Classification of Sinus Membrane Perforations Occurring During Transcrestal Sinus Floor Elevation and Related Treatment

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The predictability of transcrestal sinus floor elevation (tSFE) in elevating the sinus membrane following posterior maxillary ridge resorption has been widely demonstrated. To minimize complications and increase success, a literature search was conducted to validate procedures used for tSFE. A decision tree based upon timing of perforations was then developed to improve membrane-perforation management during the procedure. At each surgical procedure, the clinician is encouraged to use size of the perforation, time during the procedure in which the perforation occurred, and resulting symptoms to determine the best treatment approach. This article discusses all possible sinus membrane perforations based on timing of that surgical procedure, allowing the clinician to recognize and successfully rectify this clinical complication while successfully completing the surgery. With this aim, a classification of sinus membrane perforations occurring during tSFE is proposed, simultaneously providing guidelines to effectively manage these complications. Int J Periodontics Restorative Dent 2020;40:111–118. doi: 10.11607/prd.3602

The current most documented modality of augmenting atrophic posterior maxillary ridges is the maxillary sinus floor elevation (SFE).1 Despite the high success rate of this procedure accompanied by the long-term success rates of implants placed in these augmented sinuses,2 a relatively large frequency of associated complications still exists.3 In particular, sinus membrane (SM) perforation is the most common of these complications, reportedly presenting at up to 56%.4 Unfavorably, the incidence of SM perforation during SFE will bear down on the overall intra- and postoperative complication rate of surgery.5 In addition to a significantly reduced implant survival rate,6 a wide array of additional complications might arise from SM perforation, including graft infection and/or failure,7 reduced bone formation,6 increased peri-implant marginal bone loss,6 and sinus infection/sinusitis.8 SM perforation’s negative impact on the outcome of bone regeneration following maxillary sinus elevation has also been documented.9 Therefore, SM integrity during SFE is considered to be essential for promoting osteogenesis and bone formation.10

Maxillary transcrestal SFE (tSFE) was introduced in the 1980s and later modified by Summers11 as an alternative to the more invasive lateral window sinus floor elevation.
(LSFE), to be applied at sites with sufficient bone width and a residual bone height of ≥ 5 mm. Primarily due to the limited intraoral visibility, intraoperative membrane perforation is not an uncommon event. One systematic review reported an incidence of membrane perforation between 0% and 21.4% with tSFE. Nonetheless, this incidence is thought to be underestimated, mainly due to the objective difficulty in clinical detection of such perforations. Indeed, when endoscopy was used to verify SM perforations during tSFE, this rate booms to a resounding 40%. It is quite important to mention that complications resulting from these “confined” tSFE perforations are not much different from complications associated with perforations during LSFE.

Since the traditional osteotome tSFE technique is accompanied by the risk of SM perforation and causing benign paroxysmal positional vertigo due to extensive trauma from the mallet, several authors have introduced novel techniques to overcome these limitations. These minimally invasive techniques aim to expose and elevate the SM with specifically designed devices, such as balloon catheters and piezoelectric units. However, despite the application of advanced instruments, perforations during tSFE do occur, and no prior mention of managing these complications is present in the literature.

Several classifications, with correlated treatment options, of SM perforations associated with LSFE have already been proposed. More specifically, a couple of classifications were introduced to weigh the classes of perforation most correlated with implant failure. Although tSFE-related perforations tend to occur more often than their LSFE-related counterparts, no authors have previously proposed a classification for SM perforation, as well as related treatment, during tSFE. Hence, the purpose of this paper is to introduce a classification system for transcrestal SM perforations and further discuss possible therapeutic options, enabling a surgeon to proceed with implant placement despite membrane tearing.

**tSFE Perforation Classification and Treatment Recommendation**

When performing a tSFE, clinicians may encounter SM perforations during osteotomy preparation, sinus membrane elevation, bone graft placement, and implant insertion (Figs 1 and 2).

The present classification numbered the perforation types according to the phase of surgery in which the perforation may occur. Consequently, clinicians can base...
their perforation classification not solely upon direct visualization but also upon the surgical phase in which the perforation has taken place. This method simplifies the classification process to a great extent, thus enabling instant clinical decision-making for perforation management.

Multiple authors suggested that the most reliable method to detect SM perforations during tSFE is endoscopy. Because using endoscopy to control the membrane’s integrity for each tSFE procedure is not feasible in daily dental practice, it may be reasonable to assume that unacknowledged SM perforations may occur. Beyond endoscopy, the authors believe that the most effective methods for assessing the presence of a perforation include the Valsalva maneuver, periapical radiographs (once the bone graft has been inserted), and evaluation via microscope or magnifying loupes.

The Valsalva maneuver involves moderately forceful exhalation against a closed airway; easily achieved by the patient closing his/her mouth and nostrils while simultaneously gently breathing out. A negative result does not necessarily imply membrane integrity, while a positive result, recognized as exhaled air moving from the maxillary sinus through the prepared implant site, indicates the incidence of an oroantral communication as a result of membrane perforation.

**Type I**

Type I perforations are those caused by implant drills that have unintentionally torn the SM during osteotomy preparation (Figs 1 and 2).

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Fig 2 *Sinus membrane perforations occurred during tSFE in cadavers.* (a) Intact sinus membrane. (b) Perforation provoked by a pilot drill (type I). (c) Large laceration caused by an implant drill (type I). (d and e) Perforations that occurred during membrane elevation with manual instruments. (f) Membrane collapse following an overfill of bone graft.
The size of the perforation may depend on the diameter of the drill that lacerates the SM. If the perforation is relatively small (approximately < 2 mm) (type I), the clinician must first assess the exact residual bone height underlying the SM by utilizing a radiographic positioning pin and an intraoral periapical radiograph. Implant site osteotomy should then be continued with the additional use of drill stoppers. Once the SM is exposed, the clinician must use a manual sinus elevator to gently detach and elevate the SM. The elevation of the SM in this fashion may allow it to simply fold over the central perforation induced by the drill, thus self-correcting the perforation. However, before inserting the implant to the correct planned length, the authors suggest the prior application of a cushion material, such as a collagen tape or a bioresorbable collagen membrane/plug, over the perforation. In these situations, to avoid potential graft particles passing through the SM perforation during the early stages of healing, additional bone grafting is not recommended. The literature reports that perforations and the eventual subsequent graft dislodgment into the sinus may increase the incidence of maxillary sinusitis, infections, and Both graft and implant failures. Alternatively, a bone graft mixed with microfibrillar collagen can be used due to the “paste-like” consistency of this biomaterial, rendering graft dislodgment into the sinus unlikely. However, if for some reason the perforation is augmented during elevation of the SM, the residual alveolar ridge height dictates whether short implant placement is possible. Indeed, the efficacy of 6-mm implants in the maxilla has been well-demonstrated in randomized clinical trials. However, it is recommended to position a collagen sponge in contact with the perforation before insertion of the short implant.

**Type II**

Where the residual alveolar ridge does not allow the placement of a short implant, one viable option is to perform an LSFE to correct the perforated sinus membrane while completing the sinus lift augmentation procedure. According to techniques described by Vlassis and Fugazzotto, the clinician has the capability to repair the membrane perforation through the lateral sinus window. When the SM perforation caused by a drill is configured into a large or extensive laceration (approximately ≥ 2.0 mm) (type I), placement of a short implant (if possible) or performing an LSFE are alternative treatment options for managing the perforation. The reason for choosing 2.0 mm as cutoff value between small and large perforations is based on the diameter of the initial osteotome drill. The authors recommend trying to elevate a lacerated membrane only when the perforation size is smaller than 2.0 mm, while a larger perforation requires alternative treatment. However, when the perforation occurring during tSFE is wide (approximately ≥ 5.0 mm), aborting the surgery may be considered if short implant insertion is not possible and the laceration cannot be repaired even through the lateral window approach.

The authors recognize that distinguishing between small or large size perforation is not always feasible. However, the use of microscope or magnifying loupes can often help in visualizing the lacerated SM.

The SM lacerations resulting from SM elevation or bone graft placement are classified as type II perforations (Figs 1 and 2). These perforations are typically caused by improper membrane detachment from the underlying sinus floor or from collapse of the SM consequent to graft insertion.

Many factors are believed to play a key role in overstretching the membrane beyond its physical limits. The configuration of bone graft particles can be rounded or relatively sharp, and overfilling the space underlying the elevated SM, especially with sharp bone graft particles, may cause microperforations of the membrane or may provoke membrane collapse and perforation. Another factor that can provoke or facilitate type II perforations is insufficient membrane detachment from the surrounding bone; this leads to an increased risk of perforation during graft positioning or implant insertion due to the membrane’s excessive resistance to elevation. The clinician’s tactile sensitivity, membrane thickness and morphology, the anatomy of the sinus, and membrane elevation technique may also be involved in the physiologic threshold of stretching the SM. As demonstrated by
Pommer et al,15 a thicker membrane expresses enhanced tolerance to stretching and loading.

For this class of perforations, the best applicable therapeutic option is reverting tSFE to LSFE, which enables the clinician to repair the perforation and place the implant simultaneously with the bone graft. Once again, whenever possible, short implants represent an alternative compromise to avoid lateral bony antrostomy.

**Type III**

Type III perforations belong to the class comprised of lacerations resulting from the collapse of the SM following implant placement (Figs 1 and 2). According to Garbacea et al, most perforations occur during implant placement.14 Overfilling the area with bone graft can also be responsible for perforations that occur during implant placement, where the membrane collapses under the pressure of bone particles forced against the membrane surface.14 Moreover, it has been suggested that an adequate or slightly less adequate amount of bone graft promotes improved and faster healing.7,20 It can be speculated that bone graft overfilling and vertical elevation of the SM beyond its stretching limit25 are the main cause for laceration occurring during implant insertion.

Unfortunately, most type III perforations can go unacknowledged and the clinician is, in turn, helpless. Accordingly, a postoperative radiograph is mandatory, as it can sometimes reveal graft dislodgment into the sinus resulting from an unrecognized perforation (Fig 3). If the periapical radiograph is suggestive of SM perforation with or without bone graft in the sinus, the situation should be monitored over time with frequent follow-ups. In case of postoperative sinus symptoms (such as chronic nasal drainage, headache, inflammation of the oral buccal mucosa, and mucosal fistula) and abnormal signs on the computed tomography scan suggesting an infection process, a surgical approach has been proposed by Urban and coworkers involving the removal of the infected graft particles and the local application of doxycycline together with a systemic antibiotic.26 This protocol also includes the use of a nasal decongestant spray in case of concomitant sinusitis. However, these authors highlight that when this approach fails to resolve the infection, a more aggressive surgery involving complete graft removal and/or endoscopic surgery with the otolaryngologist is recommended.26

A flowchart of recommended managing of perforations is depicted in Fig 4.

**Discussion**

Several authors agree that tSFE is recommended in the presence of an initial residual bone height of at least 4 to 5 mm.12 When the ridge is severely resorbed, performing tSFE instead of LSFE puts a strain on the membrane’s physical threshold. Pommer et al15 reported that
Cadaver sinus membranes can be stretched up to 132.6% of its original site in one-dimensional elongation. Insufficient all-round membrane detachment before the final elevation is believed to show negative correlation with membrane integrity; unfortunately, this procedure is too often underestimated.

Due to limited access and visibility, repairing perforations that occur during TSFE often poses some difficulty. For this reason, only a limited number of overall perforations can be successfully handled by proceeding with membrane detachment and elevation followed by using cushioning agents (collagen tape, bioresorbable membrane). Unfortunately, most of the perforations require the insertion of an implant shorter than planned or the LSFE, the latter being undoubtedly more invasive. The authors want to emphasize that placing shorter implants in the case of a perforation should be considered only when

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**Fig 4** Flowchart of the recommended treatment of each perforation according to the proposed classification. LSFE = lateral window sinus floor elevation; SM = sinus membrane; CBCT = cone beam computed tomography.
the residual alveolar ridge is at least 6 mm.23

It has also been proposed that the SM be repaired endoscopically through the canine fossa; however, the authors themselves recognize that the presence of specialized instruments in the daily surgical practice is one of the main limitations of this approach.27 Bearing in mind that the most successful approach to managing intraoperative perforations is preventing them rather than successively treating them, careful preoperative CBCT assessment is highly recommended. This integral prerequisite allows for the detection of several parameters that are associated with increased perforation risk, such as an oblique sinus floor, the presence of Underwood’s septa, and a membrane thickness narrower than 0.5 mm or wider than 3 mm.24,28

While there is still an ongoing debate on whether bone grafting in the created subantral space is accompanied by added benefits,24 there is no doubt that an intact SM contains the existing blood clot, providing a superior healing environment around the implant’s apex.22,24 Jung et al showed that implants protruding < 2 mm into the sinus can be totally and spontaneously covered by newly formed membrane, while implants protruding > 4 mm can be only partially covered by the new membrane without developing postoperative complications.29 However, the authors believe that every case should aim to place implants completely surrounded by bone, including during tSFE. There is evidence that new bone formation can be achieved without the addition of bone graft; this is probably due to the membrane’s integrity that, together with the implant’s tenting effect, allows the blood clot to fill the maxillary sinus space and to make de novo bone formation possible. The integrity of the membrane is thus the key factor involved in the healing process and in the formation of new bone without augmenting the potential for postoperative complications.

The limitation of this classification is the need for high magnification (such as a microscope and magnifying loupes) to assess the perforation. Nonetheless, it is the authors’ opinion that a new device of endoscope entrance from the osteotome access hole will soon be developed to facilitate and simplify the process, thus allowing for this classification’s easier chairside application.

Conclusions

The presented classification offers a feasible method of recognizing and managing perforations that may occur during tSFE. Clinical studies remain necessary to validate this proposed classification and subsequent management of tSFE perforations.

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References


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