Original Article

A Systematic Review of the Comparative Efficacy of Allografts and Xenografts in Alveolar Bone Defect Reconstruction

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ABSTRACT

The dimensions of the alveolar ridge are becoming increasingly significant due to the greater trend towards implant rehabilitation. Ridge augmentation involves the use of bone transplants to encourage bone regrowth. Although autogenous bone grafts taken from patients are thought to be the gold standard, they can cause postoperative pain and increase the risk of infection at the donor site. Therefore, there is a need for alternative materials, including the use of allogeneic and xenogeneic transplants. Considering the importance of regenerating alveolar bone defects and the variety of bone graft sources, along with the diverse studies examining the effects of each graft type, The present research compares the efficacy of xenografts and allografts in the regeneration of alveolar bone lesions using a systematic review methodology.

Without limiting the start date, a thorough literature search was conducted until September 2024. Guidelines for meta-analyses and Preferred Reporting Items for Systematic Reviews were followed while choosing articles. Included were five researches. There was one retrospective analysis and four randomized clinical trials. No statistically significant difference between the two treatment methods was found in the majority of the investigations. Both allografts and xenografts are effective in the reconstruction of alveolar bone defects. Studies involving larger sample sizes and more extensive augmentation procedures are recommended.

Keywords: Alveolar bone loss, Allografts, Xenografts, Osteogenesis, Dental implant

Introduction

Dental microbial biofilm causes periodontitis, a chronic inflammatory condition that weakens the teeth's supporting tissues and may eventually lead to tooth loss [1-3]. The size of the extraction socket significantly decreases as a result of a sequence of bone remodeling events that follow tooth extraction [4]. The shape and size of the alveolar ridge after extraction are important for both the surgical and restorative stages of implant therapy, especially with the recent trend toward prosthetically guided implant placement procedures [5]. To mitigate ridge resorption and ensure the implant is positioned according to prosthetic requirements, alveolar bone augmentation is frequently necessary [6].

Bone graft materials are frequently utilized in dentistry to encourage bone growth and regeneration during treatments such as sinus elevation, ridge augmentation, socket preservation, and restoration of periodontal bone abnormalities [7]. Depending on the kind of bone transplant used, there are several methods for preserving the socket, such as autografts, allografts, xenografts, and alloplasts, in addition to bioactive substances and membranes to promote guided bone regeneration (GBR) [8-11]. Despite the use of diverse techniques and materials for preserving or augmenting the alveolar ridge, no single material or method has demonstrated superior results or completely prevented bone loss [12]. An autogenous bone graft taken from the patient and placed in the defect location is now the gold standard. Despite its effectiveness, this technique has a higher risk of infection at the donor site and frequently causes the patient significant postoperative pain [13].

Given the drawbacks associated with autogenous transplantation, there is a recognized need for alternative materials for tissue

reconstruction. Options include the use of allogeneic and xenogeneic transplants. Allografts serve as a viable substitute for autogenous bone, particularly in the reconstruction of both vertical and horizontal alveolar defects. This type of bone substitute offers various forms, such as partitioned states, blocks with specific structures, and cortical-spongy compositions, enabling the reconstruction of extensive areas with minimal complications [14]. Human-derived allografts are collected, meticulously prepared, and stored through various methods, with strict adherence to processing protocols, donor selection, and storage criteria being crucial for ensuring safety [15]. Among the available grafts, bone allograft is often regarded as the optimal choice due to its elimination of the need for a second surgical procedure, and its structural similarity to natural bone [16, 17].

Conversely, recent research into bovine bone materials has indicated that protein-free bovine bone mineral (DBBM) shows promise for bone regeneration. Additionally, demineralized freeze-dried bovine bone xenograft (DFDBBX) has emerged as a potential alternative [18]. However, despite extensive studies on alveolar bone regeneration using bovine-derived xenografts, some research has raised concerns about the risk of transmitting bovine spongiform encephalopathy (BSE) through such transplants [19]. Furthermore, the possibility of foreign body reactions throughout 2 to 10 years must be taken into account for bovine grafts, given the non-biodegradable nature of the mineral particles involved [20].

Given the significance of regenerating alveolar bone defects and the variety of bone graft sources, along with the diverse studies examining the effects of each graft type, this study aims to compare the effectiveness of allografts and xenografts in the regeneration of transverse alveolar bone defects in the form of a systematic review.

Materials and Methods

Following the recommendations given by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), this systematic review [21].

The primary research question was developed using the "PICO" framework, where "P" refers to patients with transverse alveolar bone defects, "I" denotes allografts, "C" signifies xenografts, and "O" represents new bone formation. The central inquiry was, "Are there differences in new bone formation between allografts and xenografts in cases of transverse alveolar defects?".

Search strategy

An extensive electronic search was conducted without restrictions on publication dates up to September 3, 2024, utilizing the PubMed database. For the search, "OR" and "AND" operators were used to combine a wide range of free text and MESH (Medical Subject Headings) phrases. We also looked through the chosen papers' reference lists to find further pertinent research. The EndNote Basic program helps find and remove duplicate entries, making reference management easier. The precise search terms are listed in Appendix 1.

Eligibility criteria

Randomized controlled trials, case-control studies, and English-language cohort studies were all considered eligible. Experiments, in vitro or animal research, republished publications using the same sample data, email communication, letters to the editor, review articles, case reports, surveys, and studies that included sinus lifts as an intervention were all excluded.

Screening and selection

The titles were screened by M.M. and F.A., two independent reviewers. The abstracts were then assessed to confirm that they met the qualifying requirements. The final studies that met the inclusion criteria were found by looking over the entire texts of the publications that made it past this first screening. When the authors couldn't agree, they turned to a third reviewer, A.M. Cohen's Kappa score was used to measure the reviewers' degree of agreement.

Data extraction

After the studies were finally chosen, pertinent data was taken out and arranged in a table made in Microsoft Excel. The information was acquired by two independent reviewers, M.M. and A.M., and included the first author, publication year, nation, study type, study duration in months, follow-up time in months, mean age, participant gender, sample size, and changes in bone dimensions.

Risk of bias assessment

The risk of bias was assessed by two independent reviewers, H.A. and M.M., using the risk of bias in non-randomized studies of exposures (ROBINS-E) tool [22] and the updated Cochrane risk-of-bias tool for randomized trials (RoB2) [23]. Any disputes were settled after consulting with F.A., a third reviewer.

Results and Discussion

The electronic search conducted in the specified database resulted in the identification of 110 articles. Following the removal of duplicates, 99 articles were evaluated; among these, 69 were pertinent to the topic. This subset included eight in-vitro or animal studies, ten case reports, eight review articles, five studies related to sinus lifting, and 33 exclusively utilized allograft or xenograft materials. In the end, five pieces satisfied the requirements for inclusion. **Figure 1** shows the PRISMA 2020 flow diagram, which displays the search's full findings. During the abstract and full-text article selection procedure, the k value for inter-reviewer agreement was 0.84, indicating an "almost perfect" degree of agreement.

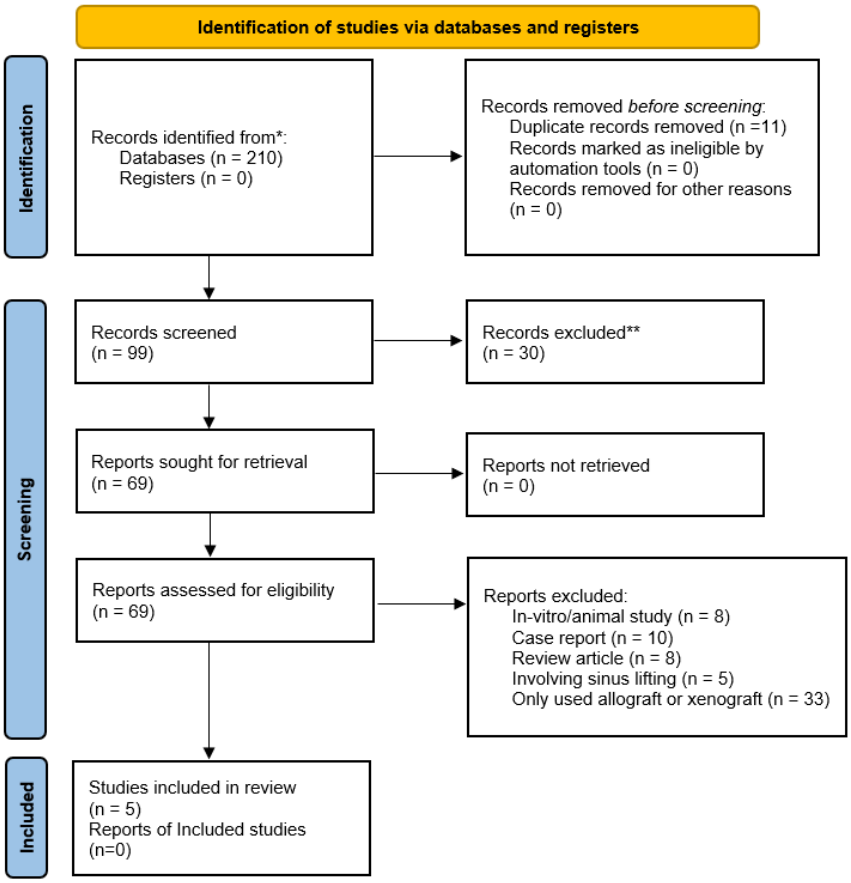


Figure 1. PRISMA flowchart of the articles' selection process

Characteristics of the studies

Tables 1 and 2 display the descriptive features and findings of the included research. These five investigations were published between 1999 and 2022 and included 154 individuals. There was one retrospective study and four randomized controlled trials (RCTs) among the five.

Table 1. Characteristics of the included studies

First author, year	Country	Study type	Mean age	Gender (%men)	Sample size		Follow-up period (mo)
					Total	Intervention / Control	
Abellán 2022	Spain	RCT	44.84	61.9%	21	10 / 11	5
						23	
Zampara 2022	Greece	RCT	NR	59.4%	16*	8 / 8	3
Mae 2021	Malaysia, UAE	Retrospective	NR	NR	77	18 / 59	3,6,8
Serrano Mendez 2017	Colombia	RCT	44.25	50%	20	10 / 10	6
Richardson 1999	USA	RCT	NR	NR	20	10 / 10	6

Mo: month
RCT: randomized controlled trial
NR: not reported
*: The total sample size was 32, but only 16 were given our desired treatment

Table 2. Results of the included studies

First author	Analysis method	Surgical intervention	Parameters assessed	Result
Abellán 2022	Histologic, histomorphometric, radiographic	Tooth extraction and insertion of dental implant	Dimensional changes, vital bone, non-mineralized connective tissue, and graft particles	Similar dimensional and histomorphometric results
Zampara 2022	Histologic, histomorphometric	Tooth extraction and insertion of dental implant	New vital bone, graft particle content, soft tissue, and bone marrow	The greatest GBR potential was associated with the allograft material
Mae 2021	Radiographic	Tooth extraction and insertion of dental implant	Alveolar crestal bone level changes	No statistical difference
Serrano Mendez 2017	Histologic, histomophometric	Tooth extraction and insertion of dental implant	Vertical and horizontal bone dimension	No statistical difference
Richardson 1999	Clinical	Reconstruction of periodontal bone defects	Bone fill, PD, CAL, and surgical defect depth	No statistical difference

PD: pocket depth
CAL: clinical attachment loss

Patients who needed to have their maxillary or mandibular first or second teeth extracted and then have implants placed were treated with either allograft or xenograft combined with a collagen membrane in the Abdellán *et al*. trial. Cone-beam CT scans were carried out both immediately after extraction and five months later. The analysis found that the bone ridge had significantly shrunk. The largest loss in height was seen in the buccal area, measuring -1.97 ± 2.21 mm ($p = .0006$), whereas the most significant alterations in breadth were observed at 1 mm from the bone crest, with a decrease of -2.93 ± 2.28 mm ($p = .0002$). Nevertheless, there were no statistically significant changes between the therapy groups. Histological examination revealed that the tissue compositions formed by the two biomaterials were similar, and thicker buccal bone plates displayed less remodeling. Following a five-month period, the available bone height at the implant location dropped from 7.30 $\pm$ 3.53 mm to 6.8 $\pm$ 3.61 mm, enabling implant implantation without the need for lateral sinus augmentation in every case. The transcrestal sinus lift was necessary for 55% of the conserved regions, however. The study found that employing either mineralized allograft or xenograft to preserve ridges in molar locations produces comparable dimensions and histomorphometric results after five months [24].

The clinical efficacy of guided bone regeneration (GBR) in extraction sockets employing allograft, xenograft, and alloplastic materials in combination with resorbable membranes was evaluated by Zampara *et al*. Three experimental groups and a comparative control group were involved in the study. Each group received an allograft, xenograft, or alloplast, while the negative control group received no regenerative material. There was sufficient bone volume in all three experimental groups for dental implant insertion to be effective. Comparing the xenograft group to the allograft and alloplast groups, however, revealed a noticeably reduced quantity of essential bone. In addition, the xenograft group had a much larger percentage of remaining graft particles than the other two groups. Comparing the xenograft group to the others, a notable rise in the proportion of soft tissue was also noted. The proportion of vital bone among the allograft, alloplast, and control groups did not differ significantly, nor did the percentage of remaining graft particles between the allograft and alloplast groups. The proportion of bone marrow in the xenograft and alloplast materials differed just little. No patients experienced any side effects, including fever, malaise, purulence, or fistula, during the clinical trial. With the largest proportion of remaining graft particles and the most live bone, the allograft material showed the highest GBR potential. For alveolar ridge preservation operations, all of the bone replacement materials under investigation were successful since they promoted bone apposition [25].

Allografts or xenografts were used for bone grafting at implant sites in the Mae *et al*. trial. There was no significant difference ($p = 0.791$) in the alveolar bone loss measured in the crestal area during bone graft implantation, which was -1.85 ± 1.26 mm at the xenograft sites and -1.75 ± 1.51 mm at the allograft sites. Bone measurements were 1.17 ± 0.83 mm for xenografts and 1.00 ± 1.14 mm for allografts at reentry three months after tooth extraction and ridge preservation ($p = 0.523$). The bone-grafted sites at the final reentry were divided into two groups according to the amount of time that had passed after surgery: six months and eight months. In comparison to the xenografts (1.25 ± 1.00 mm), the allografts showed decreased bone resorption after three months (0.9 ± 0.52 mm). After eight months, however, there was no statistically significant difference ($p > 0.05$) in the bone loss for allografts and xenografts, which rose to 1.83 ± 0.42 mm and 1.37 ± 1.12 mm, respectively. The study found that when inserted simultaneously during the surgical process, allografts and xenografts produced comparable alterations in crestal bone levels surrounding dental implants [26].

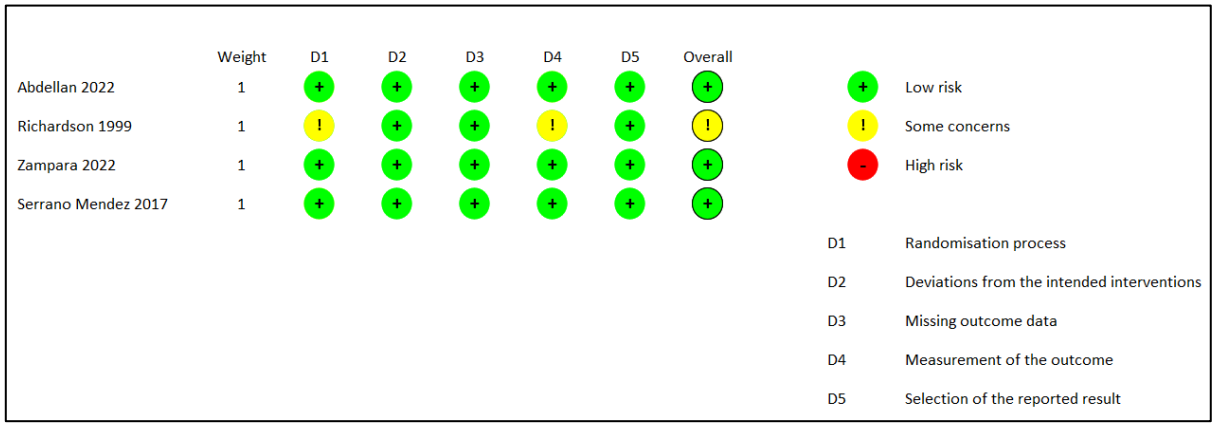
Patients who needed to have a single-rooted tooth extracted before an implant could be placed were treated using two different grafting materials in the study by Serrano Mendez *et al*. One group received a demineralized freeze-dried cortical bone allograft, while the other group received a deproteinized cancellous bovine bone xenograft mixed with a 10% collagen matrix. The flaps were sutured after a collagen membrane was placed over the grafts. Bone dimensions were reduced in both treatment groups. The allograft showed vertical changes of 20.6, 0.5, and 20.1 mm at the mesial, central, and distal locations, whereas the xenograft showed vertical changes of 21.1, 20.4, and 20.9 mm. For the allograft and xenograft, the measured horizontal alterations were 21.4 mm and 22.6 mm, respectively. Remaining graft material and new bone percentages for the

allograft were 25.5 ± 10.1% and 33.8 ± 9.4%, respectively, whereas those for the xenograft were 35.3 ± 16.8% and 22.2 ± 13.4%. Not a single difference was statistically significant. The study found that the alveolar ridge may be effectively maintained using both kinds of grafting materials [27].

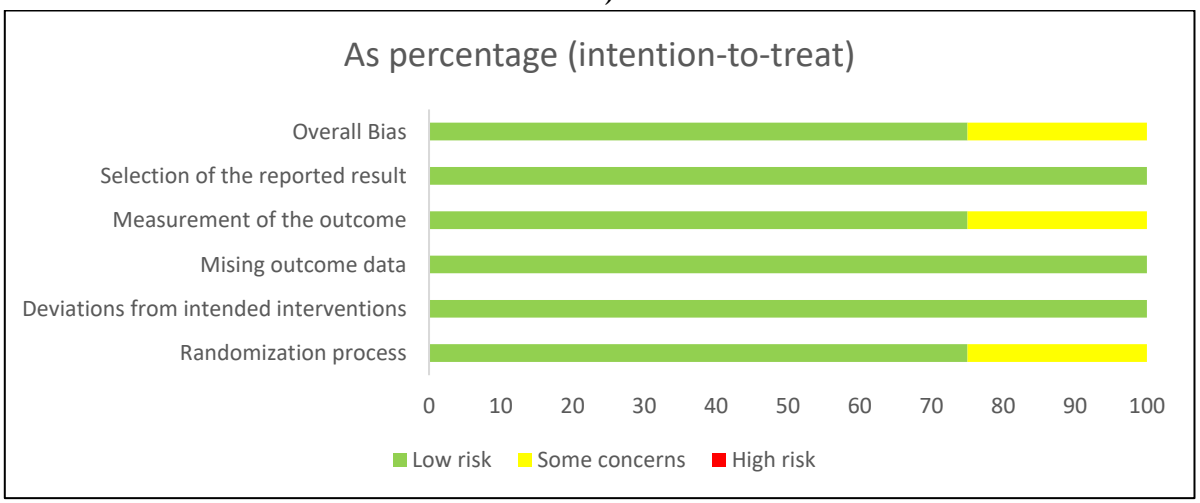
In Richardson *et al*.'s study, allograft (DFDBA) or xenograft (BDX) were used to treat patients with moderate to severe periodontitis with intrabony defects. Defects were considered in the research only if the depth of the intraosseous defect was around 3.0 mm. No negative healing reactions were seen, and the allograft group's average baseline pocket depth (PD), clinical attachment loss (CAL), and surgical defect depth were similar to those of the xenograft group. At six months, the results showed a statistically significant improvement in PD and AL for both graft materials across 26 defects, despite the fact that four defects did not react to the therapy. The BDX group showed a PD reduction of 3.0±1.7 mm and an AL gain of 3.6±1.8 mm, whereas the DFDBA group showed a PD reduction of 2.0±1.3 mm and an AL gain of 2.6±1.6 mm in terms of soft tissue outcomes. Osseous measures showed that the DFDBA group had 2.4 mm (46.8%) of bone fill, whereas the BDX group had 3.0 mm (55.8%). The DFDBA and BDX groups had defect clearance rates of 59.4% and 77.6%, respectively. No statistically significant differences were found between the two materials in any of the characteristics that were assessed [28].

Assessing the risk of bias

Four out of five articles included were RCT studies [24, 25, 27, 28] and the RoB2 tool was used for assessing them. Retrospective studies were used in one paper [26] and the ROBINS-E tool was employed. Three of the four RCTs had a low risk of bias, according to the RoB2 tool. Conversely, one had some reservations **(Figure 2)**. Measurement issues plagued this investigation, and the randomization of the samples was not made explicit [28]. The one research that was evaluated using the ROBINS-E program raised various issues around quantifying the results and missing data **(Figure 3)**.



A)



B)

Figure 2. (A) The risk of bias for each study; (B) Risk of bias in each domain, based on Cochrane risk of bias tool 2

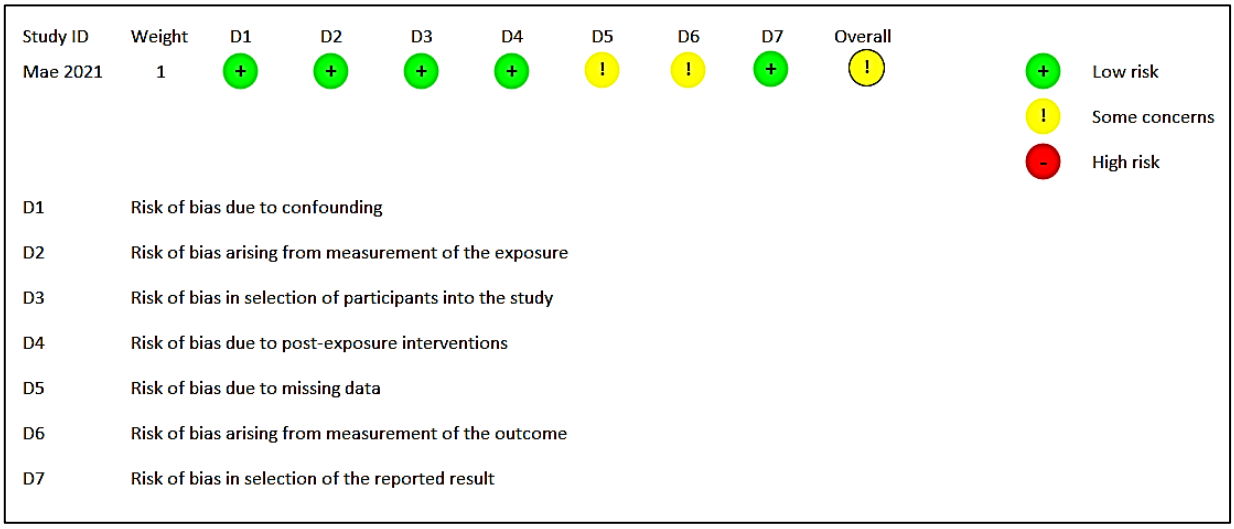


Figure 3. The risk of bias for each study based on the risk of bias in non-randomized studies of exposures (ROBINS-E) tool

Comparing the success rates of allografts and xenografts in the restoration of alveolar bone defects was the goal of this systematic study. The research comprised five publications in total. The surgical interventions performed in four studies were tooth extraction and placement of dental implants [24-27], and in one study, the surgical intervention was reconstruction of bone defects caused by periodontal disease [28]. Almost all studies stated that the results of these two interventions (allograft and xenograft) are not significantly different and both can be used in the reconstruction of alveolar bone defects; However, one study attributed the greatest bone regeneration potential to allograft. Nevertheless, in this study, it was stated that both of these grafts can be used successfully in the reconstruction of bone defects [25].

The alveolar bone experiences a series of resorptive changes after tooth extraction, leading to a reduction in bone volume [29]. An optimal functional and aesthetic outcome in implant rehabilitation relies on the presence of adequate alveolar bone volume and suitable architecture [30]. To address this loss, various augmentation techniques and materials have been developed [31]. Among the different types of bone grafts, autogenous bone is regarded as the gold standard due to its biological and histological properties [32].

To mitigate the limitations associated with autografts, alternatives such as bone substitutes (including allografts and xenografts) have been introduced. While autografts are known for their reliable characteristics—such as histocompatibility, nonimmunogenicity, and the ability to promote osteoinduction, osteogenesis, and osteoconduction—harvesting them can be impractical due to extended surgical times and potential comorbidities [25].

Before being deposited in the recipient location, allografts—which are from the same species—go through a number of processing and sanitation procedures. Their benefits include having an adequate supply and being able to be processed into many forms to suit patient demands, such as putty, gel, block, or particle. Allografts do, however, come with the potential of immunogenic reactions and, in certain situations, the spread of disease [33]. To lower the possibility of immunologic responses, xenografts—which come from other animals, usually cows—have all of their organic components eliminated. During the remodeling process, the residual inorganic structure helps to sustain the physical dimensions of the increased site by acting as a natural architectural matrix and a rich supply of calcium [25].

Per clinically, allografts are numerous and can be prepared in various forms that may be modified according to the surface area and location of the defect in addition to the overall needs of the client. They can be used as a final covering over a barrier membrane to improve the ridge augmentation procedure or act as a primary graft material in minor surgical interventions. Conversely, xenografts are used in situations where graft volume is desired to be stable over time and especially where resorption may affect prosthetic results around aesthetic zones. It is recognized that patient-rated results can be improved using these materials with suitable surgical procedures like socket maintenance before implant placement or guided bone regeneration [34, 35].

Comparing the interfacial zone of integrated bony grafting materials at the microscopic level specifies varying degrees of osteoconductivity and osteoinductivity. Histological examination of xenografts reveals that they have acceptable stability in long-term observation and function as osteoconductive matrices stimulating gradual direct bone apposition. Allografts give osteoconductive and osteoinductive capabilities since protein and growth factor sources are preserved during processing; stimulating bone cell migration and proliferation. However, there is variability to the quality of allografts due to the processing technique that can theoretically enhance osteoinductivity [36, 37]. From a histological perspective then, it must be understood that both allografts and xenografts are osteoinductive and osteoconductive but have specific differences in the regeneration processes. This procedure is senior and accepted due to well integration of allografts with host tissue where the FDBA and DFDBA have Bone morphogenetic proteins (BMPs) that are fundamental to direct new bone formation. Specifically, 'Advanced Bioactive Matrix

Proteins' contained in the BMP content of DFDBA furnishes improved osteoinductivity that enables the formation of new bone mass within a shorter time. Thus while the DBBM is primarily osteoconductive being far from the reliance on the host-stimulated bone regeneration, it serves to afford a scaffold upon which progressively becomes incorporated into the native hard tissue. On the other hand, there could be the drawback of high retention of residual grafted material that might be essential for volume conservation, but detrimental in the way it could hinder the remodeling process into host bone [34, 38].

The speed of bone replacement is a critical distinction. Xenografts, due to their minimal resorption, are ideal when longer-lasting volume stability is required, particularly in cases of extensive defects. The slower resorption of xenografts is attributed to the mineralized component that remains at the site, which can provide ongoing support but may delay full bone integration compared to allografts. In contrast, allografts tend to undergo quicker resorption and replacement by natural bone, a factor that can expedite the healing process. However, some studies have indicated that xenografts, with or without combination therapies like platelet-rich plasma, can support new bone formation effectively, balancing longer resorption with volumetric stability [36, 37, 39].

In terms of previous studies, allografts as well as xenografts present similar results in terms of the alveolar ridge height and width augmentation; however, differences include mineralized bone production rate and the degree of bone density and healing time. Structural characteristics of human bone and ability to retain dimensions of xenografts by contrast favors usage of xenografts especially of bovine origin. They provide predictable bone filling for horizontal and vertical ridge augmentation although they are resorbed more slowly than allografts. In the present study, allografts displayed faster integration and remodeling in the host bone as compared to autografts, which could be attributed to the higher osteoinduction potential of allografts because of their ability to support the endogenous bone healing. This property can make allografts somewhat slightly better for patients who require the grafts to incorporate at a faster rate so they can possibly have some implant placed [37, 39].

Alveolar ridge preservation strategies' effects on histology and clinical results have been the subject of several systematic evaluations. These treatments are successful in minimizing both vertical and horizontal variations in ridge size, according to the majority of these assessments. However, the whole volume of the ridge is not entirely preserved. Furthermore, no particular surgical method or grafting substance has been found to be better for preserving the alveolar ridge [40-44]. Nine clinical studies comparing alveolar ridge preservation techniques with unaided extraction socket healing were examined in a recent systematic review [37]. clinical studies and case series concentrating on three specific methods—guided bone regeneration, socket grafting, and socket sealing—were included in this evaluation. The results showed that, in contrast to alveolar ridge healing without assistance, alveolar ridge preservation had a beneficial impact on the decrease of both vertical and horizontal bone dimensional alterations [41].

Concerns for both allografts and xenografts include immunogenic response and disease transmission of which most are eliminated via processing. However, allografts slightly increase the risk of immunogenic reactions that in some cases may impair the healing process. The two materials involve considerations in terms of patient-specific factors that include defect size, defect site, and overall health of the patient. Notably, several of these works call for additional studies to determine other possible combinations of bone grafts, or other techniques used in conjunction with the grafts, such as the utilization of barrier membranes or biological agents to augment the effectiveness of each graft for specific clinical applications [36, 37].

This research faced several limitations, notably that the variables assessed across the studies were inconsistent, which precluded the possibility of conducting a meta-analysis. Additionally, the limited sample size and the minor scope of bone reconstructions necessitate careful consideration when interpreting the findings of this study. Further large sample-size studies using similar protocols are needed to make certain conclusions about medium- and long-term results, particularly in relation to implant retention and functional outcome after reconstructive surgery. In ongoing work, such improvements in graft selection criteria will be valuable for increasing the tailoring of treatment plans to the unique advantages of each graft type toward a more favorable clinical outcome.

Presently, the literature does not suggest that one form of transplantation, either allografts or xenografts, is generally preferable over the other, although there are occasions when one might be more appropriate than the other. Given the constraints of this study, it can be concluded that the findings align with earlier research, indicating that both allografts and xenografts are viable options for the reconstruction of alveolar bone defects, yielding positive outcomes. The suitability of each bone substitute is contingent upon the nature of the defect, the location of the surgical site, and the aesthetic considerations, provided that it is appropriately tailored within a comprehensive treatment plan.

Conclusion

The present systematic review demonstrated that allografts and xenografts are valid alternatives for the reconstruction of alveolar bone defects. Both materials have their indications: while allografts show faster integration and greater osteoinductive potential, therefore potentially being indicated in all cases where speed of healing is desirable, xenografts have the advantage of a steady volume over time that may turn out to be more useful in extended or aesthetic reconstructions. Choices between allografts and xenografts should, therefore, be determined by specific clinical needs of the defect site and size, the patient's overall health, and aesthetic outcome. More research is required with increased sample sizes and standardized protocols to more

clearly outline the long-term success of these materials and to work out an optimum treatment plan for a variety of clinical situations.

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Conflict of interest: None

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