Responses of Sinus Membrane and Antral Pseudocyst Following Lateral Window Sinus Augmentation with Bone Grafting: A Retrospective Study

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Purpose: To investigate the influence of lateral window sinus augmentation on sinus physiology, including sinus membrane thickness and the outcome of antral pseudocysts. ***Materials and Methods:*** This retrospective study was performed by reviewing all lateral window sinus augmentation procedures, which were done between the years 2013 and 2015. Each enrolled patient had CBCT images preoperatively (T0), immediately postoperatively (T1), and 6 months postoperatively (T2). The sinus membrane thickness, pseudocyst dimensions, and intraoperative perforation were evaluated. Patient-related factors such as age and sex that could influence the mucosal properties were also analyzed. ***Results:*** Based on established inclusion criteria, 306 patients with 320 sinuses were included in this study. The overall mean thickness of the sinus membrane (T0) was 1.30 ± 1.08 mm, and membrane thickening (> 2 mm) was observed in 22.19% of the sinuses. Preexisting pseudocysts were identified in 24 sinuses (7.50%), most of which remained unchanged or disappeared after 6 months. The intraoperative membrane perforation rate was lowest (1.96%) when the membrane thickness was 1.0 to 1.5 mm, and the perforation rate was increased in patients with thickened (> 2 mm) or thinned (≤ 1 mm) membrane. Membranes swelled immediately after operation (T1 vs T0, $P < .01$) and gradually recovered at 6 months. No significant change in membrane thickness was shown after the sinus augmentation procedure in the perforation group and pseudocyst group. The mean thickness of the sinus membrane at T0 and T1 was significantly higher for male subjects ($P < .01$). ***Conclusion:*** Lateral window sinus augmentation has little or no impact on sinus membrane thickness and antral pseudocysts after a 6-month healing period, except for a transient mild membrane swelling. Thickened and thinned membrane were risk factors for intraoperative perforation. Small-sized perforation and pseudocysts might not contraindicate sinus augmentation from the standpoint of the surgical impact on the sinus membrane. *Int J Oral Maxillofac Implants 2021;36:885–893. doi: 10.11607/jomi.8842*

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The loss of maxillary posterior teeth is usually accompanied by resorption of alveolar crest and pneumatization of the maxillary sinus, which makes dental implant placement challenging. To date, two major techniques aiming to raise the sinus floor and rehabilitate an atrophic posterior maxilla have been used: lateral window sinus augmentation and transalveolar sinus augmentation. It has been proposed that the lateral window technique is preferred to the transalveolar approach when < 5 mm of the alveolar bone is available.[1] Systematic reviews on the success of the lateral window technique revealed a high 5-year implant survival rate, ranging from 88% to 100%.[2,3] Various bone grafts have been used for sinus augmentation, including autograft,[4] allograft,[5] and xenograft (bioglass, hydroxyapatite, anorganic bovine bone, etc[6–8]), which have been reported to show comparable and satisfactory clinical performance.[9,10] However, the maxillary sinus has anatomical limits, such as arteries and septa around the lateral window site, that make the lateral window technique more challenging.[11]

The maxillary sinus is lined with the sinus membrane, which is characterized by a thin layer of ciliated pseudostratified epithelium and highly vascularized connective tissue. The intact membrane not only plays

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the role of a physical barrier and mechanical cleaning system,[12–14] but also ensures blood supply to provide nutrition and osteoprogenitor cells to facilitate bone graft maturation.[15] It cannot be discarded that the lateral window sinus augmentation procedure stimulates an acute inflammatory reaction, resulting in functional and morphologic changes in the sinus membrane.[16,17] The resolution of these inflammatory changes is accomplished by adequate mucociliary clearance and sinus drainage into the nasopharynx via the ostium,[16] which may be impaired following sinus augmentation procedures. Sinus membrane thickness is considered as a critical anatomical factor reflecting membrane properties and quality. Although mild mucosal thickening is often asymptomatic and considered a normal radiographic finding, membrane thickness > 2 mm was selected as the threshold for indication of an inflammatory condition.[18] Until now, the information on the physiologic changes in sinus following lateral window sinus augmentation has been limited and conflicting, especially when sinuses displayed clinical and radiographic signs of pathology, such as membrane thickening, cysts, and polyps.

Among sinus pathologies, antral pseudocysts are found with a relatively high incidence, ranging from 1.4% to 23.6% of the population when assessed by imageologic methods.[19,20] Pseudocysts arise from an accumulation of inflammatory exudates within the loose connective tissue of the sinus membrane.[21] The radiographic presentation of pseudocysts are homogeneous, dome-shaped, radiopaque masses situated on the sinus floor.[21] The presence of large antral pseudocysts can present as an obstacle during a sinus augmentation procedure and impair the patency of the osteomeatal complex after sinus augmentation.[22] Several strategies have been described to remove these cystic lesions or to reduce their volume, including pseudocyst enucleation,[23] simple suction of the cystic liquid,[23] and leaving them alone when the sinus floor is elevated.[21,24] Thus far, the necessity of complete surgical removal of pseudocysts prior to or at the time of sinus augmentation procedures remains controversial.[25] A procedure that combines a high degree of effectiveness and reproducibility with minimal invasiveness is still lacking.

Therefore, it was hypothesized that sinus mucosal lining was affected after the lateral window sinus augmentation procedure; the dimensions of sinus membrane and antral pseudocyst may correlate with intraoperative perforation and clinical outcomes during healing. Thus, the objectives of this retrospective study were as follows: *(1)* to measure the dimensional changes of sinus membranes and pseudocysts following lateral window sinus augmentation; *(2)* to evaluate whether the changes in membrane thickness are associated with intraoperative perforations and the presence of preexisting pseudocysts; and *(3)* to explore the patient-related factors that may influence membrane thickness, occurrence of pseudocysts, and intraoperative perforation.

MATERIALS AND METHODS

Patient Selection

This study was approved by the Ethics Committee of the authors' hospital (No. 2018002). CBCT scans from routine patients who received sinus augmentation via the lateral approach between the years 2013 and 2015 were retrospectively screened. To be included in the study, patients had to meet the following criteria.

Inclusion Criteria. The inclusion criteria were as follows: *(1)* male and female patients ≥ 18 years of age; *(2)* residual alveolar ridge height ≤ 5 mm, or ≤ 6 mm with insufficient alveolar bone width requiring simultaneous horizontal bone augmentation based on presurgical assessment; *(3)* a combined use of a bovine-derived xenograft (Bio-Oss, Geistlich Pharma) and a collagen barrier membrane (Bio-Gide, Geistlich Pharma); and *(4)* in good general and oral health.

Exclusion Criteria. The exclusion criteria were as follows: *(1)* compromised systemic health; *(2)* history of head and neck radiotherapy; *(3)* alcohol misuse or heavy smoking (> 10 cigarettes per day); *(4)* severe temporomandibular joint syndrome; *(5)* current ENT and active periodontal disease; *(6)* abnormal sinus anatomy (eg, multiple partitioned sinus, concha bullosa, deviated nasal, paradoxical convexity of middle turbinate); and *(7)* complete sinus membrane perforation during the augmentation procedure.

All patients signed informed consent for the use of their clinical and radiologic data and publication.

Surgical Procedure

After administration of local anesthesia, a modified triangular flap with a relieving incision in the mesial region was made. Occasionally, when extensive bone augmentation was required, a trapezoidal flap was made to provide proper release. Then, a full mucoperiosteal flap was elevated to expose the alveolar ridge and the buccal wall of the maxillary sinus. A bony window was formed using a low-speed bone bur. The sinus membrane was carefully detached and elevated. Membrane integrity was assessed by direct visualization or Valsalva test. In the case of perforation, a resorbable collagen membrane (Bio-Gide, Geistlich Pharma) was trimmed and applied to seal the rupture. Pseudocysts, if presented, were left untreated or aspirated by using a syringe. When the cystic fluid was too sticky to be sucked through aspiration with a needle, an intentional puncture of the epithelial layers of the sinus membrane

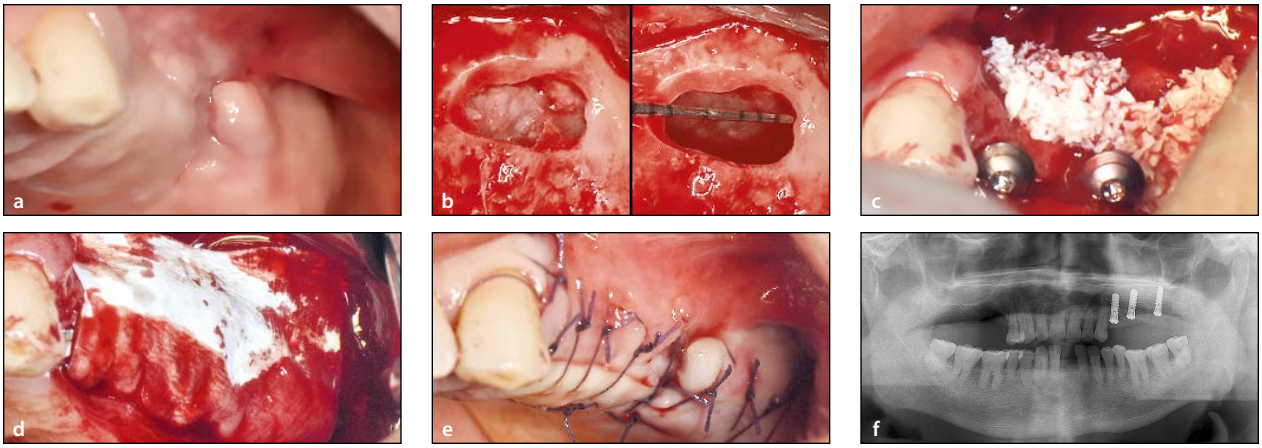

Fig 1 Clinical images showing the lateral window sinus augmentation procedure with bone grafting. *(a)* Preoperative intraoral image showing the partially edentulous alveolar ridge. *(b)* A lateral bony window was created, and the sinus membrane was elevated. *(c)* Bone grafting materials were inserted into the sinus cavity with simultaneous implant placement. *(d)* A collagen membrane was adapted to cover the lateral window. *(e)* Soft tissues were closed with horizontal mattress sutures and single interrupted sutures. *(f)* Postoperative panoramic radiograph.

was made, followed by thorough suction of the liquid with a metal aspirator (Appendix Fig 1; see Appendix in online version of this article at quintpub.com). After irrigation with saline solution, the sinus membrane was gently reflected, and the puncture site was closed with a collagen membrane (Bio-Gide, Geistlich Pharma). In all cases, bone augmentation was continued with placement of bone grafting materials (Bio-Oss, Geistlich Pharma) that had been hydrated with saline. The fenestrated lateral wall was covered with a collagen membrane (Bio-Gide, Geistlich Pharma). Finally, the flap was repositioned and sutured with 4-0 absorbable sutures in a horizontal mattress pattern to obtain tension-free primary wound healing, and then, single interrupted sutures closed the edges of the flaps. Dental implants were inserted simultaneously or by a staged approach (Fig 1).

Patients received a perioperative antibiotic prophylaxis with cefprozil (0.5 g/day) and tinidazole (1.0 g/day) for 5 days. Additional postoperative management included prednisolone (5 mg/day) for 3 days, compound paracetamol (0.3 g/tablet, prn), ephedrine hydrochloride and nitrofurazone nasal drops (1 to 2 drops, tid) for 1 week, and 0.2% chlorhexidine mouthrinses twice daily for 2 weeks. The sutures were removed 10 to 14 days postoperatively.

CBCT scans were taken preoperatively (T0), immediately postoperatively (T1), and 6 months postoperatively (T2). Failure was defined as any requirement for unplanned surgical intervention, such as debridement and abscess drainage, or failure of any implant migrated into the sinus.

Imaging Procedure and Evaluation

The CBCT images were obtained by an experienced operator manipulating the NewTom 3G unit (QR), with the scan parameters as follows: 6.0 mA, 110 Kv, and exposure time of 9.0 seconds. The data were reconstructed in NNT software (290-μm thickness at a 500-μm interval).

The measurement of sinus membrane thickness included the following steps[26] (Fig 2):

1. On the sagittal view, a horizontal line was drawn along the longest anterior-posterior path of the sinus, obtaining three planes at ¼, ½, and ¾ of this line.
2. Coronal sections corresponding to the three planes were retrieved.
3. On each coronal view, a vertical line passing through the bottom of the maxillary sinus was drawn to get Point A.
4. Then, a horizontal line was drawn 5 mm above Point A, and the intersections between this line and sinus walls were defined as Point B (palatal) and Point C (buccal).
5. The sinus membrane thickness was measured at Points A, B, and C of each coronal view; thus, a total of 9 points were measured. The dimensions of the pseudocysts were recorded with the longest diameter along the anterior-posterior, buccal-palatal, and vertical axes.

CBCT scans were selected and analyzed by a single examiner (M.N.-L.), who was instructed by an experienced implantologist and an oral radiologist. For assessment of intraexaminer reliability, 25 randomly selected cases were measured twice by the examiner with a 1-week interval, resulting in an acceptable repeatability frequency ≥ 95%.

Statistical Analysis

Statistical analysis was performed with SPSS 21 (IBM) software. One sinus procedure was used as the unit

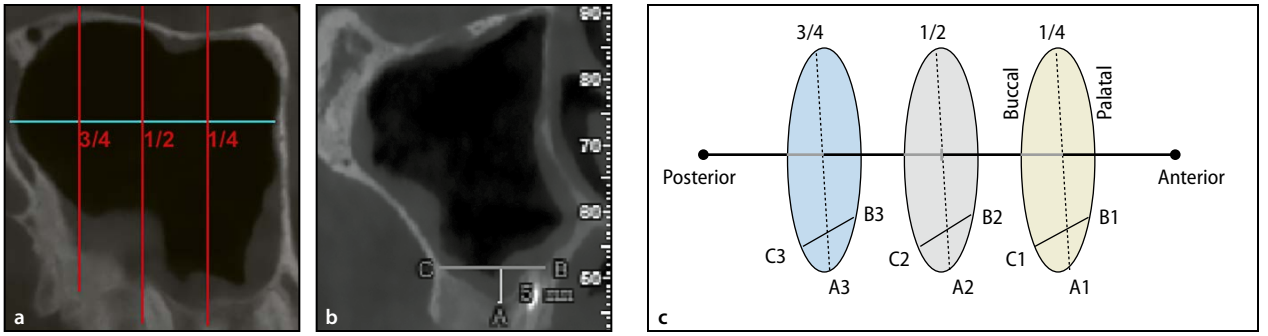

Fig 2 *(a)* Location of the slice of interest in sagittal view of CBCT. *(b)* Three measurement points were selected at each coronal section of the sinus. *(c)* Schematic overview of the nine measurement points (A1-3, B1-3, and C1-3) in the elevated region of the sinus.

Table 1 Sinus Membrane Thickness Scored at T0, T1, and T2

	Mean sinus membrane thickness (mm)			
	Total	Normal group	Perforation group	Pseudocyst group
T0	1.30 ± 1.08	1.20 ± 1.01	1.40 ± 1.44	2.24 ± 0.83
T1	1.48 ± 1.19**	1.43 ± 1.16**	–	2.02 ± 1.15
T2	1.27 ± 1.24	1.11 ± 0.09##	1.11 ± 0.9	2.67 ± 2.41

T0 as the comparison, ***P* < .01. T1 as the comparison, ##*P* < .01.

for analysis. The normality distribution of continuous variables was tested by the Kolmogorov-Smirnov test. Descriptive statistics were reported as means, medians, ranges, and standard deviations (SD) for continuous variables, and as frequencies and percentages for categorical variables. The nonparametric Kruskal-Wallis test was used to determine the difference between continuous variables. Associations between categorical variables were evaluated using the Pearson chi-squared (χ^2) and Fisher exact tests. $P < .05$ was considered statistically significant for all statistical tests.

RESULTS

Descriptive Analysis

A total of 306 patients (149 men and 157 women) with a mean age of 51.5 ± 12.9 years (range: 20 to 82 years) were included in the study. Three hundred twenty lateral window sinus augmentation procedures were performed, and 374 dental implants were simultaneously placed in 222 patients. Osseointegration failure occurred in four patients (four implants) who had undergone simultaneous dental implant placement (Appendix Table 1). No complication with infection occurred in sinuses. Based on the preoperative CBCT scans (T0), membrane thickening (> 2 mm) was observed in 71 (22.19%) sinuses, and the prevalence was found to be 7.50% (24 sinuses) for preexisting antral pseudocysts. In 31 (9.69%) sinuses, the sinus membrane was perforated incidentally during the surgical procedure. In all 24 cases of preexisting pseudocysts, sinus augmentation was successfully completed without membrane perforation. In consideration of the conditions of the membrane, the sinuses were further classified as the normal group, perforation group, and pseudocyst group.

Changes in Sinus Membrane Thickness

CBCT images indicated that the mean thickness of the sinus membrane was 1.30 ± 1.08 mm (range: 0.30 mm to 8.67 mm, n = 320), 1.48 ± 1.19 mm (range: 0.30 mm to 9.73 mm, n = 284), and 1.27 ± 1.24 mm (range: 0.30 mm to 12.19 mm, n = 284) at T0 (preoperation), T1 (immediately postoperation), and T2 (6 months), respectively. Mean membrane thickness was significantly increased immediately postoperatively compared with that before surgery (T0 vs T1, $P < .01$, Table 1). There was a significant difference in preoperative values of membrane thickness (T0) among the three groups ($P < .01$), and the membrane thickness (T0) was significantly higher in the pseudocyst group than in the other two groups ($P < .01$). Immediately postoperation (T1), an obvious membrane swelling in the normal group was observed (T0 vs T1, $P < .01$), and then, the membrane recovered after 6 months of healing (Fig 3). In cases of perforation, the initial hemorrhagic fill and sinus membrane were difficult to differentiate given their almost similar densities. Nevertheless, the traumatic signs totally subsided after 6 months (Fig 4). No obvious change in membrane thickness was shown between the preoperative and postoperative CBCT scans in the perforation group and pseudocyst group.

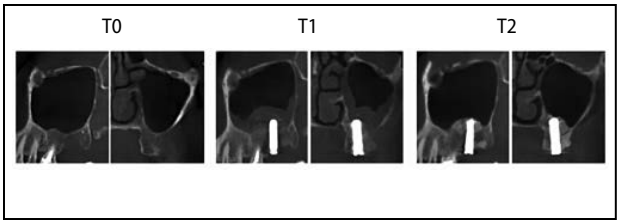

Fig 3 Representative sagittal and coronal CBCT slides from a patient who received lateral window sinus augmentation in conjunction with bone grafting. The sinus membrane showed a moderate but clear swelling immediately postoperatively (T1), which fully disappeared after 6 months (T2).

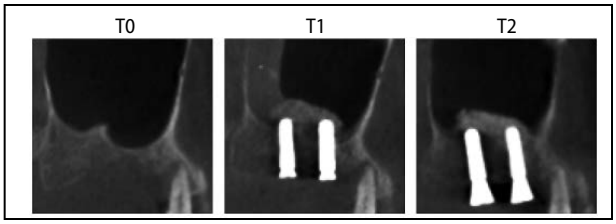

Fig 4 Representative sagittal CBCT slices showing a case of membrane perforation. An air-fluid level (*) was visualized in the affected sinus at T1. At 6 months (T2), the fluid level was not present, and the sinus was clear.

Table 2 Membrane Thickness Classification and Perforation Rate in Each Group

	Sinus membrane thickness (mm)			
Group	Mean	Median	SD	Perforation rate
Total	1.30	0.97	1.08	9.69% (31/320)
≤ 1	0.57	0.55	0.21	11.83% (20/169)
1–≤ 2	1.38	1.31	0.29	2.50% (2/80)
> 2	2.91	2.70	1.10	12.68% (9/71)

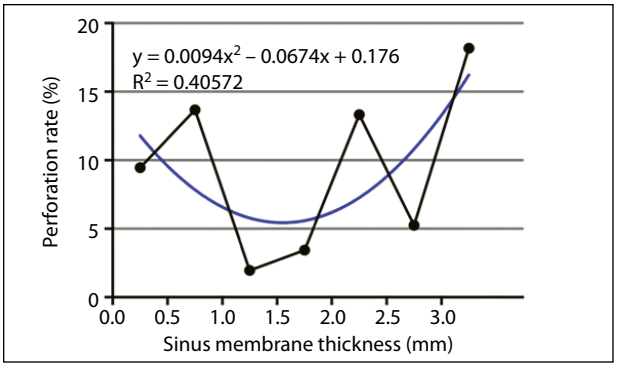

Fig 5 Line chart showed the relationship between sinus membrane thickness and perforation rate.

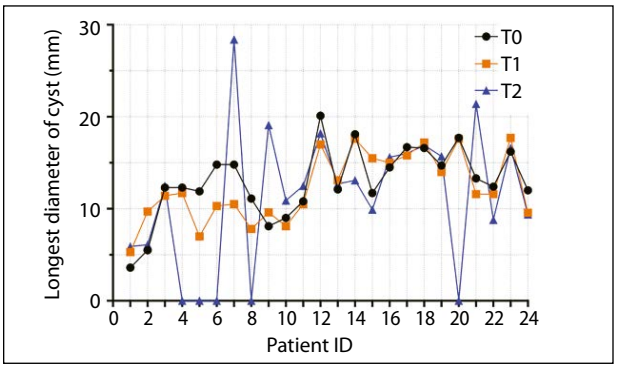

Fig 6 The longest diameter of pseudocysts at T0, T1, and T2.

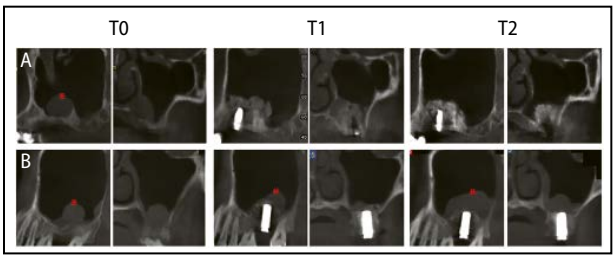

Fig 7 Representative CBCT images showing well-defined, hyperdense, unilocular, dome-shaped mass in the sinuses (*). Case A: The pseudocyst was removed, and no evidence of a recurrent cyst was observed after 6 months. Case B: The pseudocyst was much larger 6 months postoperatively.

Incidence of Sinus Membrane Perforation

To investigate the correlation between membrane thickness and perforation rate, the sinus membrane was classified as three categories based on the thickness (Table 2). There was a statistically significant difference in perforation rate among different groups ($P < .042$), and the perforation rate was obviously lower for a thickness of 1.0 mm to 1.5 mm (1.96%; Fig 5). As the sinus membrane became thinner or thicker, the perforation rate increased.

Antral Pseudocyst Recurrence

Twenty-four (7.50%) pseudocysts were observed preoperatively, and the mean value of the longest diameter of pseudocysts was 12.93 ± 3.88 mm (range: 3.60 mm to 20.10 mm, n = 24) preoperatively (T0), 12.30 ± 3.69 mm (range: 5.30 mm to 17.70 mm, n = 24) immediately postoperatively (T1), and 11.24 ± 7.62 mm (range: 0.00 mm to 28.40 mm, n = 24) after a 6-month follow-up (T2). Pseudocysts in five sinuses (No. 4, 5, 6, 8, and 20) completely disappeared after 6 months, while three pseudocysts (No. 7, 9, 21) were obviously enlarged (Figs 6 and 7). No significant differences in pseudocyst dimensions were observed during the healing period.

Patient-Related Factors

Table 3 provides the influence of patient-related factors (sex and age) on sinus membrane thickness, perforation rate, and incidence of pseudocysts. Increased membrane thickness was observed in male subjects compared with female subjects preoperatively (T0,

Table 3 Patient-Related Factors for Sinus Membrane Thickness, Perforation Rate, and Incidence of Cysts

	Sex			Age (y)			
	Male	Female	*P* value	18–35	36–55	≥ 56	*P* value
SMT (mm)							
T0	1.49 ± 1.23	1.11 ± 0.88	.002**	1.13 ± 1.06	1.28 ± 1.11	1.36 ± 1.07	.741
T1	1.67 ± 1.28	1.31 ± 1.02	.009**	1.25 ± 1.08	1.59 ± 1.33	1.47 ± 1.02	.150
T2	1.43 ± 1.48	1.13 ± 0.96	.05	1.08 ± 0.84	1.33 ± 1.48	1.27 ± 1.09	.341
Sinuses (N, %)							
Total	156, 48.75%	164, 51.25%	–	47, 14.69%	130, 40.63%	143, 44.69%	–
Normal	129, 82.69%	136, 82.93%	.956	43, 91.49%	108, 83.08%	114, 79.72%	.178
Perforation	17, 10.90%	14, 8.54%	.596	2, 4.26%	14, 10.77%	15, 10.49%	.394
Pseudocysts	10, 6.41%	14, 8.54%	.377	2, 4.26%	8, 6.15%	14, 9.79%	.344

** $P < .01$.

$P < .01$) and immediately postoperatively (T1, $P < .01$). Neither sex nor age was associated with postoperative membrane swelling, perforation, and incidence of pseudocysts.

DISCUSSION

The main observations of the present study were as follows: *(1)* a moderately but clearly transient thickening in the sinus membrane was observed immediately after sinus augmentation surgery by the lateral approach, which spontaneously subsided after 6 months without obvious sequelae; *(2)* a lower perforation rate (1.96%) was found for the sinus membrane thickness between 1.0 mm and 1.5 mm; *(3)* with appropriate treatment, preexisting pseudocysts and intraoperative perforation may not influence the sinus membrane physiology following the sinus augmentation procedure; *(4)* the lateral approach in the presence of pseudocysts did not increase the risk of perforation, nor did it aggravate the original pseudocysts in most cases. To the authors' knowledge, this is the first large-sample retrospective report on the responses of the normal and pathologic sinuses to a lateral window sinus augmentation procedure.

The great interindividual variability in sinus membrane thickness has been described by multiple studies. Janner et al,[27] in a CBCT study (n = 168 sinuses), showed a wide range of measurements varying between 0.16 mm and 34.61 mm. Through a systematic review, Monje et al[28] reported the mean value of 1.33 mm for membrane thickness in noninfected sinuses as determined by CBCT or CT, whereas the mean histologic membrane thickness was 0.48 mm. The result in the present study was generally consistent with the published radiographic studies, showing a mean preoperative value of 1.30 ± 1.08 mm (range: 0.30 to 8.67 mm). The variation in membrane thickness can be attributed to sex, populations, smoking habit, seasons, odontogenic change, or gingival phenotype.[28] Male values for sinus membrane thickness were regarded to be higher than the corresponding female values,[27] which is consistent with the findings of the present study.

Like most oral surgeries, sinus augmentation surgery is usually accompanied by discomfort, with some degree of postoperative tissue swelling. The flap design is important for surgical approach, blood supply, postoperative swelling, and periodontal tissue preservation.[29,30] Usually, in lateral window sinus augmentation, a crestal incision is made over the implant site followed by unilateral or bilateral oblique/vertical releasing incisions being designed, such as trapezoidal flaps and modified triangular flaps. The more vertical and horizontal bone augmentation is required, the more critical it is to add vertical releasing incisions for tension-free primary closure.[30] Trapezoidal flaps allow for adequate visibility and great access to bone grafting. Compared with trapezoidal flaps, a modified triangular flap with one vertical incision is more effective in reducing postoperative pain and swelling due to less invasion and greater blood supply.[29] Scarano et al[29] indicated that it would be better to avoid a mesial releasing incision, because in this area, the branches of infraorbital artery are found, which vascularize the local oral mucosa, lateral sinus wall, and overlying membrane.

The present study revealed that lateral window sinus augmentation has no influence on sinus membrane thickness after 6 months of healing except for a transient swelling. This swelling is one of the earliest inflammatory symptoms in the sinus following sinus augmentation. The initial inflammatory phase predominates at 48 hours, characterized by clot formation underneath the sinus membrane along with a dense infiltration of polymorphonuclear leukocytes in the connective tissue of the sinus membrane.[26] Then, the inflammatory reaction

gradually subsides, followed by a phase of tissue remodeling that may take several months or years.[16] Makary et al,[26] in a CBCT study, showed membrane swelling after lateral window sinus augmentation with a mean value of 5.4 mm (n = 32 sinuses) within the first week. Quirynen et al[31] reported a mean membrane thickness value of 6.7 mm (n = 13 sinuses) during the first weeks of healing after a transalveolar approach. These values are higher than the mean value of 1.48 ± 1.19 mm (T1) measured in the present study. This difference may be explained by the fact that the membrane thickness was measured within 7 days postoperatively in the previous studies, whereas the patients included in the present study received their first postoperative CBCT scan immediately after surgery. Such low thickness values in the present study are the consequence of very limited inflammation. The thickened membrane totally recovered at the 6-month follow-up, indicating readaptation of sinus and adequate mucociliary clearance after surgical trauma.[26] However, further histologic studies are required to confirm this hypothesis.

Membrane perforation is one of the most common intraoperative complications of lateral window sinus augmentation, with an incidence ranging from 0.0% to 31.5%.[2,32] Possible risk factors for perforation have been identified, such as narrow tapered sinus contour,[33] chronic sinusitis, smoking habit, gingival biotype (< 1 mm), limited residual bone height, and presence of sinus septa.[34] However, sex, similar to age, seems to not be related to perforation rate,[33,35] which is consistent with the results of the present study. In recent years, reduced membrane perforation has been associated with the introduction of alternative surgical techniques. For instance, ultrasonic instruments and manual bone scrapers have shown a lower (10.9% and 6.0%, respectively) perforation rate compared with that of rotary instrumentation (20.1%)[36]; Scarano et al reported that the use of the nasal suction technique and ultrasonic approach reduced the occurrence of membrane perforation compared with the rotary instruments (0.0% vs 13.3%, n = 30, $P < .01$).[37] However, in a retrospective case series, cases treated with piezosurgery alone had the highest perforation rate (30%, n = 10) compared with the use of diamond burs alone (25%, n = 24) or a combination of piezosurgery and diamond burs (15.6%, n = 43), but the differences did not reach statistical significance.[38] In the lateral window sinus augmentation procedure, perforation was directly visualized; however, it could be covered by bone grafting materials or could happen during implant insertion.[39] In the present study, the conventional technique with rotary instruments was applied, and postsurgical CBCT was taken immediately to confirm the absence of air-fluid level or dispersion of the bone grafting materials into the sinus, by which an underestimation of perforation was avoided.

Up to now, whether perforation is associated with sinus membrane thickness has remained unclear, as previous studies have yielded conflicting results. For instance, membrane thickness from 1.5 to 2.0 mm and 1.0 to 1.5 mm for the transalveolar and lateral augmentation approaches, respectively, demonstrated lower perforation rates.[39,40] Lin et al described greater perforation rates occurring when the membrane thickness was < 1.0 mm (20%) or > 2.0 mm (27%) compared with that between 1.0 mm and 2.0 mm (4%). This is consistent with the present findings, in which patients with sinus membrane thickness between 1.0 mm and 1.5 mm showed the lowest perforation rate (1.96%) compared with the overall population (9.69%). In contrast, a systematic review analyzed 31 studies and reported no significant association between intraoperative perforation and sinus membrane thickness.[28] Ritter et al[41] reported that perforation rate was inversely related to membrane thickening of > 2.0 mm. It can be speculated that the mechanical strength of the connective tissue is positively related to membrane thickness within a certain thickness range,[42] while excessive membrane thickening can lead to microvascular rarefaction, secondary necrosis, and reduced mucosal elasticity.[41,43] Insua et al[17] indicated that the increase in the perforation rate might be more related to the membrane inflammatory status than to different thickness. Histologically, inflamed membrane showed swelling and a degree of epithelial erosion, which might be more susceptible to tearing than thinner healthy ones.[44,45] Although maintaining the integrity of the sinus membrane is desirable for proper healing, studies also indicated that small-sized perforations do not show clinical signs of ongoing sinus pathology or prevent bone formation.[1,46] In the present study, the bone and sinus membrane healing was generally uneventful, without radiologic abnormalities after 6 months, demonstrating that small perforations covered with a collagen membrane seemed to have no consequence on sinus membrane physiology.

Antral pseudocysts are common benign inflammatory lesions that exist in the maxillary sinus.[47] However, whether pseudocysts without coexisting sinonasal symptoms are a contraindication to sinus augmentation surgery remains a topic for further studies. According to some investigators, the pseudocysts should be removed before or during sinus grafting because they can hamper sinus augmentation procedures and increase the risk of ostium blockage, while recent studies showed that asymptomatic pseudocysts do not affect the surgical outcomes of sinus augmentation.[18,41,48] In the present study, pseudocysts were not treated, or were removed by suction of the cystic liquid during surgery. Sinus augmentation was successfully completed without membrane perforation in cases of pseudocysts, which is similar to that reported by Gong et al[21]

and Feng et al.[49] Moreover, most pseudocysts either changed slightly or disappeared after 6 months, indicating that the lateral approach in the presence of such pseudocysts may not bring additional risks for aggravation of the original lesion in most cases. The recurrence of the pseudocysts can be explained by the fact that cystic liquid drainage alone is inadequate for complete clearance of the pseudocysts.[23] Chiapasco and Palombo[23] recommended removal of the epithelial layer of the pseudocyst with preservation of the periosteal layer of the sinus membrane, which achieves complete pseudocyst enucleation and avoids perforation. However, dissection of the cyst epithelium increases the technical difficulty of the sinus augmentation surgery. It is worth noting that although the punctured site was repaired with a collagen membrane, complications like contamination and dispersion of the bone grafting materials can still potentially arise. Longer follow-up periods are necessary to confirm and update the outcomes of these cystic lesions.

Nonetheless, the present study was limited by its retrospective, nonrandomized design. Clinical data regarding detailed operation records and patient-related history or symptoms (anatomical variation, mild sinonasal symptoms, and comorbid conditions) were incomplete. Although experienced clinicians performed all surgical procedures, their surgical experience could differ. The influence of lateral window sinus augmentation on the sinus membrane was observed only within 6 months due to loss to follow-up. Future randomly controlled clinical trials with longer follow-up periods and histologic examinations are required to confirm these findings.

CONCLUSIONS

The radiographic results showed that lateral window sinus augmentation has no significant influence on sinus membrane thickness and pseudocyst dimensions after the healing period except for transient membrane swelling. Membrane thickening (> 2 mm) and thinning (≤ 1 mm) were important risk factors for intraoperative perforation. With appropriate treatment, small-sized perforation and antral pseudocysts might not impede the clinical outcomes of lateral window sinus augmentation in asymptomatic patients.

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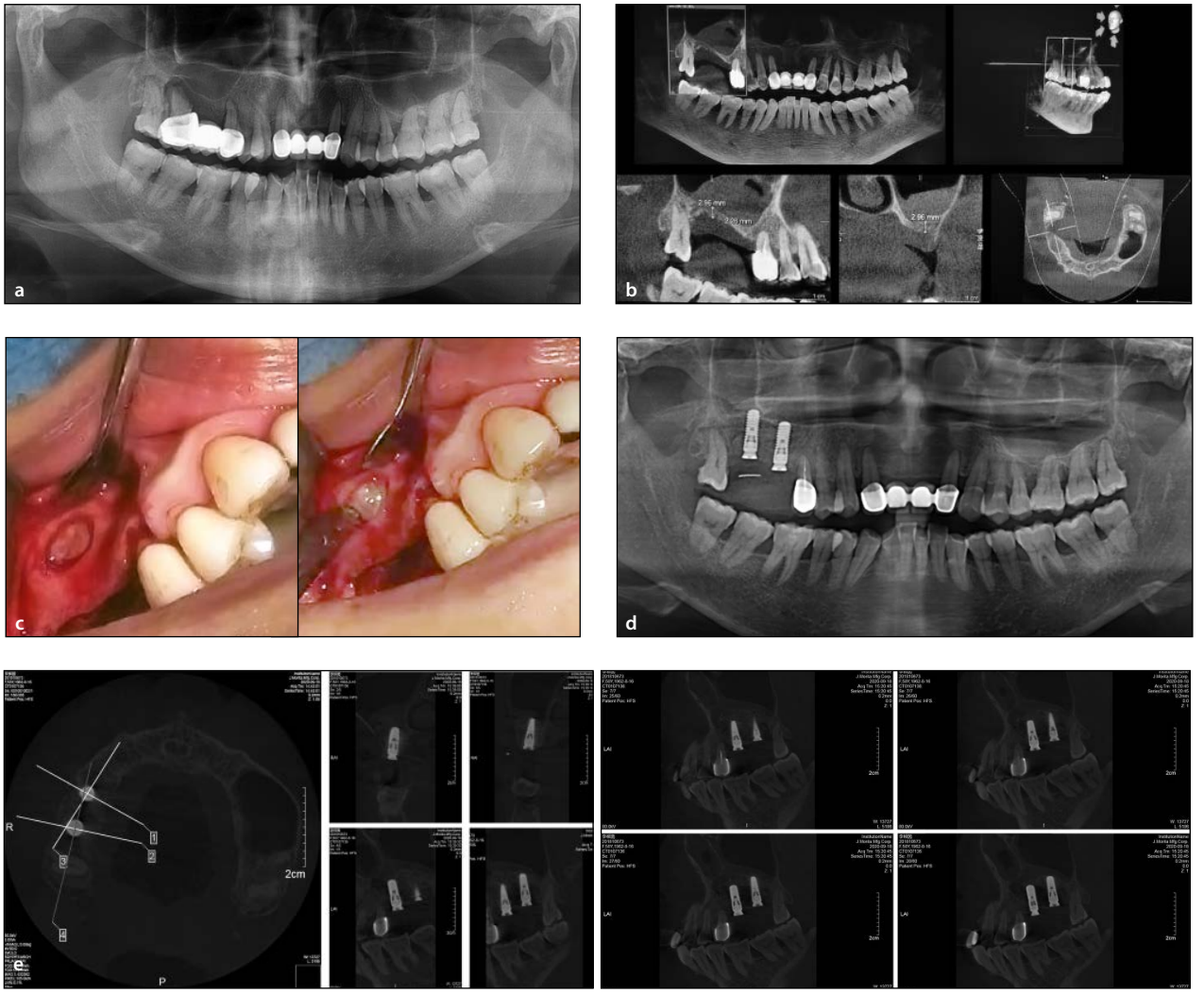
APPENDIX

Appendix Table 1 Information of 4 Cases of Osseointegration Failure

Patient	Age	Sex	Tooth position[a]	Implant	Simultaneous or by stages	SMT		
						T0	T1	T2
1	59	M	16	ITI SP 4.8 × 10 mm WN	Simultaneous	3.08	2.37	–
2	27	F	24	ITI BL 3.3 × 12 mm NN	Simultaneous	0.30	0.61	0.64
3	77	F	16	ITI SP 4.8 × 10 mm WN	Simultaneous	0.69	0.68	0.60
4	82	M	17	ITI SP 4.8 × 12 mm WN	Simultaneous	3.06	2.69	2.23

[a]FDI tooth-numbering system.



Appendix Fig 1 A case of pseudocyst removal. *(a)* Preoperative panoramic radiograph. *(b)* Preoperative CBCT scans. *(c)* Intraoperative images. Cystic fluid was sucked using a metal aspirator. *(d)* Postoperative panoramic radiograph. *(e)* Postoperative CBCT scans.