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Original Article

Possible risk factors of sinus membrane perforation during sinus floor elevation: A retrospective study

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Abstract

Aim: To investigate risk factors causing sinus membrane perforation during sinus floor elevation (SFE) performed with lateral window technique and to evaluate the sinus membrane health after SFE via Cone-Beam Computed Tomography (CBCT).

Materials and Methods: CBCT images of 33 patients with sinus membrane perforation during SFE and 33 patients without perforation during SFE as a control and a total of 80 CBCTs were evaluated. Patient-related factors (age, sex, smoking) and maxillary sinus-related factors (preoperative membrane thickness, residual bone thickness, postoperative membrane thickness, and postoperative total bone thickness, type of sinus membrane morphology, and presence of septa) were assessed.

Results: Preoperative sinus membrane thickness of the perforated group (4.38 ± 6.02 mm) was significantly higher than the non-perforated group (1.74 ± 2.81 mm) ($p = 0.02$). No significant difference was found between preoperative and postoperative membrane thicknesses of the non-perforated and perforated group ($p = 0.135$ and $p = 0.106$, respectively). The perforation rate was highest (83.3%) in the group of mucosal thickness ≥4 mm. Membrane perforation was observed in 100% of circumferential and complete type sinus membrane morphology, 80% of polyp type morphology, and 85.7% in irregular type morphology. A relationship was found between the presence of septa and membrane perforation ($p = 0.01$).

Conclusion: The study results show that the presence of septa, age of >55 years, and a sinus membrane thickness of >4 mm are associated with an increased risk of sinus membrane perforation. Perforation did not affect postoperative sinus membrane thickness.

Keywords: Cone-beam computed tomography; dental implants; membrane perforation; membrane thickness; sinus lift

INTRODUCTION

The maxillary sinus floor elevation procedure (SFE) is a considerable pre-prosthetic surgical procedure for establishing adequate bone volume in the edentulous posterior maxilla for the placement of dental implants (1). When the residual bone height is 5 mm or less, it is recommended to provide access to the sinus by the lateral window approach (2). The most common intraoperative complication reported in the literature with these surgical approaches is the sinus membrane perforation (SMP) with a prevalence ranging from 14% to 56 % (3, 4). Perforation rate may increase when the thickness of membrane is thicker or thinner (5). Also in most cases, perforation happens either while using rotary instruments to make the window or when using hand instruments to provide preoperative access to start the elevation of the membrane from the sinus walls, and owing to irregularities of the sinus floor (6). Thus, some studies reported anatomical variations of the maxillary sinus and different SFE techniques as potential risk factors for SMP (7, 8). Preoperative diagnostics based solely on panoramic radiographs may not be sufficient to display anatomic variations of the maxillary sinus. Cone-beam computed tomography (CBCT) is an integrated diagnostic method to accurately assess the risk and prognosis of treatment that provides a three-dimensional reliable diagnostic image for detecting anatomic variations of the maxillary sinus region and allows us to report more accurate data (9). During SFE, clinicians might be experienced with risk factors that could affect surgical outcomes. SMP increases the possible side effects of infection that causes impairment of sinus function, graft loss, chronic sinusitis, and even implant survival (10). Some procedures have been reported to treat SMP during SFE (11-13). Nevertheless, in the literature, there is not enough study that evaluates sinus membrane health after the treatment of SMP.

This retrospective CBCT study aimed to evaluate multiple potential risk factors in the SMP rate during SFE using lateral window technique and to determine the status of sinus membrane health after SMP.

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MATERIALS and METHODS

Patients

The study approval was done by the ethics committee of XX University. The patient group was formed by scanning the records of SFE via lateral window technique performed at the Department of Periodontology (Faculty of Dentistry, XX University) between years 2016 and 2019. 33 subjects with perforation (41 sinuses) and 33 subjects without perforation (39 sinuses) were selected randomly. Finally, a total of 80 sinuses were evaluated. Patients who had partial edentulous alveolar ridge and received SFE via lateral window technique were included in this study. The patients were divided into two groups based on the presence or absence of SMP during SFE.

Inclusion and Exclusion Criteria

Images were included if: 1) maxillary sinuses were located between premolars and molars as a result of missing single or multiple teeth; 2) teeth were present adjacent to the edentulous area to determine the location of edentulous ridge; 3) Residual ridge height was < 5 mm; 4) the entire grafted area was clearly visible without scattering or other artifacts.

Images were excluded if: (1) the location of the edentulous area could not be determined; (2) patients had previous sinus surgery; (3) patients had progressing periodontitis, sinus pathology, skeletal disorder, or taking any medications that would affect bone metabolism (bisphosphonates, glucocorticoids).

The age, gender, and smoking status of selected patients were recorded.

Surgical Procedures

All surgical procedures for SFE were performed under local anesthesia (Maxicaine Fort, VEM Drug, İstanbul, Turkey). After raising a mucoperiosteal flap, a lateral window procedure was performed using piezoelectric instruments (VarioSurg, NSK, Japan). The sinus mucosa was separated from the bony surface of the sinus floor with a series of curved elevators. Following the SFE procedure, bone allograft material (Maxxeus Dental, Kettering, OH, USA) was placed into prepared site, and the lateral window was covered with collagen membrane (Collagene AT, Padova, Italy). Intraoperative SMP was managed during surgery and recorded. SMPs were repaired with a resorbable collagen membrane (Collagene AT, Padova, Italy) or were sutured by 5-0 poly (glycolide-co-lactide), synthetic, absorbable, multifilament, polypropylene suture (Pegelak, Doğsan, Trabzon, Turkey). If the SMP was greater than 10 mm, the SFE procedure was postponed for 4 months. Oral and written postoperative instructions were given to all of the patients. Patients were advised to take one 1000 mg capsules (1 g) of amoxicillin+ potassium clavulanic acid starting 1 hour before the surgery and to take one 1000 mg capsule every 12 hours for 7 days thereafter. Furthermore, patients were informed to take pseudoephedrine for 1 week after the surgery and 25 mg of dexketoprofen every 8 hours for pain. Sutures were removed ten days after the surgery.

Radiologic Examination

CBCT was performed before SFE as well as 6 months after augmentation surgery before implant insertion (14).

Imaging Procedure

CBCT images were gained using I-CAT 3D Imaging System (Imaging Sciences International, Hatfield, PA, USA) with the following parameters: 5 mA, 120 kVp, 16 x 6-10 FOV, and a voxel size of 0.3 mm. CBCT images with good image quality, which can be monitored with all the borders of the alveolar crest and maxillary sinus in the region to be evaluated were included in the study.

CBCT Analysis

Images were examined by I-CAT vision Q imaging software. All CBCT measurements and evaluations were performed by 2 observers (GU and DGB). At the beginning of the study, the observers were calibrated internally by evaluating 25 randomly selected CBCT images. Intra-observer compliance was good for both observers (correlation coefficient = 0.869 and 0.852, for observer 1 and observer 2, respectively) When all measurements and evaluations were completed, the inter-observer agreement was found to be good (correlation coefficient = 0.821). The average of the measurements of the 1st and 2nd observers was used in the statistical analysis. When the difference between the two observers was higher than 0.2 mm, the third measurement was performed.

- In multiplane CBCT images, maxillary sinus septa were assessed and the presence of septa was recorded.

- To measure in the same section in both pre and postoperative CBCT images, the neighboring teeth in the anterior or posterior region were taken as reference, and the distance to the tooth was determined and measurements were made on the same section in both images. The regions planned to be implanted were determined in the axial sagittal and coronal sections (Figure 1 A-C). In coronal views, preoperative membrane thickness, residual bone thickness (preoperative vertical bone height), total bone thickness (residual bone thickness + elevated bone thickness) and postoperative membrane thickness were measured. All measurements of the sinus membrane were made perpendicularly to the underlying bone and the thickest area was recorded. The residual and total bone height was measured from the top of the alveolar crest to the maxillary sinus floor (Figure 1 D-F).

- Preoperative sinus membrane thickness was classified into five types; flat, polyp, irregular, circumferential, complete (15).

Statistical Analysis

Based on the previous study (16), the sample size was calculated considering Type I errors (0.05), targeted power (0.80) and effect size (0.67) due to sinus membrane thickness value ($p<0.05$) by G* power 3.1.9.4 software program (Heinrich Heine University, Dusseldorf, Germany). The minimum required sample size was calculated as 36 sinuses per group.

SPSS (IBM Statistical Package for the Social Sciences Statistics; New York, ABD) version 21.0 was used for statistical analysis. Differences in the presence of perforation between membrane thickness groups and morphology groups were compared by Chi-square test. The relations between the presence of perforation and residual and total vertical bone height, preoperative and postoperative sinus membrane thicknesses were analyzed by two samples t-test. Multivariable binary logistic regression analysis was used to model the odds ratio (OR) of SMP by the corresponding risk factors. The statistical significance level was defined as p ≤ 0.05.

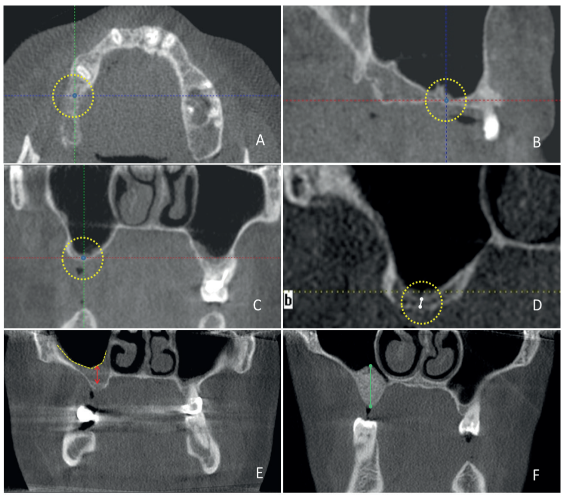

Figure 1. A-C Before the preoperative measurement, the planned location of the sinus lift and implant was determined in the central axial sagittal and coronal sections. D Residual bone thickness was measured in the coronal section (white line). E İnitial sinus membrane thickness was measured perpendicularly to the underlying bone from the thickest area (red arrow). The cases which membrane thickening could not be observed were accepted as 0 (normal). F Total bone height was measured from the top of the alveolar crest to the maxillary sinus floor (green line)

RESULTS

A total of 66 patients (39 females and 27 males), 33 subjects with sinus membrane perforations, and 33 subjects without perforations as a control group were included in the study. The mean age was 47.13 ±7.55 and 47.46 ± 11.01; for perforated and non-perforated groups respectively. Perforation status did not differ between sex (p = 0.72). Smoking status differed between groups (p = 0.043). 25 cases were smoking and 17 of them had perforated sinus membrane (68%). There was a relationship between the presence of septa in the maxillary sinus and membrane perforation (p = 0.01). Septa were observed in 23 sinuses and 73.9 % of the sinuses with septa were perforated. Sinus septa were observed in 41.5% of perforated sinuses. Preoperative membrane thickness was significantly higher in the perforated group (4.38 ± 6.02 mm) than the non-perforated group (1.74 ± 2.81 mm) (p = 0.02). No difference was observed between the groups in other linear measurements (Table 1). There was no significant difference between preoperative and postoperative membrane thicknesses of perforated and non- perforated groups (p = 0.106 and p = 0.135, respectively).

A sinus mucosal thickness classification system was used and 3 categories were created: thickness <2 mm, between ≥2 and <4 mm, and ≥4 mm (Table 2). There was a significant difference in the perforation rate between these 3 categories, with the highest rate (83.3%) seen in the group of mucosal thickness ≥4 mm (p = 0.008).

The membrane thickness of each membrane morphology classification is shown in Table 3. In the patients with mucosal thickness, 51.2% of the membrane morphologies were a flat type. Perforation was observed in all cases with the circumferential and complete morphological mucosal thickness (100%). Perforation was observed in 80% of polyp morphology and 85.7% in irregular morphology (p = 0.003).

Table 1. Measurements and descriptive data of the patients

Variables	Perforated sinuses (41)	Non-perforated sinuses (39)	Total sinuses (80)	P value
Sex (N)				
Female	20	19	39	0.072
Male	13	14	27	
Age				
≤55	21	30	51	0.013*
>55	12	3	15	
Smoking (N)				
Yes	17	8	25	0.043*
No	16	25	41	
Septa				
Absent	24	33	57	0.01*
Present	17	6	23	
To membrane thickness (Mean±SD)	4.38 ± 6.02	1.74 ± 2.81	3.09 ± 4.88	0.02*
T1 membrane thickness (Mean±SD)	3.06 ± 4.51	2.52 ± 3.13	2.79 ± 3.88	0.13
T0 vertical bone height (Mean±SD)	1.77 ± 1.63	1.52 ± 1.34	1.65 ± 1.49	0.26
T1 vertical bone height (Mean±SD)	14.57 ± 3.20	12.80 ± 2.79	13.71 ± 3.12	0.37

SD: Standard Deviation. N. number *statistically significance level is p<0.05. T0: Initial, T1: Postoperative

Table 2. Membrane thickness classification and perforation rate Statistically significance level is p<0.05

Membrane thickness	Min (mm)	Max (mm)	Mean (mm)	Std. Deviation	Perforation rate (%)	P value
0-2 mm (50%)	0.00	1.30	0.03[a]	0.20	42.5	
2-4 mm (27.5%)	2.16	3.61	2.91[b]	0.44	40.9	0.008
≥4 mm (22.5%)	4.21	22.80	10.12[c]	6.00	83.3	

*Different superscript letters indicate statistically significance

Table 3. Membrane morphology classification and perforation rate

Group	Membrane Morphology Classification						Total	P value
	Normal	Flat	Polyp	Irregular	Circumferential	Complete		
Perforated	17 (43.5%)[a]	6 (28.6%)[b]	4 (80%)[c]	6 (85.7%)[c]	4 (100%)[d]	4 (100%)[d]	41	
Non- Perforated	22 (56.5%)	15 (71.4%)	1 (20%)	1 (14.3%)	0 (0%)	0 (0%)	39	0.03*
Total	39 (100%)	21 (100%)	5 (100%)	7 (100%)	4 (100%)	4 (100%)	80	
Mean Membrane Thickness ± SD	0.00	2.94 ± 0.69	6.68 ± 2.89	7.30 ± 3.17	5.19 ± 2.91	20.06 ± 2.70		

SD: Standard Deviation. *Statistically significance level is p<0.05. % values show perforation rates for each membrane morphology . *Different superscript letters indicate statistically significance

Table 4. Risk factors for sinus membrane perforation

Risk Factors	S.E.	P Value	OR	95% C.I. Lower	Upper
Smoking	.640	.069	3.205	.915	11.224
Septa	.640	.004	6.487	1.849	22.761
2-4 mm membrane thickness	.642	.763	.824	.234	2.899
>4 mm membrane thickness	.791	.021	6.168	1.309	29.059
Age > 55 Years	.783	.006	8.488	1.830	39.360

SE: Standard Error; OR: Odds Ratio; CI: Confidence Interval

In a multivariable binary logistic regression analysis of sinus membrane perforation with smoking, presence of septa, membrane thickness and age as risk factors (Table 4), the presence of septa (OR = 6,487, P = 0.004), the membrane thickness of > 4 mm (OR = 6.168, P = 0.021) and age of > 55 years (OR = 8,488, P = 0.006) were identified as significant risk factors.

DISCUSSION

The success of the operation in sinus lift surgery depends primarily on the experience and knowledge of the surgeon, but also the thickness of the sinus membrane, residual bone height, presence of septa, smoking status, excessive force on graft material, and gingival phenotype affect the perforation risk of the sinus membrane (17). In this study, the effect of sinus membrane thickness on the risk of sinus membrane perforation and the relationship between perforation and postoperative sinus mucosa health were evaluated. The relationship between the presence of sinus septa, smoking status, patient related factors as sex and age, and the risk of perforation was evaluated.

In recent studies on CBCT (18,19), sinus membrane thickness has been reported to be significantly thinner in women. Becker et al. (4) reported perforations at 26.5% in women and 11.9% in men. Von arx et al. (20) stated perforation rate as higher in females (29.2%) than in males (24.1%) but this difference was not statistically significant. Similarly, in this study, the perforation rate was higher in female but it was not statistically significant. Age did not change the perforation rate in some studies (4,20,21), but in the present study, it was found that perforation was observed 8 times more in patients older than 55 years.

Smoking has several adverse effects on surgical outcomes and the development of intra- or postoperative complications in many types of surgeries. The relative risk for the development of postoperative complications has been reported to be 1.2 to 5.5 times higher in smokers than nonsmokers (22). In this study, membrane perforation was seen in 68 % of the smokers and 39.02 % of the non-smokers, but in multivariable regression analysis, smoking was found not to be an important risk factor for membrane perforation. Smoking is thought to increase the risk of perforation by increasing sinus membrane thickness. Ardekian et al. [3] have identified an association with perforation. Similarly, Schwartz et al. (23) stated that smoking increased the risk of sinus membrane perforation. Whereas Lum et al. (17) and Tükel et al. (21) reported no statistically significant association between smoking and membrane perforation.

Determination of the location and morphology of the sinus septa can provide a precise surgical plan and prevent complications from sinus surgery. The location of sinus septa might complicate SFE and the perforation might occur, therefore the management of the lateral wall during sinus augmentation via lateral approach should be done accurately (24). Previous studies have reported that the presence of septa is associated with the risk of perforation (23,25). Tükel et al. (21) found that the risk of perforation increased four times in septated sinuses compared to non-septated sinuses. Similarly, the present study showed a perforation increased six times in presence of septa.

In the literature, sinus membrane perforation is strongly associated with the development of postoperative complications such as chronic sinus inflammation, bacterial invasion, swelling, bleeding, wound dehiscence, and graft loss (6). In Pommer's study, 72% of sinuses demonstrated membrane thickening after bone grafting (14). In the present study, postoperative sinus membrane thickness did not show a significant difference for both groups similar to the study of Anduze-Acher et. al (26). This discrepancy may be related to sinus membrane morphology, usage of different graft materials, smoking status, and distribution of the population.

In previous studies, a significant relationship between preoperative membrane thickness and perforation rate was indicated (5,27-29). Lin et al. (5) reported higher perforation rates in patients with membrane thickness >2 mm (27%). Besides, Wen et al. (27) stated a high perforation rate that exceeded the two folds of average values in patients with membrane thickness >3 mm. Similarly, in the present study mean preoperative membrane thickness was significantly higher in the perforated group than in the non-perforated group ($p = 0.02$). Besides, our study data showed the perforation rate six times higher in the group of mucosal thickness ≥4 mm. This may be explained that thick sinus membrane does not have structures, including pseudostratified columnar ciliated epithelium, lamina propria, and periosteum-like connective tissue, with the same strength as in healthy status. On the other hand, several studies concluded that a thinner membrane was related to a higher perforation rate (17,28-30). The possible reasons for this may be the difficulties in elevation in cases where the membrane is thin, skills of ability, and the presence of septa may be other factors. In this study, there was no statistically significant difference between perforation rates of the cases with a membrane thickness of 0-2 mm 2-4 mm, but the perforation rate of 0-2 mm thickness was slightly higher. These results may be related to the present study design, the distribution of membrane morphology and the membrane thickness, and the bone thickness of the lateral window.

Residual bone height is an important factor for determining the location of the bony window osteotomy, and the level of sinus membrane elevation. In our study, there was no significant difference in residual bone height between perforated and non-perforated groups. Similarly, Wen et al. (27) reported no significant difference between the perforation rate and residual bone height. In contrast, Lum et al. (17), Schwarz et al. (23) and Ardekian et al. (3) reported that residual bone height was significantly smaller in the perforated group than in non-perforated group (($p<0.001$, $p<0.001$ and $p<0.01$, respectively). These findings were inconsistent with our results that could be affected by the presence of confounding factors such as the presence of sinus septa or membrane morphology.

According to the present study, perforation was observed in all cases (100%) with circumferential and complete type morphological mucosal thickness. Carmeli et al. (15) found that rounded (6.1%), circumferential (55.2%), irregular (38.8%), and complete (100%) mucosal thickness were related to sinus obstruction. Wen et al. (27) stated no significant difference between the perforation rate and the sinus membrane morphology ($p = 0.099$), but the perforation rate was highest in irregular shape (28.95%) and lowest in a flat shape (13.76%). These differences in the results can be explained by the fact that not only membrane morphology is effective in membrane perforation, but also other factors such as membrane thickness, smoking, and surgical technique are effective in perforation.

LIMITATIONS

Our study had some limitations, first of which was that no histologic and histomorphometric analyses were done to evaluate the bone formation. The second limitation was the short-term outcome of implants. Randomized controlled longitudinal studies with large sample sizes would be needed. Additional studies are also needed to investigate the physiologic impact of sinus membrane perforation during sinus floor augmentation on mucociliary clearance.

CONCLUSION

SMP is a common complication of SFE performed by the lateral window method. In this retrospective study, when the factors that increase the SMP rate are evaluated by regression analysis, the presence of septa, the sinus membrane thicker than 4 mm, and the age older than 55 increased the SMP rate. Prospective studies with larger samples are needed to support these results.

Competing interests: The authors declare that they have no competing interest.

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Ethical approval: The study protocol was approved by the Clinical Research Ethics Committee of Bolu Abant Izzet Baysal University (protocol number: 2019/06).

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