Evaluation of Bone Density in Sinus Elevation by Using Allograft and Xenograft: A CBCT Study

Reza Tabrizi, DMD1/Hassan Mirmohammad Sadeghi, MD, DDS1/Maryam Mohammadi1/ Mehrdad Dehghanpour Barouj, DMD1/Mahtab Kheyrkhahi, DDS2

Purpose: The stability and density of the grafted bone in the maxillary sinus are essential for dental implant survival. This study aimed to compare bone density following mineralized allogeneic bone and deproteinized bovine bone and evaluate the volumetric changes as the secondary outcome. Materials and Methods: In this prospective cohort study, subjects were randomly allocated into two groups of mineralized bone and deproteinized bone to augment the maxillary sinus. Subjects underwent CBCT immediately after augmentation and 9 months later. The relative bone density was the primary outcome, and the volumetric change after 9 months was the secondary outcome of the study. The authors used an independent t test for assessing the bone density and volumetric change between the two groups. Results: Fifty patients were studied (n = 25 in each group). At 9 months after sinus elevation, the mean bone density was 237.20 ± 55.72 Hounsfield units (HU) in group 1 (mineralized bone) and 634.8 ± 166.11 HU in group 2 (deproteinized bone). There was a substantial difference statistically for the mean of HU between groups 1 and 2 (P < .001). The mean volume change was 0.25 ± 0.13 cm³ in group 1 (mineralized bone) and 0.06 ± 0.05 cm³ in group 2 (deproteinized bone). Assessment of the data showed a substantial difference in the mean volume change at 9 months after sinus elevation between groups 1 and 2 (P < .001). Conclusion: Considering the results of this study, the deproteinized bone was associated with higher relative bone density than the mineralized bone 9 months after sinus elevation. The volume change of the deproteinized bone was less than the mineralized bone in the study time. Int J Oral Maxillofac Implants 2022;37:114–119. doi: 10.11607/jomi.9116

Keywords: bone substitutes, cone beam computed tomography, maxillary sinus, sinus floor augmentation

Sinus elevation is an acceptable approach for rehabilitating deficient bone of the posterior maxilla due to tooth loss and pneumatization of the maxillary sinus.1 The volume of bone formation after bone graft maturing and the survival of implants in the long term indicate the success of maxillary sinus elevation.2 Primary stability is considered an essential factor in dental implant success. Bone density is an important factor that has an impact on the primary stability of dental implants.3 Several bone substitutes have been applied in maxillary sinus elevation, including xenogeneic bone, allogeneic bone, autologous bone, and alloplasts.4 The volumetric changes of bone graft materials have been previously studied.5,6 However, few studies have investigated the bone density and quality of the new bone following maxillary sinus elevation.7 Deproteinized bovine bone and mineralized allogeneic bone are the two bone substitutes commonly used for maxillary sinus elevation.8 A literature review revealed no studies comparing bone density following the application of mineralized bone and deproteinized bone for maxillary sinus elevation.

The purpose of this study was to address the following question: Would there be any difference in the density of bone in the use of mineralized bone and deproteinized bone for maxillary sinus elevation? The similarity of bone density following the application of mineralized bone and deproteinized bone was considered as the study hypothesis. Therefore, the study aimed to compare bone density following mineralized bone and deproteinized bone and evaluate the volumetric changes as the secondary outcome of the study.

MATERIALS AND METHODS

The authors conducted a prospective cohort study. The study sample was chosen from subjects presented to the Oral and Maxillofacial Surgery department to rehabilitate a partially edentulous area in the posterior maxilla from September 1, 2017, to December 31, 2019. The research was accepted in the medical ethics committee of Shahid Beheshti University of Medical Sciences (no: IR.SBMU.DRC.REC.1398.069). Subjects were included in

1School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
2Oral and Maxillofacial Radiology, Private Practice, Tehran, Iran.

Correspondence to: Dr Hassan Mirmohammad Sadeghi, OMFS Department, Shahid Beheshti Dental School, Velenjak, Tehran, Iran. Email: mardsadeghi.hassan@yahoo.com

Submitted November 18, 2020; accepted June 12, 2021. ©2022 by Quintessence Publishing Co Inc.
the research if they had a partially edentulous area in the posterior maxilla. They were candidates for open sinus elevation surgery because of insufficient bone height (< 5 mm). The exclusion criteria consisted of a history of previous sinus elevation or a vertical or horizontal septum in the maxillary sinus, requiring horizontal bone augmentation, smoking, a systemic disease affecting bone metabolism, consuming any drugs or nasal spray that affect bone regeneration such as corticosteroid, failing to show up for the follow-up, or declining study enrollment. No dental implants were placed simultaneously with a sinus elevation. Participants signed a consent form.

Subjects were randomly allocated into two groups. Subjects in group 1 received the mineralized allogeneic bone (Hamanand Saz Baft) for maxillary sinus augmentation, while the deproteinized bovine bone (Cerabone, Botiss) was used for this purpose in group 2. Age, sex, and the initial augmented bone volume were the study variables, while the type of bone substitute (mineralized bone or deproteinized bone) was the predictive factor of the study. The bone density, measured based on Hounsfield units (HU), was the primary outcome, and the volumetric change after 9 months was the secondary outcome of the study.

Sinus Elevation Technique

An incision with two releasing incisions was made on the crest of the alveolar ridge. A full-thickness mucoperiosteal flap was raised to expose the lateral wall of the sinus. A window was opened in the lateral wall of the maxillary sinus with a horizontal bone cut at 3 mm above the maxillary sinus floor. A high-speed handpiece was used. A no. 4, 6, and 8 round bur under sufficient saline irrigation was applied to prepare the osteotomy site. The bony island was separated into adjacent walls using sinus lift elevators. The membrane that was detached from the sinus floor placed in the maxillary sinus was filled by the bone substitutes (size: 0.25 to 1 mm) to reach the desired height for augmentation. A membrane (Jason, Botiss) was placed over the window. The mucoperiosteal flap was replaced, and the incision site was closed by 4-0 vicryl sutures (Ethicon, Johnson & Johnson). None of the patients received simultaneous dental implants. One oral and maxillofacial surgeon (R.T.) performed all surgeries. All subjects underwent unilateral open sinus elevation.

CBCT Evaluation

CBCT was taken immediately after sinus elevation surgery and 9 months later. The CBCT scans (NewTom VGi) were obtained with the exposure settings of 110 kVp, automatic exposure control, 300 µm voxel size, and variable (8 × 10) field of view. The DICOM data were administered using medical imaging software (OnDemand3D application, Version 10.0.1, Cybermed), which allows using a virtual probe to determine the values of the bone density in the grafted regions and transfer the data to Excel (Microsoft) software for tabulation. The probe extracts the voxel gray-level data of the region of interest. For volumetric evaluation, all CBCT images in DICOM format underwent volumetric 3D image reconstruction to have the capability of augmented bone volume measurement. The segmentation of the maxillary sinus was done by using interactive segmentation tools. First, the axial slices were traced. Next, all sagittal and coronal slices were made (Fig 1). The sinus volume was measured by using the axial, coronal, and sagittal segmentations. The volume change in T1 (immediately after augmentation) and T2 (9 months after augmentation) was documented (Figs 2 and 3). One oral and maxillofacial radiologist (M.K.) evaluated all CBCT scans.

Statistical Analysis

The Statistical Package for the Social Sciences for PCs, version 21 (SPSS) was used. The independent t test was applied to assess bone density (HU) and volumetric change between the two groups. The chi-square test was utilized to juxtapose the number of male and female patients in the two studied groups. P values < .05 were considered statistically significant.

RESULTS

Fifty patients were studied (n = 25 in groups 1 and 2). The mean age of subjects was 51.16 ± 9.99 years in group 1 and 51.36 ± 11.89 years in group 2. There was no difference in the mean age between the studied groups (P = .95). The number of male and female patients was not different statistically in groups 1 and 2 (P = .57; Table 1).

At 9 months after sinus elevation, the mean bone density was 237.20 ± 55.72 HU in group 1 (mineralized bone) and 634.8 ± 166.11 HU in group 2 (deproteinized bone). Analysis of the data revealed a substantial difference between the two studied groups in this respect (P < .001). The mean bone substitute volume immediately after sinus elevation was 1.79 ± 0.16 cm³ in group 1 (mineralized bone) and 1.74 ± 0.15 cm³ in group 2 (deproteinized bone; P = .29). The mean volume change was 0.25 ± 0.13 cm³ in group 1 (mineralized bone) and 0.06 ± 0.05 cm³ in group 2 (deproteinized bone). The data assessment showed a substantial difference in the mean volume change at 9 months after sinus elevation between the two studied groups (P < .001; Table 2).

DISCUSSION

Stability of the grafted bone volume and bone density are essential factors for implant success. The grafted
Fig 1  The measurement of bone volume and density.

Fig 2  (Left) The augmented maxillary sinus immediately using mineralized allogeneic bone.

Fig 3  (Right) Mild resorption was seen 9 months after the augmentation of the maxillary sinus by mineralized allogeneic bone.

Table 1  Comparison of Variables Between the Two Groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group 1 (deproteinized bone)</th>
<th>Group 2 (mineralized bone)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>15</td>
<td>.57a</td>
</tr>
<tr>
<td>Female</td>
<td>13</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
<td>51.16 ± 9.99</td>
<td>51.36 ± 11.89</td>
<td>.95b</td>
</tr>
</tbody>
</table>

*aChi-square test.  bIndependent t test.*
bone resorption and repneumatization can affect the success of dental implants in the long term after sinus elevation. In this study, the bone density and volume change were compared between the two bone substitute groups (mineralized bone and deproteinized bone) 9 months after sinus elevation. The main hypothesis of the study was the dependence of bone density and the grafted bone volume stability on the bone substitute material.

The use of mineralized bone and deproteinized bone for sinus grafting resulted in different bone densities. In the grafted bone, the mean bone density was 237.20 ± 55.72 HU in the mineralized bone group, which corresponded to the D4 bone type according to the Misch classification. The mean bone density was 634.8 ± 166.11 HU in the deproteinized bone group, corresponding to the D3 bone type. A recent study by Stumbras et al showed that there was more new mineralized tissue formation in alveolar ridge preservation with the bovine bone mineral group than freeze-dried bone allograft. There is no unanimous agreement to describe the bone quality at the preparation sites for dental implants in the literature. The bone quality depends on the cortical bone thickness, mineralization degree, and trabecular bone morphology. Poor bone quality resulted in decreased primary stability and increased implant failure rate. Bone density measurement is helpful for treatment planning in dental implant surgery.

The assessment of grafted bone volume indicated a smaller volume change in the deproteinized bone group compared with the mineralized group (0.06 ± 0.08 cm³ and 0.22 ± 0.13 cm³, respectively). A previous study on various bone substitutes (deproteinized bovine bone, mineralized allogeneic bone, a composite of mineralized allogeneic bone, and a demineralized allograft) indicated that biomaterials affected the bone graft volume change in sinus elevation before dental implant placement. Deproteinized bovine bone had higher volume stability through the healing period comparing mineralized allogeneic bone and composite allografts. Umanjec-Korac et al demonstrated that volume change in deproteinized bovine bone was approximately 20% ± 10% at the 2-year follow-up. In the present study, the volume change was 3% at the 9-month follow-up for deproteinized bone and 11% for mineralized bone. Salem et al reported no difference between deproteinized bovine bone and mineralized allogeneic bone 6 months after grafting. They reported adequate bone volume stability in both deproteinized bone and mineralized allogeneic bone groups. Grolli Klein et al described an increase in the grafted bone volume at 8 months following sinus elevation with the use of deproteinized bovine bone.

### Table 2: Comparison of Bone Density and Grafted Bone Volume Change Between the Two Groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group 1 (mineralized bone)</th>
<th>Group 2 (deproteinized bone)</th>
<th>Independent t test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual bone height before sinus elevation (mm)</td>
<td>2.92 ± 0.76</td>
<td>2.76 ± 0.88</td>
<td>.49</td>
</tr>
<tr>
<td>Bone height immediately after augmentation (mm)</td>
<td>11.76 ± 1.16</td>
<td>12.08 ± 1.15</td>
<td>.33</td>
</tr>
<tr>
<td>Bone height 9 months after augmentation (mm)</td>
<td>9.24 ± 1.01</td>
<td>10.52 ± 2.24</td>
<td>.01</td>
</tr>
<tr>
<td>Bone height change 9 months after augmentation (mm)</td>
<td>2.48 ± 0.87</td>
<td>1.24 ± 0.66</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Bone density (HU)</td>
<td>237.20 ± 55.72</td>
<td>634.8 ± 166.11</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Bone volume immediately after augmentation (cm³)</td>
<td>1.79 ± 0.16</td>
<td>1.74 ± 0.15</td>
<td>.29</td>
</tr>
<tr>
<td>Bone volume 9 months after augmentation (cm³)</td>
<td>1.54 ± 0.19</td>
<td>1.68 ± 0.17</td>
<td>.01</td>
</tr>
<tr>
<td>Bone volume change at 9 months after augmentation (cm³)</td>
<td>0.25 ± 0.13</td>
<td>0.06 ± 0.05</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

### Table 3: Misch Bone Type Classification and Related Bone Density

<table>
<thead>
<tr>
<th>Bone type</th>
<th>MDCT density range (HU)</th>
<th>Clinical status</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>&gt; 1,250</td>
<td>Dense cortical bone</td>
</tr>
<tr>
<td>D2</td>
<td>850–1,250</td>
<td>Thick dense to porous cortical bone on crest with rough trabecular bone</td>
</tr>
<tr>
<td>D3</td>
<td>350–850</td>
<td>Thin porous cortical bone on crest with fine trabecular bone</td>
</tr>
<tr>
<td>D4</td>
<td>150–350</td>
<td>Fine trabecular bone</td>
</tr>
<tr>
<td>D5</td>
<td>&lt; 150</td>
<td>Nonmineralized and immature bone</td>
</tr>
</tbody>
</table>
Previous studies indicated that microcomputed tomography (micro-CT) is a gold standard in determining the microstructure and density of the alveolar bone.\(^\text{20,21}\) The excessive radiation and the cost are disadvantages of using CT. Subsequent studies focused on the CBCT reliability for evaluation of bone density at the dental implant recipient site.\(^\text{22-24}\) Suttapreyasri et al concluded that CBCT is an accurate tool for evaluating bone density. However, they mentioned that the gray value might not be precisely associated with bone density concerning micro-CT reports.\(^\text{25}\) Wang et al described a good association between CBCT and micro-CT for the grayscale posterior of the mandible.\(^\text{26}\) Soardi et al proposed that CBCT is a reliable tool for evaluating bone substitute behavior following maxillary sinus augmentation.\(^\text{26}\) HU is a measurement unit for the evaluation of bone density. HU is defined based on the distilled water and air radiodensity at a standard temperature and pressure (0 and –1,000, respectively). In fact, HU represents the relative density that is obtained from voxel density in CT or CBCT. Bone HU value varies +700 for the cancellous bone and +2,000 for very dense bone.\(^\text{27}\)

It was suggested that the voxels of CBCT images were not associated with gray values.\(^\text{28}\) The excessive scattered radiographs with artifacts were considered as the explanations for the inaccuracy of CBCT for the assessment of bone mineral density.\(^\text{29}\) CBCT is usually used at a lower mA and kVp than micro-CT, leading to a reduced signal-to-noise ratio.\(^\text{30}\) The increased noise level results in more discrepancies and a significant standard deviation when evaluating values of the voxel gray.\(^\text{31}\) However, other studies indicated a good correlation comparing CBCT and CT gray values. Despite certain limits, it is advocated that CBCT voxel values can be applied to assess bone mineral density.\(^\text{32}\) In CBCT, HUs are not actually what is being looked at; instead, it is relative density (based on voxel density).

Recently, Kim et al showed that the HU and trabecular microstructure pattern could be analyzed and reported using CBCT.\(^\text{33}\) The present study used OnDemand3D software with a virtual probe to measure the bone density in the augmented sites. The OnDemand3D software was used in previous studies for determining bone density using CBCT.\(^\text{34}\) As previous studies used a 300-µm voxel size, the same voxel size was applied in this study.\(^\text{35}\) Previous studies demonstrated that a large voxel size could result in decreased bone density incrementally.\(^\text{36}\) As the present study used the same voxel size for the two studied groups, it could not provide any bias in comparing bone density between them.

Various bone substitutes can bring about acceptable outcomes in maxillary sinus augmentation. Reasonable success rates have even been reported in sinus elevation without graft materials.\(^\text{37}\) Silva et al demonstrated a 99.60% survival rate for sinus elevation performed with bone substitutes and 96% for sinus elevation completed without graft materials within a follow-up time of 48 to 60 months.\(^\text{1}\) However, the bone quality would be different following the application of various materials for sinus augmentation. Also, bone quality may affect the survival of dental implants placed in grafted sites in the long term. Thus, the application of promising materials is critical to achieving acceptable clinical results.

**CONCLUSIONS**

Considering the results of this study, the deproteinized bone was associated with higher relative bone density than the mineralized bone 9 months after sinus elevation. The volume change of the deproteinized bone was less than the mineralized bone in the study time.

**ACKNOWLEDGMENTS**

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

**REFERENCES**


