Original Article

Grafted bone remodeling following transcrestal sinus floor elevation: A cone-beam computed tomography study

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ABSTRACT

Background: Transcrestal sinus floor elevation is a reliable procedure when additional bone height is needed for maxillary implant placement. However, the grafted bone undergoes remodeling and the dimensional stability of grafted bone height may be affected by several clinical factors, including graft material, sinus anatomy and the morphology of grafted space.

Methods: This retrospective study examined patients who had undergone transcrestal sinus floor elevation with synthetic biphasic calcium phosphate and single implant placement. The reduction of sinus graft height (GHR) after 6–8 months healing period was measured with cone-beam computed tomography (CBCT) images. Correlating factors, including vertical amount of implant protrusion (IP), sinus width, and the morphology of grafted space were analyzed by Spearman's correlation test.

Results: A total of 25 implant sites were analyzed. The mean GHR was 0.57 ± 0.49 mm, which was positively correlated with IP, vertical elevation height (VEH), and the ratio of vertical to horizontal elevation of the grafted space. However, GHR was not correlated with sinus width and mesial-distal or buccal-palatal width of the grafted space.

Conclusions: Synthetic biphasic calcium phosphate used in transcrestal sinus floor elevation underwent shrinkages and graft remodeling. Grafted height reduction was associated with IP, VEH, and the ratio of vertical to horizontal elevation of the grafted space.

At a glance of commentary

Scientific background on the subject

Transcrestal approach by osteotome is a commonly applied technique for SFE. Over the years, several studies demonstrated the grafted area apical to the implant undergoes remodeling and shrinkage. The patient-related factors(ex: membrane elastic properties), site-related factors (ex: residual bone height, sinus width, etc.) and material-related factors(ex: grafting material) are possible to be correlated with graft remodeling.

What this study adds to the field

Following transcrestal sinus augmentation, grafted bone height may be reduced in areas where implant protrusion, vertical elevation height, and the ratio of vertical to horizontal elevation of the grafted space are large. Clinicians should evaluate these variables in decision making during the preoperative planning stage of transcrestal sinus augmentation.

Resorption of the alveolar ridge and sinus pneumatization after tooth loss in the posterior maxilla leads to insufficient bone height for implant placement. Consequently, maxillary sinus augmentation is needed for standard implant placement. Currently, sinus floor elevation is achieved using a lateral window approach [1] or a less invasive transcrestal approach, originally suggested by Tatum [2], which used a "socket former" with no grafting material. In 1994, Summers [3,4] proposed preparing the implant site with bone-added osteotome sinus floor elevation (BAOSFE); by using graft materials in osteotome technique, the hydraulic force is created along with the trapped fluid, which exerts pressure in all directions to elevate the membrane.

Recent studies have demonstrated the grafted area apical to the implant undergoes remodeling and shrinkage [5−11]; the pattern of graft remodeling determines the final availability of bone surrounding the implant to support the functional load. A systematic review was conducted to monitor 3D volumetric stability of different sinus grafting materials over time. Comparing to autograft, the results showed greater volume stability by using bone substitutes [12].

Sinus configurations also have an impact on graft remodeling [13−19]. A narrow sinus or a short distance between the buccal and palatal sinus wall can facilitate new bone formation following sinus augmentation [16−19]. Grafting materials are prone to collapse in a wide sinus, which is devoid of sufficient bone wall and could not provide enough mechanical support [13,14]. Despite the variations in maxillary sinus anatomy, the morphology of grafted space is an additional factor influencing the dimensional stability of the grafted bone. The elastic properties of the sinus membrane can influence the morphology of grafted space. A recent study demonstrated longer mesial−distal width of the grafted space

immediately following surgery results in higher graft height reduction at 18-months postloading [20].

A better understanding of factors that influence graft remodeling and the dimensional stability following BAOSFE could improve surgical outcomes. Therefore, the aim of this study was to evaluate the dimensional stability of alloplastic materials in BAOSFE technique. In addition, the correlating factors to graft height reduction, including sinus configuration and the morphology of grafted space were also assessed with CBCT images.

Methods

Patient selection

This retrospective study examined patients who had undergone maxillary sinus floor elevation and single implant placement from 2016 to 2018. Cone-beam computed tomography (CBCT) images were obtained from the department of periodontics at a hospital in northern Taiwan. The following inclusion criteria were used for selection: (1) Partially edentulous patients who underwent transcrestal sinus floor elevation and simultaneous implant placement, (2) synthetic biphasic calcium phosphate (BCP) consisting of a mixture of 60% hydroxyapatite and 40% of β-Tricalcium phosphate was used for sinus augmentation; (Sinbone HT®, Purzer Pharmaceutical, Taipei, Taiwan), and (3) availability of complete CBCT images obtained preoperatively, immediately following surgery, and 6−8 months post-surgery. Patients were excluded due to the following condition: (1) uncontrolled periodontitis, maxillary sinus pathology, or skeletal disorder; (2) use of medications known to affect bone metabolism; and (3) the grafted sites exhibited signs of membrane perforation. The study was conducted in accordance with the standards of the Declaration of Helsinki (World Medical Association Declaration of Helsinki, 2002) and was approved by the Medical Ethics Committee of the Institutional Review Board (IRB) of the study hospital (IRB 201801134B0).

Surgical procedure

BAOSFE with simultaneous implant placement was performed by three experienced clinicians. The surgical procedure was a modification of the original technique described by Summers [3,4]. After block anesthesia, full-thickness buccal flap was raised following crestal incision with or without vertical releasing incisions. Implant position was first marked with a small round bur and then a 2 mm twist drill was used for initial osteotomy. After reaching the depth of 1 mm away from the sinus floor, a series of osteotomes (3i Biomet Osteotome Kits, United States) were implemented to create a 'greenstick' fracture on the compact bone of the sinus floor. Before introducing any graft material, the sinus membrane was tested for any perforations with Valsalva maneuver. If there weren't any sign of membrane perforation, alloplastic materials (Sinbone HT®, particle size: 0.25mm−1.0 mm, Purzer Pharmaceutical, Taipei, Taiwan) were grafted into the sinus under a gentle malleating force on tapered osteotomes. This procedure was repeated several times and the tip of the

osteotome was allowed to gradually enter the maxillary sinus cavity. Finally, the implant was inserted with a submerged healing protocol. All implants utilized were dual acid-etched surfaces with internal connection (BIOMET 3i, Implant Innovations Inc., Palm Beach Gardens, FL, USA). The incidence of membrane perforation was further evaluated by the post-operative CBCT scan. Postoperatively, all patients received antimicrobials (Amoxicillin 500 mg TID for 5 days or clindamycin 600 mg TID for 5 days) as well as analgesics (Ibuprofen 400 mg Q6H for 5 days). In addition to standard oral home care, antiseptic rinsing with 0.12% chlorhexidine twice daily for the first 2 weeks was recommended. Sutures were removed in 14 days. Postoperative complications such as patient discomfort, infection, hemorrhage, wound dehiscence and signs of any sinus complications were recorded. After a healing period of 6−8 months, second-stage surgery was performed. The implant stability quotient (ISQ) was measured during second-stage surgery with a resonance frequency analysis equipment (Osstell TM, Osstell AB, Gothenburg, Sweden), and the final prostheses were fabricated 6−8 weeks thereafter.

Evaluation of CBCT images

All included CBCT images were acquired using the i-CAT Cone Beam 3D Dental Imaging System (Imaging Sciences International, Hatfield, PA, USA) with a standardized protocol. The acquisition parameters were as follows: slice thickness 0.25 mm, pixel size 0.25 mm, tube voltage 120 kVp, tube current 36.12 mA/s, and acquisition period 40s. The CBCT scans of each patient were transferred to a desktop computer and coronal, sagittal, and axial images were reformatted and analyzed with the dental CT software (i-CAT 3D Dental Imaging System). The precision of the measuring system is 0.01 mm. Fig. 1 is a schematic of the linear measurements. The abbreviations, and measurements of linear items are as follows and described in Table 1:

- Residual bone height (RBH): Within estimated implant site, the shortest distance from the alveolar crest to the maxillary sinus floor on preoperative CBCT;
- Sinus width (SW): the distance between lateral sinus wall and medial wall at the level of graft apex on postoperative CBCT;
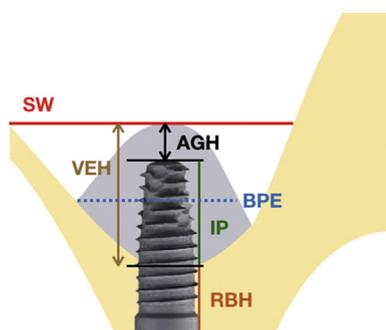
Fig. 1 **Schematic representation of the parameters for linear measurements.** RBH, residual alveolar bone height; SW, sinus width at the level of graft apex; IP, implant protrusion; AGH, height of the graft apical to the implant; VEH, vertical elevation height; BPE, buccal-palatal elevation.

- Implant protrusion (IP): the distance between initial sinus floor and implant apex calculated as subtraction of implant length and RBH;
- Apical graft height immediately after implant placement (AGHi): the distance between the implant apex and the elevated sinus floor (upper border of the grafting material) was measured immediately after implant placement
- Apical graft height during 6−8 months follow-up (AGHf): the distance between the implant apex and the elevated sinus floor (upper border of the grafting material) was measured at 6−8 months post-surgery.
- Graft height reduction [GHR]: the difference of apical graft height immediately after surgery and at 6−8 months post-surgery as the subtraction of AGHi and AGHf;
- Vertical elevation height [VEH]: the distance between the initial sinus floor and the elevated sinus floor calculated as the sum of IP and AGHi;
- Buccal-palatal elevation [BPE]: the greatest buccal-palatal distance of the grafted space was measured on cross-sectional CBCT image;
- Mesial-distal elevation [MDE]: the greatest mesial-distal distance of the grafted space was measured on reformatted panoramic CBCT image;
- The ratio of vertical to buccal-palatal elevation of sinus membrane (VEH/BPE);
- The ratio of vertical to mesial-distal elevation of sinus membrane (VEH/MDE) were also calculated.

Fig. 2 shows representative CBCT images used for linear measurements at three separate time points: pre-surgery, immediately following surgery, and 6−8 months post-surgery. The planned implant site on preoperative images [Fig. 2A] were adjusted to the same coronal section as the postoperative images. In order to measure linear items parallel to the implant axis, coronal and sagittal images [Fig. 2B and C] were rotated until the orientation axis was parallel to the implant axis. For the coronal cut, the axial image [Fig. 2D] was rotated until the orientation axis was perpendicular to the buccal cortex, where the implant was situated [Fig. 2E]. All measurements were performed on cross-sectional CBCT and reformatted panoramic images using the analysis software. Fig. 2F and G show CBCT images immediately following surgery. Fig. 2H shows a CBCT image at 6−8 months post-surgery.

Measurements of the CBCT images and analyses were performed by a single trained investigator. To evaluate the intra-examiner reliability, all measurements were repeated after a week. Cohen's k coefficient was calculated from average of the first and second measurements; intra-examiner agreement was 0.935.

The appearance of graft maturation was also evaluated at 6−8 months post-surgery with CBCT images. A sinus graft remodeling index (SGRI) [5] was used for qualitative assessment of grafted sites. Images are scored from 0 to 3; 0 = no bone/grafting material visible above the implant apex; 1 = cloudy structures with hazy demarcation; 2 = clearly visible dense structures apical to the implant; and 3 = appearance of dense periapical bone structure with a well-defined new lamina dura, which demonstrate the original lamina dura has been resorbed and formation of a new maxillary sinus floor; a higher score indicates better remodeling of the graft.

Table 1 Abbreviations and descriptions of linear measurements analyzed.

Abbreviation	Description	Parameters
RBH	Residual Bone Height	Within the estimated implant site, the shortest distance from the alveolar crest to the maxillary sinus floor on the preoperative CBCT image.
SW	Sinus Width	The distance between the lateral sinus wall and medial wall at the level of the graft apex on the postoperative CBCT image.
IP	Implant Protrusion	The distance between the initial sinus floor and implant apex calculated by subtraction of the implant length and RBH.
AGH	Apical Graft Height	The distance between the implant apex and the elevated sinus floor.
AGHi	AGH immediately following surgery	AGH measured immediately after implant placement
AGHf	AGH at 6—8 months follow-up	AGH measured at 6—8 months post-surgery
GHR	Graft Height Reduction	GHR = AGHi - AGHf
VEH	Vertical Elevation Height	The distance between the initial sinus floor and the elevated sinus floor calculated as the sum of the IP and AGHi.
BPE	Buccal-palatal elevation	The greatest buccal-palatal distance of the grafted space measured on cross-sectional CBCT images.
MDE	Mesial-distal elevation	The greatest mesial-distal distance of the grafted space measured on reformatted panoramic CBCT images.
VEH/BPE	Ratio of VEH to BPE	Ratio of vertical to buccal-palatal elevation of the grafted space
VEH/MDE	Ratio of VEH to MDE	Ratio of vertical to mesio-distall elevation of the grafted space

Statistical analysis

All data analyses were performed using statistical software (IBM SPSS Statistics for Mac, Version 25.0. Armonk, NY: IBM Corp.). Descriptive statistics were calculated as means ± standard deviation (SD). The Spearman's rank correlation coefficient was used to evaluate the relationships between GHR and other linear items, including IP, SW, VEH, BPE, MDE, VEH/MDE and VEH/BPE.

Results

Patients and post-surgical complications

A total of 25 sites in 25 patients (14 males and 11 females) qualified for analysis. The mean age was 55.8 years (range = 26—76 years). RBH was <5 mm in 8 sites; $\geq$ 5 mm in 17 sites; 3 sites were in premolar areas; and 22 sites were in molar regions. All surgical sites healed uneventfully without specific complaints, including infection, hemorrhage and wound dehiscence. During the healing period of 6—8 months post-surgery, none of the patients developed any kind of sinus complications and no implant failure was recorded. At the second-stage surgery, all implants presented a high level of implant stability as shown by ISQ >70.

CBCT evaluations of implants

Mean values of the CBCT measures (mean ± SD) are shown in Table 2. The mean RBH was 6.16 ± 2.52 mm. Immediately following surgery, the mean AGHi was 2.71 ± 0.87 mm, IP was 4.61 ± 2 mm, obtained by subtracting the RBH from the implant length, and SW was 14.59 ± 3.81 mm. VEH, BPE, and
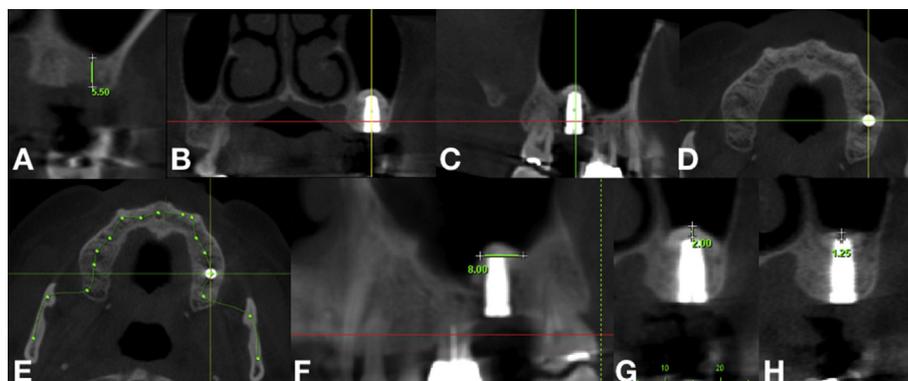
Fig. 2 **Representative images of CBCT scans used for linear measurements.** (A) Preoperative CBCT image. Green line indicates residual bone height. B through G show CBCT scans immediately following surgery: (B, C) Linear items obtained by rotating coronal (B) and sagittal (C) images such that the orientation axis is parallel to the implant axis. (D, E) Coronal cut obtained by rotating the axial image (D) until the orientation axis is perpendicular to the buccal cortex (E) where the implant is situated. (F) Mesial-distal elevation measurement (green line) on reformatted panoramic CBCT image immediately following surgery. (G) Representative cross-sectional CBCT image used for measurements of apical graft height (green line) immediately following surgery. (H) Representative image from CBCT scan 6—8 months postoperative showing measurement of postoperative apical graft height (green line). Graft height reduction can be seen by comparing the difference between (G) & (H).

Table 2 Mean parameter measurements from CBCT images at the implant sites (N = 25): preoperative, immediately following surgery, and at 6–8 months follow-up.

Parameter	Mean	SD
Preoperative, mm		
RBH	6.16	2.52
Immediately following surgery, mm		
IP	4.61	2.00
AGHi	2.71	0.87
SW	14.59	3.81
VEH	7.33	2.06
BPE	7.34	1.68
MDE	7.88	2.26
Ratios of means		
VEH/BPE	1.01	0.24
VEH/MDE	0.98	0.35
6–8 months post-surgery, mm		
AGHf	2.13	0.77
GHR	0.57	0.49

Abbreviations: SD: standard deviation; RBH: residual bone height; SW: sinus width; IP: implant protrusion; VEH: vertical height elevation; MDE: mesial-distal elevation; BPE: buccal-palatal elevation; AGHi: apical graft height, immediately following surgery; AGHf: apical graft height, at 6–8 months post-surgery; GHR: graft height reduction.

MDE were 7.33 ± 2.06 mm, 7.34 ± 1.68 mm, and 7.88 ± 2.26 mm, respectively. The ratio of the mean of VEH:MDE was 0.98; VEH:BPE was 1.01. At 6–8 months post-surgery, apical graft height was reduced to 2.13 ± 0.77 mm (AGHf); the GHR was 0.57 ± 0.49 mm. When the apical graft height at 6–8 months post-surgery (AGHf) was compared to the graft height immediately following surgery (AGHi), there was a significant reduction of augmented bone in the vertical direction ($p < .001$).

Spearman's correlation analysis was conducted to determine the relationship of GHR to other parameters [Table 3]. There was a positive correlation between GHR and VEH ($p < .01$) as well as IP ($p < .05$), and the ratio of VEH/BPE ($p < .05$), VEH/MDE ($p < .01$). Coefficient values were 0.63, 0.461, 0.462, and 0.545 respectively which indicated the moderate strength of correlation. However, graft height reduction was not

Table 3 Spearman's correlation of graft height reduction (GHR) with associated linear variables.

Parameter	r	p
IP	0.461	0.02*
SW	0.275	0.183
VEH	0.63	0.007**
BPE	0.259	0.21
MDE	−0.142	0.499
VEH/BPE	0.462	0.02*
VEH/MDE	0.545	0.005**

Abbreviations: SW: sinus width; IP: implant protrusion; VEH: vertical height elevation; MDE: mesial-distal elevation; BPE: buccal-palatal elevation; AGHi: apical graft height, immediately following surgery; AGHf: apical graft height, at 6–8 months follow-up; GHR: graft height reduction.
*$p < .05$; **$p < .01$

significantly associated with SW, MDE and BPE. Fig. 3 shows scatterplots displaying the linear relationships between the GHR and the significant variables.

Graft maturation was also assessed with a sinus graft remodeling index (SGRI) [5] from CBCT images. All 25 sites presented a radiopaque area interposed between the sinus membrane and the implant apex. At 6–8 months post-surgery follow-up examination, most of the implants scored a SGRI of 2 (n = 14). Two out of 25 implants scored a SGRI of 1, and 9 implants scored a SGRI of 3. Fig. 4 shows representative images of the three maturation stages: cloudy structures with hazy demarcation [Fig. 4A]; clearly visible dense structures apical to the implant [Fig. 4B]; and dense periapical bone structure with a well-defined new lamina dura [Fig. 4C], indicating resorption of the original lamina dura and formation of a new maxillary sinus floor. Evaluation of SGRI scores suggest most sites had undergone significant graft maturation with 6–8 months of healing.

Discussion

Transcrestal sinus floor elevation is a safe and reliable procedure for implant placement. However, historically, it has been limited to patients with a residual bone height ≥5 mm [21–24] due to reduced implant survival rates observed for sites with lesser RBH [21,22]. Our study examined 25 implants placed in maxillary sinuses grafted with alloplastic material. The survival rate was 100% with a high level of implant stability (ISQ>70) at 6–8 months post-surgery, which includes the 8 sites with RBH less than 5 mm. Despite modern implant design and drilling techniques, the assessment of sinus anatomy, membrane detachment force, and elasticity or deformation capacity of membrane are all important keys to success [25].

There is evidence that various grafting materials are effective in sinus augmentation and have been well-documented in literatures for decades. Less dimensional reduction of grafted bone over time can be expected after sinus grafting with bone substitutes or bone substitutes in different mixtures compared to autogenous bone [12]. The alloplastic material used in present study was synthetic BCP, which has been evidenced to have similar outcome compared with inorganic bovine bone regarding the amount of newly formed bone [26–28]. As for the graft dimensional stability over time, Mordenfeld and colleagues demonstrated 0.7 mm loss of grafted bone height in first 2 years and volume decreased by 15% over the 6 months of healing according to the study by Kuhl S et al. [29,30]. The small reduction of grafted bone height (0.57 mm) in the presented study is in line with previous studies, demonstrating the ability of synthetic BCP to maintain the vertical height gained in sinus augmentation.

Despite the grafting material used, several variables related to bone remodeling patterns following sinus augmentation have been demonstrated: configuration of the sinus wall and sinus width [13–19]. These variables may affect blood supply of the graft as well as bone induction effect provided by the periosteum, and thus lead to greater and faster vital bone formation. According to the study by Galindo-
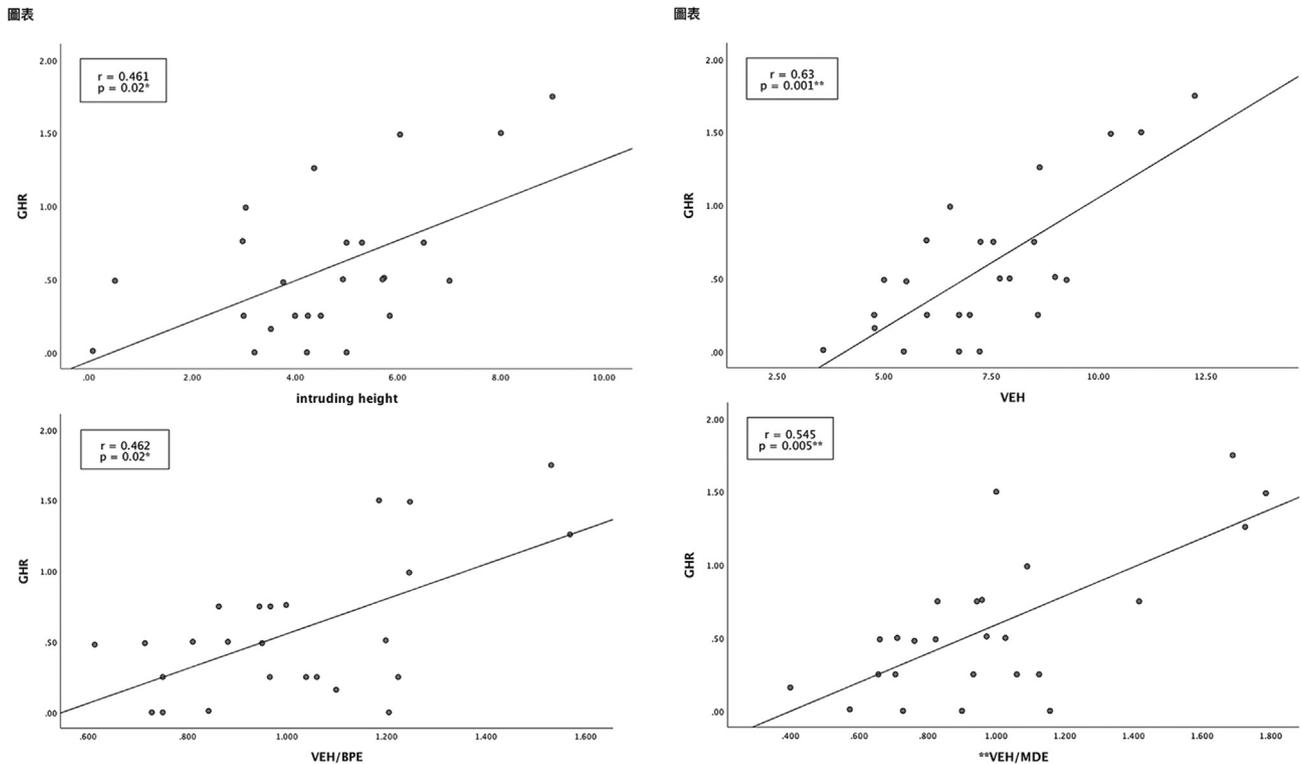
Fig. 3 **Scatter plots showing the associated variables to the graft height reduction (GHR).** Distribution between GHR and implant protrusion (IP, upper left), vertical elevation height (VEH, upper right), the ratio of vertical elevation height to buccal-palatal elevation (VEH/BPE, lower left) and the ratio of vertical elevation height to mesial-distal elevation (VEH/MDE, lower right). Spearman's correlation r-values and p-values are shown in the box at the upper left of each panel.

Moreno P et al., the faster the graft maturation occurred, the less likely the graft would collapse due to hyper-pneumatization or air pressure [20]. However, sinus width was not statistically correlated to GHR in our study, and the result is inconsistent with previous studies [13,14]. Due to the different image reference and different type of bone substitute used, comparing previous studies with our present study should be cautious.

There was a moderate positive correlation between GHR and VEH (r = 0.63, p < 0.01). It has been suggested that the greater elevation of the sinus membrane, the greater the membrane tension will be, and the tension may be transferred to the force of compression on the grafting materials [13,20].

Our findings provide support for a correlation between a higher vertical dimension of the grafted site and faster graft reduction, with additional support from our findings regarding the positive correlation between GHR and IP.

The ratio of vertical to horizontal elevation of the Schneiderian membrane (VEH/MDE) (VEH/BPE) was also positively correlated with GHR. A more vertically elevated grafted space pattern has been shown to increase tension on the Schneiderian membrane [31]. It has been suggested a ratio >1.0 for VEH/MDE may jeopardize membrane integrity, while a ratio ≤0.8 might indicate a lower risk of membrane perforation [32]. Several authors have reported the vertical extent of membrane elevation by transcrestal approach was limited to
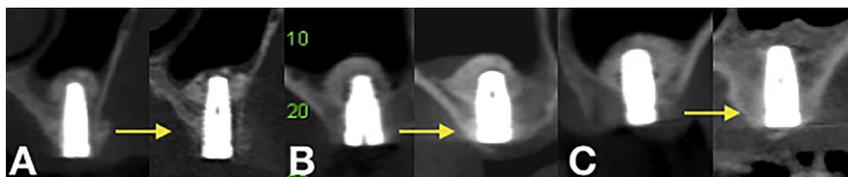
Fig. 4 **Representative cross-sectional CBCT images used for graft remodeling index, demonstrating graft maturation.** Yellow arrow indicates change in graft site, from immediately after sinus augmentation (left) to 6−8 months post-surgery (healing period, right). (A) Cloudy structures with hazy demarcation noted after 6−8 months post-surgery. (B) Clearly visible dense structures apical to the implant are present. (C) Formation of a new recognizable lamina dura bordering the maxillary sinus. Note the original outline of the maxillary sinus on the left is no longer visible on the right.

5 mm–9.4 mm [33–38]. Maximum elevation height and morphology are correlated with sinus anatomy, elastic properties of the Schneiderian membrane, and the quality of membrane attachment underlying the sinus floor. Our findings suggest meticulous evaluation of VEH should be mandatory, in order to avoid membrane perforation and graft resorption.

The scores of SGRI demonstrated most grafting sites had undergone significant maturation within 6–8 months of healing. All implants were inserted using BAOSFE, and a dome-shaped image of grafting materials was apparent in all 25 sites immediately following surgery. When examined at 6–8 months post-surgery, the apex of all implants was wrapped with radiopaque tissue and values for implant stability quotients were high (ISQ>70). In addition, SGRI confirmed 9 sites had generated a new maxillary sinus floor outline with a well-defined lamina dura. Graft-Free Sinus Floor Elevation (GFSFE) has also been shown to result in high implant survival rates [39–43]. GFSFE is thought to be in line with the biological concept of tissue regeneration; a tented area is created to maintain the Schneiderian membrane in an elevated position, and the use of blood clots in place of bone substitutes stimulate new bone formation. However, a recent systematic review reported mean vertical bone gains of only 3.8 mm, which was relatively low and wide ranging (1.8–7.9 mm) [44]. When compared to the graft-free tenting technique, BAOSFE results in more predictable outcomes on vertical bone gain, bone density, and tissue remodeling [7,43,45]. Bone grafts not only facilitate vertical bone formation, but also act as shock absorbers to reduce the risk of membrane perforation; a recent cadaver study suggested the elevation height in non-grafted areas should not exceed 5 mm to avoid membrane perforation [46]. Therefore, in areas with an expected higher vertical elevation of sinus floor, BAOSFE technique is a more suitable treatment modality.

One of the strengths of this study is using a single implant system, as previously describe, the influence of different implant topography or microstructure was eliminated. The other strength is the 3-D image used for measurement. To the best of our knowledge, most studies evaluating bone remodeling after trancrestal sinus grafting were mainly by 2-D radiographs [5,7,9,11,15,20]. Cross-sectional images from CBCT scans resolve the problems of distortion, magnification, and superimposition, which are noted in peri-apical films and panoramic radiographs. Thus, the application of CBCT in this study provided optimal accuracy for measurements of linear variables.

In spite of the many strengths, the present study had some limitations. First, the osteotome procedure was not endoscopically controlled; undetected small perforations within the dome-shaped elevated membrane may cause graft material to directly communicate with the sinus cavity and may result in loss of graft volume. Second, follow up focused only on early healing of the grafted site. However, current data from long-term studies (>4 year follow up) suggest most significant dimensional changes occur primarily during the initial postoperative phase, and subsequent changes are minimal [6,12,47–50]. Although it is unlikely that graft reduction is a continuous phenomenon, further long-term clinical trials are required to assess the dimensional stability of the grafted bone. Third, even though we got the favorable outcome, well-designed parallel and non-inferior study might be required to reveal the strength of alloplastic material regarding to long-term stability. Finally, due to the limitation of retrospective study which only included subjects with complete CBCT images, further prospective cohort study with larger sample sizes is required to avoid the potential spectrum bias.

Conclusion

The present study showed that the BAOSFE technique in conjunction with synthetic biphasic calcium phosphate is a predictable modality for bone augmentation in areas with insufficient residual bone height. Grafted bone height reduction was associated with the amount of implant protrusion, vertical elevation height, and the ratio of vertical to horizontal elevation of the grafted space. The current findings suggest clinicians should evaluate these variables in decision making during the preoperative planning stage of transcrestal sinus floor elevation.

Conflicts of interest

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

Acknowledgements

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