Perforation Risk Assessment in Maxillary Sinus Augmentation with Lateral Wall Technique

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Maxillary sinus augmentation is a procedure commonly performed in patients in need of maxillary posterior implants with loss of vertical ridge height and sinus pneumatization. Previous studies have identified some factors associated with sinus membrane perforation during lateral-wall sinus elevation procedures. Although membrane perforation does not directly link to future implant failure, it has been shown to have an association with postoperative complications. In order to promote more predictable results and reduce complications during the sinus elevation procedure, especially for the lateral window approach, articles published in peer-reviewed journals were reviewed to support the proposal of a new risk-evaluation system prior to the sinus surgery. This article reviews anatomical and patient-related factors that might affect the risk of perforation during the surgery and also aims to provide a risk assessment table to enable clinicians to analyze these factors prior to the lateral sinus augmentation surgery. Int J Periodontics Restorative Dent 2020;40:373–380. doi: 10.11607/prd.4179

The events following tooth loss with consequent alveolar ridge resorption have been thoroughly studied.¹ Especially in cases with prolonged edentulism of the posterior maxilla, resorption of the alveolar ridge may also accompany maxillary sinus pneumatization and make placing dental implants very challenging or even impossible without advanced bone-grafting procedures. The predictability of maxillary sinus augmentation (MSA) via lateral window approach (LMSA) to increase alveolar bone height has been well established in the literature. Reports of long-term success of implants placed in an augmented sinus²,³ support the efficacy of LMSA in regenerating bone in the maxillary sinus cavity. However, incidence of intra- and postoperative complications have been reported, including membrane perforation, sinusitis, cyst formation, wound dehiscence, sequestration, loss of bone grafts, excessive bleeding, and even future implant failure.² Among all complications, perforation of sinus membrane is considered the most common, with an incidence rate ranging between 0% to 58.3%, with an average of 19.5%.³ Although membrane perforation does not seem to jeopardize bone formation or lower implant success rate if properly managed during the surgery,² it has been demonstrated that

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membrane laceration may result in acute sinusitis, bone graft infection, or dislodgement into the sinus cavity. A recent article also confirmed the detrimental effect of membrane perforation on graft success. Several factors have been reported to increase the perforation risk during MSA, such as membrane thickness, presence of septa, angle between lateral and medial sinus walls, location of the alveolar antral artery, etc. However, no presurgical sinus classification based on the perforation risk and the difficulty of MSA has yet been proposed in the literature. The aim of this article is to present a comprehensive presurgical sinus assessment score based on the risk of perforation, combining evidence from the literature and the authors’ expertise and experience.

Materials and Methods

To support the proposal of the framework for a perforation risk assessment (PRA) in presurgical evaluation of MSA, a review of all available literature was performed searching MEDLINE and the Cochrane Library databases. Articles published in peer-reviewed journals were included and reviewed to identify the risk factors associated with membrane perforation during LMSA.

### Perforation Risk Factors

MSA may be challenging with the presence of anatomical and patient-related factors that have been demonstrated to increase the likelihood of complications. A comprehensive presurgical evaluation of the risk-associated parameters may help the clinician to evaluate the risk of complication during MSA and, further on, establish a plan to avoid them during procedure. Table 1 summarizes the risk factors and the situation related to low, moderate, and high risks of perforation. Based on the presence of anatomical and patient-related risk factors with high risk of perforations, a PRA tool was proposed.

### Anatomy-Related Risk Factors

#### Sinus Membrane Thickness

According to a systematic review, average sinus membrane thickness is 1 mm; it should also be noticed that cone beam computed tomography (CBCT) images tend to overestimate...
membrane thickness by 2.5 times compared to histologic findings. Although this article concluded that there is not enough evidence linking membrane thickness and perforation risks, several authors have reported a correlation between membrane thickness and perforation rate. Lum et al demonstrated that patients who experienced membrane tearing during LMSA had a much thinner membrane (average: 0.84 mm) than patients who did not have a perforation (average: 2.65 mm). A similar conclusion was obtained by Pommier et al, who investigated the mechanical characteristics of the sinus membrane, showing the advantage of thicker membranes in tolerating higher forces than thinner ones. In addition, membrane thickness could also be affected by age (> 40 years), but not by gender or the time at which the scan was taken; and excessive thickness may represent a pathologic condition, which might result in a higher chance of perforation (eg, sinusitis or inflammation).

Similar to a previous review paper, 1.5 to 2.0 mm was also determined to be a favorable membrane thickness, while 0.8 to 1.49 mm and 2.01 to 2.99 mm were considered normal thickness and < 0.8 mm and > 3 mm unfavorable thickness. Membrane thickness between 1.5 to 2.0 mm is less prone to perforations (Fig 1).

Presence of Sinus Septa
The presence of sinus septa (Underwood's septa) can be found inside the maxillary sinus with a frequency between 28.4% to 44.8% (Fig 2), and a study has also linked the presence of sinus septa to the thinning of the sinus membrane, which may account for a higher perforation rate when performing MSA. The presence of septa also affects the design of the osteotomy window for sinus elevation. Single septum is more commonly observed than multiple septa (4.2%), with an average height ranging between 6.3 to 7.5 mm. In particular, Wen et al identified a 6-mm septa height as the cutoff point for clinicians to carefully address the surgical design, as these cases might have a higher membrane perforation rate.

Direction of Sinus Septa
The majority of the septa orientation observed in the sinus cavity has a mediolateral direction (transverse) with a frequency between 59.2% to 87.6%, while fewer patients presented with septa running anteroposterior (sagittal). While transverse septa can be bypassed by creating two separate bony windows or by creating one large window over the septa, MSA in the presence of sagittal septa can be very challenging with an increased risk of membrane perforation (Fig 3).

Type of Edentulism and Root Position Relative to the Sinus Cavity
The risk of membrane perforation can also be associated with the type of edentulism at the area planned for LMSA and future implant placement. Von Arx et al showed...
that mixed premolar-molar sites have a relatively higher perforation rate (41.2%) than premolar sites (16.7%) or molar sites (26.2%).

Moreover, more challenging situations arise from cases with a single missing tooth; in these conditions, the membrane elevation could have a higher risk of perforation due to the elevation area being closer to adjacent teeth roots or the thicker lateral wall of the sinus.

**Residual Bone Height**

Two retrospective studies reported an increased risk of membrane perforation when the patients presented with a residual ridge height less than 4 mm. However, a 7-times–higher perforation risk has been shown in patients with residual bone height of 3 to 6 mm compared to patients with less than 3 mm of bone height. Despite the conflicting results presented, it is generally accepted that in the presence of reduced bone height, particularly less than 4 mm, there might be a higher chance of membrane perforation during MSA.

**Sinus Width**

Cho et al showed that a narrow sinus anatomy could relate to increased perforation risk. When the angle between the lateral and medial walls of the sinus is < 30 degrees, the risk of
membrane tearing was found to be higher (62.5%), compared to sinuses with an angle between 30 to 60 degrees or even wider sinuses (> 60 degrees), where the perforation rate decreased to 0% to 28.6% (Fig 5). In addition, it has been shown that a narrow sinus morphology is more often found in the second premolar area, where the elevation may be more prone to perforation.19

**Palatonal Recess Angle**
The palatonal recess is defined as the angle between the roof of the hard palate and the lateral wall of the nasal cavity20 (Fig 6). An acute angle of the palatonal recess could increase the complexity and difficulty when performing MSA and limit the height of elevation, especially if the acute recess angle is presented less then 15 mm away from the alveolar ridge. In a CBCT study, the incidence of an acute palatonal recess was found to be 15%, 8.2%, and 2.4% at the second premolar, first molar, and second molar sites, respectively.20

**Alveolar Antral Artery**
The infra-osseous anastomosis of the posterior superior alveolar artery and the infraorbital artery has been
defined as alveolar antral artery (AAA)²¹ (Fig 7). It has been shown that the intraosseous anastomosis is always present, while the extraosseous anastomosis only exists in 44% of cases.²¹ Injury to the AAA during MSA may result in bleeding that may impair the visualization of the membrane during the detachment, therefore increasing the risk of membrane laceration. According to Rosano et al, the AAA can display three different patterns: completely intraosseous, partially intraosseous, or under the periosteum of the lateral sinus wall. In particular, at the area from second premolar to second molar, the AAA is commonly found to be adjacent to the sinus membrane with no bony layer interposed between the vessel and the membrane.²² Based on CBCT scans, it was reported that in 62.2% of cases the diameter of the AAA is less than 1 mm, while the remaining 37.8% exhibited a diameter of greater than 1 mm.²³ Another study also showed that a diameter ≥ 2 mm was found in only 4.3% of the cases.²² An AAA with a diameter between 0.5 to 1 mm accounts for intraoperative bleeding in about 10% of the cases, while the likelihood of hemorrhage is around 57% when the AAA diameter is 1 to 2 mm.²⁴ The location of AAA also has to be taken into account when designing the bony window, as well as its distance from the alveolar crest or sinus floor (11.25 to 26.9 mm and 5.8 to 10.4 mm, respectively).²⁵

### Patient-Related Factors

Patient-related factors may affect the risk of intra- and postoperative complications. Among all the factors, a smoking habit has been associated with higher incidence of perforation and postoperative complications, such as sinusitis and wound dehiscence.¹⁷ However, whether smoking affects implant survival in an augmented sinus remains controversial.²⁶ It has been reported that sex, similar to age, is not related to increased membrane perforation.¹⁵ However, one study concluded that preoperative chronic sinusitis might be a significant cause of postoperative infection and implant loss, suggesting an appropriate treatment of this condition before MSA.²⁷ Lastly, Yilmaz and Tözüm discovered a strong correlation between gingival phenotype and membrane thickness, yet only a moderate correlation was observed between gingival phenotype and membrane perforation.⁹

### Discussion

Membrane perforations during MSA have been correlated with an increased risk of postoperative complications.⁴,⁵ An acute or chronic sinus inflammation, bacterial contamination, and graft infections may jeopardize the success of MSA.⁴–⁶ Furthermore, despite the fact that membrane perforation is not an absolute contraindication to continue the procedure, it may prompt the clinician to abort the surgery, particularly if the size of the perforation is substantial. Several techniques have been proposed to manage sinus membrane perforation.²⁸ However, it seems that it is the dimension of the perforation rather than the repairing technique that affects the outcomes. Although membrane

### Table 2 Perforation Risk Assessment

<table>
<thead>
<tr>
<th>Risk</th>
<th>Definition</th>
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<tr>
<td>Unlikely</td>
<td>All conditions meet low risk of perforation or &lt; 3 conditions at moderate risk</td>
</tr>
<tr>
<td>Possible</td>
<td>One condition at high risk of perforation or ≥ 3 conditions at moderate risk</td>
</tr>
<tr>
<td>Likely</td>
<td>At least two conditions at high risk of perforation</td>
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Perforation Risk Assessment

Based on the reviewed literature and the expertise of the present authors, an assessment tool with low, moderate, and high perforation risks were identified for each of the previously discussed factors (Table 1). When all the anatomical and patient-related risk factors meet low risk of perforation or when less than three conditions are at moderate risk, then perforation is unlikely. In the presence of one condition at a high risk of perforation or when at least three conditions at a moderate risk, the perforation is considered possible. Similarly, when more than one risk factor is found to be at a high risk of perforation, the perforation is likely (Table 2).
perforations do not necessarily result in postoperative complications or affect the survival rate of future placed implants, there is no doubt that avoiding perforation will reduce the time of the surgery and increase the likelihood of achieving an uneventful healing. In addition, it has been speculated that the membrane periosteum may possess the cells that have the capacity for bone regeneration and that membrane tearing may reduce the amount of regeneration. On the other hand, placing a collagen membrane over the perforation was shown to be an effective technique for repairing membrane tearing.

The present article discussed the main factors that have proved to be associated with an increased risk of membrane perforation, identifying for each one a low-, moderate-, and high-risk condition for membrane tearing (Table 1). By analyzing all the proposed risk factors presurgically, clinicians can easily assess the difficulty level of the surgery and rate the risk of membrane perforation. The PRA will also facilitate communication between clinicians in describing the characteristics of the maxillary sinus. Previous classifications were exclusively focused on a single risk factor and therefore could not be used for describing the overall risk of the perforation or the difficulty of the procedure. Lastly, the present article will also contribute to literature by classifying the maxillary sinus before the elevation and providing a source of uniform data in terms of incidence of membrane tearing and postoperative complications.

Conclusions
The presented assessment tool offers a feasible method of assessing the risk of perforation during LMSA based on the presurgical evaluation of key factors related to membrane tearing. Prospective clinical studies are necessary to validate the proposed risk of perforation risk assessment.

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