

Review

Graft-Free Maxillary Sinus Floor Elevation: A Systematic Review and Meta-Analysis

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Background: This systematic review and meta-analysis aims to investigate survival rates of dental implants placed simultaneously with graft-free maxillary sinus floor elevation (GFSFE). Factors influencing amount of vertical bone gain (VBG), protruded implant length (PIL) in sinus at follow-up (PILf), and peri-implant marginal bone loss (MBL) are also evaluated.

Methods: Electronic and manual searches for human clinical studies on simultaneous implant placement and GFSFE using the lateral window or transcrestal approach, published in the English language from January 1976 to March 2016, were conducted. The random-effects model and mixed-effect meta-regression were used to analyze weighted mean values of clinical parameters and evaluate factors that influenced amount of VBG.

Results: Of 740 studies, 22 clinical studies were included in this systematic review. A total of 864 implants were placed simultaneously with GFSFE at edentulous sites having mean residual bone height of 5.7 ± 1.7 mm. Mean implant survival rate (ISR) was $97.9\% \pm 0.02\%$ (range: 93.5% to 100%). Weighted mean MBL was 0.91 ± 0.11 mm, and it was significantly associated with the postoperative follow-up period ($r = 0.02$; $R^2 = 43.75\%$). Weighted mean VBG was 3.8 ± 0.34 mm, and this parameter was affected significantly by surgical approach, implant length, and PIL immediately after surgery (PILi) ($r = 2.82, 0.57, 0.80$; $R^2 = 19.10\%, 39.27\%, 83.92\%$, respectively). Weighted mean PILf was 1.26 ± 0.33 mm (range: 0.3 to 2.1 mm).

Conclusion: Within limitations of the present systematic review, GFSFE with simultaneous implant placement can achieve satisfactory mean ISR of $97.9\% \pm 0.02\%$. *J Periodontol* 2017;88:550-564.

KEY WORDS

Alveolar bone loss; bone regeneration; bone substitutes; dental implants; sinus floor augmentation; systematic review.

The edentulous posterior maxilla is frequently a challenging site for dental implant rehabilitation because of inadequate alveolar ridge height and poor bone quality.^{1,2} As such, maxillary sinus augmentation techniques that use lateral window or transcrestal approaches³ have been proposed so that a dental implant of regular length (e.g., 10 mm) can be placed in a deficient posterior maxillary edentulous site. Numerous systematic reviews have documented that transcrestal or lateral window maxillary sinus augmentation can predictably increase vertical bone height using bone substitutes to fill the elevated space.⁴⁻⁷ Different types of bone substitutes have been used in sinus augmentation to maintain the space created after lifting the Schneiderian membrane off the bone surface.^{4,8-10} Autogenous bone is the gold standard bone graft because of its osteogenicity, osteoinductivity, and osteoconductivity.¹¹ However, it is not commonly used in maxillary sinus augmentation because of significant graft resorption over time and donor site morbidity.¹²⁻¹⁴ Other bone substitutes, such as human allograft, bovine xenograft, and synthetic alloplast, have been associated with disease transmission,^{15,16} low vital bone to biomaterial ratio, and low resorption rate.^{10,17} Also, they have been suggested to delay bone regeneration compared with autogenous bone or blood clot alone.^{12,18,19} Some studies even showed that sinuses grafted

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with bone substitutes demonstrated repneumatization^{20,21} and implants placed in grafted sinuses had higher peri-implant marginal bone loss (MBL) compared with native bone.^{22,23}

Therefore, some clinicians advocated use of blood clots in place of bone substitutes in sinus floor elevation (SFE).²⁴⁻²⁶ High implant survival rates (ISRs) were reported with graft-free maxillary SFE (GFSFE), in which implants acted as a tent against the elevated Schneiderian membrane.²⁴⁻²⁸ The purpose of this systematic review and meta-analysis is to evaluate effectiveness of GFSFE by assessing amount of vertical bone gain (VBG), protruded implant length (PIL) in sinus immediately after surgery (PILi) and at follow-up (PILf), MBL, and ISR. To the best of the authors' knowledge, this report is the first systematic review and meta-analysis of the value of GFSFE with simultaneous implant placement.

MATERIALS AND METHODS

Search Strategy

This systematic review was conducted at the University of Michigan, Ann Arbor, Michigan, from February to May 2016. A search of two electronic databases (PubMed/MEDLINE and Cochrane Central Register of Controlled Trials) for relevant studies published in the English language from January 1976 to March 2016 was performed. Search terms used were: (“sinus” OR “maxillary sinus”) AND (“floor elevation” OR “lift” OR “augmentation” OR “elevation” OR “lateral approach” OR “Cosci” OR “crestal approach” OR “transcrestal approach” OR “BAOSFE” OR “OSFE” OR “Summers technique” OR “osteotome-mediated” OR “osteotome”) AND (without graft [Title/Abstract] OR no graft [Title/Abstract] OR graftless [Title/Abstract] OR graft free [Title/Abstract] OR nongraft [Title/Abstract] OR without bone graft [Title/Abstract] OR no bone graft [Title/Abstract] OR nongrafts [Title/Abstract] OR grafts free [Title/Abstract]). Additionally, manual search of dental- and implantology-related journals, including *Journal of Dental Research*, *Clinical Implant Dentistry and Related Research*, *Clinical Oral Implants Research*, *International Journal of Oral & Maxillofacial Implants*, *Journal of Oral Implantology*, and *Journal of Oral and Maxillofacial Surgery* from January 1976 to March 2016, was also performed to ensure a thorough screening process. Furthermore, a search in the references of included papers was conducted for publications that were not identified electronically. Two examiners (D-HD and WQ) performed the literature search independently. Any disagreement was resolved either through discussion or after consultation with a third examiner (JP). This systematic review was conducted based on PRISMA guidelines.

Eligibility Criteria

Articles were included in this systematic review if they fulfilled the following inclusion criteria: 1) human prospective or retrospective clinical studies, cohort studies, or case series; 2) simultaneous implant placement with GFSFE via lateral window or transcrestal approach; 3) sample size of ≥ 10 implants; and 4) reported information on ISR, VBG, PILi, PILf, or MBL. Systematic reviews, animal trials, and those studies using platelet-rich fibrin/plasma as graft material were excluded.

Data Extraction

Data were extracted from studies that met inclusion criteria. Parameters tabulated were: 1) demographics – patient sample size, number of augmented sinuses, number of implants placed, and implant system used; 2) independent variables – lateral or transcrestal approach, implant diameter, implant length, presence or absence of sinus window bone plate, percentage of membrane perforation, residual bone height (RBH), PILi (computed as the difference between implant length and RBH), and longest follow-up period after implant placement; and 3) dependent variables – VBG, PILf, MBL, and ISR.

Statistical Analyses

Extracted data were analyzed using statistical software.^{||} Study heterogeneity was assessed using DerSimonian and Laird Q test and I-square index. If significant heterogeneity was found, the random-effects model was chosen to minimize any bias caused by methodologic differences among studies. When heterogeneity values were high, meta-regression was carried out on dependent variables. Forest plots were generated to graphically represent the difference in outcomes for all included studies. *P* value of 0.05 was used as level of significance, and R^2 was used as proportion of variance explained by the regression model.

RESULTS

Literature Search

A total of 740 studies were found through electronic and manual searches. Of these, 80 studies were selected for full-text evaluation after screening titles and abstracts. After full-text evaluation, 58 studies were excluded (Table 1).^{6,8,24,25,28-81} There were 22 studies that fulfilled the inclusion and exclusion criteria (Table 2) and thus were selected for systematic review and meta-analysis.^{26,27,82-101} Interexaminer reliability was 0.87. There were three studies^{19,83,88} with two treatment arms, and results from both arms were combined in the analysis.^{27,87,92,97}

|| Comprehensive Meta-Analysis (version 2.2), Biostat, Englewood, NJ.

Table 1.
Summary of Excluded Studies

Authors/Year	Number of Studies	Reason for Exclusion
Chen et al. 2007; ²⁸ Altintas et al. 2013; ²⁹ Bassi et al. 2015; ³¹ Bruschi et al. 1998; ³⁵ Cricchio et al. 2011; ³⁷ Ellegaard et al. 1997; ³⁹ Gabbert et al. 2009; ⁴³ Hatano et al. 2007; ⁴⁵ Lai et al. 2008; ⁴⁹ Lundgren et al. 2004; ⁵⁰ Lundgren et al. 2008; ⁵¹ Markovic et al. 2016; ⁵² Pjetursson et al. 2009; ⁶³ Pjetursson et al. 2009; ⁶² Qian et al. 2016; ⁶⁴ Rammelsberg et al. 2015; ⁶⁵ Rasmusson et al. 2012; ⁶⁶ Schleier et al. 2008; ⁶⁸ Senyilmaz and Kasaboglu 2011; ⁶⁹ Smedberg et al. 2001; ⁷¹ Sohn et al. 2008; ⁷⁴ Sohn et al. 2010; ⁷⁵ Winter et al. 2002; ⁷⁹ Winter et al. 2003 ⁸⁰	24	Reported data were incomplete
Bruschi et al. 2012 ³⁴	1	Implants were not placed simultaneously with sinus augmentation
Atef et al. 2014; ³⁰ Kaneko et al. 2012; ⁴⁷ Munakata et al. 2016; ⁵⁴ Groeneveld et al. 1999; ⁴⁴ Felice et al. 2009; ⁴¹ Esposito et al. 2010; ⁴⁰ de Oliveira et al. 2013 ³⁸	7	Sinus was grafted with a space-maintaining device
Diss et al. 2008; ²⁴ Triplett et al. 2009; ⁷⁷ Boyne et al. 1997; ⁸ Boyne et al. 2005; ³³ Yamada et al. 2008; ⁸¹ Sohn et al. 2011; ⁷³ Simonpieri et al. 2011; ⁷⁰ Mazor et al. 2009; ⁵³ Kim et al. 2014; ⁴⁸ Kanayama et al. 2016 ⁴⁶	10	Sinus was grafted with platelet rich fibrin or bone morphogenetic proteins
van den Bergh et al. 2000; ⁷⁸ Nedir et al. 2009; ⁵⁹ Nedir et al. 2014; ⁵⁶ Chipaila et al. 2014; ³⁶ Biscaro et al. 2012 ³²	5	Ten or fewer implants were placed
Del Fabbro et al. 2012; ⁶ Riben and Thor 2012; ⁶⁷ Pinchasov and Juodzbaly 2014; ⁶¹ Taschieri et al. 2012; ⁷⁶ Sohn 2015; ⁷² Nedir et al. 2014 ⁵⁷	6	Systematic review
Nedir et al. 2006; ²⁵ Nedir et al. 2009; ⁵⁵ Nedir et al. 2010; ⁶⁰ Nedir et al. 2013; ⁵⁸ Fermørgård and Astrand 2008 ⁴²	5	Sample population was reported in a subsequent study

Demographics

There were 864 implants placed simultaneously with GFSFE at edentulous sites with mean RBH of 5.7 ± 1.7 mm. Mean ISR was reported to be $97.9\% \pm 0.02\%$ (range: 93.5% to 100%) with 18 failed implants after mean follow-up duration of 26.6 ± 24.3 months (range: 6 months to 10 years). Out of 18 failed implants, 14 reported time of failure, of which 10 implants (71.4%) failed before they were loaded.

Results of Peri-Implant MBL

Data on MBL were reported in 12 studies.^{82,84,85,88,90,93,94,96-98,100,101} Meta-analysis demonstrated that weighted mean MBL was 0.91 ± 0.11 mm after mean follow-up period of 41.5 ± 27.7 months (range: 9 months to 10 years) with a high degree of heterogeneity ($I^2 = 98.92\%$; $P < 0.001$) (Fig. 1A). To explore influence of postoperative follow-up on MBL, the mixed-effect model was used, and residual Q was reported to be 18.46 with $P = 0.03$. Therefore, one study⁹⁸ was excluded for its high heterogeneity despite its long follow-up period of

10 years. Regression analysis showed that MBL was significantly related to postoperative follow-up ($r = 0.02$; $R^2 = 43.75\%$) (Fig. 1B). The surgical approach, implant diameter, implant length, presence or absence of sinus window bone plate, percentage of membrane perforation, RBH, and PILi did not show any significant influence on MBL.

Results of PIL in Sinus at Follow-Up (PILf)

Data on PILf were reported in seven studies.^{82,84,89,91,97-99} Weighted mean PILf was 1.26 ± 0.33 mm (range: 0.3 to 5.5 mm) (Fig. 2) with a high degree of heterogeneity ($I^2 = 97.55\%$; $P < 0.001$) among selected studies. However, the surgical approach, implant diameter, implant length, presence or absence of sinus window bone plate, percentage of membrane perforation, RBH, and PILi did not show any significant influence on PILf.

Results of VBG

Data on VBG were reported in 18 studies.^{26,27,82-87,89,91,93,94,96-101} Meta-analysis showed that weighted mean VBG was 3.80 ± 0.35 mm (Fig. 3A)

Table 2.
Characteristics of Included Studies

Authors/Year	No. Patient/ Sinus/Implant Placed	Implant Diameter (mm)	Implant Length (mm)	Surgical Approach	RBH (mm)	PIL at Baseline (mm)	PILf (mm)	Follow-Up (month)	Membrane Perforation (%)	Presence of Lateral Window Bone Plate*	ISR (%)	Peri-Implant MBL (mm)	VBG (mm)
Balleri et al. 2012 ⁸²	15/15/28	3.8	14.2	Lateral window	6.2 ± 1.6	8.2 ± 1.0	5.5 ± 1.6	18	37.5	Displaced	100.0	0.4 ± 0.2	5.5 ± 1.6
Borges et al. 2011 ⁸³	15/15/28	4.0	14.8	Lateral window	5.9 ± 2.9	9.0 ± 3.5	NR	6	6.7	Displaced	96.4	NR	7.9 ± 3.6
Brizuela et al. 2014 ⁸⁴	36/36/36	4.0	9.8	Transcrestal	7.4 ± 0.4	NR	2.1 ± 0.3	24	11.1	NA	97.2	0.7 ± 0.1	1.8 ± 0.3
Cara-Fuentes et al. 2016 ⁸⁵	26/28/38	4 ± 0.4	11.1	Lateral window	5.8 ± 0.9	NR	NR	38.7	NR	Replaced or Discarded	97.4	0.5 ± 0.5	2.7 ± 0.9 on distal 2.6 ± 0.9 on mesial
Crespi et al. 2010 ⁸⁶	20/NR/30	5	12.3	Transcrestal	6.6 ± 1.9	NR	NR	36	0.0	NA	100.0	NR	3.8 ± 1.6
Crespi et al. 2012 ⁸⁷	80/NR/120 80/NR/120	4.8 4.8	12.3 12.1	Transcrestal Transcrestal	6.7 ± 1.6 6.5 ± 1.7	NR NR	NR NR	24 24	0.0 0.0	NA NA	98.3 98.3	NR NR	4.2 ± 1.0 4.1 ± 1.0
Fermegård and Astrand 2012 ⁸⁸	36/NR/53	4.5	10.1	Transcrestal	6.3 ± 0.4	4.4 ± 0.3	NR	36	NR	NA	94.0	0.5 ± 0.1	NR
Fornell et al. 2012 ⁸⁹	14/NR/21	4.1/4.8	10	Transcrestal	5.6 ± 2.1	4.4 ± 2.1	1.4 ± 1.5	12	NR	NA	100.0	0.0	3.0 ± 2.1
Gu et al. 2016 ⁹⁰	25/NR/37	NR	NR	Transcrestal	2.8 ± 0.7	NR	NR	60	0.0	NA	94.6	1.5 ± 1.0	NR
He et al. 2013 ⁹¹	22/NR/27	4.7 ± 0.4	10	Transcrestal	6.7 ± 1.2	3.8 ± 1.8	1.3 ± 1.3	25	0.0	NA	100.0	NR	2.5 ± 1.5
Johansson et al. 2013 ⁹²	NR/10/NR NR/9/NR	3.3 3.3	10 10	Lateral window Lateral window	4.3 ± 1.3 3.5 ± 1.3	NR NR	NR NR	7 7	NR NR	Displaced Discarded	100.0 90.0	NR NR	NR NR
Lai et al. 2010 ⁹³	25/NR/30	4.4	9	Transcrestal	5.0 ± 1.5	3.9 ± 1.1	NR	9	3.3	NA	100.0	1.2 ± 0.5	2.7 ± 0.9
Leblebicioglu et al. 2005 ²⁷	40/54/29 40/54/44	NR NR	11 ± 1.7 13.5 ± 1.1	Transcrestal Transcrestal	9.1 ± 2.0 9.1 ± 2.0	NR NR	NR NR	25 25	3.7 3.7	NA NA	97.3 97.3	NR NR	3.9 ± 1.9 2.9 ± 1.2
Lin et al. 2011 ⁹⁴	44/NR/80	NR	12.8	Lateral window	5.1 ± 1.5	7.8 ± 1.7	NR	60	NR	Replaced and Discarded	100.0	2.1 ± 0.5	7.4 ± 1.9
Moon et al. 2011 ⁹⁵	14/17/31	4.1	13	Lateral window	5.2 ± 1.6	NR	NR	24	11.8	Displaced	93.5	NR	NR

Table 2. (continued)
Characteristics of Included Studies

Authors/Year	No. Patient/ Sinus/Implant Placed	Implant Diameter (mm)	Implant Length (mm)	Surgical Approach	RBH (mm)	PIL at Baseline (mm)	PILf (mm)	Follow-Up (month)	Membrane Perforation (%)	Presence of Lateral Window Bone Plate*	ISR (%)	Peri-Implant MBL (mm)	VBG (mm)
Nedir et al. 2009 ⁹⁷	32/NR/54	4.1/4.8	8.3	Transcrestal	3.8 ± 1.2	4.0 ± 1.7	1.8 ± 1.7	12	15.0	NA	100.0	0.2 ± 0.8	2.6 ± 1.7
Nedir et al. 2016 ⁹⁸	15/16/23	4.1/4.8	9.6	Transcrestal	5.4 ± 2.3	4.9 ± 2.1	1.9 ± 1.2	120	18.8	NA	100.0	1.0 ± 0.9	3.0 ± 1.4
Nedir et al. 2016 ⁹⁶	12/19/37	4.1/4.8	8	Transcrestal	2.4 ± 0.9	NR	NR	36	0.0	NA	94.1	0.6 ± 1.1	4.1 ± 1.0
Schmidlin et al. 2008 ⁹⁹	24/24/24	4.4 ± 0.4	8.6	Transcrestal	5.0 ± 1.5	2.6 ± 1.8 on mesial 2.8 ± 1.7 on distal	0.3 ± 0.6 on mesial and distal	17.6 ± 8.4	8.3	NA	100.0	NR	2.2 ± 1.7 on mesial 2.5 ± 1.5 on distal
Si et al. 2013 ¹⁰⁰	20/20/20	4.5	8.7	Transcrestal	4.6 ± 1.5	3.9 ± 1.6	NR	36	0.0	NA	95.0	1.4 ± 0.2	3.1 ± 1.7
Thor et al. 2007 ²⁶	20/27/44	4.5/5.0/3.5	13.3	Lateral window	4.6	NR	NR	27.5	40.7	Displaced	97.6	NR	6.5 ± 2.5
Volpe et al. 2013 ¹⁰¹	20/NR/29	NR	NR	Transcrestal	7.2 ± 1.5	NR	NR	16.4	0.0	NA	100.0	0.7 ± 0.3	2.8 ± 1.1

NR = not reported; NA = not applicable.

* Displaced: Lateral window buccal bone plate displaced superiorly with SFE; Replaced: Lateral window buccal bone plate removed from the sinus membrane and replaced at its original spot after SFE; Discarded: Lateral window buccal bone plate removed from sinus membrane and discarded.

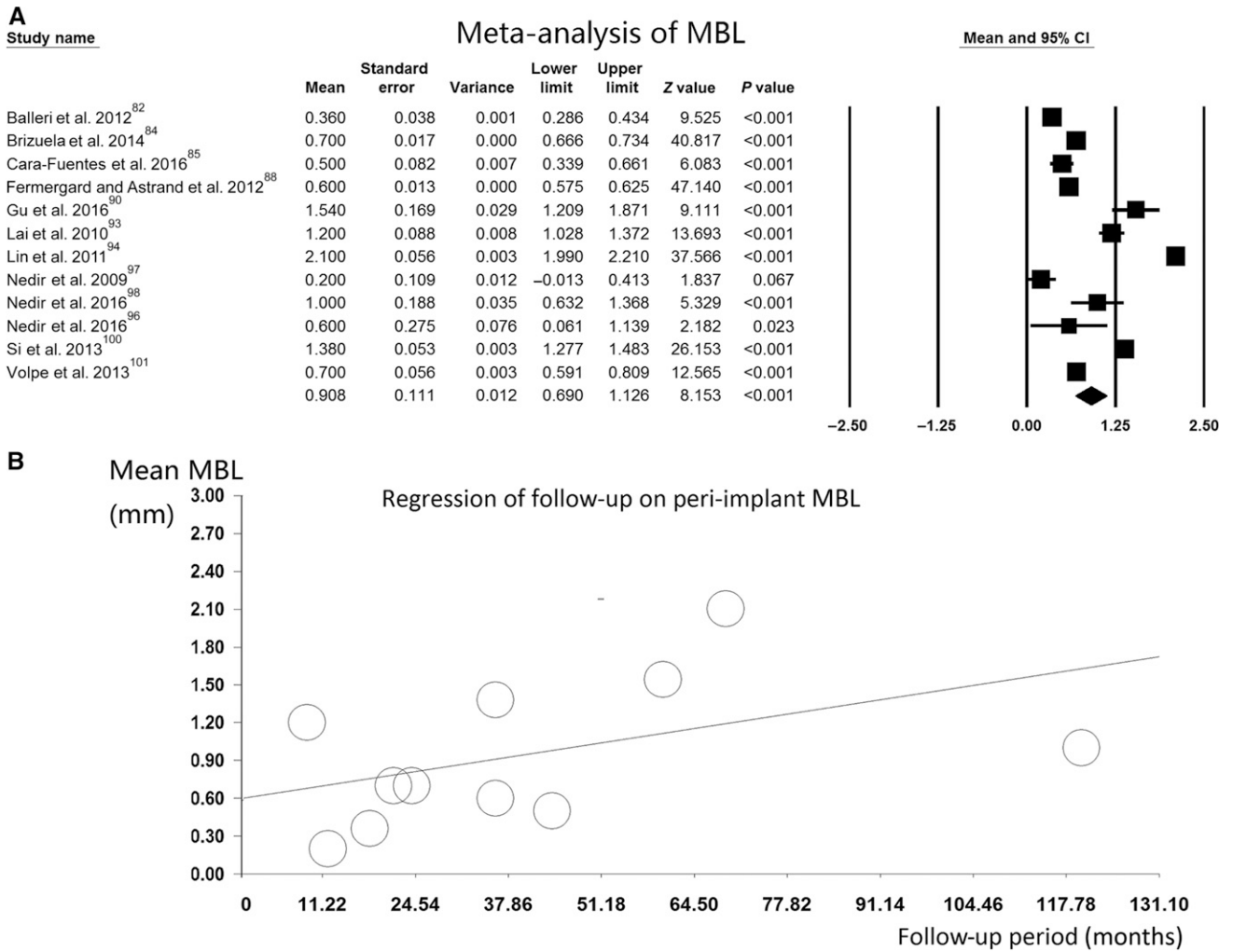


Figure 1. **A)** Forest plot representing weighted mean MBL of 0.91 mm (95% confidence interval [CI] of 0.69 to 1.13 mm). **B)** Meta-regression graph illustrating effect of postoperative follow-up on mean MBL.

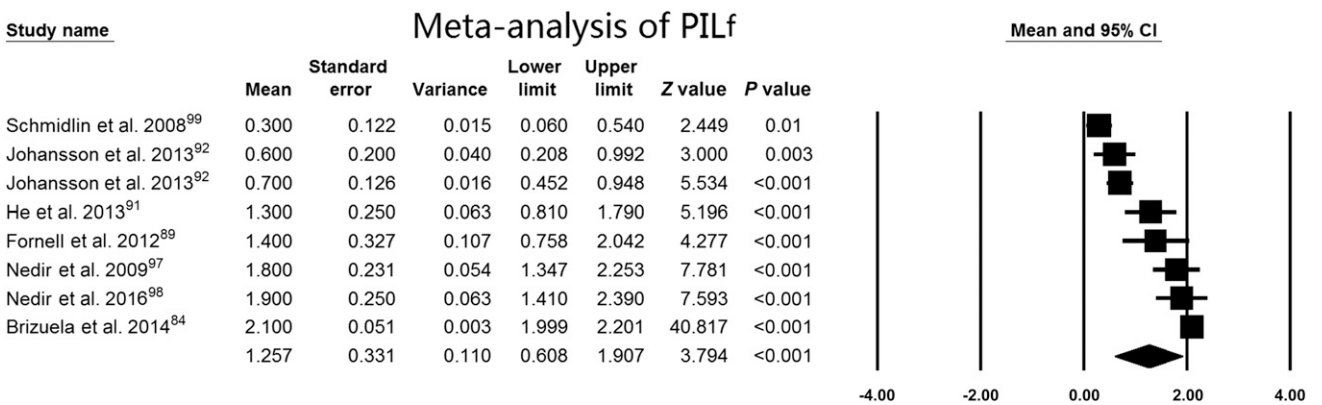


Figure 2. Forest plot representing weighted mean PILf of 1.26 mm (95% confidence interval [CI] of 0.61 to 1.91 mm).

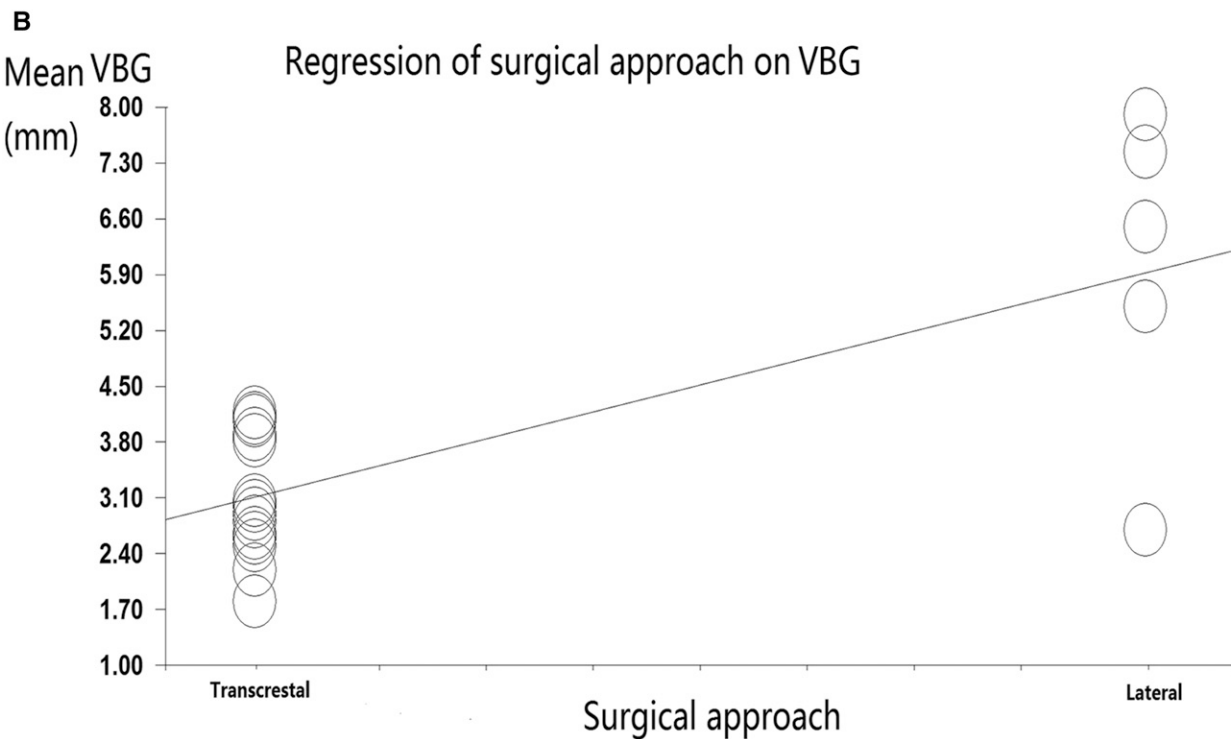
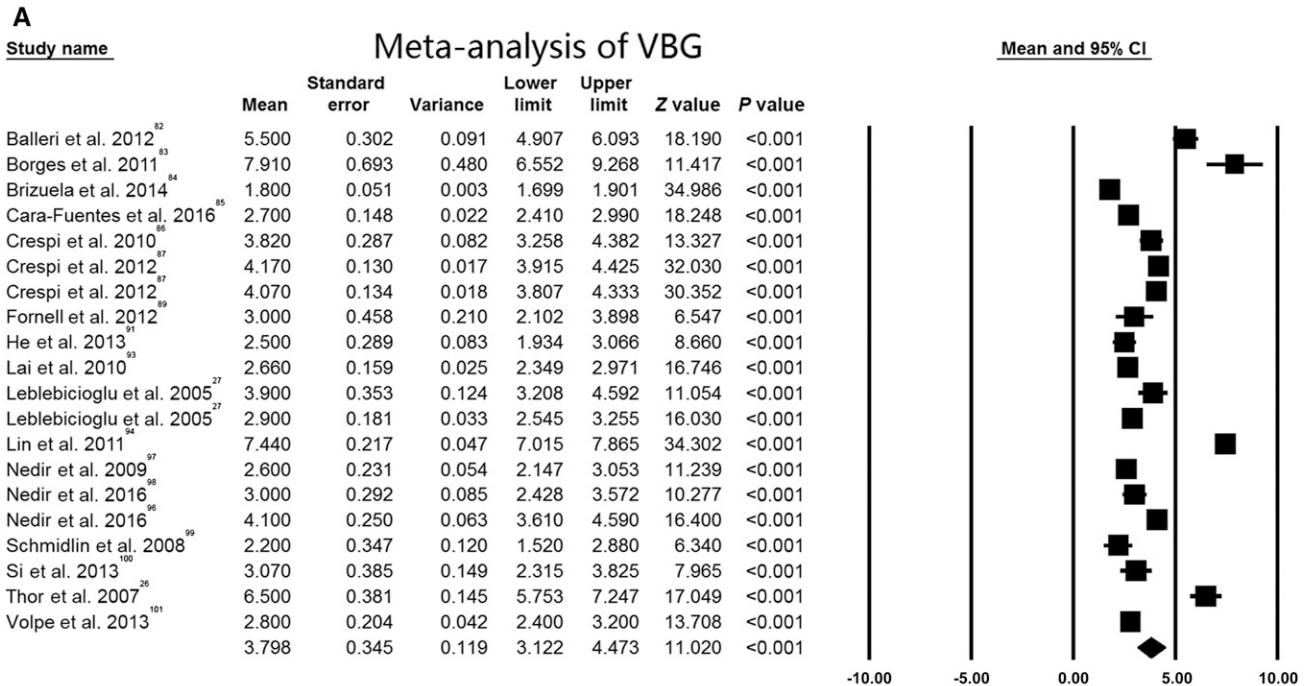


Figure 3.

A) Forest plot representing weighted mean VBG of 3.80 mm (95% CI of 3.12 to 4.47 mm). **B)** Meta-regression graph illustrating effect of surgical approach (transcrestal versus lateral window) on mean VBG. **C)** Meta-regression graph illustrating effect of implant length on mean VBG. **D)** Meta-regression graph illustrating effect of PILi on mean VBG.

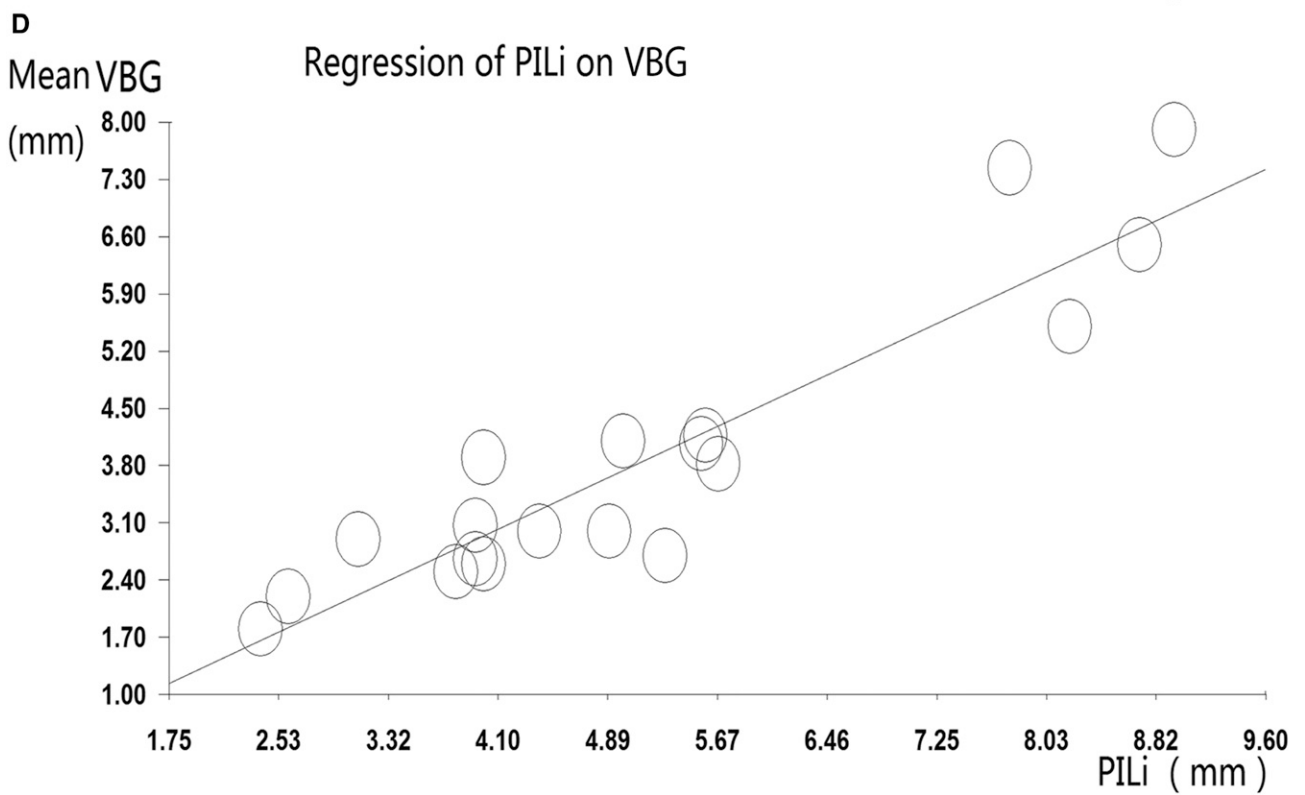
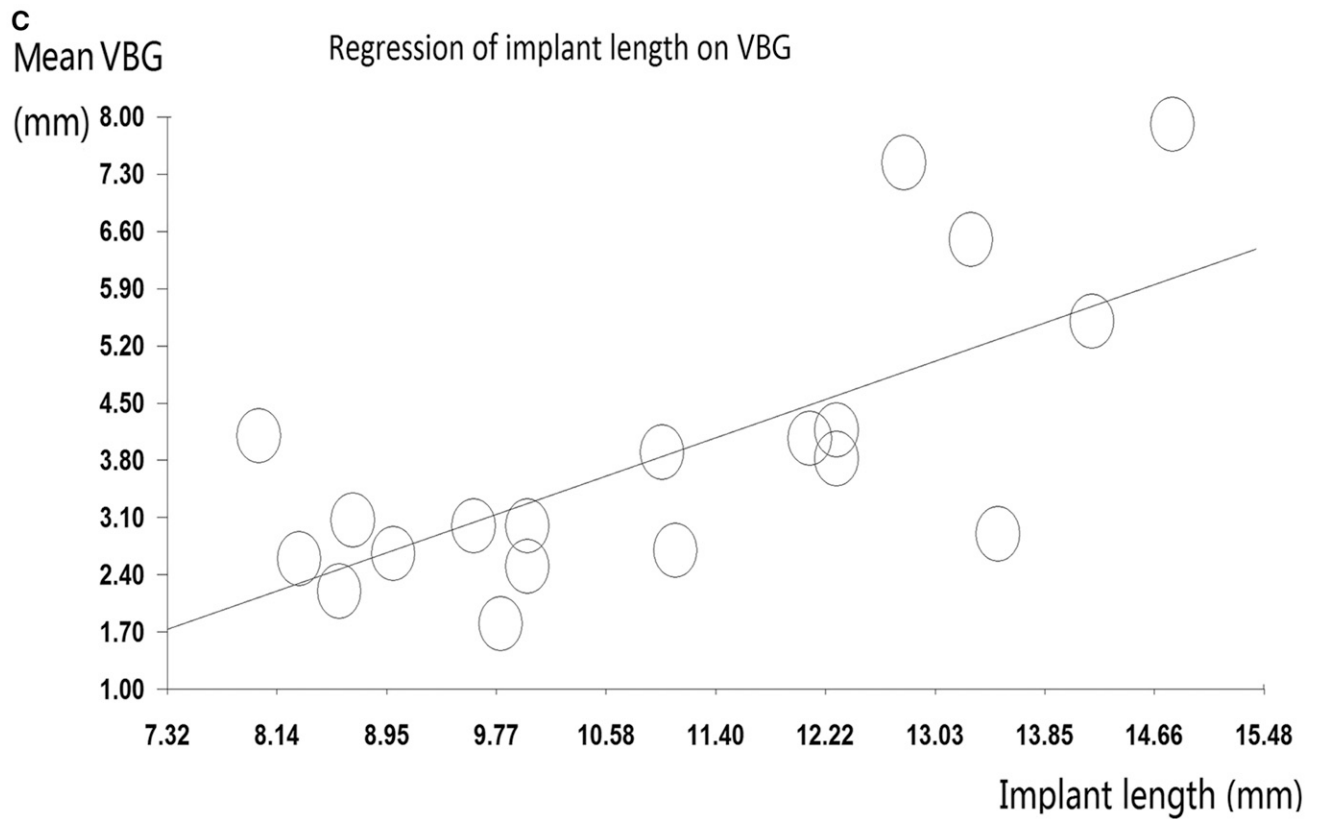


Figure 3.
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with a high degree of heterogeneity ($I^2 = 98.56\%$; $P < 0.001$) among selected studies. VBG was found to be greater for the lateral window approach than for the transcresal approach, and it increased with implant length and protrusion into the sinus cavity. Regression analysis demonstrated a statistically significant effect of the surgical approach, implant length, and PILi on VBG ($r = 2.82, 0.57, 0.80$; $R^2 = 19.10\%, 39.27\%, 83.92\%$, respectively) (Figs. 3B through 3D).

DISCUSSION

Cells, scaffolds, and signaling molecules are integral components in periodontal tissue engineering.¹⁰² The scaffold holds the space for cells and signaling molecules to act in a well-orchestrated symphony termed *regeneration*. In implant therapy, bone is the main structure that is regenerated. Numerous techniques, such as tenting titanium mesh,³⁰ long titanium screws,⁴⁷ or customized space-maintaining devices,⁵⁴ have been proposed to create and maintain space so that osteogenic cells can proliferate in a protected environment. Therefore, in GFSFE, the implant fixture acts as the tenting device for space creation and maintenance beneath the Schneiderian membrane. This allows formation of a stable blood clot that initiates the wound-healing cascade and promotes bone regeneration.^{103,104}

In line with the biologic concept of tissue regeneration, the present study shows that GFSFE appears to perform sufficiently well compared with the conventional approach of adding bone substitutes during augmentation. Meta-analysis highlighted weighted mean VBG of 3.80 ± 0.35 mm (range: 1.8 to 7.9 mm), which concurred with mean increase in bone height in the transcresal approach and minimum VBG in the lateral window approach.^{3,104} Therefore, GFSFE was capable of regenerating bone vertically, and amount of VBG was determined by the vertical space generated by protruded implants.

Some studies have suggested a relationship between VBG and types of graft materials¹⁰⁵ and sinus width/size,¹⁰⁶⁻¹⁰⁸ but not with PILi¹⁰⁹ and RBH.¹¹⁰ Interestingly, the present study found that VBG was significantly related to PILi ($r = 0.80$; $R^2 = 83.92\%$; $P < 0.001$) but not to RBH ($r = -0.19$; $P = 0.37$). This finding can be explained by the PASS principle¹¹¹ of guided bone regeneration, which stands for primary wound closure, angiogenesis, space creation and maintenance, and wound stability. Healing in a graft-free augmented sinus is a temporal sequence of hemostasis, inflammation, proliferation, and maturation/remodeling.¹⁹ Space and wound stability are crucial for undifferentiated mesenchymal stem cells or precursor cells within sinus to form bone.¹¹² Clinically, mechanical instability in the augmented sinus occurs

mainly from air pressure within the sinus associated with respiration.^{113,114} When the Schneiderian membrane is tented by the protruded implant, space created beneath the membrane is relatively stable, thus favoring bone regeneration within the space.^{103,104,113} As such, the amount of VBG is determined by the amount of implant protruding into the sinus.

According to the Wolff law,^{115,116} architecture and volume of regenerated bone within the sinus will change based on the functional load it bears. Maxillary sinuses augmented with bone substitutes, especially autogenous bone, generally undergo continuous bone resorption with a decreasing resorption rate over time.^{20,21,105,117} During the first 6 months of healing, rate of bone resorption was reported to be relatively high,^{20,21} and it gradually tapered down until 6 years after surgery.^{105,117} However, studies reported that GFSFE sites showed continuous but gradually decreasing bone formation. In initial stages of wound healing, VBG approached 2.5 mm at 6 months after surgery. This value gradually reduced to ≈ 1.5 mm at 24 months after surgery.^{86,87} Longitudinal studies reported that GFSFE had mean VBG of 2.5, 4.1, 3.2 to 3.8, and 3.0 mm at 1-, 3-, 5-, and 10-year follow-up periods, respectively,^{25,60,96-98,118} thereby indicating a plateauing effect on amount of VBG over time.

Faster bone formation was demonstrated in GFSFE compared with sinuses grafted with xenografts.¹⁹ In addition, graft-free sinuses had higher bone density than those grafted with allografts²⁹ and similar bone-to-implant contact (BIC) as autogenous bone grafted sinuses at 6 months after surgery.⁹² The present systematic review found that weighted mean PILf was 1.26 ± 0.33 mm, which was greatly reduced from mean PILi of 3.9 ± 1.1 mm, thus implying that bone regeneration occurred along the implant surface over time. A total of 97.9% of implants placed simultaneously with GFSFE survived after a mean follow-up period of 28.8 months. This high ISR was perhaps attributed to continuous formation of dense peri-implant bone leading to high BIC and thus functional stable implant restorations. Early implant failure rate of 71.4% was detected in this analysis, which concurred with implant failure rate of 85.7% in sinuses augmented with bone substitutes.¹¹⁹ Therefore, one can conclude that the early wound-healing phase is critical for osseointegration regardless of whether the sinus is augmented with bone substitutes or blood clot.

Peri-implant MBL is influenced by many biomechanical factors, for example, crown/implant ratio,¹²⁰ excessive cantilever length,¹²¹ and discrepancy in width of occlusal table and implant fixture diameter.¹²² Finite element analyses have suggested that load distribution and MBL of implants placed in grafted sinuses may be strongly related to

characteristics of the grafting materials.¹²³⁻¹²⁵ It was observed that when native bone was stiffer than regenerated bone, functional loading increased concomitant stress at crestal bone level,¹²⁵ resulting in MBL around implants.¹²⁶ Clinical studies corroborated conclusions drawn from finite element analyses, in that MBL around implants in grafted sinuses was significantly greater than that in pristine bone within the first 12 months of functional loading.^{22,23} The present meta-analysis demonstrated that weighted mean MBL around implants placed at sites with GFSFE was 0.91 ± 0.11 mm after a follow-up period of 41.9 months. This figure was lower than MBL around implants placed in grafted sinuses^{23,127,128} and pristine maxillary posterior sites.¹²⁸ It could be speculated that the wound-healing cascade in a bone-grafted sinus occurred in an altered manner compared with that in a graft-free sinus, hence the difference in MBL over time. In addition, meta-regression of MBL on duration of postoperative follow-up showed that MBL in GFSFE was time dependent ($r = 0.02$; $R^2 = 43.75\%$), with a resorption rate of 0.2 mm per year. This value was similar to the proposed implant success criteria of MBL < 0.2 mm per year from the second year of follow-up.^{129,130}

An area of concern with maxillary SFE is changes to the maxillary sinus cavity and quality of the sinus membrane. Previous animal and human studies found that penetration of dental implants through the Schneiderian membrane and into the sinus cavity had minimal effect on participants.¹³¹⁻¹³³ A canine model showed that there were no significant differences between untreated and membrane-lifted sinuses in terms of connective tissue and epithelium thickness, distribution and quantity of goblet cells, and cilia orientation.¹³⁴ This implies that SFE did not affect ciliary function and sinus membrane quality and thus could be considered a safe procedure.

There are two limitations associated with this analysis. First, vertical bone dimension was measured on different radiographs; for example, dental panoramic tomograms, standardized or non-standardized periapical radiographs, spiral computed tomograms, and cone-beam computed tomography scans. Second, there was high heterogeneity among studies.

CONCLUSION

Within the limitations of this systematic review and meta-analysis, GFSFE using the lateral window or transcresal approach with simultaneous implant placement appears to be a predictable treatment modality.

ACKNOWLEDGMENTS

This work was partially supported by the University of Michigan Periodontal Graduate Student Research

Fund. The authors report no conflicts of interest related to this study.

REFERENCES

1. Al-Dajani M. Recent trends in sinus lift surgery and their clinical implications. *Clin Implant Dent Relat Res* 2016;18:204-212.
2. Sogo M, Ikebe K, Yang TC, Wada M, Maeda Y. Assessment of bone density in the posterior maxilla based on Hounsfield units to enhance the initial stability of implants. *Clin Implant Dent Relat Res* 2012;14(Suppl. 1):e183-e187.
3. Mohan N, Wolf J, Dym H. Maxillary sinus augmentation. *Dent Clin North Am* 2015;59:375-388.
4. Jensen T, Schou S, Stavropoulos A, Terheyden H, Holmstrup P. Maxillary sinus floor augmentation with Bio-Oss or Bio-Oss mixed with autogenous bone as graft: A systematic review. *Clin Oral Implants Res* 2012;23:263-273.
5. Tan WC, Lang NP, Zwahlen M, Pjetursson BE. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part II: Transalveolar technique. *J Clin Periodontol* 2008;35(Suppl. 8):241-254.
6. Del Fabbro M, Corbella S, Weinstein T, Ceresoli V, Taschieri S. Implant survival rates after osteotome-mediated maxillary sinus augmentation: A systematic review. *Clin Implant Dent Relat Res* 2012;14(Suppl. 1):e159-e168.
7. Pjetursson BE, Tan WC, Zwahlen M, Lang NP. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. *J Clin Periodontol* 2008;35(Suppl. 8):216-240.
8. Boyne PJ, Marx RE, Nevins M, et al. A feasibility study evaluating rhBMP-2/absorbable collagen sponge for maxillary sinus floor augmentation. *Int J Periodontics Restorative Dent* 1997;17:11-25.
9. Cannizzaro G, Felice P, Leone M, Viola P, Esposito M. Early loading of implants in the atrophic posterior maxilla: Lateral sinus lift with autogenous bone and Bio-Oss versus crestal mini sinus lift and 8-mm hydroxyapatite-coated implants. A randomised controlled clinical trial. *Eur J Oral Implantology* 2009;2:25-38.
10. Danesh-Sani SA, Engebretson SP, Janal MN. Histomorphometric results of different grafting materials and effect of healing time on bone maturation after sinus floor augmentation: A systematic review and meta-analysis [published online ahead of print August 18, 2016]. *J Periodontol Res*. doi:10.1111/jre.12402.
11. Rosenberg ES, Cutler SA. Guided tissue regeneration and GTAM for periodontal regenerative therapy, ridge augmentation and dental implantology. *Alpha Omega* 1992;85:25-28.
12. Klijn RJ, Meijer GJ, Bronkhorst EM, Jansen JA. A meta-analysis of histomorphometric results and graft healing time of various biomaterials compared to autologous bone used as sinus floor augmentation material in humans. *Tissue Eng Part B Rev* 2010;16:493-507.
13. Wallace SS, Tarnow DP, Froum SJ, et al. Maxillary sinus elevation by lateral window approach: Evolution of technology and technique. *J Evid Based Dent Pract* 2012;12(Suppl. 3):161-171.

14. Klijn RJ, Meijer GJ, Bronkhorst EM, Jansen JA. Sinus floor augmentation surgery using autologous bone grafts from various donor sites: A meta-analysis of the total bone volume. *Tissue Eng Part B Rev* 2010; 16:295-303.
15. Goldberg VM, Stevenson S. Natural history of autografts and allografts. *Clin Orthop Relat Res* 1987; (225):7-16.
16. Trotter JF. Transmission of hepatitis C by implantation of a processed bone graft. A case report. *J Bone Joint Surg Am* 2003;85-A:2215-2217.
17. Corbella S, Taschieri S, Weinstein R, Del Fabbro M. Histomorphometric outcomes after lateral sinus floor elevation procedure: A systematic review of the literature and meta-analysis. *Clin Oral Implants Res* 2016;27:1106-1122.
18. Handschel J, Simonowska M, Naujoks C, et al. A histomorphometric meta-analysis of sinus elevation with various grafting materials. *Head Face Med* 2009;5:12.
19. Lambert F, Léonard A, Drion P, Sourice S, Layrolle P, Rompen E. Influence of space-filling materials in subantral bone augmentation: Blood clot vs. autogenous bone chips vs. bovine hydroxyapatite. *Clin Oral Implants Res* 2011;22:538-545.
20. Kühl S, Payer M, Kirmeier R, Wildburger A, Acham S, Jakse N. The influence of particulated autogenous bone on the early volume stability of maxillary sinus grafts with biphasic calcium phosphate: A randomized clinical trial. *Clin Implant Dent Relat Res* 2015; 17:173-178.
21. Kühl S, Payer M, Kirmeier R, Wildburger A, Wegscheider W, Jakse N. The influence of bone marrow aspirates and concentrates on the early volume stability of maxillary sinus grafts with deproteinized bovine bone mineral – First results of a RCT. *Clin Oral Implants Res* 2014;25:221-225.
22. Galindo-Moreno P, Leon-Cano A, Ortega-Oller I, et al. Marginal bone loss as success criterion in implant dentistry: Beyond 2 mm. *Clin Oral Implants Res* 2015;26:e28-e34.
23. Galindo-Moreno P, Fernández-Jiménez A, Avila-Ortiz G, Silvestre FJ, Hernández-Cortés P, Wang HL. Marginal bone loss around implants placed in maxillary native bone or grafted sinuses: A retrospective cohort study. *Clin Oral Implants Res* 2014; 25:378-384.
24. Diss A, Dohan DM, Mouhyi J, Mahler P. Osteotome sinus floor elevation using Choukroun's platelet-rich fibrin as grafting material: A 1-year prospective pilot study with microthreaded implants. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;105:572-579.
25. Nedir R, Bischof M, Vazquez L, Szmukler-Moncler S, Bernard JP. Osteotome sinus floor elevation without grafting material: A 1-year prospective pilot study with ITI implants. *Clin Oral Implants Res* 2006;17:679-686.
26. Thor A, Sennerby L, Hirsch JM, Rasmusson L. Bone formation at the maxillary sinus floor following simultaneous elevation of the mucosal lining and implant installation without graft material: An evaluation of 20 patients treated with 44 Astra Tech implants. *J Oral Maxillofac Surg* 2007;65(7, Suppl. 1):64-72.
27. Leblebicioglu B, Ersanli S, Karabuda C, Tosun T, Gokdeniz H. Radiographic evaluation of dental implants placed using an osteotome technique. *J Periodontol* 2005;76:385-390.
28. Chen TW, Chang HS, Leung KW, Lai YL, Kao SY. Implant placement immediately after the lateral approach of the trap door window procedure to create a maxillary sinus lift without bone grafting: A 2-year retrospective evaluation of 47 implants in 33 patients. *J Oral Maxillofac Surg* 2007;65:2324-2328.
29. Altintas NY, Senel FC, Kayipmaz S, Taskesen F, Pampu AA. Comparative radiologic analyses of newly formed bone after maxillary sinus augmentation with and without bone grafting. *J Oral Maxillofac Surg* 2013;71:1520-1530.
30. Atef M, Hakam MM, Elfaramawey MI, Abou-EIFetouh A, Ekram M. Nongrafted sinus floor elevation with a space-maintaining titanium mesh: Case-series study on four patients. *Clin Implant Dent Relat Res* 2014;16:893-903.
31. Bassi AP, Pioto R, Faverani LP, Canestraro D, Fontão FG. Maxillary sinus lift without grafting, and simultaneous implant placement: A prospective clinical study with a 51-month follow-up. *Int J Oral Maxillofac Surg* 2015;44:902-907.
32. Biscaro L, Beccatelli A, Landi L. A human histologic report of an implant placed with simultaneous sinus floor elevation without bone graft. *Int J Periodontics Restorative Dent* 2012;32:e122-e130.
33. Boyne PJ, Lilly LC, Marx RE, et al. De novo bone induction by recombinant human bone morphogenetic protein-2 (rhBMP-2) in maxillary sinus floor augmentation. *J Oral Maxillofac Surg* 2005;63:1693-1707.
34. Bruschi GB, Crespi R, Capparè P, Gherlone E. Transcrestal sinus floor elevation: A retrospective study of 46 patients up to 16 years. *Clin Implant Dent Relat Res* 2012;14:759-767.
35. Bruschi GB, Scipioni A, Calesini G, Bruschi E. Localized management of sinus floor with simultaneous implant placement: A clinical report. *Int J Oral Maxillofac Implants* 1998;13:219-226.
36. Chipaila N, Marini R, Sfasciotti GL, Cielo A, Bonanome L, Monaco A. Graftless sinus augmentation technique with contextual placement of implants: A case report. *J Med Case Reports* 2014;8:437.
37. Cricchio G, Sennerby L, Lundgren S. Sinus bone formation and implant survival after sinus membrane elevation and implant placement: A 1- to 6-year follow-up study. *Clin Oral Implants Res* 2011; 22:1200-1212.
38. de Oliveira GR, Olate S, Cavalieri-Pereira L, et al. Maxillary sinus floor augmentation using blood without graft material. Preliminary results in 10 patients. *J Oral Maxillofac Surg* 2013;71:1670-1675.
39. Ellegaard B, Kølsten-Petersen J, Baelum V. Implant therapy involving maxillary sinus lift in periodontally compromised patients. *Clin Oral Implants Res* 1997; 8:305-315.
40. Esposito M, Piattelli M, Pistilli R, Pellegrino G, Felice P. Sinus lift with guided bone regeneration or anorganic bovine bone: 1-year post-loading results of a pilot randomised clinical trial. *Eur J Oral Implantology* 2010;3:297-305.
41. Felice P, Scarano A, Pistilli R, et al. A comparison of two techniques to augment maxillary sinuses using the lateral window approach: Rigid synthetic resorbable barriers versus anorganic bovine bone. Five-month post-loading clinical and histological results of a pilot randomised controlled clinical trial. *Eur J Oral Implantology* 2009;2:293-306.

42. Fermergård R, Astrand P. Osteotome sinus floor elevation and simultaneous placement of implants – A 1-year retrospective study with Astra Tech implants. *Clin Implant Dent Relat Res* 2008;10:62-69.
43. Gabbert O, Koob A, Schmitter M, Rammelsberg P. Implants placed in combination with an internal sinus lift without graft material: An analysis of short-term failure. *J Clin Periodontol* 2009;36:177-183.
44. Groeneveld EH, van den Bergh JP, Holzmann P, ten Bruggenkate CM, Tuinzing DB, Burger EH. Histomorphometrical analysis of bone formed in human maxillary sinus floor elevations grafted with OP-1 device, demineralized bone matrix or autogenous bone. Comparison with non-grafted sites in a series of case reports. *Clin Oral Implants Res* 1999;10:499-509.
45. Hatano N, Sennerby L, Lundgren S. Maxillary sinus augmentation using sinus membrane elevation and peripheral venous blood for implant-supported rehabilitation of the atrophic posterior maxilla: Case series. *Clin Implant Dent Relat Res* 2007;9:150-155.
46. Kanayama T, Horii K, Senga Y, Shibuya Y. Crestal approach to sinus floor elevation for atrophic maxilla using platelet-rich fibrin as the only grafting material: A 1-year prospective study. *Implant Dent* 2016;25:32-38.
47. Kaneko T, Masuda I, Horie N, Shimoyama T. New bone formation in nongrafted sinus lifting with space-maintaining management: A novel technique using a titanium bone fixation device. *J Oral Maxillofac Surg* 2012;70:e217-e224.
48. Kim JM, Sohn DS, Bae MS, Moon JW, Lee JH, Park IS. Flapless transcrestal sinus augmentation using hydrodynamic piezoelectric internal sinus elevation with autologous concentrated growth factors alone. *Implant Dent* 2014;23:168-174.
49. Lai HC, Zhang ZY, Wang F, Zhuang LF, Liu X. Resonance frequency analysis of stability on ITI implants with osteotome sinus floor elevation technique without grafting: A 5-month prospective study. *Clin Oral Implants Res* 2008;19:469-475.
50. Lundgren S, Andersson S, Gualini F, Sennerby L. Bone reformation with sinus membrane elevation: A new surgical technique for maxillary sinus floor augmentation. *Clin Implant Dent Relat Res* 2004;6:165-173.
51. Lundgren S, Cricchio G, Palma VC, Salata LA, Sennerby L. Sinus membrane elevation and simultaneous insertion of dental implants: A new surgical technique in maxillary sinus floor augmentation. *Periodontol 2000* 2008;47:193-205.
52. Markovic A, Misic T, Calvo-Guirado JL, Delgado-Ruiz RA, Janjić B, Abboud M. Two-center prospective, randomized, clinical, and radiographic study comparing osteotome sinus floor elevation with or without bone graft and simultaneous implant placement. *Clin Implant Dent Relat Res* 2016;18:873-882.
53. Mazor Z, Horowitz RA, Del Corso M, Prasad HS, Rohrer MD, Dohan Ehrenfest DM. Sinus floor augmentation with simultaneous implant placement using Choukroun's platelet-rich fibrin as the sole grafting material: A radiologic and histologic study at 6 months. *J Periodontol* 2009;80:2056-2064.
54. Munakata M, Tachikawa N, Yamaguchi Y, Sanda M, Kasugai S. The maxillary sinus floor elevation using a poly-L-lactic acid device to create space without bone graft: Case series study of five patients. *J Oral Implantol* 2016;42:278-284.
55. Nedir R, Bischof M, Vazquez L, Nurdin N, Szmukler-Moncler S, Bernard JP. Osteotome sinus floor elevation technique without grafting material: 3-year results of a prospective pilot study. *Clin Oral Implants Res* 2009;20:701-707.
56. Nedir R, Nurdin N, El Hage M, Bischof M. Osteotome sinus floor elevation procedure for first molar single-gap implant rehabilitation: A case series. *Implant Dent* 2014;23:760-767.
57. Nedir R, Nurdin N, Khoury P, et al. Paradigm shift in the management of the atrophic posterior maxilla. *Case Rep Dent* 2014;2014:486949.
58. Nedir R, Nurdin N, Khoury P, et al. Osteotome sinus floor elevation with and without grafting material in the severely atrophic maxilla. A 1-year prospective randomized controlled study. *Clin Oral Implants Res* 2013;24:1257-1264.
59. Nedir R, Nurdin N, Szmukler-Moncler S, Bischof M. Osteotome sinus floor elevation technique without grafting material and immediate implant placement in atrophic posterior maxilla: Report of 2 cases. *J Oral Maxillofac Surg* 2009;67:1098-1103.
60. Nedir R, Nurdin N, Vazquez L, Szmukler-Moncler S, Bischof M, Bernard JP. Osteotome sinus floor elevation technique without grafting: A 5-year prospective study. *J Clin Periodontol* 2010;37:1023-1028.
61. Pinchasov G, Juodzbalys G. Graft-free sinus augmentation procedure: A literature review. *J Oral Maxillofac Res* 2014;5:e1.
62. Pjetursson BE, Ignjatovic D, Matuliene G, Brägger U, Schmidlin K, Lang NP. Transalveolar maxillary sinus floor elevation using osteotomes with or without grafting material. Part II: Radiographic tissue remodeling. *Clin Oral Implants Res* 2009;20:677-683.
63. Pjetursson BE, Rast C, Brägger U, Schmidlin K, Zwahlen M, Lang NP. Maxillary sinus floor elevation using the (transalveolar) osteotome technique with or without grafting material. Part I: Implant survival and patients' perception. *Clin Oral Implants Res* 2009;20:667-676.
64. Qian SJ, Gu YX, Mo JJ, Qiao SC, Zhuang LF, Lai HC. Resonance frequency analysis of implants placed with osteotome sinus floor elevation in posterior maxillae. *Clin Oral Implants Res* 2016;27:113-119.
65. Rammelsberg P, Mahabadi J, Eiffler C, Koob A, Kappel S, Gabbert O. Radiographic monitoring of changes in bone height after implant placement in combination with an internal sinus lift without graft material. *Clin Implant Dent Relat Res* 2015;17 (Suppl. 1):e267-e274.
66. Rasmusson L, Thor A, Sennerby L. Stability evaluation of implants integrated in grafted and non-grafted maxillary bone: A clinical study from implant placement to abutment connection. *Clin Implant Dent Relat Res* 2012;14:61-66.
67. Riben C, Thor A. The maxillary sinus membrane elevation procedure: Augmentation of bone around dental implants without grafts – A review of a surgical technique. *Int J Dent* 2012;2012:105483.
68. Schleier P, Bierfreund G, Schultze-Mosgau S, Moldenhauer F, Küpper H, Freilich M. Simultaneous dental implant placement and endoscope-guided internal sinus floor elevation: 2-year post-loading outcomes. *Clin Oral Implants Res* 2008;19:1163-1170.
69. Senyilmaz DP, Kasaboglu O. Osteotome sinus floor elevation without bone grafting and simultaneous

- implant placement in the atrophic maxilla: A pilot study. *Indian J Dent Res* 2011;22:786-789.
70. Simonpieri A, Choukroun J, Del Corso M, Sammartino G, Dohan Ehrenfest DM. Simultaneous sinus-lift and implantation using microthreaded implants and leukocyte- and platelet-rich fibrin as sole grafting material: A six-year experience. *Implant Dent* 2011; 20:2-12.
 71. Smedberg JI, Johansson P, Ekenbäck D, Wannfors D. Implants and sinus-inlay graft in a 1-stage procedure in severely atrophied maxillae: Prosthodontic aspects in a 3-year follow-up study. *Int J Oral Maxillofac Implants* 2001;16:668-674.
 72. Sohn DS. Paradigm shift regarding sinus augmentation. *J Korean Assoc Oral Maxillofac Surg* 2015;41: 57-58.
 73. Sohn DS, Heo JU, Kwak DH, et al. Bone regeneration in the maxillary sinus using an autologous fibrin-rich block with concentrated growth factors alone. *Implant Dent* 2011;20:389-395.
 74. Sohn DS, Lee JS, Ahn MR, Shin HI. New bone formation in the maxillary sinus without bone grafts. *Implant Dent* 2008;17:321-331.
 75. Sohn DS, Moon JW, Moon KN, Cho SC, Kang PS. New bone formation in the maxillary sinus using only absorbable gelatin sponge. *J Oral Maxillofac Surg* 2010;68:1327-1333.
 76. Taschieri S, Corbella S, Saita M, Tsesis I, Del Fabbro M. Osteotome-mediated sinus lift without grafting material: A review of literature and a technique proposal. *Int J Dent* 2012;2012:849093.
 77. Triplett RG, Nevins M, Marx RE, et al. Pivotal, randomized, parallel evaluation of recombinant human bone morphogenetic protein-2/absorbable collagen sponge and autogenous bone graft for maxillary sinus floor augmentation. *J Oral Maxillofac Surg* 2009;67:1947-1960.
 78. van den Bergh JP, ten Bruggenkate CM, Groeneveld HH, Burger EH, Tuinzing DB. Recombinant human bone morphogenetic protein-7 in maxillary sinus floor elevation surgery in 3 patients compared to autogenous bone grafts. A clinical pilot study. *J Clin Periodontol* 2000;27:627-636.
 79. Winter AA, Pollack AS, Odrich RB. Placement of implants in the severely atrophic posterior maxilla using localized management of the sinus floor: A preliminary study. *Int J Oral Maxillofac Implants* 2002;17:687-695.
 80. Winter AA, Pollack AS, Odrich RB. Sinus/alveolar crest tenting (SACT): A new technique for implant placement in atrophic maxillary ridges without bone grafts or membranes. *Int J Periodontics Restorative Dent* 2003;23:557-565.
 81. Yamada Y, Nakamura S, Ito K, et al. Injectable tissue-engineered bone using autogenous bone marrow-derived stromal cells for maxillary sinus augmentation: Clinical application report from a 2-6-year follow-up. *Tissue Eng Part A* 2008;14:1699-1707.
 82. Balleri P, Veltri M, Nuti N, Ferrari M. Implant placement in combination with sinus membrane elevation without biomaterials: A 1-year study on 15 patients. *Clin Implant Dent Relat Res* 2012;14: 682-689 (erratum 2013;15:470).
 83. Borges FL, Dias RO, Piattelli A, et al. Simultaneous sinus membrane elevation and dental implant placement without bone graft: A 6-month follow-up study. *J Periodontol* 2011;82:403-412.
 84. Brizuela A, Martín N, Fernández-Gonzalez FJ, Larrazábal C, Anta A. Osteotome sinus floor elevation without grafting material: Results of a 2-year prospective study. *J Clin Exp Dent* 2014;6:e479-e484.
 85. Cara-Fuentes M, Machuca-Ariza J, Ruiz-Martos A, Ramos-Robles MC, Martínez-Lara I. Long-term outcome of dental implants after maxillary augmentation with and without bone grafting. *Med Oral Patol Oral Cir Bucal* 2016;21:e229-e235.
 86. Crespi R, Cappare P, Gherlone E. Osteotome sinus floor elevation and simultaneous implant placement in grafted biomaterial sockets: 3 years of follow-up. *J Periodontol* 2010;81:344-349.
 87. Crespi R, Cappare P, Gherlone E. Sinus floor elevation by osteotome: Hand mallet versus electric mallet. A prospective clinical study. *Int J Oral Maxillofac Implants* 2012;27:1144-1150.
 88. Fermergård R, Åstrand P. Osteotome sinus floor elevation without bone grafts – A 3-year retrospective study with Astra Tech implants. *Clin Implant Dent Relat Res* 2012;14:198-205.
 89. Fornell J, Johansson LA, Bolin A, Isaksson S, Sennerby L. Flapless, CBCT-guided osteotome sinus floor elevation with simultaneous implant installation. I: Radiographic examination and surgical technique. A prospective 1-year follow-up. *Clin Oral Implants Res* 2012;23:28-34.
 90. Gu YX, Shi JY, Zhuang LF, Qian SJ, Mo JJ, Lai HC. Transalveolar sinus floor elevation using osteotomes without grafting in severely atrophic maxilla: A 5-year prospective study. *Clin Oral Implants Res* 2016; 27:120-125.
 91. He L, Chang X, Liu Y. Sinus floor elevation using osteotome technique without grafting materials: A 2-year retrospective study. *Clin Oral Implants Res* 2013;24(Suppl. A100):63-67.
 92. Johansson LA, Isaksson S, Bryington M, Dahlin C. Evaluation of bone regeneration after three different lateral sinus elevation procedures using micro-computed tomography of retrieved experimental implants and surrounding bone: A clinical, prospective, and randomized study. *Int J Oral Maxillofac Implants* 2013;28:579-586.
 93. Lai HC, Zhuang LF, Lv XF, Zhang ZY, Zhang YX, Zhang ZY. Osteotome sinus floor elevation with or without grafting: A preliminary clinical trial. *Clin Oral Implants Res* 2010;21:520-526.
 94. Lin IC, Gonzalez AM, Chang HJ, Kao SY, Chen TW. A 5-year follow-up of 80 implants in 44 patients placed immediately after the lateral trap-door window procedure to accomplish maxillary sinus elevation without bone grafting. *Int J Oral Maxillofac Implants* 2011;26:1079-1086.
 95. Moon JW, Sohn DS, Heo JU, Shin HI, Jung JK. New bone formation in the maxillary sinus using peripheral venous blood alone. *J Oral Maxillofac Surg* 2011;69:2357-2367.
 96. Nedir R, Nurdin N, Khoury P, Bischof M. Short implants placed with or without grafting in atrophic sinuses: The 3-year results of a prospective randomized controlled study. *Clin Implant Dent Relat Res* 2016;18:10-18.
 97. Nedir R, Nurdin N, Szmukler-Moncler S, Bischof M. Placement of tapered implants using an osteotome sinus floor elevation technique without bone grafting: 1-year results. *Int J Oral Maxillofac Implants* 2009;24:727-733.

98. Nedir R, Nurdin N, Vazquez L, Abi Najm S, Bischof M. Osteotome sinus floor elevation without grafting: A 10-year prospective study. *Clin Implant Dent Relat Res* 2016;18:609-617.
99. Schmidlin PR, Müller J, Bindl A, Imfeld H. Sinus floor elevation using an osteotome technique without grafting materials or membranes. *Int J Periodontics Restorative Dent* 2008;28:401-409.
100. Si MS, Zhuang LF, Gu YX, Mo JJ, Qiao SC, Lai HC. Osteotome sinus floor elevation with or without grafting: A 3-year randomized controlled clinical trial. *J Clin Periodontol* 2013;40:396-403.
101. Volpe S, Lanza M, Verrocchi D, Sennerby L. Clinical outcomes of an osteotome technique and simultaneous placement of Neoss implants in the posterior maxilla. *Clin Implant Dent Relat Res* 2013;15:22-28.
102. Lynch SE, Wisner-Lynch L, Nevins M, Nevins ML. A new era in periodontal and periimplant regeneration: Use of growth-factor enhanced matrices incorporating rhPDGF. *Compend Contin Educ Dent* 2006;27:672-678, quiz 679-680.
103. Xu H, Shimizu Y, Ooya K. Histomorphometric study of the stability of newly formed bone after elevation of the floor of the maxillary sinus. *Br J Oral Maxillofac Surg* 2005;43:493-499.
104. Sohn DS, Moon JW, Lee WH, et al. Comparison of new bone formation in the maxillary sinus with and without bone grafts: Immunochemical rabbit study. *Int J Oral Maxillofac Implants* 2011;26:1033-1042.
105. Shanbhag S, Shanbhag V, Stavropoulos A. Volume changes of maxillary sinus augmentations over time: A systematic review. *Int J Oral Maxillofac Implants* 2014;29:881-892.
106. Soardi CM, Spinato S, Zaffe D, Wang HL. Atrophic maxillary floor augmentation by mineralized human bone allograft in sinuses of different size: An histologic and histomorphometric analysis. *Clin Oral Implants Res* 2011;22:560-566.
107. Spinato S, Bernardello F, Galindo-Moreno P, Zaffe D. Maxillary sinus augmentation by crestal access: A retrospective study on cavity size and outcome correlation. *Clin Oral Implants Res* 2015;26:1375-1382.
108. Zheng X, Teng M, Zhou F, Ye J, Li G, Mo A. Influence of maxillary sinus width on transcresal sinus augmentation outcomes: Radiographic evaluation based on cone beam CT. *Clin Implant Dent Relat Res* 2016;18:292-300.
109. Sul SH, Choi BH, Li J, Jeong SM, Xuan F. Effects of sinus membrane elevation on bone formation around implants placed in the maxillary sinus cavity: An experimental study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;105:684-687.
110. Avila-Ortiz G, Neiva R, Galindo-Moreno P, Rudek I, Benavides E, Wang HL. Analysis of the influence of residual alveolar bone height on sinus augmentation outcomes. *Clin Oral Implants Res* 2012;23:1082-1088.
111. Wang HL, Boyapati L. "PASS" principles for predictable bone regeneration. *Implant Dent* 2006;15:8-17.
112. Frank V, Kaufmann S, Wright R, et al. Frequent mechanical stress suppresses proliferation of mesenchymal stem cells from human bone marrow without loss of multipotency. *Sci Rep* 2016;6:24264.
113. Asai S, Shimizu Y, Ooya K. Maxillary sinus augmentation model in rabbits: Effect of occluded nasal ostium on new bone formation. *Clin Oral Implants Res* 2002;13:405-409.
114. Chanavaz M. Maxillary sinus: Anatomy, physiology, surgery, and bone grafting related to implantology – Eleven years of surgical experience (1979-1990). *J Oral Implantol* 1990;16:199-209.
115. Frost HM. From Wolff's law to the mechanostat: A new "face" of physiology. *J Orthop Sci* 1998;3:282-286.
116. Frost HMA. A 2003 update of bone physiology and Wolff's Law for clinicians. *Angle Orthod* 2004;74:3-15.
117. Sbordone C, Toti P, Guidetti F, Califano L, Bufo P, Sbordone L. Volume changes of autogenous bone after sinus lifting and grafting procedures: A 6-year computerized tomographic follow-up. *J Cranio-maxillofac Surg* 2013;41:235-241.
118. Nedir R, Nurdin N, Abi Najm S, El Hage M, Bischof M. Short implants placed with or without grafting into atrophic sinuses: The 5-year results of a prospective randomized controlled study [published online ahead of print June 13, 2016]. *Clin Oral Implants Res* 2016.
119. Barone A, Orlando B, Tonelli P, Covani U. Survival rate for implants placed in the posterior maxilla with and without sinus augmentation: A comparative cohort study. *J Periodontol* 2011;82:219-226.
120. Garaicoa-Pazmiño C, Suárez-López del Amo F, Monje A, et al. Influence of crown/implant ratio on marginal bone loss: A systematic review. *J Periodontol* 2014;85:1214-1221.
121. Anitua E, Piñas L, Orive G. Retrospective study of short and extra-short implants placed in posterior regions: Influence of crown-to-implant ratio on marginal bone loss. *Clin Implant Dent Relat Res* 2015;17:102-110.
122. Ozgur GO, Kazancioglu HO, Demirtas N, Deger S, Ak G. Risk factors associated with implant marginal bone loss: A retrospective 6-year follow-up study. *Implant Dent* 2016;25:122-127.
123. Fanuscu MI, Vu HV, Poncelet B. Implant biomechanics in grafted sinus: A finite element analysis. *J Oral Implantol* 2004;30:59-68.
124. Ingham S, Suebnukarn S, Tharanon W, Apatananon T, Sitthiseripratip K. Influence of graft quality and marginal bone loss on implants placed in maxillary grafted sinus: A finite element study. *Med Biol Eng Comput* 2010;48:681-689.
125. Huang HL, Fuh LJ, Ko CC, Hsu JT, Chen CC. Biomechanical effects of a maxillary implant in the augmented sinus: A three-dimensional finite element analysis. *Int J Oral Maxillofac Implants* 2009;24:455-462.
126. Kitamura E, Stegaroiu R, Nomura S, Miyakawa O. Biomechanical aspects of marginal bone resorption around osseointegrated implants: Considerations based on a three-dimensional finite element analysis. *Clin Oral Implants Res* 2004;15:401-412.
127. Galindo-Moreno P, Fernández-Jiménez A, O'Valle F, et al. Marginal bone loss in implants placed in grafted maxillary sinus. *Clin Implant Dent Relat Res* 2015;17:373-383.
128. Johansson B, Wannfors K, Ekenbäck J, Smedberg JI, Hirsch J. Implants and sinus-inlay bone grafts in a 1-stage procedure on severely atrophied

- maxillae: Surgical aspects of a 3-year follow-up study. *Int J Oral Maxillofac Implants* 1999;14:811-818.
129. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. *Int J Oral Maxillofac Implants* 1986;1:11-25.
130. Peñarrocha-Diago MA, Flichy-Fernández AJ, Alonso-González R, Peñarrocha-Oltra D, Balaguer-Martínez J, Peñarrocha-Diago M. Influence of implant neck design and implant-abutment connection type on peri-implant health. Radiological study. *Clin Oral Implants Res* 2013;24:1192-1200.
131. Tabrizi R, Amid R, Taha Özkan B, Khorshidi H, Langner NJ. Effects of exposing dental implant to the maxillary sinus cavity. *J Craniofac Surg* 2012;23:767-769.
132. Zhong W, Chen B, Liang X, Ma G. Experimental study on penetration of dental implants into the maxillary sinus in different depths. *J Appl Oral Sci* 2013;21:560-566.
133. Elhamruni LM, Marzook HA, Ahmed WM, Abdul-Rahman M. Experimental study on penetration of dental implants into the maxillary sinus at different depths. *Oral Maxillofac Surg* 2016;20:281-287.
134. Sul SH, Choi BH, Li J, Jeong SM, Xuan F. Histologic changes in the maxillary sinus membrane after sinus membrane elevation and the simultaneous insertion of dental implants without the use of grafting materials. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;105:e1-e5.

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Submitted October 15, 2016; accepted for publication December 25, 2016.