Bone Volume Dynamics and Implant Placement Torque in Horizontal Bone Defects Reconstructed with Autologous or Xenogeneic Block Bone: A Randomized, Controlled, Split-Mouth, Prospective Clinical Trial

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Purpose: *The aim of this study was to evaluate volumetric stability of autologous and xenogeneic block grafts and primary stability of implants in maxillary grafted areas.* ***Materials and Methods:*** *Each patient received one autologous block and xenogeneic block, both covered with a membrane. Bone thickness measurements clinically and tomographically were made before, immediately, and 6 months postoperatively. After 6 months, identical implants were placed in each grafted area, and primary stability was measured.* ***Results:*** *Eight patients with anterior horizontal bone defects were selected. Clinical outcomes at 6 months postgrafting in the autologous block revealed a mean thickness of 7.4 ± 1.6 mm, with an initial mean measurement of 3.4 ± 1.7 mm and 2.6% resorption, whereas the mean in the xenogeneic block was 8.9 ± 1.5 mm, 3.3 ± 1.6 mm, and 7.3%, respectively. Tomographic evaluation of the thickness at 6 months postgrafting in the autologous block was a mean 7.8 ± 1.8 mm, with an initial mean of 3.7 ± 1.6 mm and resorption of 0%, while the mean in the xenogeneic block was 9.3 ± 1.6 mm, 3.6 ± 1.4 mm, and 2.1%, respectively. No significant difference in bone thickness was observed immediately or 6 months after the procedure. The mean implant placement torque was 32 ± 22 Ncm in the autologous block and 18 ± 9 Ncm in the xenogeneic block (P = .004).* ***Conclusion:*** *Xenogeneic block was shown to be a suitable alternative to reconstruct horizontal defects in the alveolar ridge that had undergone extensive resorption, though lower insertion torques were obtained during implant placement.* Int J Oral Maxillofac Implants 2018;33:888–894. doi: 10.11607/jomi.6288

Keywords: *bone block graft, bone grafts, xenogeneic bone block graft*

Tooth loss, systemic factors, and/or long-term edentulous arches may lead to alveolar bone resorption in terms of both width and height.[1] The alveolar ridge undergoes a mean reduction of 3.8 mm horizontally and 1.24 mm vertically within 6 months following tooth extraction.[1,2] In cases of extensive resorption that hinders implant placement, ridge augmentation procedures may be required.[3]

Among the materials for bone grafting, autologous bone is undoubtedly the most suitable due to its biologic characteristics, such as osteoconduction, osteoinduction, and osteogenesis.[1,4] Grafting from intraoral donor sites may, however, only provide a limited amount of autologous bone while exposing the patient to additional morbidity, such as wound dehiscence, postsurgical swelling, pain, and nerve damage.[5] As an alternative to autologous bone grafting, several studies have reported the use of particulate xenogeneic graft materials. Particulate bone grafts have low mechanical stability; thus, the association of membranes or titanium mesh for ridge augmentation may be necessary. In recent studies, xenogeneic

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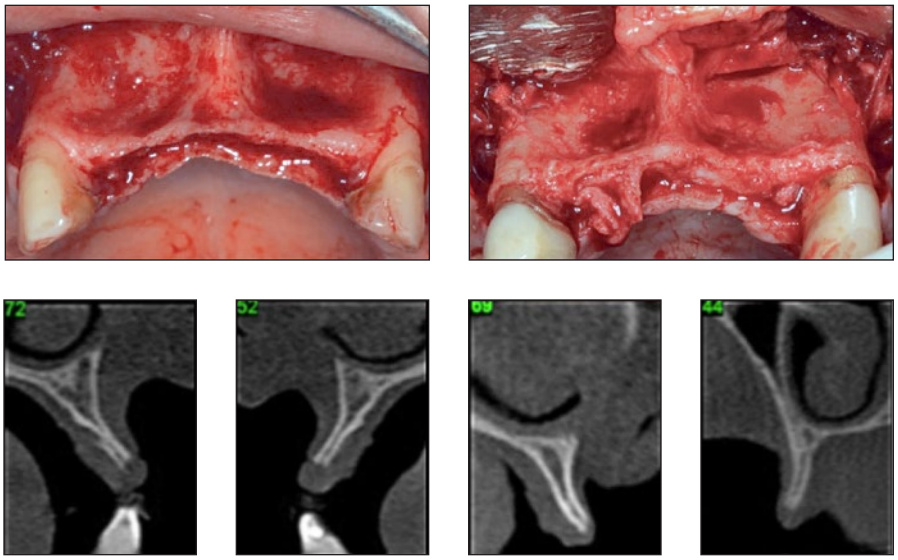

Fig 1 Clinical and CBCT preoperative views of a representative atrophic maxilla that underwent implantation as part of this study.

bovine bone block (Bio-Oss Block) has been considered an alternative to particulate bone grafts.[6,7] However, most of the studies[8,9] using xenogeneic bone blocks have been performed in animal models. Therefore, clinical studies must be conducted, especially in anterior areas of the maxilla, which have considerable labial muscle forces that can compromise mechanical stability and promote reabsorption of the bone graft.[8–12]

According to Araújo et al,[6] grafts from cortical or cancellous bone will undergo resorption during healing. In a canine model, resorption was observed during healing for autologous cortical bone grafts in single wall defects, while a xenogeneic block graft with similar features maintained its dimensions with limited amounts of new bone formed within the biomaterial. Conversely, another study reported no difference with respect to graft shrinkage, regardless of whether a block or particulate autologous graft was used with a cell-occlusive barrier.[13]

Bone volume stability after grafting is necessary to allow the placement of implants in an adequate position from both functional and esthetic viewpoints. Implant insertion torque value (ITV) is another significant clinical parameter to predict long-term implant success rates and to decide upon immediate loading.[14] For accurate assessment of the differences between autologous grafts and xenogeneic block grafts for bone regeneration that allows implant placement, the two approaches should be compared. Therefore, the aims of the present investigation were to compare volume stability between autologous and xenogeneic blocks used as onlay grafts and to compare the insertion torque of implants placed in the grafted areas.

MATERIALS AND METHODS

Patient Selection

This study was a controlled, split-mouth clinical trial conducted in accordance with the CONSORT guidelines and the Declaration of Helsinki. It was approved by the Research Ethics Committee of the São Leopoldo Mandic Institute and Research Center, Campinas, São Paulo, Brazil.

Patients undergoing implant treatment in the anterior region of the maxilla at the São Leopoldo Mandic Dental School in Campinas (São Paulo, Brazil) were considered for inclusion in this study. Patients were included if they had trauma or pathology-induced alveolar bony defects in the anterior maxilla (Fig 1), absence of the four maxillary incisors, and were in good general health at the time of surgery. Patients were excluded if they met any of the following criteria: endodontic treatment required for a tooth adjacent to the target site, smoking habit of > 10 cigarettes per day, parafunctional habits, and pregnancy.

A paired randomization algorithm accounted for bone graft position, and the operator was informed of the group allocation at the time of the surgery by a third researcher, unconnected to the study, who created a randomization schedule using a web-based randomizer (https://www.random.org/lists/).

Sample-size calculation was performed using G*Power 3.1.5 considering a repeated-measures analysis of variance (ANOVA). For the effect size of 0.77 calculated based on a pilot study with preliminary data gathered from four patients, a correlation between repeated measurements of 0.47, and a significance level of 5%, a total of eight participants would be necessary to achieve a power of 90%.

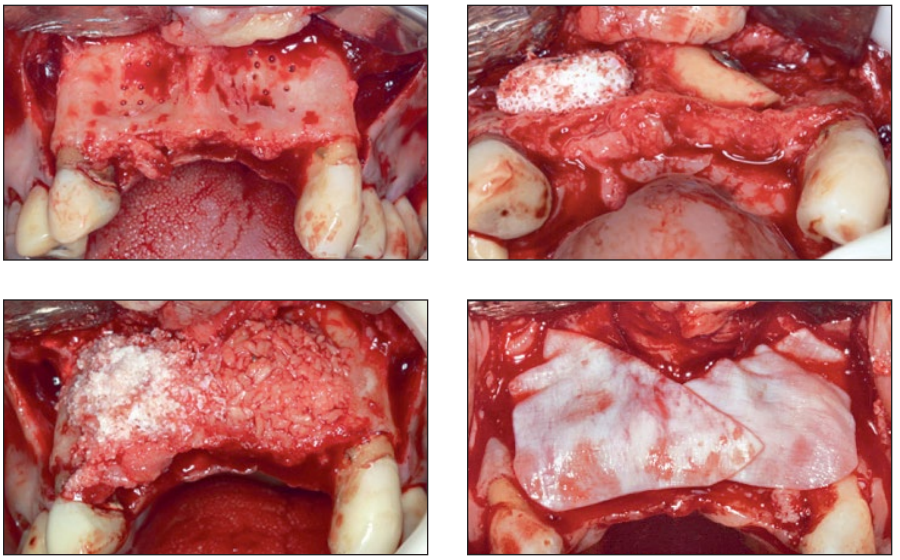

Fig 2 The cortex of the maxilla was perforated with a round bur to gain access to the marrow, and autogenous and xenogeneic block graft was placed in the concave area, filled with particulate bone graft, and covered with a collagen membrane.

Reconstructive Surgery

Patients received 2 g of amoxicillin 1 hour before surgery. They were instructed to rinse their mouth with a 0.12% chlorhexidine solution for 60 seconds immediately before surgery. All reconstructive procedures were performed by the same operator (R.G.L.).

Local anesthesia consisting of 2% lidocaine (1:100,000 epinephrine) was administered. An incision was made along the alveolar ridge through the keratinized gingiva to the alveolar crest, and a diverging lateral relieving incision was made at the base of the first incision on both sides. A full mucoperiosteal flap was raised to expose the atrophic ridge, and the cortical plate was perforated with a spherical bur multiple times to induce bleeding at various sites.

Local anesthesia (2% lidocaine, 1:100,000 epinephrine) was administered to the donor area (ramus of the mandible). An incision was performed along the mucogingival line, from the distal aspect of the second premolar extending posteriorly to the retromolar pad. In some cases, no relieving incision was needed because the available access was sufficient. A cortico-cancellous block was then removed from the oblique line of the ramus of the mandible using a 10- to 12-mm trephine drill (Maximus) attached to a 20:1 speed-reducing contra-angle with abundant saline irrigation.

Autologous blocks were shaped using rotatory burs and the xenogeneic blocks (10 × 10 × 20-mm blocks, Geistlich Bio-Oss Block) according to the outline of the bony defect. Fixation screws (2 × 11 mm, Neodent) were used to fix all the grafts to the residual alveolar bone. The gaps were filled with particulate bone of the same origin as the block used. Autologous blocks were particulated with a bone mill and xenogeneic blocks with a bone rongeur. Collagen membranes were fitted to cover the grafts (Bio-Gide, Geistlich), as suggested by previous studies[15,16] (Fig 2). The periosteum of the buccal flap was released to allow tension-free coronal advancement of the flap, wound closure, and suturing. The flaps were closed using 4–0 Nylon (Ethicon) and interrupted horizontal mattress sutures.

All patients received oral amoxicillin for 7 days (3× 500 mg), or clindamycin for 7 days in case of allergy (2× 300 mg), and dexamethasone for 4 days (2× 4 mg) after the reconstruction procedure. Postoperative instructions included liquid/soft diet and the use of 0.12% chlorhexidine mouthwash until the sutures were removed between 10 and 15 days after the ridge augmentation procedure.

Six months after the ridge augmentation procedure, implants were placed with a surgical guide at an ideal restorative position for a screw-retained prosthesis without the need for further augmentation procedures. The sites were prepared following the protocol provided by the manufacturer: initial with spherical 2.0 mm; a 2-mm pilot drill was first used to establish depth, followed by twist drills, 2 mm and 2.8 mm. After site preparation, implants were placed. All implants (Neodent) were identical both in dimensions, 3.5 × 10 mm, and in macrogeometry (tapered). Primary stability of the implant was assessed using peak insertion torque values using a torque-controlled ratchet (Neodent). No implant-supported provisional prostheses were used. After 4 months, all patients received metal-ceramic four-unit fixed screw prostheses.

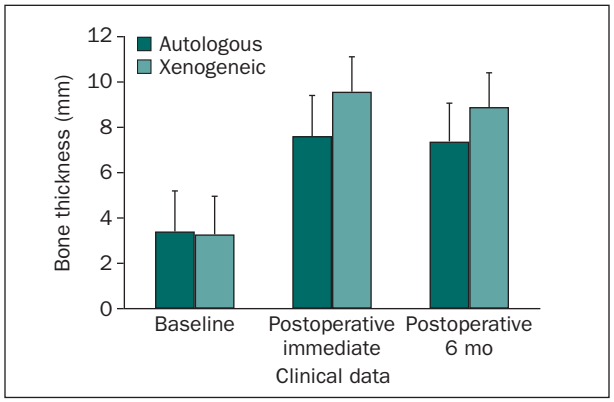

Fig 3 Means and standard deviations of bone thickness (mm) obtained clinically according to the type of graft.

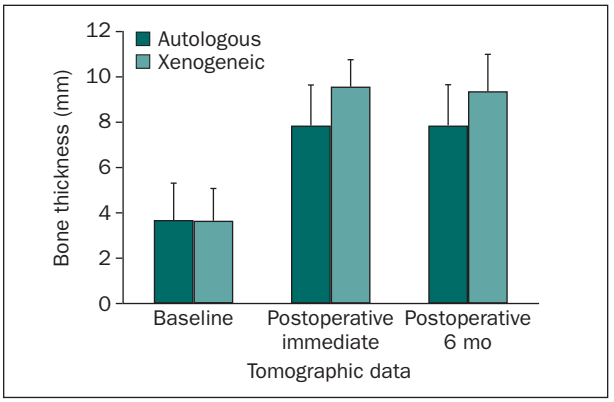

Fig 4 Means and standard deviations of bone thickness (mm) obtained tomographically according to the type of graft.

CBCT and Clinical Evaluation

All cone beam computed tomography (CBCT) scans were acquired using the same system (i-CAT 3D Imaging System, i-CAT Vision Software, Imaging Sciences International) and the soft tissue CBCT technique.[15] The maxilla was scanned preoperatively, immediately postoperatively, and 6 months postoperatively. Sagittal sections (1.0 mm in thickness) were obtained as CBCT reconstructions.

A trained oral radiologist (B.S.S.M.) assessed all CBCT images independently. For the measurements, the central sagittal slices of the bony defects (preoperative CBCT) and the slices containing the screw-fixed bone graft (immediate and 6 months postoperatively) were selected. The examiner measured the distance from the palatal border to the buccal bone ridge using the CT reference ruler adjusted against the real measurements of a manual ruler over the computer screen. All tomographic measurements were performed with a minimum of 2-week intervals, and the reproducibility was calculated using kappa statistics. Means and standard errors were calculated for each reference measurement. The examiner recorded the second set of measurements blinded to the first set, in order to evaluate the reliability of the recordings.

The clinical measurements were performed with a high-precision caliper (Talmax) during bone reconstruction surgery: adjacent to the screw hole prior to grafting, adjacent to the fixation screw after placement of the bone graft, and at implant placement surgery 6 months after bone reconstruction. Thus, the measurements were taken in the same place at all time intervals to standardize measurements throughout.

Statistical Analysis

The Student *t* test was applied to confirm that the bone thickness of the sites designated to receive autologous or xenogeneic grafts was not different at the commencement of the study. Intraclass correlation coefficients (ICCs) were used to investigate whether CBCT provided reliable bone thickness measurements in comparison to clinical measurements taken at each time point. With regard to bone thickness measurements, the pre- and postgraft data were compared using a paired *t* test. Three-way ANOVA with repeated measures in time and participants was applied to test the effect of the graft type, of the time, and their interaction on bone thickness. Data regarding placement peak torque were analyzed using two-way ANOVA, with repeated measures within each participant. Statistical calculations were performed at the 5% significance level, using SPSS 20 (SPSS).

RESULTS

Eight patients (mean age: 53.3 ± 9.5 years), five women and three men, received two implants in the lateral incisor area to support a fixed prosthesis. No postoperative complications were observed in any of the patients. All implants placed in either type of bone graft were osseointegrated. No graft displacement was observed in any case. No significant statistical differences were found between the results in both measurement periods. The Cohen Kappa coefficient was 0.68, indicating that the study was reliable.

Figures 3 and 4 present the descriptive analysis of bone thickness, measured clinically and by means of CBCT, respectively, at different time points. In addition, the difference in the bone thickness between the pre- and postgrafting procedures was shown. Preoperative bone thickness of the sites designated to receive autologous grafts did not significantly differ from that designated to receive xenogeneic grafts ($P = .886$) in the 6 months postoperatively. Measurements of bone thickness performed using CBCT showed excellent

Table 1 Absolute (mm) and Relative (%) Error of Bone Thickness from CBCT in Relation to Clinical Data and ICC

Evaluation time	Absolute error (mm)	Relative error (%)	ICC	Reproducibility
Baseline	0.3 (0.6)	17	0.751	Excellent
Postgrafting	0.1 (0.9)	1	0.952	Excellent
6 mo	0.3 (0.7)	4	0.950	Excellent

ICC = intraclass correlation coefficient; CBCT = cone beam computed tomography.

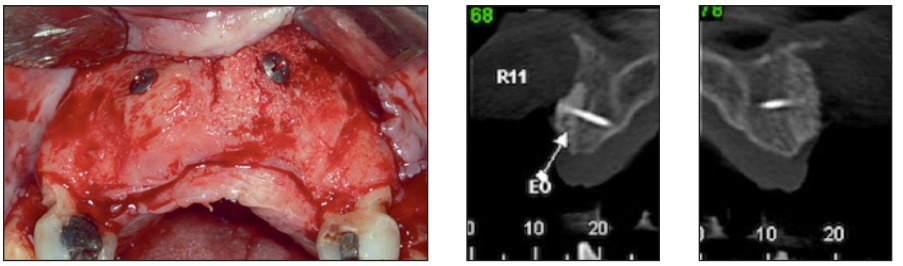

Fig 5 Clinical and CBCT images showing the bone volume gain; autologous bone graft *(right)* and xenogeneic bone graft *(left)*.

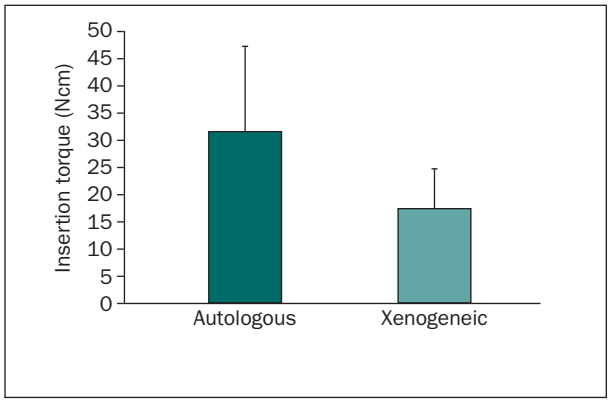

Fig 6 Mean insertion torque (Ncm) according to each group.

reliability, as found by ICCs, in all time evaluations (Table 1). The paired *t* test revealed that both grafting procedures significantly increased the bone thickness both clinically ($P < .001$) and in CBCT ($P < .001$). Three-way repeated-measures ANOVA showed no interaction between the graft type and the time ($P = .247$). Immediately and 6 months after the grafting procedure, bone thickness was significantly higher when the xenogeneic graft was used ($P = .010$). For both grafting materials, no significant difference was observed in bone thickness immediately and 6 months after ($P = .353$).

Clinical outcomes at 6 months postgrafting in the autologous group revealed a mean thickness of 7.4 ± 1.6 mm, with an initial mean measurement of 3.4 ± 1.7 mm and 2.6% resorption, whereas the xenogeneic block had a mean 8.9 ± 1.5 mm, 3.3 ± 1.6 mm, and 7.3%, respectively (Fig 5). Tomographic evaluation of thickness at 6 months postgrafting in the autologous group was a mean 7.8 ± 1.8 mm, with an initial mean of 3.7 ± 1.6 mm and 0% resorption, while for the xenogeneic graft block, it was 9.3 ± 1.6 mm, 3.6 ±1.4 mm, and 2.1%, respectively.

The placement peak torque was significantly higher when the autologous graft (32 ± 22 Ncm) was used ($P = .004$) than the xenogeneic block (18 ± 9 Ncm) (Fig 6).

DISCUSSION

The present study assessed the clinical and tomographic outcomes of autologous and xenogeneic block used as an onlay graft to the anterior maxilla as well as the insertion torque of implants placed in the grafted areas. The results showed that both techniques were successful in the maintenance of gained bone volume, although the xenogeneic group yielded lower insertion torques. The sample population was relatively small, however, as this was a split-mouth design study; the variation within patients was minimized by the fact that the alveolar ridge defects were similar between sides ($P = .886$).[13]

The results from the present study demonstrated mean horizontal gains of 7.4 ± 1.6 mm and 9.3 ± 1.6 mm, at baseline for the autologous and xenogeneic grafts, respectively. This difference in thickness gain is directly related to bone availability at the donor site for the autograft. In the xenogeneic graft group, the thickness of the block was left to the surgeon's discretion, which would be dependent on shaping and adaptation to the recipient bed.

No difference was observed between the groups with respect to horizontal shrinkage, and both grafts showed dimensional stability over the observed time.

In the present study, the use of a barrier membrane and provisional teeth-supported removable dentures may explain dimension maintenance in both groups. A recent study investigated vertical ridge augmentation using block and particulate autologous bone and reported that the presence of a cell-occlusive barrier favored success rates.[13] However, Araújo et al[6] found significant resorption foci on the autologous bone graft surface, whereas the xenogeneic graft maintained its volume and trabecular bone framework using a barrier membrane. The bony defects treated in the aforementioned studies were different in shape and sites, which could have accounted for the diverging outcomes reported.

Xenogeneic bone blocks were also successful in ridge augmentation using a subperiosteal tunneling procedure in a study by Li et al.[8] In contrast to the present study, they stated that new bone formation through the bovine bone block trabeculae may occur in the absence of a barrier membrane. They claimed that their favorable results were due to periosteal preservation secondary to careful detachment of the flap without raising it or releasing it with incisions, thus highlighting the role of the periosteum in osteogenesis.

In a systematic review, Chiapasco et al[17] recommended the use of cortico-cancellous bone blocks because they provide sufficient rigidity to withstand tension from the overlying soft tissues or from compression by provisional removable dentures. In the present study, a cortical block was used and compression to the grafted areas was eliminated using teeth-supported provisional removable dentures.

Implant stability depends on the direct mechanical friction contact between its surface and the surrounding bone and can be divided into primary and secondary stability. Primary stability depends on several factors, including the density and dimension of the host bone, implant geometry, and surgical technique used.[18,19] High peak insertion torque has been considered advantageous in improving primary stability,[19] serving as a useful parameter to aid in decision-making as to whether immediate implant loading could be applied or an unloaded healing time should be allowed beforehand. The basic architecture and the content of cortical and trabecular bone of the two types of grafts are different, and these structural and biologic differences may result in different levels of insertion torque.

Conventional radiographs do not provide any direct information concerning modifications of horizontal bone augmentation, and total loss of regenerated tissue cannot be assessed on panoramic or intraoral radiographs.[17] A second surgical procedure may be necessary to evaluate the outcome of bone regeneration procedures, or to remove a nonresorbable membrane to place an implant. However, in cases where membrane removal is not required or implants are planned to be placed using a flapless approach, long-term stability of the grafted sites may be evaluated by CBCT; this study found CBCT to be a reliable method to assess the outcome of grafting procedures.

Patient morbidity associated with the use of autogenous block grafts (intraoral and extraoral) and the limitations in terms of available volume[13] may suggest a shift in treatment regimens to less traumatic techniques.

The short period of follow-up is the primary limitation of the present study about bone graft remodeling, and the use of a clinical ratchet to measure insertion torque shows the difficulty of accurately reading between 10, 20, 32, 45, and 60 Ncm graduations.

CONCLUSIONS

Xenogeneic blocks have been shown to be a suitable alternative to reconstruct horizontal defects and alveolar ridge that has undergone extensive resorption, though lower insertion torques were obtained during implant placement. Further investigation on the behavior of these implants and the prosthetic rehabilitation is recommended and is currently underway.

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The authors reported no conflicts of interest related to this study.

REFERENCES

1. Tompkins KA. The osteoimmunology of alveolar bone loss. Connect Tissue Res 2016;57:69–90.
2. Lang NP, Pun L, Lau KY, Li KY, Wong MC. A systematic review on survival and success rates of implants placed immediately into fresh extraction sockets after at least 1 year. Clin Oral Implants Res 2012;23(suppl):s39–s66.
3. Misawa M, Lindhe J, Araújo MG. The alveolar process following single-tooth extraction: A study of maxillary incisor and premolar sites in man. Clin Oral Implants Res 2016;27:884–889.
4. Burchardt H. The biology of bone graft repair. Clin Orthop Relat Res 1983;(174):28–42.
5. Aloy-Prósper A, Peñarrocha-Oltra D, Peñarrocha-Diago M, Peñarrocha-Diago M. The outcome of intraoral onlay block bone grafts on alveolar ridge augmentations: A systematic review. Med Oral Patol Oral Cir Bucal 2015;20:e251–e258.
6. Araújo MG, Sonohara M, Hayacibara R, Cardaropoli G, Lindhe J. Lateral ridge augmentation by the use of grafts comprised of autologous bone or a biomaterial. An experiment in the dog. J Clin Periodontol 2002;29:1122–1131.
7. Lee SA, Lee CT, Fu MM, Elmisalati W, Chuang SK. Systematic review and meta-analysis of randomized controlled trials for the management of limited vertical height in the posterior region: Short implants (5 to 8 mm) vs longer implants (> 8 mm) in vertically augmented sites. Int J Oral Maxillofac Implants 2014;29:1085–1097.

8. Li J, Xuan F, Choi BH, Jeong SM. Minimally invasive ridge augmentation using xenogenous bone blocks in an atrophied posterior mandible: A clinical and histological study. Implant Dent 2013;22:112–116.
9. Mayfield LJ, Skoglund A, Hising P, Lang NP, Attström R. Evaluation following functional loading of titanium fixtures placed in ridges augmented by deproteinized bone mineral. A human case study. Clin Oral Implants Res 2001;12:508–514.
10. Araújo MG, Carmagnola D, Berglundh T, Thilander B, Lindhe J. Orthodontic movement in bone defects augmented with Bio-Oss. An experimental study in dogs. J Clin Periodontol 2001;28:73–80.
11. Wetzel AC, Stich H, Caffesse RG. Bone apposition onto oral implants in the sinus area filled with different grafting materials. A histological study in beagle dogs. Clin Oral Implants Res 1995;6:155–163.
12. Zitzmann NU, Schärer P. Sinus elevation procedures in the resorbed posterior maxilla. Comparison of the crestal and lateral approaches. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998;85:8–17.
13. Rocchietta I, Simion M, Hoffmann M, Trisciuoglio D, Benigni M, Dahlin C. Vertical bone augmentation with an autogenous block or particles in combination with guided bone regeneration: A clinical and histological preliminary study in humans. Clin Implant Dent Relat Res 2016;18:19–29.
14. Troedhan A, Schlichting I, Kurrek A, Wainwright M. Primary implant stability in augmented sinuslift-sites after completed bone regeneration: A randomized controlled clinical study comparing four subantrally inserted biomaterials. Sci Rep 2014;4:5877.
15. Januário AL, Barriviera M, Duarte WR. Soft tissue cone-beam computed tomography: A novel method for the measurement of gingival tissue and the dimensions of the dentogingival unit. J Esthet Restor Dent 2008;20:366–373; discussion 374.
16. von Arx T, Buser D. Horizontal ridge augmentation using autogenous block grafts and the guided bone regeneration technique with collagen membranes: A clinical study with 42 patients. Clin Oral Implants Res 2006;17:359–366.
17. Chiapasco M, Zaniboni M, Boisco M. Augmentation procedures for the rehabilitation of deficient edentulous ridges with oral implants. Clin Oral Implants Res 2006;17(suppl):s136–s159.
18. Mohlhenrich SC, Heussen N, Elvers D, Steiner T, Hölzle F, Modabber A. Compensating for poor primary implant stability in different bone densities by varying implant geometry: A laboratory study. Int J Oral Maxillofac Surg 2015;44:1514–1520.
19. Trisi P, Perfetti G, Baldoni E, Berardi D, Colagiovanni M, Scogna G. Implant micromotion is related to peak insertion torque and bone density. Clin Oral Implants Res 2009;20:467–471.