Comparing Operators and Imaging Techniques When Performing Trans-Crestal Sinus Augmentation: A Pilot Study

Eran Gabay, DMD, PhD
Thabet Asbi, DMD
Hadar Zigdon-Giladi, DMD, PhD
Jacob Horwitz, DMD
Eli E. Machtei, DMD*

The aim of this article was to compare baseline residual ridge height using Cone-beam Computed Tomography (CBCT) and panoramic radiographs. A secondary aim was to examine the magnitude of vertical bone gain 6 months after trans-crestal sinus augmentation and compare it between operators. Thirty patients, who underwent trans-crestal sinus augmentation simultaneously with dental implant placement, were included in this retrospective analysis. Surgeries were done by 2 experienced surgeons (EM and EG) using the same surgical protocol and materials. Preoperative residual ridge height was measured on panoramic and CBCT images. The final bone height and the magnitude of the vertical augmentation were measured on panoramic X ray taken 6 months after surgery. Mean residual ridge height measured preoperatively using CBCT was 6.07 ± 1.38 mm, whereas these same measurements on the panoramic radiographs yielded similar results (6.08 ± 1.43 mm), which were statistically insignificant ($P = .535$). Postoperative healing was uneventful in all cases. All 30 implants were successfully osseointegrated at 6 months. The mean overall final bone height was 12.87 ± 1.39 mm (12.61 ± 1.21 and 13.39 ± 1.63 mm for operators EM and EG, respectively; $P = .19$). Likewise, mean postoperative bone height gain was 6.78 ± 1.57 mm, which was 6.68 ± 1.32 and 6.99 ± 2.06 mm for operators EM and EG, respectively ($P = .66$). A moderate positive correlation was found between residual bone height and final bone height ($r = 0.43$, $P = .002$). A moderate negative correlation was found between residual bone height and augmented bone height ($r = -0.53$, $P = .002$). Sinus augmentation performed trans-crestally produce consistent results with minimal interoperator differences between experienced clinicians. Both CBCT and panoramic radiographs produced similar assessment of the preoperative residual bone height.

Key Words: sinus augmentation, trans-crestal, dental implants, surgeons, CBCT, imaging, radiographs

INTRODUCTION

Reduction in alveolar bone height in the posterior maxilla is usually the result of tooth extraction and the concomitant loss of vertical height associated with crestal bone remodeling[1,2] and maxillary sinus pneumatization.[3] Lack of alveolar bone volume may compromise dental implant installation. To negotiate such deficiencies, several treatment alternatives were proposed. These include tilted implants,[4] short dental implants,[5] and maxillary sinus augmentation.[6]

The trans-crestal approach for sinus augmentation was first published by Tatum,[7] who reported his long-term results, whereas several other authors later suggested some modifications.[8,9] Traditionally, this approach was recommended when the residual native bone was at least 5 mm high due to high risk of membrane perforation while trying to extensively elevate the membrane[10] and a risk of implant loss as a result of reduced initial implant stability.[11] However, newer implant designs with improved implants' geometry and surface characteristics[12–14] allows us to use this technique in more challenging scenarios. Different studies reported varying intra-sinus height gain in grafted maxillary sinuses: Recent studies reported a comparable and sizable vertical bone gain after both trans-crestal and lateral window approaches.[15,16] On the other hand, a volumetric analysis reported 4-fold greater gain in sinuses treated with the lateral window approach compared with the trans-crestal approach.[17] These kinds of conflicting findings raise questions about the trans-crestal approach current scope.

Nowadays, Cone-beam Computed Tomography (CBCT) is considered the gold standard in implant planning.[18] Fortin *et al*[19] reported the use of panoramic images vs 3-dimensional planning software for oral implant planning in atrophied posterior maxilla. They found that the use of a panoramic examination for oral implant planning in severely resorbed

Department of Periodontology, Rambam Health Care Campus, Haifa, Israel.
Rappaport Faculty of Medicine, Technion Institute of Technology, Haifa, Israel.
* Corresponding author, e mail: machtei@technion.ac.il
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maxillae overestimates the need for a sinus augmentation procedure compared with CBCT coupled with implant planning software. However, in yet another study where a comparison was made between panoramic and CBCT radiographs for sinus augmentation planning, it was reported that panoramic images had only a slight mesio-distal underestimation in the premolar area, but there was no conclusion regarding the maxillary residual bone height.[20]

Thus, the aim of the present study was to evaluate and compare baseline residual ridge height using CBCT and panoramic radiographs. A secondary aim included the examination of the magnitude of vertical bone gain 6 months after trans-crestal sinus augmentation and compare it between operators.

Methods

This was a retrospective study of 30 consecutive patients treated at the department of periodontology, Rambam Health Care Campus (January 1, 2018, to December 31, 2018). All 30 patients had trans-crestal sinus floor augmentation procedures performed simultaneously with dental implant placement. Treatment was done by 2 experienced periodontists (EM or EG, 15 cases each), whereas data collection and all radiographic measurements were performed by a single operator (TA). The study was planned according to the national and international guidelines of the current World Medical Association (WMA) Declaration of Helsinki–Ethical Principles for Medical Research Involving Human Subjects. This study has been independently reviewed and approved by the Rambam Health Care Campus Research Ethics Committee (institutional review board approval 0122-19-RMB).

Inclusion criteria

Patients underwent trans-crestal sinus augmentation by 1 of the 2 operators. Only cases with a single implant were included. Presence of preoperative CBCT and both pre- and postoperative panoramic radiographs was required. Residual posterior maximal ridge height was $\leq$8 mm according to the preoperative diagnostic CBCT scan. As for any standard surgical procedure, the minimal bone width was 5 mm, which is the suitable width for placing a 3.75-mm-diameter dental implant. Patients were excluded if they exhibited pathology in the sinus, had a history of medication affecting bone metabolism, or had an artifact in the radiographs that may interfere with measurements.

Surgical protocol

Before surgery, all patients received preoperative antibiotics (amoxicillin 2000 mg, or for those allergic to penicillin, clindamycin 600 mg). Following local anesthesia, full thickness flaps were elevated, and the implantation site was marked with a 2-mm round marking drill. An osteotomy was drilled up to 1 mm from the floor of the sinus. The osteotomy was widened until reaching a 1 step down drill according to the planned implant diameter. At that point, the sinus floor was penetrated using osteotomes cushioned by the graft material. Small-diameter (0.25 to 1 mm), xenogeneic bone graft granules (Bio-oss, Geistlich Pharma AG, Wolhusen, Switzerland) were inserted, thus pushing the Schneiderian membrane apically. Once the operating surgeon, based on his tactile sensation and his clinical experience, estimated that he achieved a packed dome shaped sinus augmentation, an implant was inserted to the bone crest level, a cover screw was then placed, and the flaps were sutured with 5-0 nylon sutures. Sutures were removed 10 to 14 days later. Patients were prescribed analgesics as needed and chlorhexidine 0.2% rinses for 14 days at twice a day. Antibiotics were continued for 1 week (amoxicillin 1500 mg/day, or for those allergic to penicillin, clindamycin 600 mg/day). Patients were monitored for 6 months after implants placement, at which time final panoramic X rays were taken before second-stage surgery.

The following parameters were recorded: residual bone height (RBH) using preoperative CBCT; residual bone height using preoperative panoramic radiographs; final bone height (BH) measured on the postoperative panoramic radiograph; and augmented bone height was calculated as the difference between final BH and RBH.

Radiographic calibration

The postoperative radiograph with the implants (that was of a known dimensions) served to calibrate the measurements. The preoperative radiographs were calibrated similarly if an object of a known dimension was visible. In the absence of such an object, a neighboring tooth served to calibrate the preoperative radiographs based on it calculated dimensions made on the postoperative panoramic radiographs. Preoperative CBCT radiographs were used for panoramic measurements accuracy validation (Figure 1). Measurements were performed using the Planmeca Romexis dental imaging software (Helsinki, Finland).

Sample size and power calculation

A previous systematic review and meta-analysis[21] reported the gain in BH to range from 2.07 to 4.62 mm; we therefore estimated a 2-mm difference between groups (5 vs 3 mm), with a standard deviation of 1.5 mm. The alpha error was defined as 0.05 and beta error as 0.10 (power 90%). Based on this parameters, 12 subjects in each group were required (24 in total).

Statistical analysis

Minitab 19 statistical software (Minitab cooperation, Coventry, United Kingdom) was used for these analyses. Following normality tests, the Mann-Whitney nonparametric *U* test was used to compare between the preoperative CBCT and the preoperative panoramic measurements and to compare baseline to final measurements and between operators. Pearson correlation coefficient test was used to evaluate the correlation between the preoperative ridge height measurements and the outcome variables. A 5% significance level was used.

Results

The study population included 16 women and 14 men, with a mean age of 60.73 $\pm$ 11.25 years (range: 22 to 78 years; median:

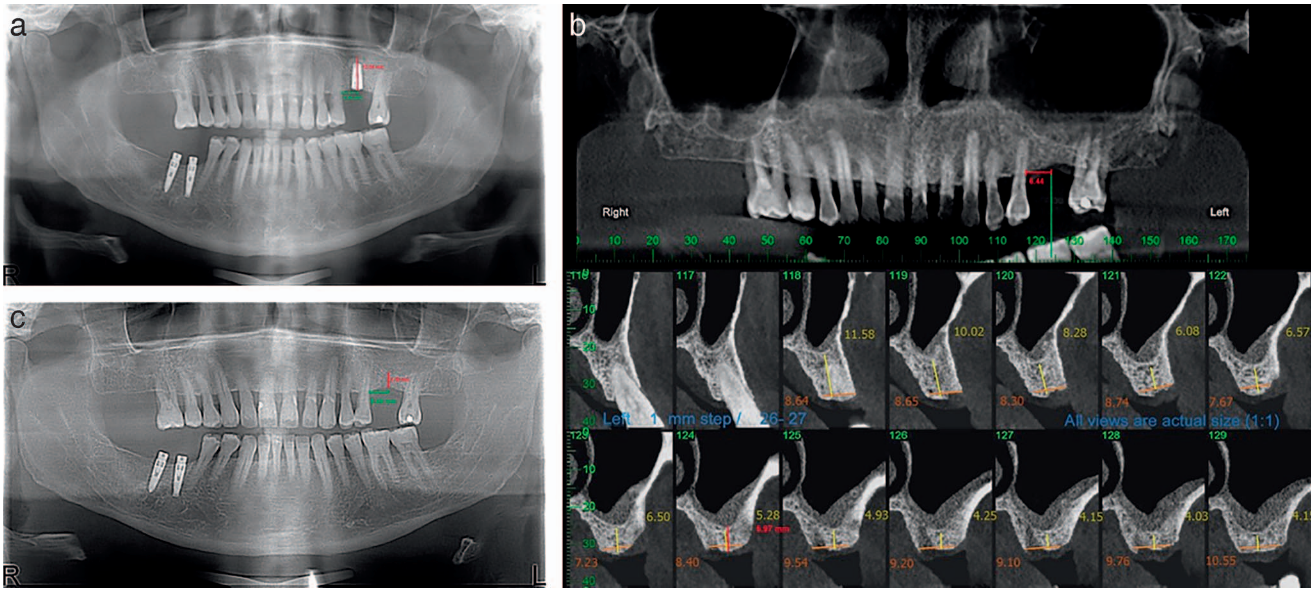

Figure 1. (a) Calibration was done (on the postoperative panoramic) according to the implant's known dimension and radiographic measurement. The distance of neighboring tooth to the implant served to locate this same site on the preoperative panoramic. (b) The residual alveolar ridge height was measured in the preoperative panoramic X ray using the above coordinate; this was further adjusted according to the implants dimension that was previously inserted in positions 30 and 31. (c) The residual alveolar ridge height was also measured in the CBCT at the same site as in the panoramic X ray. These measurements (in red) were calibrated according to original DICOM dimension (in yellow).

64 years). Postoperative healing was uneventful in all 30 patients. All implants were successfully osseointegrated and loaded after 6 months.

The mean baseline RBH measured on the CBCT was 6.07 ± 1.38 mm (range: 3.5 to 8.15 mm; median: 5.99 mm). Likewise, these same measurement using preoperative panoramic X ray was 6.08 ± 1.43 mm (range: 3.49 to 8.43 mm; median: 6.05 mm), There was no statistically significant difference between these 2 measurement tools (P = .535). The mean absolute difference between the panoramic radiograph and CBCT measurements (Absolute Δ CBCT-Panoramic) was 0.276 ± 0.24 mm. Conversion of these values into percentile calculation yielded a mean percentile difference of 4.72 ± 4.56% between these 2 measurement tools (Table 1).

At 6 months, mean final BH was 12.87 ± 1.39 mm (range: 10.81 to 15.81 mm; median: 12.64 mm). A moderate positive correlation was found between residual BH and final BH (r = 0.43, P = .002; Figure 2). Mean augmented BH was 6.78 ± 1.57 mm (range: 3.15 to 10.7 mm; median: 7.03 mm). A moderate negative correlation was found between residual BH and augmented BH (r = −0.53, P = .002; Figure 3). Data were further sorted to compare the results between the 2 surgeons (EG and EM). There were no significant differences in any of the measured parameters between operators: mean baseline RBH was 5.95 ± 1.36 and 6.35 ± 1.59 mm, respectively (P = .51). The mean final BH was 12.61 ± 1.21 and 13.39 ± 1.63 mm, respectively (P = .19). The mean augmented BH was 6.68 ± 1.32 and 6.99 ± 2.06 mm, respectively (P = .66).

All implants but one were installed in the molar area. Nineteen implants were installed in first molar sites, 10 in second molar sites, and 1 in the first premolar site. The mean residual BH in the first molar site was 6.19 ± 1.47 mm, whereas in the second molar site, it was 5.81 ± 1.52 mm (P = .52).

The mean final BH in first molar site was 12.85 ± 1.46 mm, whereas in the second molar site, it was 12.94 ± 1.39 mm (P = .88). The mean augmented BH in the first molar site was 6.62 ± 1.59 mm, whereas in the second molar site, it was 7.19 ± 1.45 mm (P = .36). None of those differences were statistically significant.

Discussion

Trans-crestal sinus augmentation using xenograft bone substitute allowed for a mean of 6.78 mm vertical augmentation without any significant complications. Pjetursson *et al*,[22] in a prospective study, compared 88 implants placed using the trans-crestal approach with grafting material to 164 implants placed without bone graft. They reported vertical bone gain of 4.1 and 1.7 mm, respectively. Santoro and Pippi,[23] in a systematic review of 17 studies in which the trans-crestal approach was performed concomitantly with implant placement and a variety of grafting materials, reported an overall intrasinus bone height gain of 4.24 mm, ranging from 3.2 ± 1.5 to 5.66 ± 0.99 mm. Our results seem to support the upper end of these reports. Other novel methods were proposed to further increase vertical bone gain. These include an implant system with a hollow body for injectable bone substitute,[24] balloon technique,[25,26] and osseous densification techniques.[27] The results of the present study are comparable with what was achieved with these newer techniques.

Both surgeons were well experienced with such a procedure, which resulted in both gaining significant vertical bone augmentation (6.68 ± 1.32 and 6.99 ± 2.06 mm) with no

TABLE 1

Preoperative residual bone height, according to CBCT and panoramic radiographs

Patient No.	CBCT Measurements (mm)	Panoramic Measurements (mm)	Δ CBCT Panoramic (mm)	Absolute Δ CBCT Panoramic (mm)	Percentile Difference (%)
1	3.85	4.01	-0.16	0.16	3.99
2	6	6.2	-0.2	0.2	3.23
3	5.77	6	-0.23	0.23	3.83
4	7.58	7.46	0.12	0.12	1.58
5	6.89	6.96	-0.07	0.07	1.01
6	7.49	7.74	-0.25	0.256	3.31
7	3.62	3.9	-0.28	0.28	7.18
8	6.3	6.6	-0.3	0.3	4.55
9	5.64	5.57	0.07	0.07	1.24
10	5.1	5.05	0.05	0.05	0.98
11	8.04	8.43	-0.39	0.39	4.63
12	5.97	6.1	-0.13	0.13	2.13
13	5.97	5.39	0.58	0.58	9.72
14	6.08	5.994	0.086	0.086	1.41
15	4.25	4.07	0.18	0.18	4.24
16	6.007	6.005	0.002	0.002	0.03
17	3.5	3.63	-0.13	0.13	3.58
18	6.98	6.93	0.05	0.05	0.72
19	5.57	5.36	0.21	0.21	3.77
20	7.95	7.58	0.37	0.37	4.65
21	7.6	8.1	-0.5	0.5	6.17
22	7.89	7.6	0.29	0.29	3.68
23	7.59	7.75	-0.16	0.16	2.06
24	7.02	7.08	-0.06	0.06	0.85
25	4.56	4.1	0.46	0.46	10.09
26	8.15	7.7	0.45	0.45	5.52
27	5.2	6.1	-0.9	0.9	14.75
28	5.23	5.86	-0.63	0.63	10.75
29	4.4	3.49	0.91	0.91	20.68
30	5.78	5.71	0.07	0.07	1.21
Means	6.07 ± 1.38	6.08 ± 1.43	−0.016 ± 0.37	0.276 ± 0.24	4.72 ± 4.56

major complications. Conversely, Tükel and Tatli,[28] in a prospective clinical trial, found a significant difference between experts, moderately experienced, and novice clinicians performing trans-crestal sinus augmentation. This suggests that a long learning curve exists.[29] In an ex vivo study of 80 maxillary sinus floor elevation procedures performed in lambs by 10 surgeons with different levels of expertise, all membrane perforations (9) occurred in the less experienced group.[30] Lundgren *et al*,[31] in a review article, stated that the variables affecting the treatment of choice for sinus augmentation are selected based on residual bone height and width, sinus anatomy, and the number of missing teeth, whereas operator surgical training and experience serves as a secondary consideration. More recently, Stacchi *et al*,[32] in guidelines for implant-supported rehabilitation in the atrophic posterior maxilla, suggested that the surgical

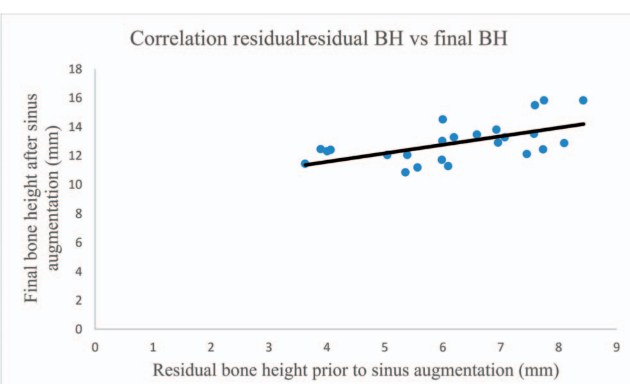

FIGURE 2. Moderate positive correlation was found between the RBH before sinus augmentation and the final BH after the augmentation ($r = 0.43$, $P = .002$).

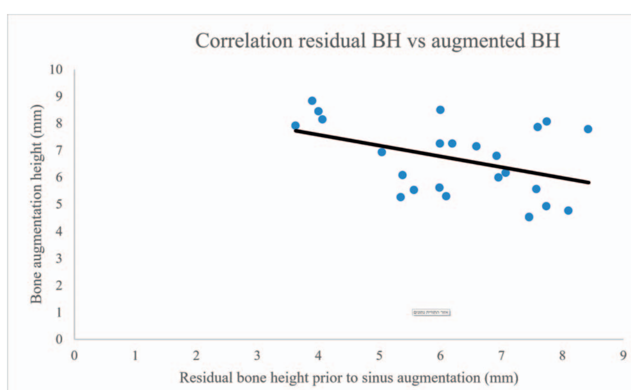

FIGURE 3. Moderate negative correlation between the RBH before sinus augmentation and the gained augmented bone height postoperatively ($r = -0.53$, $P = .002$).

solution was mostly depended on the personal experience and skills of the surgeon.

Radiographic assessment of the RBH, using CBCT and panoramic radiographs, yielded very similar results (6.07 $\pm$ 1.38 and 6.05 $\pm$ 1.43 mm, $P = .535$), respectively, with a mean absolute difference between measurements of 0.276 $\pm$ 0.24 mm. Similar results were found in measurements in the posterior mandible done to evaluate the available BH between the alveolar crest and the mandibular canal that resulted in a mean error of 0.21 mm between the 2 imaging methods.[33] To the contrary, in a study comparing digital panoramic, CT panoramic, and CBCT cross sections to measure 10-mm dental implants, the mean measured lengths were 10.57 $\pm$ 2.37, 10.24 $\pm$ 2.35, and 10.1 $\pm$ 2.94 mm, respectively; although smaller than 0.5 mm, these differences were statistically significant.[34] Similar results whereby panoramic radiographs resulted in slight overestimation of the vertical height were also reported by Fortis.[35] These findings quite resemble our findings of approximately 5% mean percentile difference in measurement values between the 2 imaging tools.

The current study, being retrospective, has several limitations: It is focused on a specific limited population; hence, it is possible that there is under- or over-representation of specific populations. The risk of bias in retrospective studies is much greater than in randomized controlled studies because of case selection and lack of randomization. In the current study, we used data of 2 highly trained experienced periodontists from the Department of Periodontology. Hence, the study is representing very specific data, which should be further investigated in a randomized controlled trial, comparing different degrees of skills.

Although the current study demonstrated a marked similarity between preoperative CBCT and panoramic radiographs measurements, the use of panoramic radiographs has some limitations: Panoramic radiographs have a nonlinear horizontal magnification in different areas of the maxilla, which may lead to an overestimation of noncalibrated measured spaces.[36] Hence, meticulous calibration, according to an object with well-defined and known dimensions, as a dental implant, is essential in panoramic radiograph-based measurements. To find the exact site for measurement, it is crucial to rely on adjacent reference points, appearing in all measured radiographs; each radiograph needed a calibration on the measured site, and the implant axis angulation had to be duplicated from the postoperative radiographs. All these discrepancies accumulated in the current study to a 0.27-mm mean absolute difference between panoramic radiographs and CBCT measurements, which is clinically expectable. Yet, because panoramic radiographs are a 2-dimensional imaging technique, volumetric measurements and 3-dimensional observation on anatomical structures are not available, and these kinds of missing data can be achieved only when using CBCT.

Conclusion

Sinus augmentation performed trans-crestally produces consistent results with minimal interoperator differences between experienced clinicians. Both CBCT and panoramic radiographs produced similar assessment of the preoperative RBH.

Abbreviations

BH: bone height
RBH: residual bone height

Note

The authors declare no conflicts of interest.

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