longer used for their disadvantages and associated complications. Among the proposed materials, biomimetics has been reported with favorable outcomes and reduced adverse events, and using combinations of these materials can furtherly enhance the prognosis. Further research is needed to innovate additional modalities that can overcome the currently reported limitations.

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