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Potentials of pure xenograft materials in maxillary ridge augmentation: A case series

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ABSTRACT

Many patients require edentulous ridge augmentation for dental implant placement. The main objective of this study was to evaluate the results of maxillary edentulous ridge augmentation exclusively with xenograft materials with and without simultaneous sinus floor elevation. This study reports the data retrieved from the records of 16 patients. The treatment outcome was assessed at least 6 months, postoperatively. Paired samples *t*-test or Wilcoxon Signed Rank test was used to compare the pre-and postoperative ridge dimensions. Dental implants were placed simultaneously in 7 patients, while 9 patients underwent delayed implant placement. In total, 68 implants were placed, and 12 patients also underwent maxillary sinus floor augmentation. A significant bone gain was achieved in both horizontal and vertical dimensions of edentulous maxillary ridges ($P < 0.001$). Ridge width increased by an average of 4.35 ± 1.90 mm (95% CI: 3.84 to 4.85 mm) while ridge height in areas of sinus floor augmentation increased by 8.19 ± 2.91 mm (95% CI: 7.33 to 9.05 mm). Within the study limitations, it appears that maxillary ridge augmentation according to the guided bone regeneration (GBR) protocols with exclusive use of xenograft particulate materials can provide optimal bone quantity for dental implant placement.

1. Introduction

Augmentation of a resorbed edentulous ridge is imperative for implant placement under optimal prosthetic and biological conditions. Several modalities have been proposed for horizontal ridge augmentation, ranging from bone splitting to autogenous bone block grafting (Chiapasco and Casentini, 2018), with limited information regarding their efficacy (Smeets et al., 2022). Guided bone regeneration (GBR) is a commonly practiced technique to augment bone volume in both horizontal and vertical dimensions. Several modifications have been made in materials and techniques from flap design to the application of biomaterials for this purpose, aiming to increase the success and predictability of the procedure (Tolstunov et al., 2019).

Several factors including the ridge morphology, number of available bony walls, amount of cancellous bone at the graft site, the blood supply of the area, wound stability, and tension-free wound closure affect the success of treatment. Also, creating a suitable scaffold for new bone formation is highly important. Autogenous and allogenic bone substitutes and even autogenous block grafts have been used for horizontal ridge augmentation in clinical studies (Starch-Jensen et al., 2022). However, granular graft materials have been used for horizontal ridge augmentation in the majority of GBR-based procedures (Amoian et al., 2016). Nonetheless, clinical information regarding the 1:1 ratio of autogenous bone/xenograft material or even autogenous bone/synthetic material is much more abundant than other graft materials (Elamrousy et al., 2021). The logic behind the use of autogenous bone particles is to benefit from the higher capacity for new bone formation, while xenografts are primarily used for space maintenance. It may be stated that methods that induce the release of greater amounts of growth factors from autogenous bone may have higher clinical efficacy (Miron et al., 2013). It is generally believed that the ratio of autogenous bone/graft material should increase to 60:40 or 70:30 as the number of available bony walls and subsequently the osteogenic potential of the recipient site decrease. However, the use of xenograft particles alone has been proposed for multi-wall defects such as fresh extraction sockets (Di Stefano et al., 2022).

The available studies indicate a higher desire of patients for non-autogenous graft materials due to lower levels of pain and discomfort, and faster recovery (Chavda and Levin, 2018). On the other hand, procurement of a sufficient amount of autogenous bone for extensive

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defects may not be feasible. Given that horizontal ridge augmentation can be performed only with graft materials without autogenous bone, such procedures can be performed faster with less complexity. Allografts, however, are banned for use in some countries; also, the available data regarding active bone remodeling, amount of newly formed bone, and amount of residual graft particles in treated areas are highly variable (Solakoglu et al., 2019), which can be due to variations in graft donor sites. The alternative bone-derived graft material is the cancellous bone grafts harvested from animal sources.

Considering all the above, this study aimed to assess the outcome of augmentation of horizontal maxillary ridge defects exclusively with xenograft materials with and without simultaneous sinus floor augmentation.

2. Materials and methods

This study was conducted at a private clinic (Shiraz, Iran) and followed the Helsinki Declaration guidelines. The data were retrospectively retrieved from the patient records.

2.1. Patient selection

The inclusion criteria were (I) partial/complete edentulism of the maxillary ridge with or without the need for maxillary sinus floor augmentation, (II) patients requiring implant-supported fixed dentures, and (III) availability of follow-up data of patients for a minimum of 6 months after edentulous ridge augmentation.

The exclusion criteria were (I) smoking, (II) alcohol consumption, (III) substance abuse, (IV) uncontrolled metabolic disorders, (V) untreated periodontal disease, (VI) history of radiotherapy or intake of immunosuppressants, and (VI) history of intake of anti-resorptive medications.

2.2. Augmentation procedure

2.2.1. Treatment planning

Clinical data regarding the residual teeth status that could be preserved, edentulous areas, and soft tissue defects were collected. The amount of bone required in vertical and horizontal dimensions was quantified on panoramic radiographs and cone-beam computed tomography (CBCT) scans. The number and position of required implants and the time table of treatment were explained to patients, and written informed consent was obtained from them.

2.2.2. Surgical procedure

Local anesthesia was administered in the maxilla by injection of 4% articaine plus 1:100,000 epinephrine. A mid-crestal incision was made from the most anterior tooth to 5 mm beyond the augmentation area using a 15c surgical scalpel. An oblique releasing incision was made at the mesial end of the first incision and extended beyond the mucogingival line. A full-thickness flap was reflected using a periosteal elevator. In case of requiring maxillary sinus floor augmentation, the lateral window was outlined with 5 mm distance from the floor and anterior wall of the sinus by piezosurgery. Intentional perforation of cortical bone of the edentulous ridge was performed at 5 mm intervals using a round diamond bur. A barrier membrane of natural collagen (Bio-Gide, Geistlich Biomaterials, Switzerland) was prepared to correspond to the dimensions of the augmentation site and fixed in the most apical part of the vestibular region by using fixation tacks. Bovine xenograft material (Bio-Oss, Geistlich Biomaterials, Switzerland) was hydrated with sterile saline and applied in the sinus cavity and over the lateral wall of the edentulous ridge. The barrier membrane was extended over the crest to cover the palatal wall of the ridge and fixed in place by using additional tacks. The flap was released with periosteal-releasing incisions at the flap base, and also by releasing the muscle attachments at the vestibular side. The flap margins were coronally displaced with tension-free mattress sutures (poly-glycolic acid). Additional simple sutures were applied to ensure complete sealing of the incision site. Oblique incisions were approximated by using simple single sutures (Fig. 1 and Supporting Fig. S1). All surgical procedures were conducted by an experienced periodontist (M. L.).

2.2.3. Patient follow-up

All patients were prescribed 500 mg amoxicillin every 8 h, and 400 mg ibuprofen every 6 h for the first 7 days, postoperatively. Postoperative instructions included having a soft diet and 0.2% chlorhexidine rinse twice a day for the first week. The sutures were removed after 2 weeks, and the patients were instructed to refrain from using a removable partial denture during the healing period. A minimum of 6 months after surgery, CBCT of the augmented area was requested and the treatment results were assessed.

2.3. Implant placement

In patients eligible for implant placement simultaneous with ridge augmentation, dental implants were placed during the first surgical procedure. Otherwise, dental implants were placed at least 6 months after the first-stage surgery. Osteotomy holes were drilled by the standard technique 1–2 mm deeper than the implant height, but without using the crestal drill and bone tapping. Depending on the prosthetic treatment plan, an adequate number of implants with a minimum of 4 mm diameter and 10 mm height were placed. The implant platform was positioned subcrestally with a minimum torque of 25 N/cm^2. The flap was returned over the implants to allow healing with primary intention. At 4–6 months after implant placement, healing abutments were placed. Impressions were made after a minimum of 2 weeks for prosthetic treatment.

2.4. Data collection

Data regarding bone width and height were collected from CBCT scans on reproducible cuts with a fixed reference point such as the wall/floor of the nasal cavity or the maxillary sinus by an examiner not involved in the treatment process of patients. Calibration was performed by using the implant height. Since the implants were to be placed subcrestally, the buccolingual width of the ridge was measured at 2 mm apical to the ridge crest. To assess the magnitude of augmentation, depending on the extent of the region, 3 to 7 sections were assessed on CBCT scans.

2.5. Statistical analysis

The data were analyzed using SPSS version 26 (IBM, Armonk, New York). To determine if the data followed a normal distribution, the Shapiro-Wilk test was conducted. For comparisons between pre- and postoperative data, the paired samples *t*-test was employed if the data followed a normal distribution. Otherwise, the Wilcoxon Signed Rank test was used. The results were reported as the mean difference between pre- and postoperative measurements, along with a 95% confidence interval (CI). $P < 0.05$ was considered statistically significant.

3. Results

A total of 16 patients underwent augmentation procedures; out of which, 7 received horizontal ridge augmentation and 9 received horizontal ridge augmentation along with sinus floor elevation. A total of 68 dental implants were placed.

3.1. Augmentation results

No complications occurred during or after the surgical interventions. The mean buccolingual ridge width increased from 3.71 ± 1.40 mm

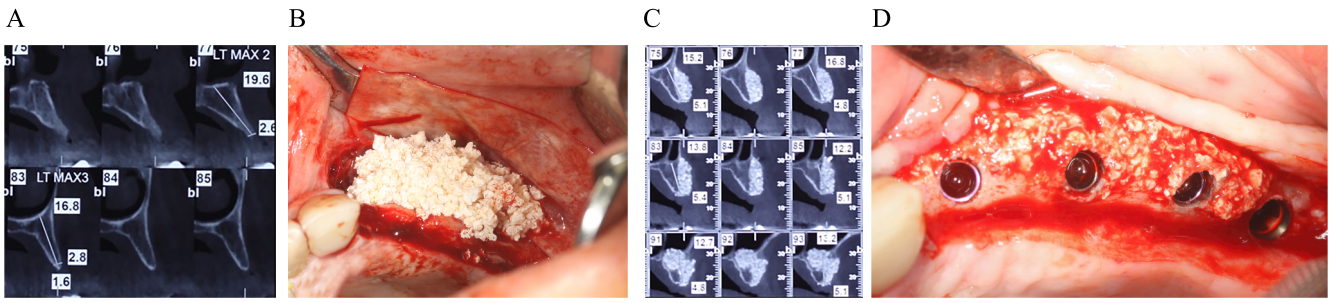

Fig. 1. A. Initial situation before the surgical procedure. B. Sinus floor elevation and simultaneous horizontal ridge augmentation. C. CBCT scan of the augmented ridge before implant placement. D. Clinical view of the regenerated area at the time of implant placement, exhibiting marked augmentation of the hard tissue.

(95% CI: 3.37–4.04 mm) at baseline to 8.17 ± 2.44 (95% CI: 7.53–8.82 mm) after treatment, indicating 4.35 ± 1.90 mm (95% CI: 3.84–4.85 mm) gain. The minimum and maximum values of gain were 2 and 7 mm, respectively. The mean gain was 4.77 ± 1.18 mm (95% CI: 3.78–5.76 mm) in horizontal ridge augmentation alone, and 4.61 ± 2.19 mm (95% CI: 3.94–5.28 mm) in horizontal ridge augmentation plus sinus floor augmentation, which were both statistically significant ($P < 0.001$); however, the difference between the two groups was not statistically significant ($P = 0.243$, Fig. 2).

The mean bone height was 12.59 ± 3.81 mm (95% CI: 11.47–13.71 mm) and 4.07 ± 1.46 mm (95% CI: 3.64–4.50 mm) in the groups without and with sinus floor augmentation at baseline, which increased to 13.43 ± 3.27 mm (95% CI: 12.47–14.39 mm) and 12.26 ± 2.24 mm (95% CI: 11.60–12.92 mm), respectively. The minimum and maximum values of gain in bone height in sinus floor augmentation areas were 5.2 mm and 14.4 mm, respectively (Table 1). No significant correlation was noted between the magnitude of bone gain in the horizontal dimension and the percentage of primary cancellous bone ($P = 0.241$) or primary edentulous ridge height ($P = 0.724$).

Table 1
Change in horizontal and vertical bone dimensions after intervention.

	Mean difference ± SD (mm)	*P* values
Horizontal augmentation	4.35 ± 1.90 (95% CI: 3.84 – 4.85)	<0.001*
Horizontal augmentation (immediate implants)	4.65 ± 1.73 (95% CI: 4.06–5.25)	<0.001¥
Horizontal augmentation (delayed implants)	4.17 ± 2.05 (95% CI: 3.46–4.89)	<0.001*
Vertical augmentation	4.46 ± 4.52 (95% CI: 3.57–5.36)	<0.001¥
Vertical augmentation (sinus floor elevation)	8.19 ± 2.91 (95% CI: 7.33–9.05)	<0.001*
Vertical augmentation (immediate implants/sinus floor elevation)	8.05 ± 3.40 (95% CI: 6.61–9.48)	<0.001*
Vertical augmentation (delayed implants/ sinus floor elevation)	8.34 ± 1.86 (95% CI: 7.53–9.14)	<0.001*

SD = standard deviation; CI = confidence interval.
* Paired Samples T Test.
¥ Wilcoxon Signed Ranks Test.

3.2. Implant placement results

All implants were placed with over 25 N/cm^2 torque, and no sign of > 1 mm crestal bone loss was seen for up to 36 months after healing. Of the available bone for implant placement, 55.54% was natural recipient site bone, and 44.46% was augmented bone tissue.

4. Discussion

Although the long-term durability of dental implants placed in newly formed bone has yet to be confirmed, the success of augmentation procedures in the provision of adequate bone tissue for successful implant placement has been well documented (Benic and Hammerle, 2014).

The success of augmentation procedures with xenograft alone depends on accurate biological assessment of the defect, and estimation of the healing capacity of the graft recipient site. Horizontal bone gain of 3.6 mm (3.2–6.9 mm) after 9–10 months of GBR with pure xenogeneic grafting materials has been reported (Hammerle et al., 2008). It appears that bone-derived or completely synthetic scaffolds can be used in defects with higher osteogenic potential. Histological assessments have shown that in 60% of non-contained horizontal defects, the connective tissue is present between the particles of synthetic graft material and new bone, and suitable integration does not occur (Sabet et al., 2017). Thus, the application of synthetic materials is only approved for non-

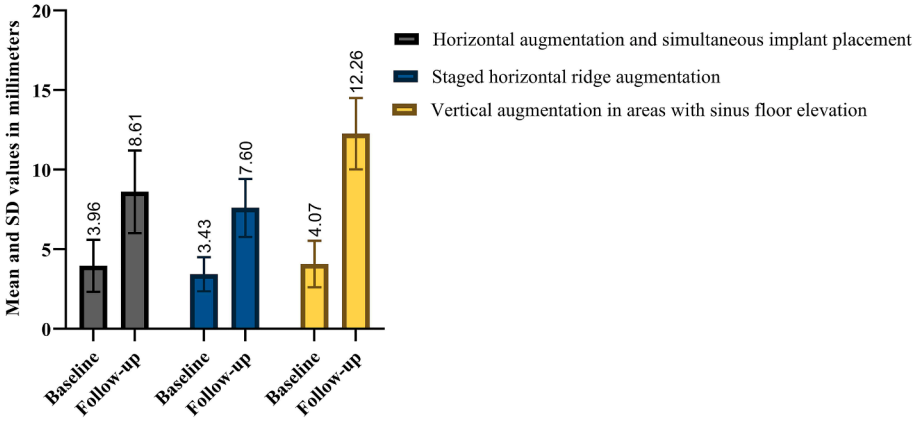

Fig. 2. Changes in bone level in horizontal and vertical dimensions.

critical defects such as maxillary sinus defects and those caused by the removal of intrabony cysts (Kawai et al., 2020).

In the present study, the use of xenograft granules resulted in a mean increase of 4.35 ± 1.90 mm (95% CI: 3.84–4.85 mm) in the ridge width. A similar study used a 1:1 ratio of autogenous bone and xenograft and reported 5.68 mm lateral augmentation after approximately 9 months (Urban et al., 2013). The magnitude of augmentation was sufficient for implant placement, and implant survival was 100% during the entire follow-up period. The high survival rate of dental implants placed in horizontally augmented bone by GBR has been confirmed in other clinical studies, with an augmented volume comparable to that in the use of autogenous bone grafts for up to 18 months after the procedure, but with lower levels of discomfort and hematoma (Mendoza-Azpur et al., 2019).

The optimal efficacy of GBR with xenograft materials has been confirmed in animal studies (Tien et al., 2021), and good clinical stability after horizontal augmentation of the maxillary anterior ridge with simultaneous dental implantation has been reported (Kamadjaja et al., 2019). Also, a *meta*-analysis of CBCT data following augmentation with xenograft materials confirmed space maintenance capacity and optimal dimensional stability of the augmented area (Pickert et al., 2022). Histological analysis also showed that the mineralized viable bone accounted for 26.9%, residual xenograft particles accounted for 21.3%, and non-mineralized tissue comprised 47.1% of the augmented volume (Ortiz-Vigon et al., 2017).

The maxillary sinus with accessible bony walls and Schneiderian membrane can promote the procurement of osteoprogenitor cells. Healing time is a factor of residual alveolar ridge bone, augmented sinus volume, and type of graft material. Although the highest amount of newly formed bone is achieved following the use of autogenous bone grafts, mineralized allografts or xenografts are now more commonly used for this purpose. The higher the absorption rate of graft material, the sooner the new bone forms; however, the risk of dimensional changes and dropping of elevated sinus floor also increases as such. However, the healing process may be up to 4 months longer in cases for whom particulate xenograft is used compared with autogenous bone substitute (Buser, 2022). The healing process may be enhanced by using autogenous growth factors such as platelet-rich fibrin (Ortega-Mejia et al., 2020).

A noteworthy issue is that various types of commercially available xenografts have differences; however, this topic has been less commonly addressed. Variations have been reported in morphology, pore size, porosity, crystalline structure, mesh structure, and even the percentage and ratio of calcium/phosphorous in xenografts as shown in a systematic review (Amid et al., 2021), which may affect the clinical results. In the augmentation of fresh extraction sockets with bovine and porcine xenografts, the treatment indices had no significant difference after 4 months; however, high variability has been reported in the treatment results (Lee et al., 2018).

In particulate grafting, the granule size is also important. In general, smaller granules provide larger volume and surface area (Fujioka-Kobayashi et al., 2021). Nonetheless, such findings have different interpretations and consequences in different clinical scenarios. For instance, the use of large-granule xenografts in sinus floor augmentation was associated with new bone formation, higher bone volume, and higher levels of angiogenesis; however, the clinical success rate of implants placed in augmented bone with large- and small-granule xenografts was comparable (Kamolratanakul et al., 2022).

In the present study, no case of soft tissue dehiscence occurred after augmentation. Evidence shows that an inverse correlation exists between postoperative complications and width gain (Barbu et al., 2021). It should be noted that soft tissue dehiscence occurs in up to 33% of treated cases with severe defects (Ortiz-Vigon et al., 2017).

Due to the small number of patients treated with the technique employed in the present study, the present results can be used as preliminary data to pave the way for further investigations; although similar studies on five (Tunkel et al., 2021) to seventy (Barbu et al., 2021) patients also exist. Controlled clinical trials along with histological and immunohistochemical assessments can enhance our clinical and basic knowledge in this respect. Some experimental data indicate the active role of barrier membrane in osteogenesis, and no longer consider it as a passive membrane that is only responsible to keep epithelial cells and connective tissue away from the augmented space. This topic should be further evaluated in future studies by comparing the applications of different barrier membranes.

5. Conclusions

Maxillary ridge augmentation by GBR with and without sinus floor augmentation using demineralized bovine bone matrix can sufficiently increase the ridge width and height to allow the implementation of implant-supported treatment plans.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sdentj.2023.10.005.

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