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A prospective randomized controlled trial of two-window versus solo-window technique by lateral sinus floor elevation in atrophic posterior maxilla: Results from a 1-year observational phase

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Abstract

Background: Implant failures are more common when multiple missing posterior teeth need lateral sinus floor elevation owing to inadequate tissue maturation after grafting. Effects of lateral window dimensions on vital bone formation have rarely been compared.

Purpose: To compare endo-sinus bone formation between two- and solo-window techniques to rehabilitate multiple missing posterior teeth that need substantial augmentation.

Methods and materials: Patients with severely atrophic posterior maxilla were randomized to receive lateral sinus floor elevation via solo or two bony windows. Bone core specimens harvested from lateral aspect of the augmentation sites were histomorphometrically analyzed. Proportions of mineralized bone (MB), bone substitute materials (BS), and nonmineralized tissue (NMT) were quantified.

Results: Twenty-one patients underwent 23 maxillary sinus augmentations. One patient in each group dropped out during the follow-up period. Lateral window dimensions were 81.65 ± 4.59 and 118.04 ± 19.53 mm^2 in the test and control groups, respectively. Histomorphometric analysis revealed mean MB of $42.32\% \pm 13.07\%$ and $26.00\% \pm 15.23\%$, BS of $40.34\% \pm 9.52\%$ and $60.03\% \pm 10.13\%$, and NMT of $18.14\% \pm 14.24\%$ and $14.75\% \pm 10.38\%$ in test and control groups, respectively, with significant differences.

Conclusion: The two-window technique could facilitate faster maturation and consolidation of the grafted volume and is an effective alternative for rehabilitation of severely atrophic posterior maxilla with multiple missing posterior teeth.

KEYWORDS

atrophic maxilla, bone formation, maxillary sinus floor elevation, randomized controlled trial

1 | INTRODUCTION

Lack of available bone height is often a major challenge for placement of dental implants in the posterior maxilla. Functional rehabilitation of edentulous posterior maxilla requires adequate bone quantity and quality for long-term stability and survival of dental implants.[1,2] Maxillary sinus augmentation via the lateral window approach is commonly used when large bone gain is required.[3,4] The surgical procedure, first reported in 1976 by Tatum, has undergone development, and several variations exist.[5]

Following maxillary sinus elevation with or without graft materials, endo-sinus bone gain requires healing and consolidation periods to develop certain biomechanical and biological features.[6] This process requires a stable scaffold, ingrowth of capillaries, and migration of osteogenic cells.[7] Implant failure can be more frequent when the functional force exceeds the capacity of the endo-sinus bone structures to

adapt owing to an insufficient rate of maturation of the new bone tissue.[8]

Typically, the amount of bone attained after sinus augmentation procedure ranges from 5% to 59% in human specimens depending on the grafting materials and the time of biopsy.[9,10] Elevation of the Schneiderian membrane, which exposes the bony walls, contributes toward wound healing.[11] Although the role of the Schneiderian membrane in bone formation remains controversial,[12] its effect is relatively limited. It is believed that formation of new bone, sprouting from the vicinity of existing bony walls of the sinus, including floor and lateral walls, grows toward the middle of the elevated area.[13] Considering the high osteogenic capacity of the lateral wall bone, as reported by Zaffe and D'Avenia, preservation of the lateral wall as much as possible is critical in bone remodeling.[14] A study by Peleg and colleagues[15] demonstrated that creating a large lateral window could negatively affect the maturation and early vascularization of a grafted site. In a study by Gustavo and colleagues,[16] the mean lateral window area was 69.71 ± 26.24 (range: 35.75–146.25 mm^2), and correlation between the window size and the proportion of vital bone, remaining allograft, and nonmineralized tissue was assessed; the results strongly suggested that preparation of large lateral windows for maxillary sinus augmentation have a negative influence on the rate of vital bone formation. However, the authors did not take into account anatomical and technical factors that influence bone formation and prepared the lateral window in a quadrilateral shape, which further increased the window size.

In cases of multiple missing posterior teeth that need large-scale sinus elevation, recommended dimensions of the lateral window must be large enough depending upon the amount of augmentation[17]; however, this increased distance to the bony wall results in slower vital bone production.[18] The two-window technique is applied to avoid fracturing the septa in the presence of maxillary sinus septa.[19] This technique can be an effective treatment option for large-scale sinus elevation to avoid excessive lateral bone cut. To date, no published reports have documented application of the two-window technique for maxillary sinus floor elevation via the lateral approach, and few prospective studies have compared the quality of bone formation after preparation of lateral windows of varying sizes.

The primary aim of the present randomized controlled trial (RCT) was to compare the effects on endo-sinus bone formation between two-window and conventional solo-window techniques when used to rehabilitate multiple missing posterior teeth, while the secondary aim was to compare the encleftation of connective tissue, peri-implant bone resorption, and surgical complications associated with both strategies. The null hypothesis was that there are no differences between the 2 techniques in terms of bone volume formation, survival rates, and clinical function over a 1-year follow-up duration.

2 | METHODS AND MATERIALS

This study was designed as a prospective RCT. Patients were recruited according to inclusion and exclusion criteria detailed in Table 1. The sample size was 20. In total, 19 partially edentulous patients with atrophic posterior maxillae were included. The sample size was calculated for the primary outcome measure (ie, MB formation) based on a previous trial[16] to evaluate the effects lateral window dimensions may have on maxillary sinus augmentation outcomes: vital bone (VB)% was 3.98% when the lateral window dimension is >90 mm^2, while it was 41.12% when this dimension is <90 mm^2. A chi-square test with a 0.050 two-sided significance level will have 80% power to detect the difference between the null hypothesis proportion of 0.500 and the alternative proportion of 0.900 when the sample size is 10.

TABLE 1 Inclusion and exclusion criteria for study participation

Inclusion criteria
· Voluntary informed consent · Age >18 y · Multiple missing maxillary posterior teeth (2 molars and one or 2 premolars) · Adequate RBH<3 mm under the maxillary sinus · The oro-vestibular distance >12 mm at the level of center of lateral window sites · Buccolingual bone width of at least 6.5 mm · Absence of bony septa in the area of the augmented sinus · Edentulous opposing dentition with a denture (implant-borne or conventional) or natural teeth · A minimum healing period of 4 mo after tooth extraction
Exclusion criteria
· General contraindications for implant surgery · Severe hemophilia · History of irradiation in the head and neck region <1 year before study initiation · Poor oral hygiene · Uncontrolled diabetes · Pregnancy or lactating status · Psychiatric problems or unrealistic expectations · HIV infection · Smoking of >10 cigarettes or cigar equivalents per day or chewing of tobacco corresponding to >10 cigarette equivalents per day · Acute infection in the area intended for implant placement · Local inflammation, including untreated periodontitis · Severe bruxism or clenching habits · Presence of osseous lesions

The study protocol was evaluated and approved by the institutional ethics committee (PKUSSIRB-201630090) before patient selection. The registration number was ChiCTR-INR-17010493. This clinical research was conducted and was in agreement with GCP guidelines (2016W10458).

2.1 | Study design

Patients were consecutively selected from those seeking implant rehabilitation between February 1, 2015, and August 15, 2016, at the Forth Division of Peking University Hospital of Stomatology. Patients were randomized to receive either two- or solo-window technique of maxillary sinus elevation via the lateral approach. All patients were randomized using computer-generated permuted block randomization with an allocation ratio of 1:1. Treatment allocation was assigned by means of sealed envelopes containing a code derived from the randomized list and were opened after bone exposure during surgery. If both sinuses

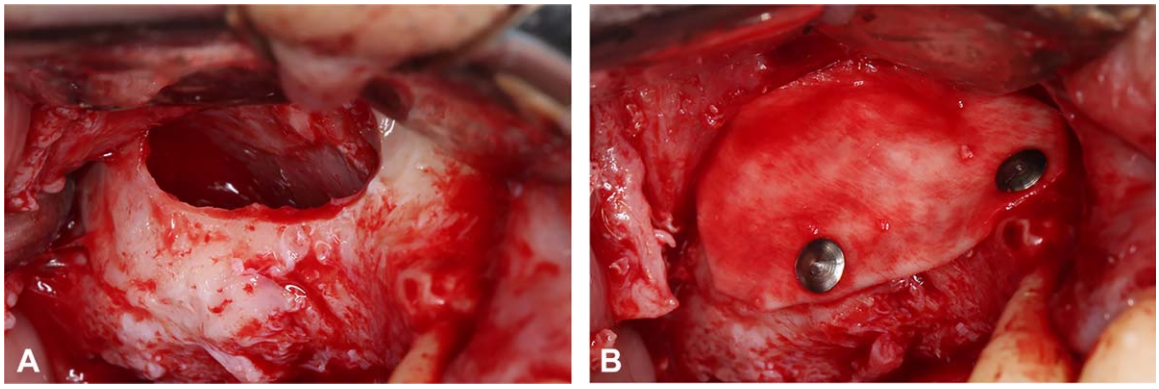

FIGURE 1 Conventional solo-window preparation on the lateral wall. A, Solo-window was prepared at the osteotomy site with the sinus membrane reflected and elevated above the sinus floor. B, Bioresorbable membrane in place, obturating the osteotomy site created in the lateral wall of the maxillary sinus

met the enrollment requirements, the right side was treated by the procedure assigned through randomization and the left side was treated by the other procedure.

2.2 | Clinical procedures

2.2.1 | Preoperative procedure

Following selection, all patients were evaluated and treated for periodontal and dental health and received oral hygiene instructions until a clinically acceptable oral environment was achieved. Cone beam CT and panoramic radiography were performed to evaluate the presence of the septum, dimensions of the alveolar process, and thickness and status of the sinus membrane. If the criteria were fulfilled, the requirements for 3-dimensional restoration-driven implant placement were identified.

2.2.2 | Surgical procedure

All patients received prophylactic antibiotic therapy with 2 g of amoxicillin (500 mg of clarithromycin in case of penicillin allergy) 1 hour before treatment. After surgery, amoxicillin (750 mg 3 times a day), ibuprofen (600 mg 3 times a day), and chlorhexidine mouthwash (0.2% 3 times a day) were prescribed for 7, 4, and 10 days, respectively. Surgery was performed under local anesthesia with 4% articaine according to a standardized protocol.[20] A crestal incision along with vertical releasing incisions was made, followed by full-thickness flap elevation. In the control group, a solo lateral window was prepared, determined by the amount of augmentation. The inferior cut was made approximately 2–3 mm from the sinus floor, and the vertical and horizontal lengths were related to the number of missing posterior teeth (Figure 1). In the test group, 2 separate lateral windows were prepared with a 5 to 10-mm bone beam left between the windows (Figure 2). In all cases, the lateral window shape resembled the shape of a circle. Subsequently, specifically designed hand instruments were used for elevation (Salvin Dental Specialties, Inc, Charlotte, North Carolina). To calculate the approximate window dimensions, the maximum and minimum diameter of the lateral window were measured using a periodontal probe, rounding to the nearest half millimeter (Figure 3). Large-particle Bio-Oss combined with approximately 10% autogenous bone was used as the graft material and inserted into the space between the sinus bone and the elevated sinus membrane. Bio-gide barrier was cut to cover the osteotomy site, extending 2–3 mm beyond its borders and then stabilized using Frios tacks (Friadent GmbH, Mannheim, Germany). At the end of the procedure, the soft tissue sections were closed.

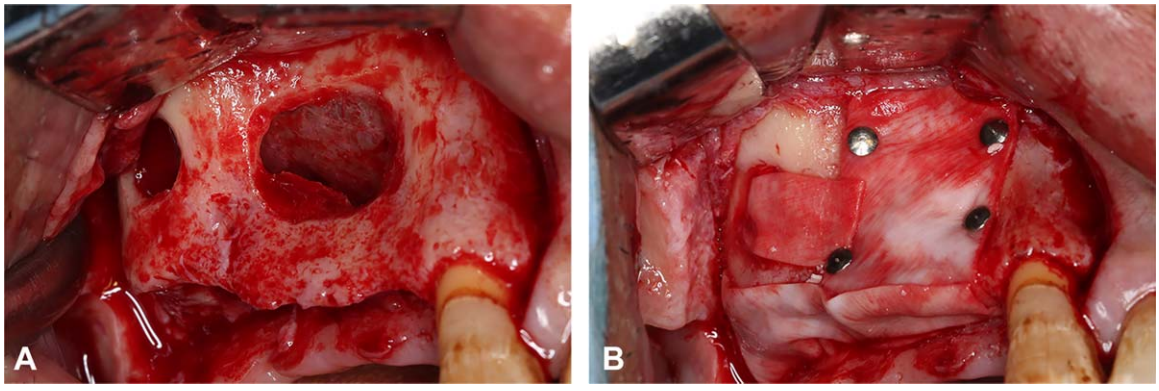

FIGURE 2 Two-window preparation on the lateral wall. A, Two separate windows were prepared with retention of a bony beam of >5 mm. Note the bony beam located at the first molar site. B, A bioresorbable membrane was used to cover the osteotomy site

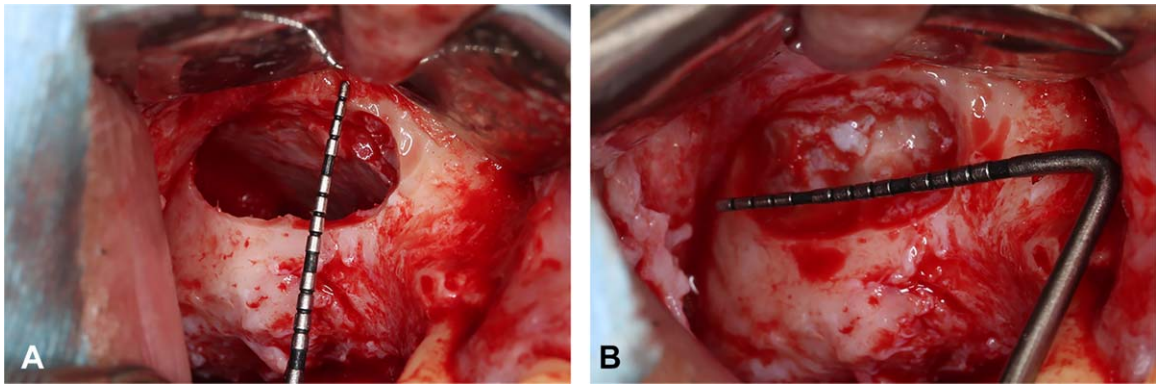

FIGURE 3 Maximum and minimum diameters of each lateral window were measured using a periodontal probe to calculate approximate window dimensions

2.2.3 | Postoperative management

For the initial 3 days after surgery, patients were instructed to use a 0.2% chlorhexidine rinse for 20 seconds and to take 500 mg of amoxicillin, both 3 times per day. Patients were advised to consume a soft diet during the first postoperative week, and their healing outcomes were evaluated after 14 days.

2.2.4 | Re-entry and harvesting of bone biopsy

Six months after the bone graft surgery, a second-stage surgery was performed. In this study, bone biopsy specimens were obtained from the lateral aspect of the former augmentation site, 3 mm above the inferior margin of the lateral access window and 6 mm below from the lateral wall. Bone core specimens were harvested using a trephine bur with a maximum diameter of 2 mm (Figure 4). The biopsy core was obtained under external irrigation with sterile saline, and a threaded titanium implant (Element, Thommen Medical AG, Grenchen, Switzerland), with a length of 11.0 or 12.5 mm, was placed by following standard surgical protocols. Given that an implant-abutment connection is a butt-butt connection, all implants with a sandblasted and thermally acid-etched surface were placed with a 1.0-mm machined neck resting at or slightly below the level of the alveolar crest. Healing abutment connection and soft-tissue adjustments were conducted at the same time. The final screw-retained, all-ceramic zirconia restoration was completed 3 months later.

2.3 | Preparation of biopsy samples for histological analysis

Immediately after harvesting, bone biopsy samples were fixed in 4% paraformaldehyde, demineralized in 15% EDTA, and then embedded by paraffin. Consecutive horizontal sections (4 μm) were obtained along the central axis of the biopsy core. Four to six sections from the central section of each biopsy specimen were obtained and used for hematoxylin and eosin (HE) staining.

2.3.1 | Histomorphometric analysis

The central region of the biopsy, which was situated at the medial aspect of the augmented tissue within the sinus, was analyzed. Histomorphometric analysis was performed to calculate the percentages of mineralized bone (MB), bone substitute materials (BS), and NMT components.

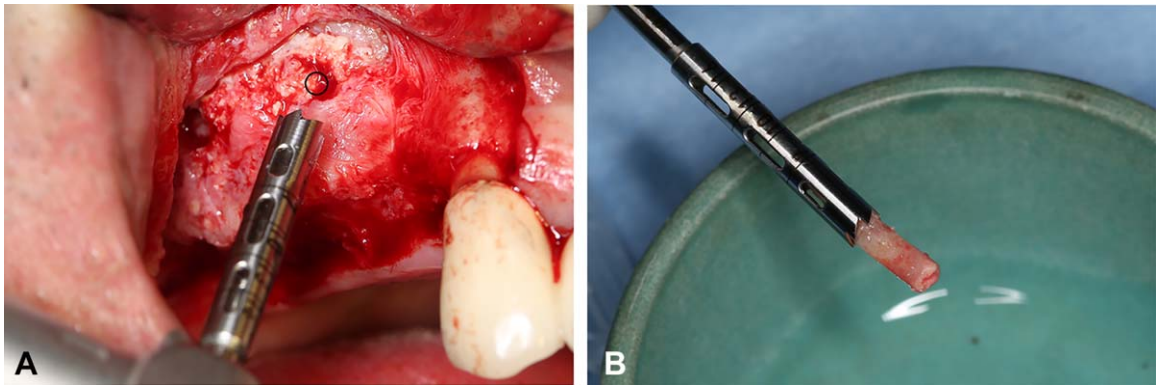

FIGURE 4 A, Re-entry 6 months after augmentation, harvesting the bone biopsy specimen with a trephine bur. Bone biopsy specimens were obtained 3 mm above the inferior margin of the lateral access window, as indicated by the black circle. B, Bone specimen obtained from the lateral aspect of the former augmentation site

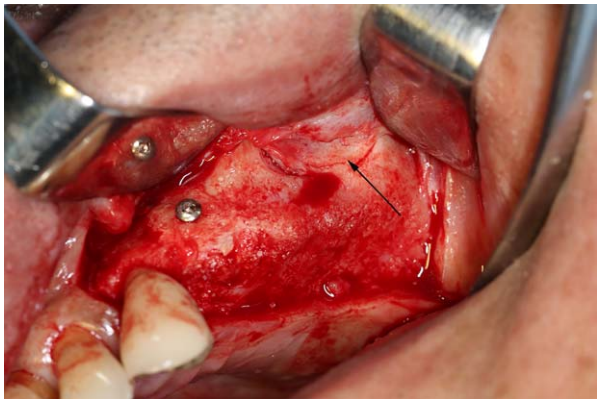

FIGURE 5 Healing of the lateral osteotomy wall 6 months after grafting. Note the encleftation of connective tissue into the maxillary sinus

2.3.2 | Follow-up procedures and clinical assessments

The follow-up protocol included patient assessments every 3 months during the first year. Standardized panoramic radiographs were acquired immediately after surgery and 12 months after implant placement. All radiographs were obtained by the same operator with the same device (Planmeca ProMax Dimax3 Ceph, Planmeca) set at 60–62 kV and 8–12 mA with a 16-second exposure time and standardized positioning of the head and body. The primary and secondary outcome measurements were as follows:

2.4 | Primary parameters

Percentages of MB, BS, and NMT. Each section was examined using light microscopy (Leitz Laborlux 12, Leitz) at ×4 magnification, superimposing a 100-square graticule (1.23 × 1.23 mm, Leica microscope systems) at the ocular level. Analysis for percentages of MB, BS, and NMT was performed using Image Pro Plus 6.0 software (Media Cybernetics, Silver Spring, Maryland). The area fraction percentage of each component was determined. Counting was performed 3 times per bone core and patient.

2.5 | Secondary parameters

2.5.1 | Implant failure

Implant survival was assessed on the basis of the following criteria: absence of clinically detectable implant mobility, absence of pain or any subjective sensation, absence of recurrent peri-implant infection, absence of continuous radiolucency around the implant, and absence of progressive marginal bone loss.[21]

2.5.2 | Peri-implant marginal bone level changes and radiographic endo-sinus bone gain

The mesial and distal bone levels were measured as the distance between the uppermost level of the implant shoulder and the most coronal visible point of bone-implant contact (BIC). For each implant, the BIC value was taken as the average of the mesial and distal measurements, and the BIC values calculated at 1-year follow-up visit were compared with those calculated at baseline.

2.5.3 | Soft tissue invagination

Invagination of soft tissue into the sinus was assessed during the second-stage surgery (Figure 5).

2.6 | Biological complications

The primary outcome of the study was histomorphometric analysis recorded by one previously calibrated examiner (Dr He) who was blinded to treatment group assignment.

All clinical assessments were performed by a clinician who was not involved in the treatment of the patients.

2.7 | Statistical analysis

A median value and standard deviation of the percentage area of each component was calculated. t-test was used to analyze the lateral window dimensions and perception of MB formation between both groups. Differences in the amount of bone resorption, implant survival rates, and soft tissue invagination were compared between the 2 groups by using Fisher's exact chi-square tests. The chi-square test was used for encleftation of connective tissue, and Fisher's exact test was considered when needed. All statistical comparisons were performed at a significance level of .05.

3 | RESULTS

Overall, 22 patients were screened to participate in the study. Of these, 1 patient who refused randomization was excluded. Eventually, 21 patients were considered eligible and enrolled in this trial. One patient in each group dropped out after 6 and 12 months of follow-up after loading, but they were contacted by phone and reported no issues in relation to the implant-supported prostheses. Only 19 patients completed the 1-year examination (Figure 6). The study

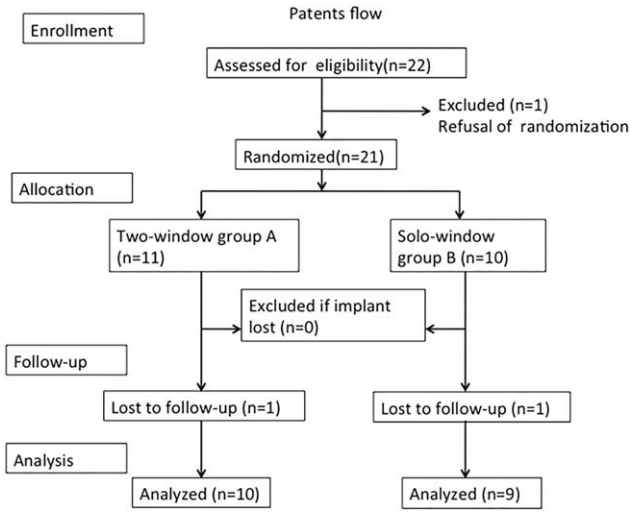

FIGURE 6 Study flowchart

TABLE 2 Patient and intervention characteristics

	Two-window	Solo-window
Female	4 (40%)	5 (55.6%)
Mean age at implant insertion (y)	49.8	51.2
No. of elevated maxillary sinus	11	9
Total number of inserted implants	33	29
Patients who received 2 implants	2	1
Patients who received 3 implants	7	5
Patients who received 3 implants	2	3
Total number of 4.0-mm-diameter implants	9	4
Total number of 4.5-mm-diameter implants	10	14
Total number of 5.0-mm-diameter implants	11	8
Total number of 6.0-mm-diameter implants	3	3

population included 9 women and 10 men with a mean age of 50.3 years. The primary baseline patient characteristics are presented in Table 2. No septa were noticed in the area of the augmented sinus. The amount of lateral window dimension was 81.65 ± 4.59 mm^2 in the test group, with 40.56 ± 5.62 and 41.10 ± 3.55 mm^2 in the anterior and posterior bony windows, respectively. The window dimension in the group, which was 118.04 ± 19.53 mm^2, was significantly larger than that observed in the test group (Table 3). Furthermore, 1 patient underwent bilateral maxillary sinus augmentation, and hence, a total of 20 procedures were performed.

3.1 | Primary outcomes

A total of 19 bone biopsy specimens were obtained and prepared; however, 2 of these specimens were too deteriorated for us to be able to perform appropriate histomorphomentric analysis on them and were thus discarded. Histomorphometric analysis of the remaining 17 specimens revealed that the mean percentage of MB was $42.32\% \pm 13.07\%$ and $26.00\% \pm 15.23\%$ in the test and control groups, respectively (Figures 7 and 8). Significant differences were noted in both dimension and percentage of MB of the lateral window between the 2 groups ($P < .001$ and $P = .031$, respectively).

Proportions of each tissue compartment are graphically expressed in Table 3.

TABLE 3 Window dimensions and histomorphometric data values

Elevation technique group	Two-window	Solo-window	T-test
Window dimensions (mm^2)	81.65 ± 4.59 (40.56 ± 5.62, 41.10 ± 3.55)*	118.04 ± 19.53	$P < .001$
MB%	42.32 ± 13.07	26.00 ± 15.23	$P = .031$
BS%	40.34 ± 9.52	60.03 ± 10.13	$P < .001$
NMT%	18.14 ± 14.24	14.75 ± 10.38	$P = .017$

Abbreviations: BS, bone substitute materials; MB, mineralized bone; NMT, nonmineralized tissue.
*() indicates the average dimension of anterior and posterior bony window.

TABLE 4 Radiographic parameters over 1 year for maxillary sinus elevation by lateral approach with two-window and solo-window techniques

Group	Two-window	Solo-window	
Initial RBH	2.50 ± 0.39	2.35 ± 0.36	$P = .088$
Crestal bone loss	-0.55 ± 0.60	-0.40 ± 0.71	$P = .740$
Endo-sinus bone gain	11.94 ± 1.71	12.19 ± 1.25	$P = .182$

Abbreviation: RBH, residual bone height.

3.2 | Secondary outcomes

3.2.1 | Implant survival rates

No patients reported adverse effects after dental implant placement. No implant failed in both test and control groups.

3.2.2 | Peri-implant bone level change

No significant differences were noted in bone level changes and radiographic endo-sinus bone gain at baseline and 1 year after surgery between the test and the control groups (Table 4).

3.2.3 | Soft tissue invagination

Although the chi-square test revealed a negative statistical significance between the 2 groups ($P = .336$), soft tissue invagination occurred at a greater proportion in the control group than in the test group (Table 5).

3.2.4 | Surgical complications and safety

Rupture of the sinus membrane occurred in one of the two-window cases and in none of the solo-window cases (Table 5). Most common complications were minor inflammation at the implant site, loosening of a prosthetic component, and minor discomfort owing to the surgical procedure. Nevertheless, the chi-square test revealed a negative statistical significance between the 2 groups ($P = .336$).

TABLE 5 Incidence of surgical complications

Complication	Two-window ($n = 11$) Maxillary sinus (n)	%	Solo-window ($n = 9$) Maxillary sinus (n)	%
Intraoperative complications	1	10.0	0	0
Rupture of the sinus membrane	1	10.0	0	0
Postoperative complications	4	18.2	5	55.6
Infection	0	0.0	1	11.1
Encleftation of connective tissue	2	18.2	4	44.4

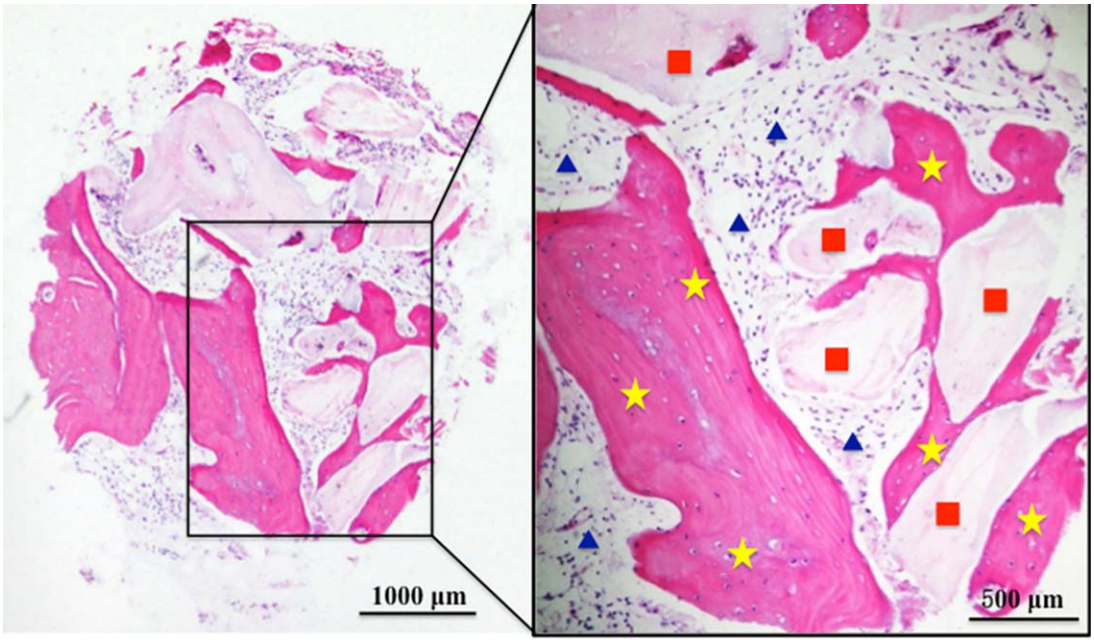

FIGURE 7 (Left) Histological section of a bone core biopsy (two-window group) obtained from the lateral aspect of an augmented maxillary sinus (H&E 4×). (Right) Details of the same sample showing vital bone (yellow stars) in intimate contact with remaining allograft particles (red squares), embedded in a nonmineralized tissue matrix (blue triangles) (H&E 10×)

4 | DISCUSSION

This study evaluated the performance of two-window and conventional solo-window techniques for rehabilitation of multiple missing posterior teeth that required large-scale sinus elevation. The results suggested that the two-window technique could improve maturation of the graft site and induced greater MB formation. Appearance of connective tissue invagination or encleftation was lesser in the test group. Both techniques could rehabilitate the posterior maxilla with no statistically significant differences in survival rates, bone level change, radiographic endo-sinus bone gain, and complications.

The two-window technique could effectively induce greater maturation of the endo-sinus bone (42.32% MB) compared with the solo-window technique (26% MB). MB formation observed with the

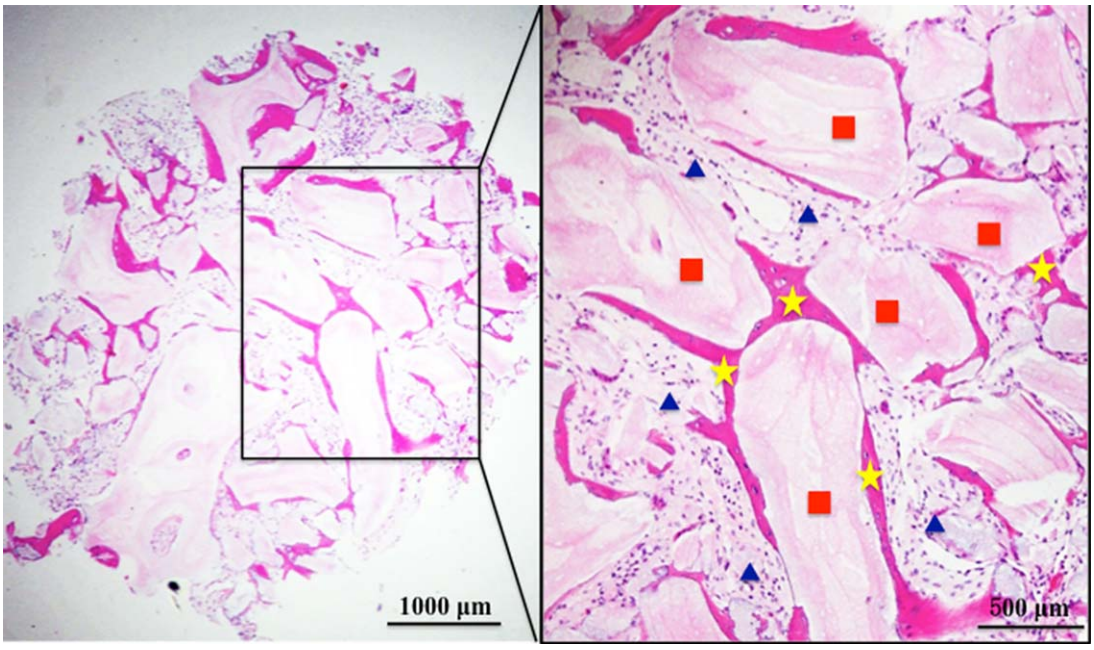

FIGURE 8 (Left) Histological section of a bone core biopsy providing an overview at fourfold magnification (solo-window group). (Right) Image at a higher magnification showing details of the same sample. Note newly formed vital bone over remaining allograft particles embedded in a nonmineralized matrix (H&E 10×)

conventional method used in the present study was comparable to those reported in previous relevant studies, wherein the amount of bone attained after application of bovine bone mineral at sites covered by membrane ranged 25.5%-30.7% when the healing time was 6 months.[22–24] Soft tissue and biomaterial remnant rates vary greatly based on the methods used and the time of biopsy.[22–24] A meta-analysis detected no statistically significant differences between different grafting materials in terms of the amount of VB in grafted sinuses; however, a significant difference was noted in the proportion of connective tissue/bone marrow among the different types of graft materials used.[25] Endo-sinus bone formation is a complex process wherein elevation of the sinus membrane creates a space in which vascularization occurs, followed by migration of bone-forming cells.[26] New bone formation was found to initiate from surrounding bony walls and septa, which then advanced toward the central area of the graft.[12] Although certain studies have demonstrated that the Schneiderian membrane possesses stem cells that potentially stimulate bone formation,[27] a major source of osteogenic cells is the vicinity of bony walls.[12,13] When large-scale maxillary sinus elevation is needed, a lower production of MB in a large graft can be expected. In a study by Avila-Ortiz and colleagues, a remarkable negative correlation was observed between the osteotomy site and vital bone formation.[16] Considering the high osteogenic capacity of the lateral wall bone,[14] it can be inferred that preparing lateral windows with the minimum size necessary to perform sinus augmentation may contribute toward enhanced and faster maturation and consolidation of the grafted volume. Based on this principle, the two-window technique, with >5-mm length of remaining bony beam, can effectively decrease the lateral window dimensions (81.65 ± 4.59 vs 118.04 ± 19.53 mm^2) and ensure graft stabilization to the sinus cavity until progressive wounding healing occurs. Histomorphometric analysis in this study showed positively influences on MB formation compared with the conventional solo-window technique, which is accordance with findings from the aforementioned studies. The determining factors for endo-sinus bone regeneration include, but are not limited to, size of the window, buccopalatal dimensions of the sinus cavity, remaining ridge height, and location from where the biopsy specimens are collected.[28] To appropriately control these influential factors to accurately determine the effects of lateral window size, patients were included only when the orovestibular distance at the level of center of lateral window sites was >12 mm and residual bone height (RBH) <3 mm. In addition, bone biopsy specimens were harvested at the same position, and all surgical procedures were performed by a single surgeon.

Although no statistical significance was detected between the 2 study groups, lesser connective tissue encleftation occurred when the two-window technique was applied. The lateral osteotomy site is the last area to mineralize and, thus, the indication of density in the deeper parts of the graft.[29] Limited osteotomy site could prevent connective invasion, which has been proven by this study. Moreover, lesser encleftation of connective tissue (2/11) occurred in the test group. Encleftation of soft tissue into the sinus can lead to scarring and possible exposure of implants, thereby resulting in implant failure.[30] In addition, it has been speculated that epithelial remnants trapped in wounds can potentially cause postoperative maxillary cysts.[31] Although a membrane can be used to cover the osteotomy site, the potential for invagination of soft tissue to the sinus still exists.[32] Certain bone defects have a tendency toward spontaneous healing, thus supporting bone regeneration.[33] The diameter of the 2 separate windows was approximately 40.56 ± 5.62 mm^2 and 41.10 ± 3.55 mm^2, and healing could finish more easily before biodegradation of the membrane. According to a study by Tawil and colleagues, external cortex at the time of abutment connection may accurately predict the outcome of implant therapy.[29] However, no significant differences were observed between the 2 groups in terms of implant survival rates during the 1-year follow-up.

Presence of bone beam between 2 windows preserves the lateral bone as much as possible, which has additional advantages. Quality and quantity of the lateral wall of maxillary sinus is extremely important in several surgical interventions such as Caldwell-Luc surgery, Lefort I osteotomy, and jaw bone fracture fixation.[34] In addition, stress trajectories in the maxilla primarily comprised 3 pairs of vertical pillars, including canine pillars, zygomaticomaxillary pillars, and pterygomaxillary pillars.[35] The masticatory forces are dissipated from the alveolar process to these 3 enhanced bone pillars in the maxilla, located at each antimere and bypassed by nasal and orbital cavities.[36] Of these 3 pairs of force pillars, the maxillozygomatic stress trajectory, which corresponds to lateral osteotomy sites during elevation of the maxillary sinus, begin from the first upper molar area and reaches the zygoma through the zygomatic process of the maxilla.[35] Any excessive osteotomy in this site will destroy the force trajectory produced by occlusal loads, which has a potentially negative influence on bone maturation and implant survival. In cases of multiple missing teeth, conventional solo windows were prepared around the bone above the first molar area, with an average area of 118.04 mm^2. Although it allows better access and facilitates sinus membrane elevation, the conventional technique destroys much more bone. Conversely, the bone beam in the two-window technique, located at the lateral bone wall above the first molar, preserves the zygomaticomaxillary pillow as much as possible. In addition, Baumgaertel and colleagues reported that the thickest wall was observed in the bone above the first molar owing to the presence of the buttress of the zygoma.[37] A thick sinus lateral wall corresponds to a large vessel diameter.[38] Preservation of the lateral bone of this site could reduce the risk of bleeding.

Although the two-window technique is slightly technique sensitive, owing to limited surgery sight, no significant difference was noted in the incidence of membrane rupture between the 2 groups (Table 5).

A limitation of this study was the systematic difference in maxillary sinus volume in various cases, although this has been limited in the inclusion criteria. The sample size was small, and a longer follow-up period would have been desirable. However, changes in bone height and endo-sinus bone gain were analyzed using 3-dimensional projections, which is known to be a more accurate and reliable technique. Nevertheless, additional clinical studies are warranted to explore the potential advantages and disadvantages of using the two-window technique.

5 | CONCLUSIONS

The present study compared the 1-year performance of the two-window technique to that of the conventional solo-window technique when used for rehabilitation of multiple missing posterior teeth that need a large amount of augmentation.

1. Histologically, lateral window dimensions have an important influence on maturation and consolidation of endo-sinus bone augmentation.
2. The two-window technique with decreased dimension can improve the external cortical plate reconstruction and enhance faster maturation and consolidation of the grafted volume.
3. The two-window technique may be a favorable choice for rehabilitation of multiple missing maxillary posterior teeth.

Nevertheless, this study did not show a correlation between lateral window dimensions and implant survival rates. Additional clinical studies are warranted to evaluate long-term performance of the assessed techniques.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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