

Original Article

Slot-like window technique for maxillary sinus floor elevation

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Abstract: Purpose: To evaluate the clinical outcome of accomplishing maxillary sinus floor elevation by using a slot-like window technique. Patients and Methods: 43 patients (51 implant sites) with edentulous posterior maxilla were included in this study, whose residual bone height (RBH) was from 0.61 mm to 4.98 mm. A lateral technique with slot-like window was adopted to accomplish the sinus floor elevation. Implants were placed immediately or 6 months later (when the RBH could not provide sufficient primary stability for implant placement). The surgery-related complications, such as bleeding, the facial swelling and pain were recorded and radiographic measurements were performed. Results: All implants were well restored and maintained during the follow-up. The average RBH was 3.29 ± 0.93 mm. The mean augmented bone height was 6.50 ± 1.44 mm at the day of the sinus lift surgery and 6.06 ± 1.46 mm 6 months later. Among 51 implant sites, only one membrane perforation occurred. The surgery-related complications were mild. Conclusions: The results of this study suggest that application of slot-like window technique is less invasive than conventional technique. The surgery-related complications could be reduced obviously.

Keywords: Slot-like window, sinus floor elevation, maxillary sinus, dental implant

Introduction

Using dental implants for both function and esthetics has been successfully reported to restore the missing teeth [1]. But the posterior edentulous maxilla still presents special challenges to the implant surgeon due to its poor bone quality and insufficient bone quantity caused by the resorption of alveolar crest and ongoing maxillary sinus pneumatization after tooth extraction [2-4].

Sinus floor elevation is one of the most common and effective ways to compensate for inadequate vertical bone dimension in atrophic posterior maxilla. There are two major techniques used in clinical practice. One is called lateral window sinus floor elevation, which is to obtain an access to the maxillary sinus by drilling a bony window in the lateral sinus wall. When the sinus membrane is detached and elevated carefully from the sinus inner wall, an empty space can be obtained for inserting an implant with/without bone grafts [5-8]. Another one is called transcresal sinus floor elevation,

to achieve an access to the maxillary sinus through the alveolar ridge following the preparation of the implant socket. When the sinus floor is fractured or drilled, the sinus membrane is detached and lifted blindly from the inner wall of the sinus floor.

Compared with transcresal technique, the lateral window approach is more predictable because it can provide the direct visibility through the open window to separate the Schneiderian membrane from the sinus floor. However, it is more invasive and usually results in more complications, such as bleeding, marked postoperative swelling and pain [9].

Though transcresal technique is well acceptable due to its less invasiveness and mild postoperative reaction, the risk of membrane perforation caused by excessive distension is usually higher than lateral technique, which is always difficult to be repaired during the surgery and increases the incidence of sinus infection or implant failure.

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Table 1. Clinical summary of the included patients

	Gender		Unilateral/bilateral		Timing of implant placement	
	F	M	Unilateral	Bilateral	Simultaneous	Delayed
Age (Y)						
≤40	2	4	6	0	5	2
41-50	7	5	10	2	7	7
51-60	6	11	15	2	9	13
≥61	5	3	8	0	3	5

So, the lateral window technique is still an irreplaceable method in the rehabilitation of the posterior edentulous maxilla. In order to reduce the adverse reaction of this kind of approach while maintain the reliable augmented bone volume, we modified the conventional surgical method. The objective of this study is to introduce our experience and evaluate its clinical effectiveness.

Materials and methods

Patients and implant sites evaluation

Fifty-one modified lateral window sinus floor elevation were performed on 43 consecutive patients (20 females and 23 males) between April 2012 and March 2014 who visited the outpatient clinic of the Department of Oral & maxillofacial Implantology, School of Stomatology, Tongji University, Shanghai, China. All of the patients have lost their teeth for more than 3 months. They opted for implant-retained prosthesis but had a low sinus floor and insufficient vertical bone dimension.

Systemic health and intraoral conditions were evaluated before surgery. Every patient underwent a pre-surgical examination consisting of their dental condition, blood test, and radiographic examination. The distance between the sinus floor and the alveolar crest was measured by digital panoramic radiographs. The range of residual bone height (RBH) was 0.61~4.98 mm among 43 patients (51 implant sites). Detailed information about the patients is listed in **Table 1**.

The patients who had systemic diseases or uncontrolled sinus pathology were excluded. Exclusion criteria included: diabetes mellitus, immune suppression, osteoporosis, chemotherapy or radiotherapy and a pathologic lesion

in the sinus: benign/malignant tumor or active sinusitis.

The average age of the patients was 51.7 years (range 24~71 years), no patient smoked and patients with active periodontal lesions were treated before surgery.

All patients were carefully informed of the intended procedures, possible risks and complications. Written informed consent was signed by each patient. Due to the retrospective nature of this study, it was granted an exemption in writing by the University of Tongji IRB.

Instruments and materials

Dental implant installation machine system: Nouvag MD20 (NOUVAG Co., Switzerland). Dental implants: Straumann standard cylindrical implants with sand blasted, large-grit, acid-etched (SLA) surface (Institute Straumann AG, Waldenburg, Switzerland) were used. The diameter of the implant was 4.1/4.8 mm and the length was between 8 and 10 mm. Piezosurgery system (Mectron Co., Italy): the functional frequency is about 25~29 Hz; the linear vibration ranges from 60 μm to 200 μm; a series of working tips with different forms, directions and angles can fit with the requirements of sinus floor elevation. Graft materials: inorganic bovine bone granulates of Bio-Oss with dimensions of 0.25 to 1 mm were used and absorbable porcine collagen membranes of Bio-Gide (13×25 mm) were used to cover the open window, to protect sinus membrane or to repair the membrane perforation. (Geistlich, Switzerland).

Surgical procedures

All patients were locally anesthetized by 4% articaine with 1:100,000 epinephrine (Satelec-Pierre Rolland Company, France). A horizontal crestal incision slightly beveled toward the palatal aspect and vertical releasing incisions were made. And a full-thickness mucoperiosteal flap with wide base was raised from the incision buccally and superiorly to reveal the operation area in lateral sinus wall. According to the preoperative measurement data and anatomical landmarks provided by the image of radiographic examination, a slot-like bony window was created in the lateral sinus wall

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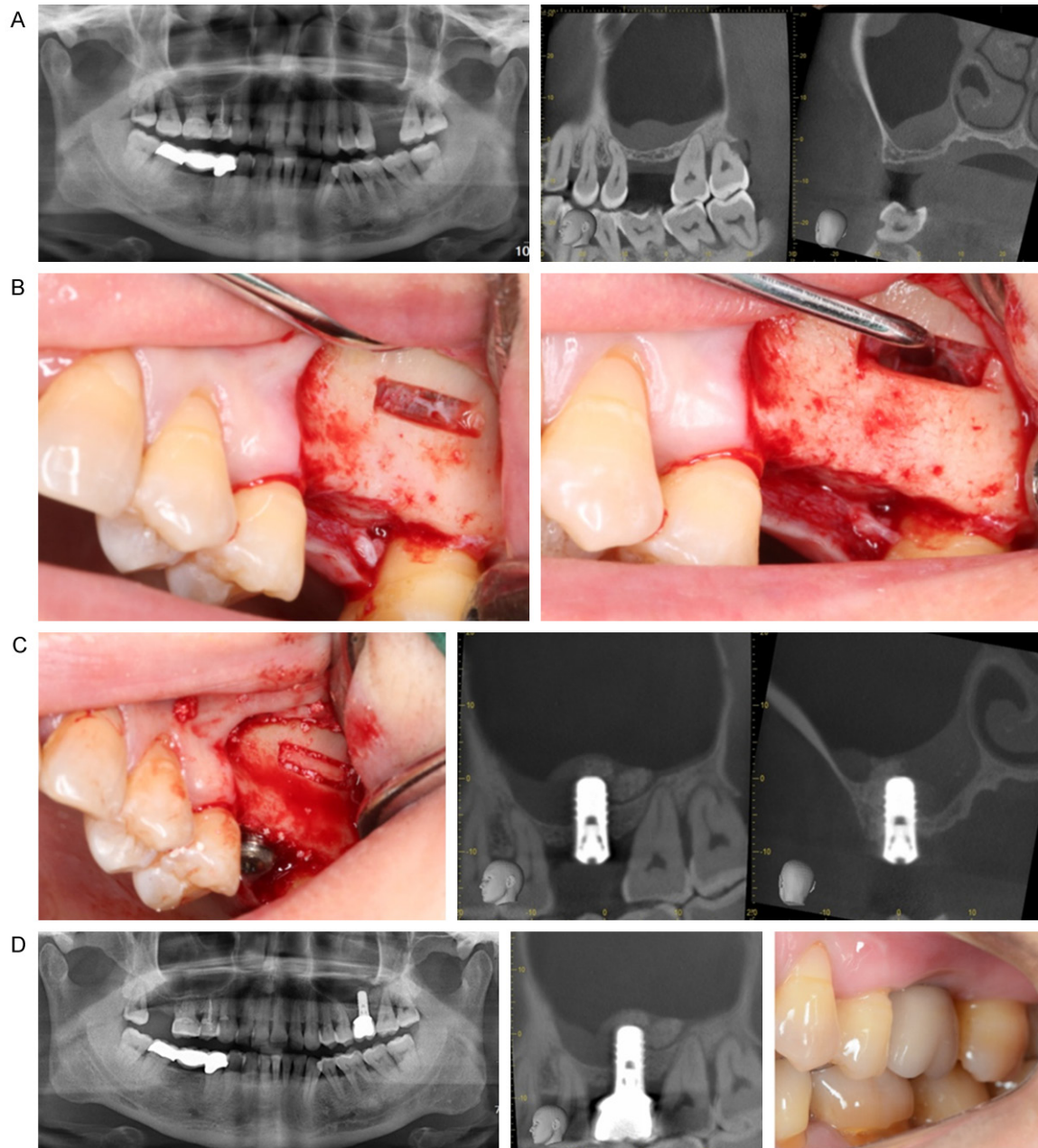


Figure 1. A: Severely resorbed posterior maxilla, the residual bone height is only 1 to 2 mm; B: A slot-like window in the lateral sinus wall; releasing and elevating the sinus membrane through the bony window; C: Graft materials were packed into the void space and the final elevated height was decided by the insertion depth of simultaneously inserted implant; D: Radiological images at the day of restoration. Note the good osseointegration and ideal prostheses effect.

demarcating the maxillary sinus using a piezo-electric device (Piezosurgery, Mectron, Carasco, Italy). From our clinical experience, the initial stability of posterior maxillary implants could be obtained by the accurate bicortical engagement of the implant with the crestal cortical bone and the floor of the sinus cortical bone, even the RBH was less than 5 mm. So we chose

the thinnest area in lateral wall above the level of sinus floor as the location of the bony window in cases which the primary stability of implant was predictable. The actual lifting height was decided by the insertion depth of the implant into the sinus cavity (**Figure 1**). If the RBH was less than 2 mm or there was no clear crestal cortical bone, it was usually dif-

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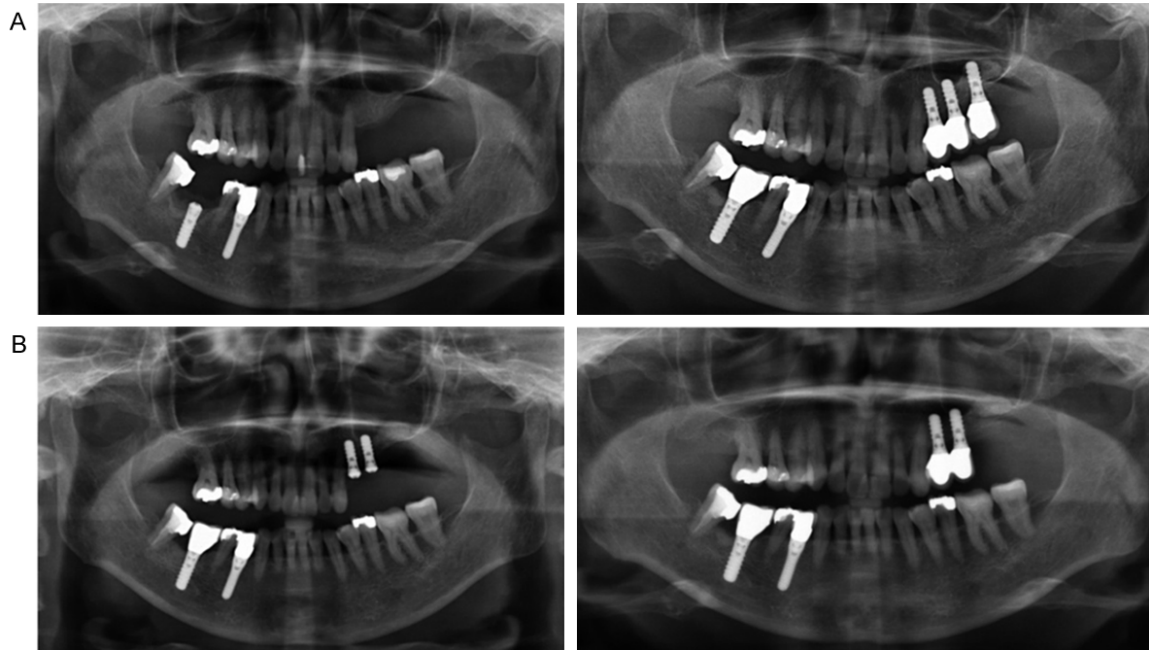


Figure 2. A: Extremely resorbed and pneumatized posterior maxilla. Note the less than 1 mm alveolar bone height remained. Panoramic image at the day of restoration, note the stable elevated space and good osseointegration. B: Panoramic images at the day of surgery and 6 months later. Note the elevated sinus like a dome.

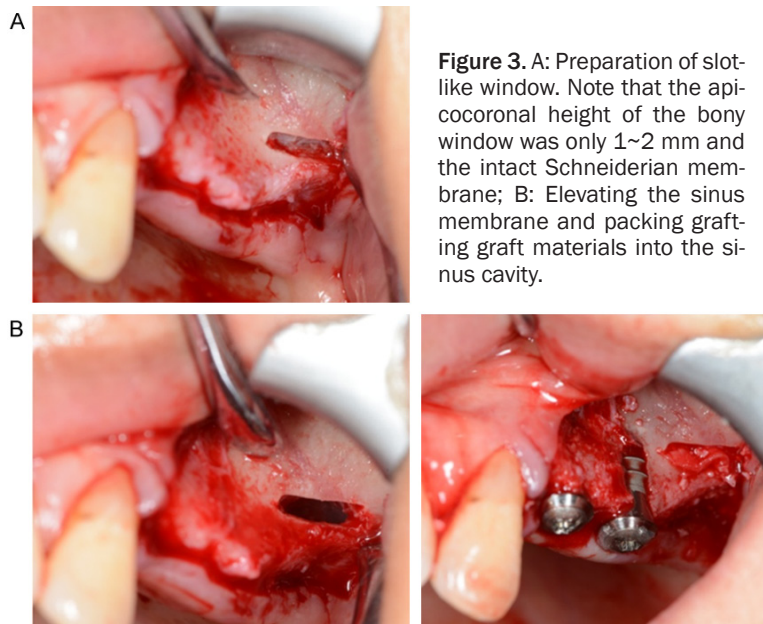


Figure 3. A: Preparation of slot-like window. Note that the apicoronal height of the bony window was only 1~2 mm and the intact Schneiderian membrane; B: Elevating the sinus membrane and packing grafting materials into the sinus cavity.

at the level of 2 mm higher than the planned implant length, which was measured from the most coronal aspect of the crestal bone.

The design of the lateral wall erosion is represented by a rectangular area of 2~3 mm in apicoronal height, which could allow proper access of the gingival separator. The mesiodistal width of the bony window varied individually according to the range of edentulous area, which extended just to contain the implant sites. Then the small bone block of the window was completely removed to expose Schneiderian membrane.

Along the lower margin of the access window, the sinus membrane was carefully detached from the inner wall using a gingival separator manually. Meanwhile, the patient was told to breathe deeply when his nose was nipped, which could lead to negative air pressure to make the sinus membrane separate from the sinus inner wall easily. The sinus mem-

difficult to achieve the satisfying initial stability for simultaneous implant placement. In such cases, the position of the bony window was usually designed depending on the planned implant length in order to get a predictable regenerated height in the sinus. For example, if a 10 mm-long implant were planned to insert, the upper edge of the window would be made

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brane reflection was extended mesiodistally and medially just over the implant sites.

No matter whether the sinus membrane perforation occurred or not, a suitable size of Bio-Gide collagen membrane was placed underneath Schneiderian membrane. Then the sinus membrane was pushed inward and upward together with the covering Bio-Gide membrane by use of the curved portion of the gingival separator. Graft materials were added into the void space through the open window. The bony window was finally covered with Bio-Gide collagen membrane to prevent soft tissue invasion into the graft. Simultaneous or staged implant placement was chosen depending on the different conditions of RBHs which we mentioned above (**Figures 2 and 3**).

The flap was repositioned by simple interrupt sutures using 3-0 polyester sutures. The patients were treated with oral antibiotics for 3 days (cefradine-1.5 mg/day) and rinsed with 0.2% chlorhexidine solution 3 times per day over 1 week. Patients were also advised to avoid sneezing, nose blowing or other actions, which might create high intranasal pressure. The sutures were removed at the 10th day after surgery.

Prosthetic treatment

The prosthetic treatment was performed at 3 to 6 months after the implant insertion. Screw-retained or cemented porcelain-fused-metal crown was provided according to the individual condition.

Follow-up

All patients were followed up post-operatively at the 1st day, 3rd day, and 10th day for checking soft tissue swelling, nasal bleeding, pain and other uncomfortable symptoms. Radiological images of the augmented bone height in the sinus were measured at the day of surgery and 6 months later. After the final setting of the crown, patients received follow-up care every 3 months. Gingival index (GI) and probing depth (PD) were checked around the implants at the last follow-up.

Clinical and radiographic evaluation

The follow-up time for all patients was at least 1 year after the final setting of the prosthesis. Any intraoperative and postoperative comp-

lications, such as excessive bleeding, membrane perforation, swelling, ecchymosis, pain and nasal bleeding were recorded. Radiographic parameters including preoperative remaining bone height and augmented bone height were evaluated preoperatively and at the 6th months after surgery.

Statistical analysis

The cumulative surviving rate (CSR) of the implants placed in augmented sinus by using slot-like window lateral technique was calculated by life-table analysis [10]. Life tables included the following parameters: observation time, number of implants at the start of insertion, number of failed implants during follow-up period, number of implants lost to follow-up, cumulative surviving rate. Implants were characterized as surviving by the following criteria: absence of persistent pain; absence of peri-implant infection with suppuration; absence of mobility; absence of continuous peri-implant radiolucency [11].

Results

All 43 patients received sinus augmentation via this modified lateral window technique, and 51 implants were placed. 24 implants were simultaneously inserted with sinus lift in 21 patients, and 22 patients received 27 implants 6 months after sinus lift because RBHs could not provide sufficient primary stability for implants.

There were no severe bleeding, but one membrane perforation occurred during the operation. The presence of facial swelling and pain after surgery was mild. At the 1st day after the operation, nasal bleeding occurred in the membrane perforation case. Meanwhile, only 20% patients had slight swelling of local soft tissue and almost completely disappeared 3 days later. At the 10th day postoperatively, the mucosal wound healed uneventfully in all patients. Other postoperative complications like ecchymosis and loss of graft materials did not occur.

Radiographic images showed that the augmented bone graft formed a dome with a round margin under the elevated Schneiderian membrane. The mean augmented bone height in the sinus was 6.50 ± 1.44 mm (range 3.86-10.37 mm) at the day of surgery and 6.06

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Table 2. Radiographic results

		Number of implants	Mean \pm SD (mm)
Remaining bone height	0~1 mm	1	3.29 \pm 0.93
	1~3 mm	22	
	3~5 mm	28	
Augmented bone height (the day of surgery)	\leq 5 mm	6	6.50 \pm 1.44
	>5 mm	45	
Augmented bone height (6 months later)	\leq 5 mm	11	6.06 \pm 1.46
	>5 mm	40	

Table 3. Clinical parameters: gingival index (n=51)

Index	Gingival index	
	Number of implants	%
0	12	23.53%
1	33	64.71%
2	6	11.76%
3	0	0

Table 4. Clinical parameters: probing depth of implant (n=51)

mm	Probing depth	
	Number of implants	%
1~2	11	21.57%
2~3	32	62.75%
3~4	8	15.69%

\pm 1.46 mm (range 3.08-9.40 mm) 6 months later. The apices of all implants (simultaneous or delayed placement) were not exposed out of the dome or the membrane. The means and standard deviations of radiographic parameters were shown in **Table 2**.

All patients finished the follow-up visit during the study, and the cumulative surviving rate was 100% according to the criteria of surviving as mentioned before. **Table 3** showed the gingival index values measured at last follow-up examination. Most patients maintained good or acceptable oral hygiene. The normal range of probing depth was present in all patients (**Table 4**).

Discussion

After Tatum [12] and Boyne & James [13] first described the lateral window approach for sinus augmentation to resolve the problem of

insufficient vertical bone volume in atrophic posterior maxilla, the approach was generally accepted and well documented. However, it has to be realized as an invasive surgical intervention with relatively high morbidity and cost [14]. The transalveolar sinus floor elevation [15] was intro-

duced by Summers in 1994 as a less invasive and less costly alternative for sinus augmentation. But in the severely deficient posterior maxilla, with 5mm or less residual bone height, transcrestal procedures become more challenging and less predictable. In addition, other treatment modalities [16-19] have been constantly proposed over the years, such as balloon technique, short/tilted implants, zygoma implant, and tooth-implant connected bridges, whose main purposes were to simplify the procedure and reduce or avoid surgical complications. However, because different methods have their different indications and limitations respectively, few of them are adopted as routine use now. Therefore, lateral technique for sinus lift is still irreplaceable in overcoming severely inadequate bone height in posterior maxilla. This study described the novel slot-like window technique which was characterized by reduced antrotomy using miniaturized piezosurgical device and estimated its clinical results.

It is no doubt that the predictable new bone regeneration is necessary for successful implant osseointegration in augmented maxillary sinus. The key factors to the success of any bone grafting are the maintenance of stable augmented space and good revascularization.

The primary purpose of this modified lateral technique was to reduce the surgical trauma and get a more stable space for graft materials. In the conventional lateral window approach, the size of bony window was usually large enough in order to provide a clear surgical field for surgeon. Wallace [18] *et al.* recommended positioning the window approximately 3 mm from the sinus floor and 3 mm from the anterior wall, the superior border was located 15 mm away from alveolar crest. According

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to his opinion, the more difficult the elevation procedure was expected, the larger window should be made. Therefore, the apical-coronal height of the bony window could reach up to 11 mm in some cases (for example, when RBH was only about 1 mm). This surgical design could make surgeon clearly observe the inner condition of sinus cavity, easily detaching the membrane and placing graft materials into sinus. However, the disadvantages were also obvious, such as causing heavy surgical trauma, slower bony window healing, severe post-operative reactions and too much bone substitute required. Furthermore, the graft materials are prone to escape from the big open window. In order to eliminate these disadvantages, we modified the procedure by creating a slot-like window and diminishing the range of sinus membrane detached. Because the dimension of the bony window was very small whose apicocoronal height was designed only 2~3 mm, the mucoperiosteum flap was not necessary to be reflected extensively. The post-operative reactions were obviously relieved due to minimal trauma. During the postoperative follow-up, only 20% patients had slight facial swelling within 3 days after surgery. Furthermore, the slot-like bony window was helpful to confine the graft materials in a stable and relatively secluded space surrounded by more intact sinus walls and the tiny bone defect healed faster. Less detaching range of sinus membrane was another positive factor for bone regeneration. It not only reduced the required amount of bone substitute but also maintained the elevated height much better due to more stable room and appropriate membrane strain on graft materials.

Sufficient blood supply and fast revascularization in bone grafts are important for effective new bone formation. The vessel numbers in grafting tissues were found to be positively correlated with bone formation rate [20].

One way of new blood vessel proliferation was to sprout from preexisting vessels. Solar [21] et al. reported that vascularization of the graft materials placed in an augmented sinus occurred via 3 routes: the endosseous vascular anastomosis, the extraosseous anastomosis and the vessels of the Schneiderian membrane, but mostly from the bony walls [18]. From the surgical point of view, it was necessary to avoid damaging the local anatomical

structure and related vessels during the operation, which was significant to improve the effect of bone regeneration in the maxillary sinus. The smaller apicocoronal height and mesiodistal width of the bony window could contribute to less damage of the existing vessels nourishing maxillary sinus and graft materials [22, 23].

During sinus lifting, the membrane perforation or laceration was the most common complication due to its various elasticity, thickness and attachment to the underlying bone of the sinus membrane [24-26]. The Schneiderian membrane, characterized by a periosteum overlaid with a thin layer of pseudociliated stratified respiratory epithelium, constitutes an important barrier for the protection and defense of the sinus cavity. Its integrity is essential to maintain the healthy function of the sinus and to avoid dislocation of grafting material, local inflammation, and resorption of the bone graft [27, 28].

If the membrane integrity was damaged, graft particles could pass through mucosa perforation or laceration into sinus cavity resulting in severe or chronic sinusitis. Hurzeler *et al.* also found that grafting material had a tendency to penetrate the membrane [29]. In our study, in order to isolate bone graft from sinus cavity absolutely, we placed Bio-Gide collagen membrane underneath the sinus membrane no matter whether the membrane perforation was detected or not. All of these performances reduced the potential risk of membrane perforation and sinus infection.

Using Piezosurgery also gave a hand for reducing the risk of membrane perforation when preparing the lateral bony window. It can precisely cut hard tissue while precluding injury to soft tissue [30] and the small working tips can provide thinner cutting line for antrostomy. Only one membrane perforation occurred during the operation of cutting the bony window in all of our cases.

In order to avoid the surgery of sinus floor elevation, using a short dental implant in slightly atrophic posterior maxilla was also documented. But most of clinical results were short-term observations within 3 years and there was also a great variation within and between different centers [31, 32], so it is necessary

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to have a longer-term clinical study for making precise recommendations. The standard implant placement with sinus floor elevation is still the most commonly adopted method in atrophic posterior maxilla [33].

In addition, though transcresal sinus floor elevation was advocated due to minimal invasion, but it was difficult for surgeon to know the exact condition of the Schneiderian membrane without a direct surgical view. Thus, the lateral technique is still an irreplaceable method, especially in the condition which sinus membrane is planned to be elevated higher than 5 mm. In our study, this slot-like window technique not only effectively overcame the common complications but also avoided the loss of graft materials inside the sinus and got stable elevated height.

So far, sinus floor elevation is still the most predictable and effective method to augment bone volume in posterior edentulous maxilla. The challenges of improving the effective new bone formation and reducing the complications are always the direction that we work hard to improve. Within the limitations of the small number of patients and the relatively short follow-up period, our results indicate that this slot-like window technique can decrease the operation risks, reduce the required amount of bone substitute and the surgery-related complications with an obviously satisfying clinical effect.

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Disclosure of conflict of interest

None.

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