A novel approach to manage Schneiderian membrane perforation in the maxillary sinus floor augmentation: The "Sinus Pack" technique. Anatomical factors and surgical outcomes related to perforation size and handling. Part 3/3

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Abstract: Purpose: To highlight the different risk factors, whether surgical or anatomical, related to Schneiderian membrane perforation, while evaluating the predictability of currently available methods to manage such perforations. **Methods:** Charts of subjects experiencing perforation during maxillary sinus augmentation were retrospectively reviewed. Data related to possible anatomical and surgical risk factors were extracted. The correlation between membrane perforation size and anatomical risk factors (e.g., sinus septa, residual bone height and membrane thickness), surgical risk factors (satisfactory clinical management score - SCMs) and implant outcomes was statistically evaluated. **Results:** Nine out of 10 subjects with perforation size ≥ 5 mm presented a less than 1.5 mm (P= 0.011) sinus membrane thickness. About 80% of subjects with easy or fair SCMs presented a residual bone height lower than 4 mm (P= 0.02) The SCMs were significantly worse in subjects with a perforation size ≥ 5 mm (2.8 ± 1.5) compared to those with a perforation size < 5 mm (1.4 ± 0.7) (P= 0.03). (*Am J Dent* 2024;37:21A-24A).

Clinical significance: Techniques for the management of Schneider's membrane perforation should take into consideration anatomical and surgical risk factors, to render surgical therapies more predictable, reducing patient morbidity.

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Introduction

Scientific and technical advancements, as well as innovations in biomaterial science, provide operators with a variety of methods to perform sinus lift procedures. Two well-defined surgical approaches exist, each with its advantages and drawbacks: one is the trans-crestal approach, a minimally invasive intervention, and the other is the lateral technique, more invasive but recommended for extremely atrophic posterior maxillae. The Schneiderian membrane perforation is the most common intra-operative complication in both instances. Surgeons must know how to minimize the risk of perforation and, when necessary, how to manage it properly. Stacchi et al[1] created a hierarchical decisional guide, which all surgeons can adopt, based on residual height (3-5 mm) and sinus width (< or >12 mm).

The reported occurrence rate of accidental perforation of the Schneider membrane ranges from 10% to 56%.[2] A perforation can be caused by excessive pressure on the sinus membrane, which increases tensional stress, or by the use of inapt surgical instruments.[3] Vercellotti et al[4,5] showed that the utilization of piezo surgery tips has a less adverse impact on non-mineralized tissue compared to burs, avoiding accidental perforation of the Schneiderian membrane while maintaining apt bone-cutting capabilities.

Other causes are anatomical and include decreased membrane thickness,[6] diminished elasticity,[6,7] the presence of sinus septa[8] and increased bone floor adhesion.[9] Another important factor is the angle between the lateral and medial sinus walls. Cho et al[10] indicated that the more acute the angle, the higher the probability of membrane perforation, with a 62.5% risk for angles lower than 30°.

Several studies[11-13] linked perforations to surgical outcomes, such as implant survival, in sinus lift surgery. Diaz-Olivares et al[13] showed that membrane perforation did not affect implant survival, but it was necessary to know the size of the perforation in order to decide the appropriate treatment path.

Hernandez-Alfaro et al[14] also correlated some predictive factors (typology of surgical procedure) and clinical results (implant survival rate) with the dimension of the perforation, stating that implant survival rates correlated inversely. Moreover, membrane perforations were not a hindrance to sinus lift surgery if graft components do not leak into the sinus.

This study evaluated the different anatomical and surgical risk factors, related to Schneiderian membrane perforation and perforation size, while indicating the possible applicable resolution methods currently available. Coverage by collagen membrane and eventual suture was then compared with a new method of graft management, the "Sinus Pack" technique.

Materials and Methods

The present retrospective case-control study was conducted between September 2019 and October 2022. All subjects signed an informed consent form and the Helsinki Declaration guidelines, as revised in 2013, were followed. The study was approved by the Ethics/Institutional Review Board of the "Fondazione Policlinico Universitario A. Gemelli" (Protocol number 0009738/22).

The setting, population, inclusion and exclusion criteria, and clinical and surgical procedures, is described in Part 1 (1/3) of this study included in this same AJD issue.[15]

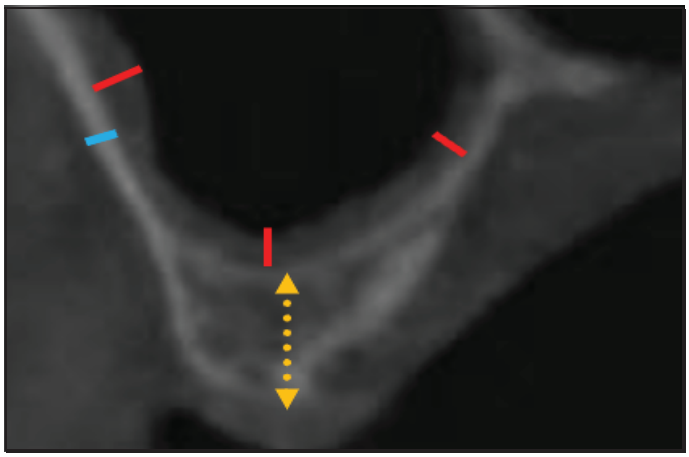

Fig. 1. Yellow line: residual bone height from the sinus floor to the alveolar crest on a coronal CBCT section at the potential implant site. Red line: Sinus membrane thickness, measured on CBCT from the top of the membrane to the sinus wall below. Blue line: lateral wall thickness measured 4-5 mm from the lowest point of the sinus floor, in the lower part of the lateral window access planned for the sinus augmentation procedure.

Outcome measures were discussed in this specific area: the link between membrane perforation size and anatomical risk factors for membrane perforation, risk factors related to surgery, surgical and post-surgical outcomes (biological and prosthetic complications, postoperative discomfort, satisfactory clinical management score of membrane perforation repair), clinical outcomes (implant survival), and radiological outcomes (marginal bone loss).

Anatomical risk factors - The following anatomical features, identified as risk factors for membrane perforations, were tracked. All anatomical measurements were taken on CBCT by two calibrated and masked examiners (P.C.P. and A.N.), properly trained for this study, twice with a 2-week interval.

1. The presence of sinus septa was assessed on sagittal, axial and coronal CBCT sections.[16]
2. Residual bone height measured in mm from the sinus floor to the alveolar crest on a coronal CBCT section at the intended implant site, classified, as ≥ 4 mm and < 4 mm[9,16] (Fig. 1).
3. Sinus membrane thickness, measured on CBCT from the internal side of the membrane to the underlying sinus wall, as a five-point (vestibular, palatal, mesial, central, distal) average of the region where surgery was planned, and classified as having a lesser risk of perforation if ≥ 1.5 mm and having a high risk of < 1.5 mm[2] (Fig. 1).
4. Lateral wall thickness (LW) was measured 4-5 mm from the lowest point of the sinus floor, in the lowest part of the lateral window access planned for the sinus augmentation procedure. Measurements were taken along the residual ridge and classified as ≥ 1 mm and < 1 mm[15] (Fig. 1).
5. Sinus angle between the medial and lateral walls at a distance of 10 mm from the sinus floor and classified as 0-30°/30-60°/> 60° 10. The first classification is the one that dictates the highest probability of membrane perforation (Fig. 2).

Surgery-related risk factors - The association of surgery-related risk factors comprised the type of membrane repair surgical method, the side of the jaw (right, left) on which the surgery was performed by a right-handed operator, the extent of sinus lift

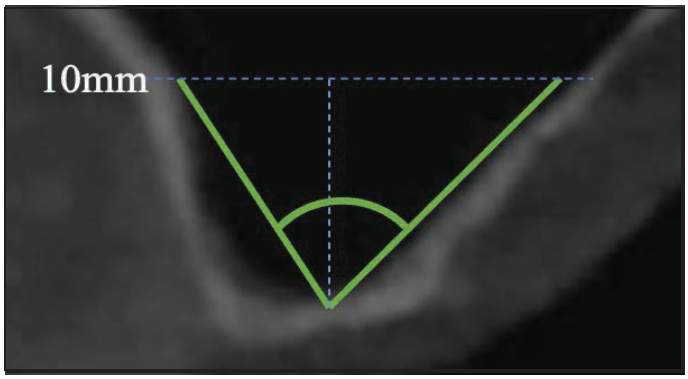

Fig. 2. Sinus angle made by the medial and lateral walls at 10mm to the floor of the sinus classified as 0-30°/30-60°/>60°.

Table 1. Subjects' characteristics.

Perforation size	
< 5 mm	9 (47.4%)
5 - 10 mm	4 (21.1%)
> 10 mm	6 (31.6%)
Residual bone height, mm	
< 4 mm	14 (73.7%)
≥ 4 mm	5 (26.3%)
Sinus membrane thickness, mm	
< 1.5 mm	14 (73.7%)
≥ 1.5 mm	5 (26.3%)
Sinus angle, degree	
0°- 29°	7 (36.8%)
30°- 60°	5 (26.3%)
> 60°	7 (36.8%)
Lateral wall thickness, mm	
< 1 mm	11 (57.9%)
≥ 1 mm	8 (42.1%)
Presence of sinus septa	12 (63.2%)
Surgical technique	
Sinus pack	11 (57.9%)
Collagen membrane covering	8 (42.1%)
Sinus lift side	
Left	8 (42.1%)
Right	11 (57.9%)
Number of implants/subjects	
1 implant	8 (42.1%)
2 implants	10 (52.6%)
3 implants	1 (5.3%)
Satisfactory clinical management	
Mean (SD)	2.2 (1.4)
Median (range)	2 (1-5)
Easy/Fair (Score 1 - 3)	15 (79.0%)
Difficult (Score 4 – 5)	4 (21.0%)

SD = Standard deviation.

based on the number of implants placed (single, multiple), and the treatment sites (premolar, molar).[2]

Adequate clinical management of sinus membrane perforation repair was evaluated by appraising the surgical efforts and maneuvers involved, the length of time, and adopted materials. A five-point Likert scale was used (1= very easy, 2= easy, 3= fair, 4= difficult, 5= very difficult).[17,18] For statistical comparison, the values were summarized into two categories: easy/fair (score 1-3) and difficult (score 4-5).

For statistical comparison, membrane perforations were categorized as small (0-5 mm), medium (5-10 mm) or wide (10-15 mm). Additional subdivision has been set in 0-5 mm and ≥ 5 mm, as indicated by de Almeida Ferreira et al.[19]

Table 2. Comparisons of anatomical, demographic, and sinus lift surgery-related risk factors concerning perforation size and satisfactory clinical management score.

		Perforation size, n (%)					Surgical performance, n (%)	
		< 5 mm (n = 9)	5 - 10 mm (n = 4)	> 10 mm (n = 6)	0-5 mm (n = 9)	≥ 5 mm (n = 10)	Easy/Moderate (n = 15)	Difficult (n = 4)
Residual bone height	< 4 mm	7 (77.8%)	3 (75.0%)	4 (66.7%)	7 (77.8%)	7 (70.0%)	3 (20.0%)	2 (50.0%)
	≥ 4 mm	2 (22.2%)	1 (25.0%)	2 (33.3%)	2 (22.2%)	3 (30.0%)	12 (80.0%)	2 (50.0%)
	P-value	0.096	0.317	0.414	0.096	0.206	0.020	1.000
Sinus membrane thickness	< 1.5 mm	5 (55.6%)	4 (100.0%)	5 (83.3%)	5 (55.6%)	9 (90.0%)	10 (66.7%)	3 (75.0%)
	≥ 1.5 mm	4 (44.4%)	0 (0.0%)	1 (16.7%)	4 (44.4%)	1 (10.0%)	5 (33.3%)	1 (25.0%)
	P-value	0.739	0.046	0.102	0.739	0.011	0.197	0.317
Sinus angle	0°- 29°	3 (33.3%)	0 (0.0%)	4 (66.7%)	3 (33.3%)	4 (40.0%)	5 (33.3%)	2 (50.0%)
	30°- 60°	2 (22.2%)	3 (75.0%)	0 (0.0%)	2 (22.2%)	3 (30.0%)	3 (20.0%)	2 (50.0%)
	> 60°	4 (44.4%)	1 (25.0%)	2 (33.3%)	4 (44.4%)	3 (30.0%)	7 (46.7%)	0 (0.0%)
	P-value	0.717	0.174	0.135	0.717	0.905	0.449	0.368
Lateral wall thickness	< 1 mm	4 (44.4%)	3 (75.0%)	4 66.7%)	4 44.4%)	7 (70.0%)	8 (53.3%)	3 (75.0%)
	≥ 1 mm	5 (55.6%)	1 (25.0%)	2 (33.3%)	5 (55.6%)	3 (30.0%)	7 (46.7%)	1 (25.0%)
	P-value	0.739	0.317	0.414	0.739	0.206	0.796	0.317
Presence of sinus secta	Yes	6 (66.7%)	3 (75.0%)	3 (50.0%)	6 (66.7%)	6 (60.0%)	9 (60.0%)	3 (75.0%)
	No	3 (33.3%)	1 (25.0%)	3 (50.0%)	3 (33.3%)	4 (40.0%)	6 (40.0%)	1 (25.0%)
	P-value	0.317	0.317	1.000	0.317	0.527	0.439	0.317
Age, years	< 50 years	5 (71.4%)	1 (14.3%)	1 (14.3%)	5 (71.4%)	2 (28.6%)	7 (46.7%)	0 (0.0%)
	≥ 50 years	4 (33.3%)	3 (25.0%)	5 (41.7%)	4 (33.3%)	8 (66.7%)	8 (53.3%)	4 (100.0%)
	P-value	0.739	0.317	0.102	0.739	0.058	0.796	0.046
Gender	Females	7 (77.8%)	2 (50.0%)	3 (50.0%)	7 (58.3%)	5 (41.7%)	10 (66.7%)	2 (50.0%)
	Males	2 (22.2%)	2 (50.0%)	3 (50.0%)	2 (28.6%)	5 (71.4%)	5 (33.3%)	2 (50.0%)
	P-value	0.096	1.000	1.000	0.096	1.000	0.197	1.000
Sinus lift side	Right	7 (77.8%)	2 (50.0%)	2 (33.3%)	7 (63.6%)	4 (36.4%)	9 (60.0%)	2 (50.0%)
	Left	2 (22.2%)	2 (50.0%)	4 (66.7%)	2 (25.0%)	6 (75.0%)	6 (40.0%)	2 (50.0%)
	P-value	0.096	1.000	0.414	0.096	0.527	0.439	1.000
Number of implants	1	3 (37.5%)	1 (12.5%)	4 (50.0%)	3 (37.5%)	5 (62.5%)	6 (40.0%)	2 (50.0%)
	≥ 2	6 (54.6%)	3 (27.3%)	2 (18.2)	6 (54.6%)	5 (45.5%)	9 (60.0%)	2 (50.0%)
	P-value	0.317	0.317	0.414	0.317	1.000	0.439	1.000

Legend: Easy/moderate: surgical performance score 1-3; Difficult: surgical performance score: 4-5, p-value determined through Mann-Whitney U test or Kruskal-Wallis with Dunn's procedure; SD=standard deviation

Results

The final sample consisted of 19 cases (12 females, 7 males, mean age 53.3 ± 10.5 years). Table 1 shows the subjects' anatomical characteristics, surgical approaches and surgical outcomes.

Regarding risk factors analysis related to the size of perforation, nine out of 10 subjects with perforation size ≥ 5 mm presented a less than 1.5 mm (P= 0.011) sinus membrane thickness. No other statistically significant differences were found. About 80% of subjects with easy or fair satisfactory clinical management scores presented a residual bone height lower than 4 mm (P= 0.02) (Table 2).

The satisfactory clinical management score was significantly worse in subjects with a perforation size ≥ 5 mm (2.8 ± 1.5) compared to those with a perforation size < 5 mm (1.4 ± 0.7) (P= 0.03).

Discussion

Correlation between perforation size and risk factors for perforation incidence - The size of the perforation has a pivotal role in the repair, because perforations smaller than 5 mm are better managed than larger ones. Some authors[19] pointed out that for small perforations coverage is unessential. When larger than 10 mm perforations are aptly handled, surgery can still be successfully completed.

In the present study, nine out of 10 subjects with perforation size ≥ 5 mm presented a thinner than 1.5 mm sinus membrane. A thin membrane was reported to be a risk factor that increases perforation frequency.[2] Another study[3] indicated that perforations occur less frequently when the membrane thickness was in a 1 to 1.5 mm scale; outside this range, the perforation rate increased two-threefold. However, the radiographic assessment did not distinguish whether the increase in membrane thickness was physiological and supported by the periosteum or caused by middle-layer subepithelial inflammation. This factor is decisive for determining the elastic resistance of the membrane and cannot be assessed retrospectively.

Evaluation of other possible anatomical risk factors (lateral wall thickness, residual bone height, sinus angle and presence of sinus septa),[8,20,21] in relation to perforation size, did not lead to statistically noteworthy results.

Demographics (age and gender) and surgery-related variables (i.e. sinus lift side, number of implants, extension of sinus lift), analyzed as risk factors for perforation size, also did not show statistical significance. This was in line with a previous study[2] in which the working position related to the treated side (right or left) and to the surgeon's working hand, the extent of sinus lift, and the number of implants, yielded no effect on the incidence of perforation.

Satisfactory clinical management score - By comparing anatomical risk factors, a statistically noteworthy difference was identified between residual bone height less than 4 mm and greater than 4 mm (Table 2). Additional significance was noted in the handling of perforations ≥ 5 mm in size that resulted more burdensome to manage surgically than smaller ones. The better results seen with the "Sinus Pack" technique, can be related to the fact that the membrane does not necessitate aggressive manipulation, thanks to the "pack", which supports the Schneiderian membrane upward instead of as it would in other techniques, therefore reducing the

risk of increasing perforation size and mechanical stress. Other techniques also entail increased time and cost, due to procedures for handling sinus membrane perforation sutures, cortical holes to stabilize sutures, and sutures to stabilize the covering collagen membranes. Conversely, the sinus pack never necessitates the use of said membranes, as the flap, lifted to insert the envelope, is then lowered to cover it. The only exception would be represented by flap periosteum shredding due to traumatic undermining, as fibers may damage the graft.

Despite the low sample size, the results of this study regarding the surgical and anatomical risk factors of Schneiderian membrane perforation, are in line with data of the scientific literature.[2,3,9,14,16] There are many effective intervention methods for the resolution of Schneiderian membrane perforation, but the "Sinus Pack" offers a solution at both preventive (it prevents accidental perforation of Schneiderian membrane and dispersion of granules) and corrective levels. Although this technique showed good clinical effectiveness, further investigations, prospective and on larger samples, are currently underway to strengthen the results, reduce bias, and create statistically and methodologically solid evidence.

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