Check for updates

Received: 21 May 2024 | Revised: 2 September 2024 | Accepted: 9 September 2024

DOI: 10.1111/cid.13397

REVIEW

WILEY

Prevention and management of intra-operative complications in maxillary sinus augmentation: A review

Pascal Valentini DDS[1] | Claudio Stacchi DDS, MSc[2]

[1]Institute of Health, Department of Implant Surgery, Tattone Hospital, University of Corsica Pasquale Paoli, Corte, France

[2]Department of Medical, Surgical and Health Sciences, University of Trieste, Trieste, Italy

Correspondence
Pascal Valentini, Université de Corse, Institut Universitaire de Santé, Campus Grimaldi, 20250 Corte, France.
Email: drpascalvalentini@gmail.com

Abstract

Maxillary sinus floor elevation is usually performed in two different ways: the lateral approach involves the creation of a bony window on the maxillary sinus lateral wall, providing direct access to the sinus cavity for membrane elevation and subsequent graft placement, and the transcrestal approach is considered less invasive. The aim of this article is to describe, based on the literature, how to anticipate, avoid, and manage the intraoperative complications that can occur with both approaches. For both approaches, the most common complication is the sinus membrane perforation. For the lateral approach, an average frequency ranging from 15.7% to 23.1% is reported, but because of the better visibility, their management will be easier compared to the transcrestal approach. Mean perforation rate reported for the transcrestal approach is lower (3.1%–6.4%), but it should be noted that a significant number of perforations cannot be detected and managed given the blind nature of this technique. Anatomical parameters such as sinus width and buccal wall thickness may be a risk factor for one approach and not the other. As it is impossible to assess the resistance of the Schneiderian membrane, the transcrestal approach is more likely to lead to infectious complications in the event of perforation. Others, such as the risk of vascular damage, are encountered only with the lateral approach, which can be prevented easily by dissecting the alveolo-antral artery. For both approaches, prevention is essential and consists in analyzing the anatomy, mastering the surgical technique, and collaborating with the ENT to manage the essentially infectious consequences of intraoperative complications.

KEYWORDS

intraoperative complications, lateral approach, maxillary sinus augmentation, membrane perforation, transcrestal approach, vascular damage

Pascal Valentini and Claudio Stacchi contributed equally to the redaction of this article.

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2024 The Author(s). *Clinical Implant Dentistry and Related Research* published by Wiley Periodicals LLC.

Summary Box

What is known

- Intraoperative complications may lead to postoperative infections.
- Transcrestal approach is less invasive compared to the lateral approach.

What this article adds

- Lateral approach allows better management of sinus membrane perforations.
- The transcrestal approach, being a blind technique, requires special care in preoperative planning to avoid complications.

1 | INTRODUCTION

Maxillary sinus floor elevation, also known as sinus lift, is a commonly performed procedure in oral implantology to increase the available bone height in the posterior maxilla, facilitating successful implant placement. The two most common surgical approaches for maxillary sinus lift are the lateral approach (the first to be proposed over 40 years ago)[1] and the transcrestal approach,[2] aimed at limiting the invasiveness of the conventional procedure while seeking to achieve similar clinical results.

The lateral approach involves the creation of a bony window on the maxillary sinus lateral wall, providing direct access to the sinus cavity for membrane elevation and subsequent graft placement. The main advantage of this technique is that the surgeon has the opportunity to directly control the most delicate part of the procedure, namely, the detachment and elevation of the sinus membrane.[3] This allows for optimal lifting of the Schneiderian membrane from the bony walls of the sinus regardless of the size of the cavity and the creation of an adequate sub-sinus space, which allows for the placement of the graft even in contact with the medial wall of the sinus, optimizing new bone formation.[4,5]

Transcrestal sinus floor elevation, also known as the osteotome technique, is a minimally invasive approach to sinus augmentation.[2] Unlike the lateral approach, transcrestal sinus floor elevation entails making a minimal antrostomy on the alveolar crest, performed using osteotomes, piezoelectric inserts, or specially designed burs.[6–8] This opening is frequently utilized for implant placement following the elevation of the sinus membrane and grafting procedure. The main limitation of the transcrestal approach is that membrane elevation occurs indirectly, lifted hydrodynamically using saline solution or by granular or injectable biomaterial (paste or gel).[9,10] The surgeon lacks direct control over the direction and extent of membrane elevation: in transcrestal sinus floor elevation, predictable exposure of both lateral and medial bone walls occurs primarily in narrow maxillary sinuses.[11]

While advancements in biological understanding and surgical techniques have improved the predictability and success rate of maxillary sinus augmentation, intraoperative complications remain a concern for clinicians.[12] In both lateral and transcrestal approaches, they can range from minor issues to more severe events, potentially leading to surgical failure or increased postoperative morbidity. Preventing and managing possible intraoperative complications is a crucial point for improving patient safety and treatment success. Clinicians should anticipate and address potential risks through strategic planning and execution and, at the same time, be aware that effective management of complications is essential for minimizing adverse effects and enhancing surgical procedure success.[12,13]

Throughout this review, we will examine various aspects of intraoperative complications in both lateral and transcrestal maxillary sinus augmentation, including anatomical considerations, surgical techniques, graft materials, and patient-related factors. By addressing each of these components comprehensively, we aim to offer practical guidance and recommendations that can inform clinical decision-making and, ultimately, improve clinical outcomes.

2 | INTRAOPERATIVE COMPLICATIONS

2.1 | Sinus membrane perforation

Sinus membrane perforation is the most frequent complication in maxillary sinus augmentation with lateral approach, with an average frequency ranging from 15.7% to 23.1%,[12,13] but with significant variations across individual studies (0%–60%)[13] depending on the surgeon's experience, surgical technique, anatomical conditions, and patient-related factors.[14–17] Mean perforation rate reported for the transcrestal approach is lower (3.1%–6.4%),[16,18–20] but it should be noted that a significant number of perforations may not have been detected, given the blind nature of this technique. Indeed, when endoscopy was employed to confirm sinus membrane perforation during transcrestal sinus floor elevation in cadaver specimens, this rate increased significantly to 40%.[21]

Perforation of the sinus membrane can result in dissemination of grafting material into the sinus cavity, potentially compromising the patency of the ostiomeatal complex and triggering local inflammation often leading to postoperative sinusitis.[22–24] Recognizing and addressing risk factors associated with membrane damage is essential to achieving successful outcomes in sinus augmentation procedures.[25]

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

2.1.1 | Risk factors and prevention

Antrostomy technique

Lateral approach. Even if some clinical studies reported no difference in membrane perforation risk between rotary and piezoelectric instruments,[26–28] systematic reviews and meta-analyses concluded that membrane perforations during lateral sinus augmentation may be significantly reduced applying piezoelectric devices.[14,29] However, in studies comparing the use of piezoelectric bone surgery for creating a lateral access to the sinus, outcomes varied depending on the surgical approach. When bone window outlining and reflection into the sinus were performed, perforation prevalence was 17.6%, similar to rotary instruments.[14] However, the prevalence decreased significantly to 4.7% when ultrasonic instruments were used to thin the lateral wall before opening the window.[30] This approach allows, especially when the lateral wall of the sinus is thick, to have better surgical control, to perceive the proximity to the membrane thanks to the change in color (the thinned area becomes darker because the sinus cavity is visible through it in transparency), and to clearly identify the position of Underwood septa, if present. Overall, within the limitations of the available studies, it appeared that thinning the lateral wall with ultrasonic instruments or bone scrapers reduces the incidence of accidental Schneiderian membrane perforations during antrostomy.

Transcrestal approach. There are no studies in the literature directly comparing the various techniques used to create crestal access to the maxillary sinus (manual or electric-driven osteotomes, piezosurgery, various burs designed for this specific application) with regard to perforation prevention. In the absence of sufficient evidence, it is suggested to apply the technique in which the operator is experienced and has achieved a good learning curve to limit the risk of perforation at this stage of the surgical protocol.

2.1.2 | Anatomy

Membrane thickness

The thickness of the sinus membrane has long been a subject of debate. While some consider a thick membrane as indicative of resilience and view a thin membrane as fragile,[31,32] studies on cadaver specimens[33] have shown that membrane thickness does not consistently correlate with resistance to tearing. Similarly, it has been demonstrated that sinus membranes measuring 1–1.5 mm in thickness exhibit greater resilience compared to those that are thinner or thicker.[34]

Since the literature reports contradictory information, it is difficult to predict the risk of perforation based solely on the thickness of the membrane observed on CBCT, which is often overestimated.[33]

Gingival phenotype

This parameter may also be considered during pre-surgical planning to aid in assessing the risk of membrane perforation.[23] It has been noted that a thick gingival phenotype is correlated with a thick sinus membrane, and vice versa.[35,36] However, as discussed earlier, establishing a direct correlation between phenotype and the risk of perforation presents challenges.

Sinus width

The width of the sinus cavity is an important factor to consider in the risk assessment for Schneiderian membrane perforations.[37–39] This parameter can be assessed by measuring the angle between the buccal and palatal walls on CBCT cross-section images. Normally, this angle is narrower in the most mesial area of the cavity as we approach the anterior wall, while it tends to become wider as we move in the distal direction.

In the lateral approach, when this angle is <30°, the prevalence of perforation exceeds 60%, decreasing as the angle becomes wider.[37] This could be due to the difficulty in finding the correct cleavage plane for membrane detachment and therefore using manual instruments appropriately in such a narrow space. Therefore, the anterior part of the sinus cavity, being a narrow zone, represents a high-risk area when performing lateral approach[12,13] (Figure 1). Consequently, the surgical window should be positioned as anteriorly as possible to allow for direct visualization and dissection of the membrane in the most critical area.[3]

Interestingly, the width of the sinus cavity seems to have completely different effects on influencing the risk of membrane perforation in the transcrestal approach. A recent multicenter study conducted on 430 patients showed a significant correlation between bucco-palatal sinus width and membrane perforation, with an extremely low perforation rate observed in narrow sinuses and a much higher incidence in wide sinuses.[40] This finding is a clinical confirmation of a principle described by Pommer et al. (2009),[32] demonstrating that the force needed for membrane detachment during transcrestal sinus elevation increases with the size of the elevated area. When this force surpasses the sinus membrane elastic properties, perforation can occur. In narrow sinuses, where the elevated area is smaller compared to wide sinuses, higher elevation heights can typically be achieved before membrane tearing occurs. It is noteworthy

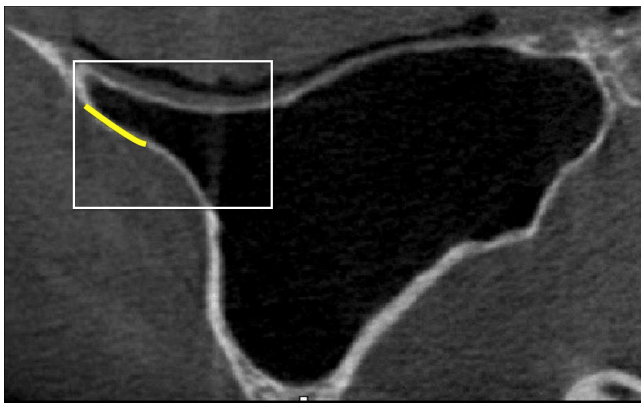


FIGURE 1 The window (yellow line) must be as anterior as possible (white rectangle).

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

that this situation is the exact opposite of what happens in sinus floor elevation with a lateral approach, creating an interesting complementarity between the two surgical techniques.

Palato-nasal recess

The palato-nasal recess, located between the roof of the hard palate and the lateral wall of the nasal cavity, can be found at various heights on the medial wall of the maxillary sinus.[41] The average height of this recess gradually decreases from the premolar to the molar sites. Its position and angulation can impact the level of difficulty encountered during membrane elevation on the medial wall, in both lateral and transcrestal approaches: the sharper this angle, the higher the risk of perforation. Taking into account both the location and angulation, ~15% of premolar sites may exhibit an acute-angled palato-nasal recess, complicating membrane elevation. In contrast, this condition is observed in only about 2% of molar sites within the surgical area of sinus floor elevation.[22,41]

Thickness of the buccal wall

The thickness of the lateral wall plays a role in the risk of perforation only during lateral approach.[39,42,43]

As said previously, the ultrasonic erosion of the lateral wall is the safest approach to avoid membrane perforation.[14] However, if the lateral bone wall is thick, erosion can be time-consuming, and complete removal may be preferred.[44,45] Nevertheless, complete removal carries a risk of perforation due to limited surgical control, especially if the membrane is strongly attached and in the presence of Underwood septa. To prevent tearing, the bony lid can be divided into several pieces and detached one by one (Figure 2a,b).[46] This approach reduces the pull-out force but is contraindicated if there is an intraosseous passage of the alveolo-antral artery.

Clearly, the thickness of the buccal wall has no influence on the risk of sinus membrane perforation during a transcrestal approach.

Septa

The identification of Underwood septa underscores the importance of thorough 3D preoperative imaging to meticulously assess the internal sinus anatomy, given its significant impact on surgical approach.[47] The anticipated risk of perforation is lower with medio-lateral septa compared to antero-posterior septa,[28] necessitating the implementation of a specific technique tailored to the anatomy.[48] As an example, when the sinus is divided into three different cavities by two full medio-lateral septa, it is preferable to plan the creation of three windows.[49] If encountering an antero-posteriorly oriented septum, it should be removed using ultrasonic osteotomy at its base after elevating the membrane to expose the septum.[46] Alternatively, it is possible to combine the buccal approach with a palatal window without the need to remove the septum. An innovative approach[50] has been suggested when the sinus presents complex septa and sinus floor convolutions. This technique involves partially cutting and removing septa followed by mucosal elevation without graft placement. After a few months, the sinus mucosa thickened due to scarring, allows for more predictable membrane elevation.

Also in the transcrestal approach, it is essential to precisely identify the position and orientation of Underwood septa to assess any potential impact on the regenerative procedure. If a medio-lateral septum is present at the augmentation site, sinus crestal access and subsequent grafting should be planned either mesially or distally to it (Figure 3a,b). When the septum orientation is antero-posterior, crestal osteotomy and graft insertion should be carried out medially or laterally to it. However, this last option is feasible only if the sinus cavity is wide enough in medio-lateral direction to allow a proper implant placement at crestal level.

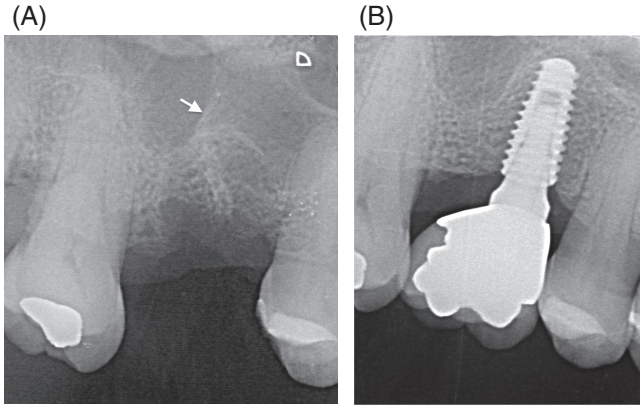


FIGURE 3 (A) The septum is in the center of the implant site (white arrow). (B) The graft and the implant are located mesially.

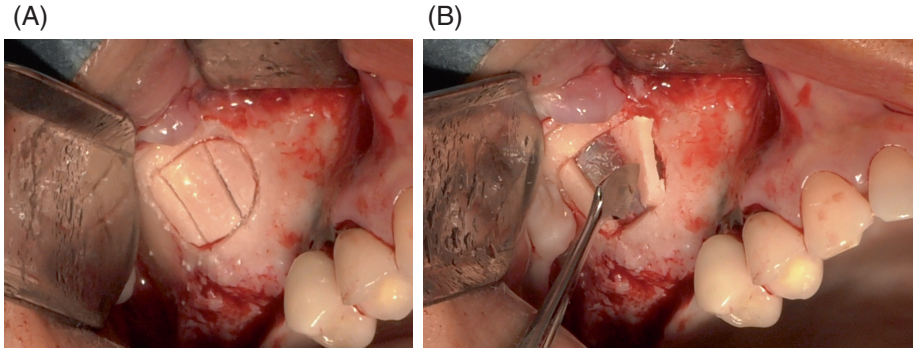


FIGURE 2 (A) The window is divided into three small pieces. (B) All pieces are removed successively.

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Residual bone height (RBH)

Regarding this parameter, due to conflicting evidence in the literature, reaching a definitive conclusion is challenging for the lateral approach.[23,51,52] An exception may arise when the residual bone height (RBH) is <4 mm and implants are placed simultaneously. To reduce the risk of fracture of the residual bone crest due to implant insertion in undersized sites, the surgical window should be moved apically.[46,53] However, in such cases, the detachment of the membrane from the lower border of the window to the sinus floor will be performed blindly and may pose a higher risk of tearing, particularly in the presence of septa.

Regarding the transcrestal approach, the available evidence in the literature does not demonstrate a significant direct influence of residual bone crest height on the risk of membrane perforation.[54] On the contrary, from a clinical perspective, a very low residual crestal height may improve surgical visibility, allowing for better control by the operator over membrane integrity and the initial stages of biomaterial insertion.

Location and type of edentulism

In the context of the lateral approach, a study[51] indicates a higher incidence of perforations (41.2%) in premolar–molar edentulous areas compared to premolar sites (16.7%) and molar sites (26.2%). However, these findings somewhat conflict with the findings regarding the influence of sinus width on membrane perforation during lateral sinus augmentation.[37] Managing a single missing tooth appears to present greater challenges.[55]

There is no evidence supporting direct associations between the risk of membrane perforation, location, and type of edentulism in transcrestal sinus lift procedures.

2.1.3 | Patient-related factors

Surgical access

In the lateral approach, the surgical access can pose a risk due to the necessity of working perpendicularly to the lateral wall for maximum effectiveness. This requirement can be met more or less easily depending on the morphological biotype of the patient. Achieving this access can be more challenging in brachycephalic patients compared to dolichocephalic patients.[12]

In transcrestal sinus augmentation, membrane perforation risk increases in regions with a sloped sinus floor: in these cases, the critical moment is during the execution of the crestal access, both with osteotomes and specific burs. The instrument initially contacts the sinus membrane at the point where the remaining bone crest is at its lowest height. As the antrostomy procedure progresses, the instrument continues to actively engage with the membrane at this location, thereby increasing the risk of tears.[21,54]

Smokers

Several clinical studies and meta-analyses have demonstrated a strong association between the prevalence of membrane perforations during sinus floor elevation with lateral approach and smoking,[25,51,52] although it was not possible yet to correlate risk with the number of cigarettes smoked per day.[56]

Although it seems reasonable to assume that membrane changes induced by smoking similarly affect the risk of perforation in both the lateral and transcrestal approaches, insufficient scientific evidence is currently available to confirm this hypothesis.

2.1.4 | How to diagnose a perforation?

Timely identification of perforations is critical for effective management. Although the Valsalva maneuver is commonly used, it has limitations and may not always be the most reliable method, especially showing a significant number of false negatives, particularly in transcrestal approaches.[57] A simpler alternative involves injecting sterile saline solution into the sub-antral space and observing if the patient feels fluid flowing into their nose, indicating a breach. The use of endoscopy is undoubtedly the most accurate and reliable method for detecting perforations in both lateral and transcrestal approaches, but this equipment is typically not readily available in routine clinical practice.

Given the challenge of accurately assessing sinus membrane resistance capacity, the use of a more comprehensive tool to evaluate the level of difficulty of the specific case, as proposed by Testori and colleagues, can be beneficial.[13] Based on the score obtained from considering anatomical and patient-related parameters, we can determine whether to adopt the lateral approach, which enables precise visualization and treatment of perforations.

The impact of perforations on new bone formation and implant success is still a subject of debate,[58,59] although recent meta-analyses have indicated a negative effect of intraoperative membrane tearing on these outcomes.[16,22,23]

However, proper management of the complication and appropriate repair of the membrane tear are fundamental elements to ensure the success of the regenerative procedure.[52,60,61]

2.2 | Management of membrane perforations

Perforations often occur during the creation of the lateral window, especially when the osteotomy line grazes the edge, making the breach partially hidden (Figure 4a). Adjusting the shape of the window to fully expose the perforation (Figure 4b) is an important initial step, as achieving optimal intraoperative visibility of the area is essential for a correct management of this complication.[46]

Starting the detachment of the membrane from the side opposite the perforation (Figure 4c) can exploit membrane elasticity to reduce and partially close the tear (Figure 4d).

The goal is to work on the membrane, continuing to detach it without causing an increase in the size of the perforation and achieving a secure seal to prevent graft material migration into the sinus cavity. Repair using a collagen membrane is the most commonly utilized method for fixing perforations and maintaining airtightness, with diverse techniques proposed across various studies.[61,62] However, even with collagen membrane repair, the integrity of the Schneiderian

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

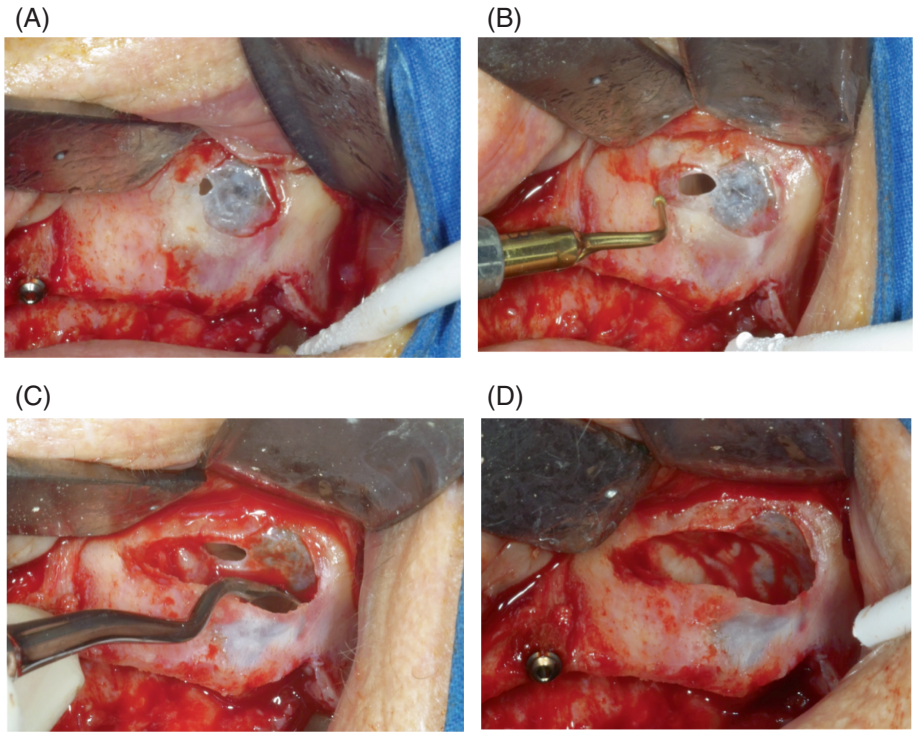


FIGURE 4 (A) The perforation is tangent to the osteotomy line. (B) The shape of the window is modified to see the perforation in its entirety. (C) The detachment is initiated opposite to the perforation. (D) The perforation size is reduced.

membrane and the potential for new bone formation could be compromised.[62–64] This challenge arises from the difficulty in assessing membrane resistance to the pressure applied during graft condensation. To address this issue, it is important to compact the graft material against solid bone surfaces, avoiding direct pressure on the membrane to prevent re-opening of the treated perforation or the creation of new tears.

Previous reports showed a higher incidence of sinusitis (31.4%) in cases of membrane perforation, despite attempts to close the perforation with resorbable membranes,[52] indicating that membrane stability during graft placement may not always be guaranteed.[65] To address this issue, techniques such as the Loma Linda Pouch Technique[66] involve the use of a large resorbable membrane that is folded into the sinus to fully enclose the graft material positioned at its center. However, during the membrane repair procedure, it is important not only to contain the graft material but also to preserve the blood and cellular supply to the grafted area, facilitating new bone formation. From a biological point of view, it is important to note that the collagen membrane used in the Loma Linda pouch technique completely isolates the graft material from the vascular and cellular supply originating from the sinus walls during the early phases of healing.[65] An alternative that allows for stabilizing the membrane without hindering the biological processes necessary for new bone formation is the Tattone Technique.[67] This approach involves shaping the membrane appropriately and then fixing it with titanium pins on the medial wall and, if necessary, on the buccal wall (Figure 5). This technique is particularly useful when the tear is located near the medial wall, a frequent occurrence in anatomies where an acute-angled palato-nasal recess is present (Figure 6).[22,41,46]

Another possibility proposed in the literature to manage membrane perforations is to suture them with 6.0 or 7.0 resorbable thread.[61] This option may be valid only when dealing with thick membranes; attempting to suture a perforation on a thin membrane could be detrimental and could potentially widen the perforation.[68]

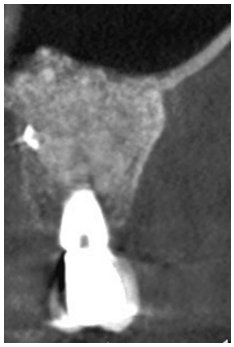


FIGURE 5 The membrane is pinned in the medial wall and the buccal wall.

Another promising strategy to mitigate complications related to granule loss through perforation could involve using PRF membranes[69,70] to cover the perforations and as grafting material or without any grafting material,[71] with reported implant survival rates of 100% and 98.7%, respectively.

In cases of large perforations, a preferable course of action may involve aborting the procedure and closing the flap, allowing for a waiting period of 4–8 weeks before resuming the procedure using a split thickness approach.[72]

In the transcrestal approach, Tavelli and colleagues (2020)[73] suggested a classification guiding the clinical management of intraoperative perforations.

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License



FIGURE 6 The palato-nasal recess is acute (white arrow).

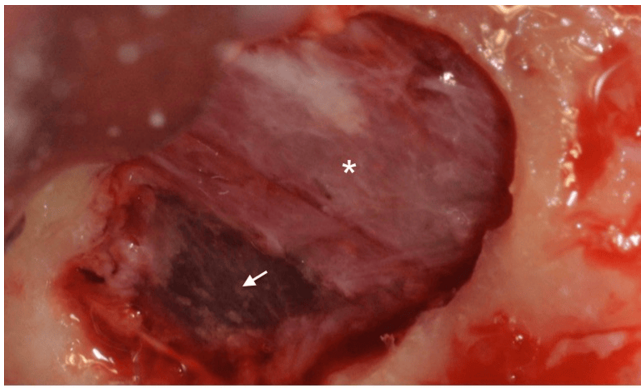


FIGURE 7 The intact periosteal part (white star) surrounding the delamination (white arrow).

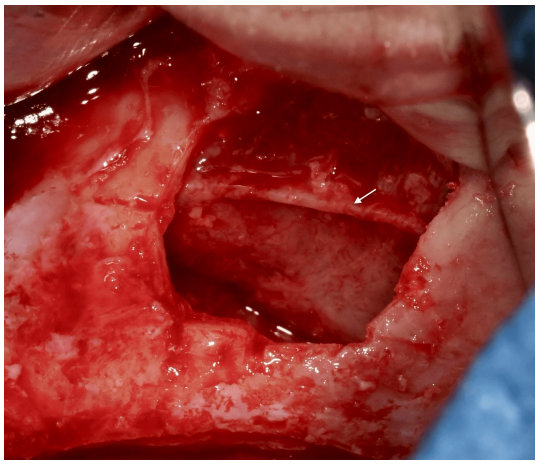


FIGURE 8 The AAA is stuck to the membrane (white arrow).

If the perforation occurs during the creation of the crestal antrostomy (Type 1), the clinician must assess whether it is possible to place a short implant, based on the height of the residual bone crest. If this is feasible, the implant should be inserted after protecting the sinus membrane with a collagen sponge, without placing any graft material. If the height of the residual alveolar crest does not allow for the placement of a short implant, it is suggested to proceed with creating a lateral window to manage the perforation. The same treatment approach should be adopted in cases of perforations occurring during membrane elevation or graft insertion (Type 2).

If perforation occurs during implant placement (Type 3), characterized by a diffuse radiopacity appearance on clinical examination, the patient should be closely monitored with frequent follow-ups. If symptoms of sinusitis develop (such as chronic nasal drainage, pain, or the presence of mucosal fistula), the patient should be treated with medical therapy, and, in consultation with the otolaryngologist, partial or complete removal of the graft should be considered.

2.2.1 | Delamination

Partial damage to the Schneiderian membrane may occur either during the lateral antrostomy or while detaching and elevating the membrane, leading to a tear in its periosteal component (Figure 7). Such damage could likely transform in a full perforation during the continuation of the surgical procedure or postoperatively, due to the fragility of the pseudostratified respiratory epithelium. These lesions require a treatment approach similar to that used for an actual perforation.[74]

Unfortunately, due to the limited intraoperative visibility of the transcrestal approach, detecting membrane delamination with this technique is virtually impossible.

3 | VASCULAR DAMAGE

Vascular injury, a risk associated only with the lateral approach, can lead to significant bleeding, primarily when the buccal osteotomy damages the intraosseous passage of the alveolo-antral artery.[75] This artery is an anastomosis between the infraorbital and posterosuperior alveolar arteries.[76]

Rosano and colleagues[76] described three possible routes for the artery:

- An internal extraosseous pathway which is usually not detectable on cross-sectional images because the vessel is stuck between the lateral wall and the sinus membrane (Figure 8). In this situation, there is no risk of bleeding during buccal antrostomy.
- A fully intraosseous path within the lateral wall of the maxillary sinus (Figure 9) is observed in 47% of cases, and this should be considered when planning the osteotomy in this area.[75] The risk of bleeding should be taken into account.
- A buccal pathway between the lateral wall and the periosteum (Figure 10) that is not identifiable on coronal sections. This may be suspected when an intraosseous pathway is observed in the distal part within a relatively thick vestibular wall. This intraosseous pathway then disappears in presence of a thinner vestibular wall and reappears mesially within the thickness of a thicker wall. The vestibular extraosseous pathway is believed to result from the externalization of vessels due to pathological horizontal bone resorption

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

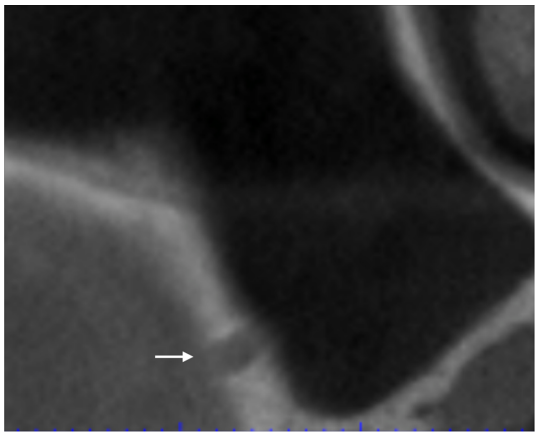


FIGURE 9 The intra osseous passage of the AAA (white arrow).

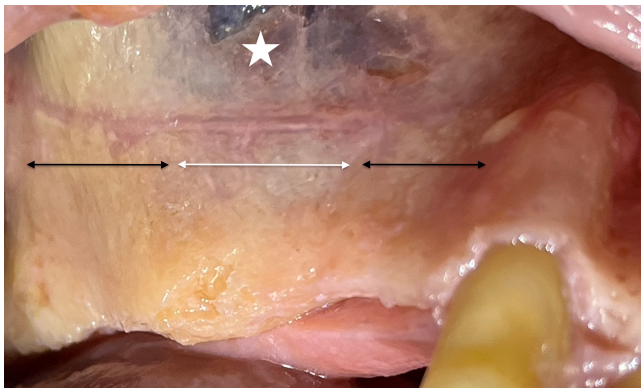


FIGURE 10 The artery has a intraosseous course distally and mesially (black double arrows) and an extraosseous course in the center (white double arrow) where the vestibular wall is extremely thin (white star).

following periodontal disease. Although this situation is uncommon, when suspected, great care must be taken when elevating the vestibular flap.

The frequency and severity of bleeding rise with the size of the artery. According to Testori et al., the probability of significant bleeding is 10% for a vessel diameter of 0.5–1 mm and increases to 57% for diameters larger than 2 mm.[13,75]

3.1 | Prevention and management of the vascular damage

Addressing intraoperative bleeding involves several approaches, including clamping the bleeding site,[77] applying pressure with gauze treated with tranexamic acid,[46] or using bone wax.[13] Each technique carries its own risks, such as the potential for postoperative bleeding recurrence. Another effective method is diathermocoagulation with a bipolar electrosurgical unit, although this poses a risk for the integrity of the sinus membrane.[13,75] In cases of intraoperative bleeding, it may

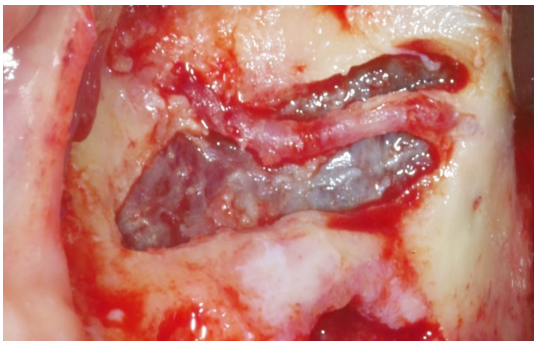


FIGURE 11 The artery is isolated.

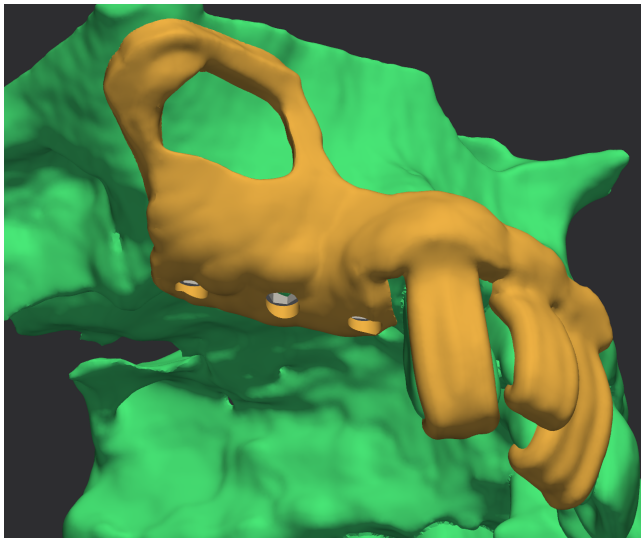


FIGURE 12 The 3D-printed surgical guide.

be beneficial to avoid suturing the distal incision as this can facilitate the expulsion of any clots.[78]

The most effective approach to prevent bleeding involves careful isolation of the alveolo-antral artery using piezoelectric surgical devices[42,46] (Figure 11). Additionally, reducing the size of the bony window and adjusting its positioning—either lower or higher when feasible—can also help minimize the risks of bleeding during the procedure. In this context, the use of 3D-printed surgical guides derived from digital workflows could represent a significant aid for the clinician, providing real-time guidance during antrostomy, and ensuring precise alignment of surgical steps with predetermined parameters established during the planning phase[79] (Figure 12). This approach also reduces the need for intraoperative adjustments, resulting in shorter surgical times and improved overall workflow, ultimately leading to enhanced patient comfort and more predictable surgical outcomes.

4 | NUMBNESS

The occurrence of neurosensory changes following sinus floor elevation with lateral approach, such as transient numbness on the operation side, is seldom highlighted but can impact patient comfort and recovery.

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

4.1 | Risk factors

This kind of discomfort may be observed on the operated side after surgery, as a consequence of severing terminal branches of the infraorbital nerve during the mesial vertical releasing incision.[46] Its frequency is related to bone atrophy degree: in more severe cases, the emergence of the infraorbital nerve is nearer to the operative area.

4.2 | Prevention

To prevent this issue, a nuanced approach involves making a shallower, partial thickness vertical releasing incision in the alveolar mucosa rather than full thickness. Subsequently, gently parting the incision edges with Metzenbaum scissors can stretch the nerve fibers without cutting them, thereby preserving sensory function (Figure 13). An alternative strategy consists of using a triangular flap without performing any mesial releasing incision.[78]

In the transcrestal approach, no extensive exposure of the lateral wall is required and a minimally invasive flap is performed, usually without releasing incisions. Therefore, postoperative numbness is not an issue when using this technique.

5 | IMPLANT DISPLACEMENT

The risk of implant displacement into the sinus cavity requires careful attention when implants are inserted alongside grafting procedures. Achieving solid implant stability is paramount to avoid the risk of the implant migrating into the sinus or possibly moving into sensitive regions.[80]

5.1 | Risk factors and prevention

Two primary factors that can contribute to implant displacement are: firstly, the presence of a residual bone crest with extremely low quality, which can be addressed by utilizing the osseodensification technique to improve bone density.[81] Secondly, very limited bone height below the sinus (<3 mm) during simultaneous implant placement. To address this, drilling should be undersized, and tapered implants should be used, although this approach may potentially fracture the vestibular wall due to high pressure transmitted to the bone during implant insertion. To mitigate this risk, the surgical window can be adjusted apically by 8–10 mm, providing a more secure setting for the implant.[46,53] Additionally, using cover screws larger than the implant diameter can also be considered.

6 | POOR GRAFT ADAPTATION

To ensure optimal bone quality, it is essential to achieve maximum contact between the graft and the surrounding native bone.[46] This necessitates avoiding gaps (Figure 14) by ensuring that the grafting material directly contacts both the medial and anterior walls. An insulin syringe with a beveled tip is employed for this purpose in the lateral sinus augmentation. The syringe, loaded with grafting material, is inserted into the sinus cavity in a backward and inward direction until it reaches the wall to be grafted,[46] aligning the bevel towards the wall (Figure 15). The material is then injected. It is important that the

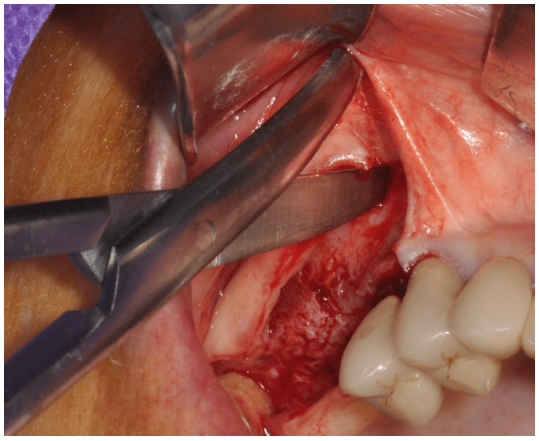


FIGURE 13 Metzenbaum scissors are inserted under the split thickness incision and opened to stretch the nerve branches without cutting them.

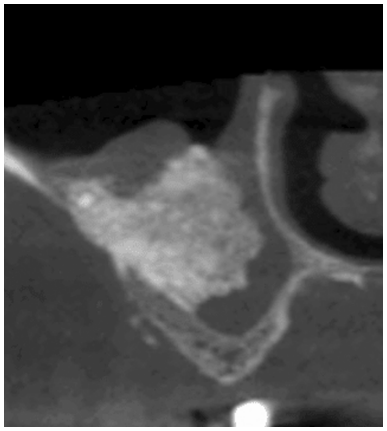


FIGURE 14 The grafting material is not in contact with the medial wall.

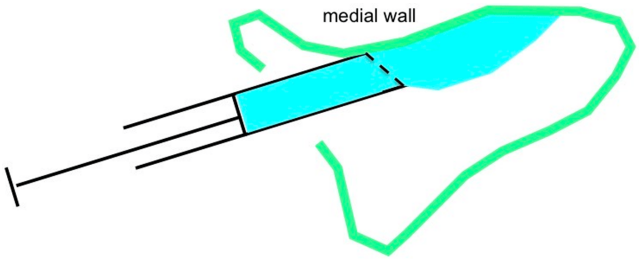


FIGURE 15 The grafting technique using a beveled (dotted line) insulin syringe to place the graft material in direct contact with the medial wall.

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

dimensions of the buccal bone window are appropriate to allow for the execution of this technique, while remaining as small as possible.[82]

Even in the transcrestal approach, it is necessary to ensure that the graft comes into contact with the sinus walls to optimize bone formation.[11,83] The clinician must take care to angle the tip of the biomaterial syringe in various directions (buccal, palatal, mesial, and distal) if using injectable material, to fill the sub-antral space as evenly as possible. The same outcome should also be achieved when using particulate graft. Once the biomaterial is placed beneath the membrane, the granules can be gently pushed in various directions using small compactors inserted through the crestal antrostomy. In transcrestal sinus augmentation, achieving a uniform distribution of the grafting material can be reliably obtained when the sinus cavity is narrow in buccopalatal direction.[11]

7 | BENIGN PAROXYSMAL POSITIONAL VERTIGO

Benign paroxysmal positional vertigo (BPPV) is an uncommon complication following transcrestal sinus floor elevation performed by using osteotomes.[84,85] BPPV can occur due to the displacement of inner ear crystals (otoconia) into the semicircular canals, leading to episodes of vertigo triggered by head movements. The etiology of BPPV is likely associated with the surgical trauma induced by osteotomes and a surgical hammer during bone malleting and condensation to create the crestal antrostomy, leading to the displacement of otoconia. Prevention strategies include minimizing excessive force or rapid movements during the procedure and ensuring careful manipulation to reduce the risk of otoconia displacement. The use of the magnetic mallet instead of the manual surgical mallet could be an effective strategy in preventing BPPV, as there have been no reported cases of BPPV in the literature with the use of this device. However, given the low frequency of this complication and the limited number of studies conducted on this topic, further data are needed to confirm the preventive action of this technology on BPPV. Treatment options for BPPV include canalith repositioning maneuvers (e.g., Epley maneuver) to guide the displaced otoconia back to their original position within the inner ear, alleviating symptoms of vertigo. Additionally, patients may benefit from vestibular rehabilitation exercises to improve balance and reduce the frequency of vertigo episodes following transcrestal sinus floor elevation.

8 | CONCLUSIONS

Intraoperative complications during sinus augmentation procedures, particularly sinus membrane perforation, pose significant challenges and necessitate careful consideration of various risk factors and preventive strategies. The prevalence of membrane perforation varies between lateral and transcrestal approaches, with distinct implications for surgical techniques and anatomical factors. Risk factors such as antrostomy technique, anatomy (including membrane thickness, gingival phenotype, sinus width, and septa), patient-related factors (such as surgical access and smoking), and specific procedural aspects must be thoroughly evaluated with a meticulous presurgical planning to minimize the occurrence of intraoperative complications. The implementation of advanced techniques and technologies, to be used both in the planning and in the operational phase, can contribute to enhance surgical precision, ultimately improving patient comfort and treatment predictability.

It is important to consider that a close collaboration with the otorhinolaryngologist is necessary in managing patients who have experienced intraoperative complications, with the aim of a rapid and effective multidisciplinary resolution of the problem.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Not applicable.

ORCID

Pascal Valentini https://orcid.org/0000-0002-2712-8819
Claudio Stacchi https://orcid.org/0000-0003-4017-4980

REFERENCES

1. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. *J Oral Surg*. 1980;38(8):613-616.
2. Summers RB. A new concept in maxillary implant surgery: the osteotome technique. *Compendium*. 1994;15(2):152-154. 158 passim; quiz 162.
3. Testori T, Scaini R, Deflorian M, Wallace SS, Tarnow D. Lateral window surgical techniques for sinus elevation. In: Jensen OT, ed. *The Sinus Bone Graft*. 3rd ed. Quintessence Publishing; 2006:59-60.
4. Busenlechner D, Huber CD, Vasak C, Dobsak A, Gruber R, Watzek G. Sinus augmentation analysis revised: the gradient of graft consolidation. *Clin Oral Implants Res*. 2009;20(10):1078-1083.
5. Pignaton TB, Spin-Neto R, Ferreira CEA, Martinelli CB, de Oliveira GJPL, Marcantonio E Jr. Remodelling of sinus bone grafts according to the distance from the native bone: a histomorphometric analysis. *Clin Oral Implants Res*. 2020;31(10):959-967.
6. Bernardello F, Righi D, Cosci F, Bozzoli P, Soardi CM, Spinato S. Crestal sinus lift with sequential drills and simultaneous implant placement in sites with <5 mm of native bone: a multicenter retrospective study. *Implant Dent*. 2011;20(6):439-444.
7. Kim JM, Sohn DS, Heo JU, et al. Minimally invasive sinus augmentation using ultrasonic piezoelectric vibration and hydraulic pressure: a multicenter retrospective study. *Implant Dent*. 2012;21(6):536-542.
8. Franceschetti G, Farina R, Stacchi C, Di Lenarda R, Di Raimondo R, Trombelli L. Radiographic outcomes of transcrestal sinus floor elevation performed with a minimally invasive technique in smoker and non-smoker patients. *Clin Oral Implants Res*. 2014;25(4):493-499.
9. Kotsakis GA, Mazor Z. A simplified approach to the minimally invasive antral membrane elevation technique utilizing a viscoelastic medium for hydraulic sinus floor elevation. *Oral Maxillofac Surg*. 2015;19(1):97-101.
10. Lombardi T, Lamazza L, Bernardello F, Ziętek G, Stacchi C, Troiano G. Clinical and radiographic outcomes following transcrestal maxillary sinus floor elevation with injectable xenogenous bone substitute in gel form: a prospective multicenter study. *Int J Implant Dent*. 2022;8(1):32.

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

11. Stacchi C, Lombardi T, Ottonelli R, Berton F, Perinetti G, Traini T. New bone formation after transcrestal sinus floor elevation was influenced by sinus cavity dimensions: a prospective histologic and histomorphometric study. *Clin Oral Implants Res*. 2018;29(5):465-479.
12. Testori T, Weinstein T, Taschieri S, Wallace SS. Risk factors in lateral window sinus elevation surgery. *Periodontol 2000*. 2019;81(1):91-123.
13. Testori T, Tavelli L, Yu SH, et al. Maxillary sinus elevation difficulty score with lateral wall technique. *Int J Oral Maxillofac Implants*. 2020; 35(3):631-638.
14. Stacchi C, Andolsek F, Berton F, Perinetti G, Navarra CO, Di Lenarda R. Intraoperative complications during sinus floor elevation with lateral approach: a systematic review. *Int J Oral Maxillofac Implants*. 2017;32(3):e107-e118.
15. Pjetursson BE, Tan WC, Zwahlen M, Lang NP. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. *J Clin Periodontol*. 2008; 35(8 Suppl):216-240.
16. Al-Moraissi E, Elsharkawy A, Abotaleb B, Alkebsi K, Al-Motwakel H. Does intraoperative perforation of Schneiderian membrane during sinus lift surgery causes and increased the risk of implants failure? A systematic review and meta regression analysis. *Clin Implant Dent Relat Res*. 2018;20(5):882-889.
17. Pommer B, Ulm C, Lorenzoni M, Palmer R, Watzek G, Zechner W. Prevalence, locations and morphology of maxillary sinus septa: systematic review and meta-analysis. *J Clin Periodontol*. 2012;39(8): 769-773.
18. Ye M, Liu W, Cheng S, Yan L. Outcomes of implants placed after osteotome sinus floor elevation without bone grafts: a systematic review and meta-analysis of single-arm studies. *Int J Implant Dent*. 2021;7(1):72.
19. Pjetursson BE, Lang NP. Sinus floor elevation utilizing the transalveolar approach. *Periodontol 2000*. 2014;66(1):59-71.
20. Călin C, Petre A, Drafta S. Osteotome-mediated sinus floor elevation: a systematic review and meta-analysis. *Int J Oral Maxillofac Implants*. 2014;29(3):558-576.
21. Garbacea A, Lozada JL, Church CA, et al. The incidence of maxillary sinus membrane perforation during endoscopically assessed crestal sinus floor elevation: a pilot study. *J Oral Implantol*. 2012;38(4): 345-559.
22. Nolan PJ, Freeman K, Kraut RA. Correlation between Schneiderian membrane perforation and sinus lift graft outcome: a retrospective evaluation of 359 augmented sinus. *J Oral Maxillofac Surg*. 2014; 72(1):47-52.
23. Tükel HC, Tatli U. Risk factors and clinical outcomes of sinus membrane perforation during lateral window sinus lifting: analysis of 120 patients. *Int J Oral Maxillofac Surg*. 2018;47(9):1189-1194.
24. Valentini P. How to prevent and manage postoperative complications in maxillary sinus augmentation using the lateral approach: a review. *Int J Oral Maxillofac Implants*. 2023;38(5):1005-1013.
25. Testori T, Yu SH, Tavelli L, Wang HL. Perforation risk assessment in maxillary sinus augmentation with lateral wall technique. *Int J Periodontics Restorative Dent*. 2020;40(3):373-380.
26. Barone A, Santini S, Marconcini S, Giacomelli L, Gherlone E, Covani U. Osteotomy and membrane elevation during the maxillary sinus augmentation procedure. A comparative study: piezoelectric device vs. conventional rotative instruments. *Clin Oral Implants Res*. 2008;19(5):511-515.
27. Rickert D, Vissink A, Slater JJ, Meijer HJ, Raghoebar GM. Comparison between conventional and piezoelectric surgical tools for maxillary sinus floor elevation. A randomized controlled clinical trial. *Clin Implant Dent Relat Res*. 2013;15(2):297-302.
28. Delilbasi C, Gurler G. Comparison of piezosurgery and conventional rotative instruments in direct sinus lifting. *Implant Dent*. 2013;22(6): 662-665.
29. Jordi C, Mukaddam K, Lambrecht JT, Kühl S. Membrane perforation rate in lateral maxillary sinus floor augmentation using conventional rotating instruments and piezoelectric device: a meta-analysis. *Int J Implant Dent*. 2018;4(1):3.
30. Stacchi C, Vercellotti T, Toschetti A, Speroni S, Salgarello S, Di Lenarda R. Intraoperative complications during sinus floor elevation using two different ultrasonic approaches: a two-center, randomized, controlled clinical trial. *Clin Implant Dent Relat Res*. 2015;17(Suppl 1): e117-e125.
31. Lum AG, Ogata Y, Pagni SE, Hur Y. Association between sinus membrane thickness and membrane perforation in lateral window sinus augmentation: a retrospective study. *J Periodontol*. 2017;88(6): 543-549.
32. Pommer B, Unger E, Sütö D, Hack N, Watzek G. Mechanical properties of the Schneiderian membrane in vitro. *Clin Oral Implants Res*. 2009;20(6):633-637.
33. Insua A, Monje A, Chan HL, Zimmo N, Shaikh L, Wang HL. Accuracy of Schneiderian membrane thickness: a cone-beam computed tomography analysis with histological validation. *Clin Oral Implants Res*. 2017;28(6):654-661.
34. Lin YH, Yang YC, Wen SC, Wang HL. The influence of sinus membrane thickness upon membrane perforation during lateral window sinus augmentation. *Clin Oral Implants Res*. 2016;27(5):612-617.
35. Aimetti M, Massei G, Morra M, Cardesi E, Romano F. Correlation between gingival phenotype and Schneiderian membrane thickness. *Int J Oral Maxillofac Implants*. 2008;23(6):1128-1132.
36. Díaz L, Fan S, Urrutia P, et al. Correlation between periodontal phenotype and sinus membrane thickness: a systematic review. *Clin Oral Implants Res*. 2023;34(9):881-891.
37. Cho SC, Wallace SS, Froum SJ, Tarnow DP. Influence of anatomy on Schneiderian membrane perforations during sinus elevation surgery: three-dimensional analysis. *Pract Proced Aesthet Dent*. 2001;13(2): 160-163.
38. Marin S, Kirnbauer B, Rugani P, Payer M, Jakse N. Potential risk factors for maxillary sinus membrane perforation and treatment outcome analysis. *Clin Implant Dent Relat Res*. 2019;21(1):66-72.
39. Pizzini A, Basma HS, Li P, Geurs NC, Abou-Arraj RV. The impact of anatomic, patient and surgical factors on membrane perforation during lateral wall sinus floor elevation. *Clin Oral Implants Res*. 2021; 32(3):274-284.
40. Stacchi C, Bernardello F, Spinato S, et al. Intraoperative complications and early implant failure after transcrestal sinus floor elevation with intraoperative complications and early implant failure after transcrestal sinus floor elevation with residual bone height ≤5 mm: a retrospective multicenter study. *Clin Oral Implants Res*. 2022;33(8): 783-791.
41. Chan HL, Monje A, Suarez F, Benavides E, Wang HL. Palatonasal recess on medial wall of the maxillary sinus and clinical implications for sinus augmentation via lateral window approach. *J Periodontol*. 2013;84(8):1087-1093.
42. Wallace SS, Tarnow DP, Froum SJ, et al. Maxillary sinus elevation by lateral window approach: evolution of technology and technique. *J Evid Based Dent Pract*. 2012;12(3 Suppl):161-171.
43. Basma H, Saleh I, Abou-Arraj R, et al. Association between lateral wall thickness and sinus membrane perforation during lateral sinus elevation: a retrospective study. *Int J Oral Implantol (Berl)*. 2021;14(1): 77-85.
44. Tawil G, Barbeck M, Unger R, Tawil P, Witte F. Sinus floor elevation using the lateral approach and window repositioning and a xenogeneic bone substitute as a grafting material: a histologic, histomorphometric, and radiographic analysis. *Int J Oral Maxillofac Implants*. 2018; 33(5):1089-1096.
45. Wang Z, Zhang J, Ren L, Yang G. Repositioning of the bone window in lateral sinus floor elevation with simultaneous implant placement: a

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

retrospective radiographic study. *Clin Oral Implants Res*. 2022;33(8):816-833.
46. Valentini P, Artzi Z. Sinus augmentation procedure via the lateral window technique. Reducing invasiveness and preventing complications: a narrative review. *Periodontol 2000*. 2023;91(1):167-181.
47. Park YB, Jeon HS, Shim JS, Lee KW, Moon HS. Analysis of the anatomy of the maxillary sinus septum using 3-dimensional computed tomography. *J Oral Maxillofac Surg*. 2011;69(4):1070-1078.
48. Wen SC, Chan HL, Wang HL. Classification and management of antral septa for maxillary sinus augmentation. *Int J Periodontics Restorative Dent*. 2013;33(4):509-517.
49. Krennmair G, Ulm CW, Lugmayr H, Solar P. The incidence, location, and height of maxillary sinus septa in the edentulous and dentate maxilla. *J Oral Maxillofac Surg*. 1999;57(6):667-671. discussion 671–672.
50. Okada T, Kawana H. Two-step procedure for the treatment of a maxillary sinus with complex sinus septa: a highly predictive method for sinus floor augmentation after perforation of the maxillary sinus membrane. *Int J Periodontics Restorative Dent*. 2019;39(5):e175-e180.
51. von Arx T, Fodich I, Bornstein MM, Jensen SS. Perforation of the sinus membrane during sinus floor elevation: a retrospective study of frequency and possible risk factors. *Int J Oral Maxillofac Implants*. 2014;29(3):718-726.
52. Schwarz L, Schiebel V, Hof M, Ulm C, Watzek G, Pommer B. Risk factors of membrane perforation and postoperative complications in sinus floor elevation surgery: review of 407 augmentation procedures. *J Oral Maxillofac Surg*. 2015;73(7):1275-1282.
53. Valentini P, Zadeh HH, Jungo S, Mangion JP, Bianca G, Ferrandi JM. Shortened treatment time for maxillary sinus grafting with simultaneous implant placement: retrospective analysis with 10-year follow-up. *Int J Oral Maxillofac Implants*. 2022;37(4):722-730.
54. Boyacıgil DU, Er N, Karaca Ç, Koç O. The effect of residual bone height and membrane thickness on sinus membrane perforation in crestal sinus grafting: a prospective clinical study. *Int J Oral Maxillofac Surg*. 2021;50(2):251-257.
55. Nemati M, Khodaverdi N, Hosn Centenero SA, Tabrizi R. Which factors affect the risk of membrane perforation in lateral window maxillary sinus elevation? A prospective cohort study. *J Craniomaxillofac Surg*. 2023;51(7–8):427-432.
56. Wang X, Ma S, Lin L, Yao Q. Association between smoking and Schneiderian membrane perforation during maxillary sinus floor augmentation: a systematic review and meta-analysis. *Clin Implant Dent Relat Res*. 2023;25(1):166-176.
57. Nkenke E, Schlegel A, Schultze-Mosgau S, Neukam FW, Wiltfang J. The endoscopically controlled osteotome sinus floor elevation: a preliminary prospective study. *Int J Oral Maxillofac Implants*. 2002;17(4):557-566.
58. Froum SJ, Khouly I, Favero G, Cho SC. Effect of maxillary sinus membrane perforation on vital bone formation and implant survival: a retrospective study. *J Periodontol*. 2013;84(8):1094-1099.
59. de Almeida Ferreira CE, Martinelli CB, Novaes AB Jr, et al. Effect of maxillary sinus membrane perforation on implant survival rate: a retrospective study. *Int J Oral Maxillofac Implants*. 2017;32(2):401-407.
60. Hernández-Alfaro F, Torradeflot MM, Marti C. Prevalence and management of Schneiderian membrane perforations during sinus-lift procedures. *Clin Oral Implants Res*. 2008;19(1):91-98.
61. Beck-Broichsitter B, Westhoff D, Behrens E, Wiltfang J, Becker S. Impact of surgical management in cases of intraoperative membrane perforation during a sinus lift procedure: a follow-up on bone graft stability and implant success. *Int J Implant Dent*. 2018;4(1):6.
62. Díaz-Olivares D, Cortés-Bretón Brinkmann J, Martínez-Rodríguez N, et al. Management of Schneiderian membrane perforations during maxillary sinus floor augmentation with lateral approach in relation to subsequent implant survival rates: a systematic review and meta-analysis. *Int J Implant Dent*. 2021;7(1):91.
63. Scala A, Lang NP, Velez JU, Favero R, Bengazi F, Botticelli D. Effects of a collagen membrane positioned between augmentation material and the sinus mucosa in the elevation of the maxillary sinus floor. An experimental study in sheep. *Clin Oral Implants Res*. 2016;27(11):1454-1461.
64. Proussaefs P, Lozada J, Kim J. Effects of sealing the perforated sinus membrane with a resorbable collagen membrane: a pilot study in humans. *J Oral Implantol*. 2003;29(5):235-241.
65. Testori T, Wallace SS, Del Fabbro M, et al. Repair of large sinus membrane perforations using stabilized collagen barrier membranes: surgical techniques with histologic and radiographic evidence of success. *Int J Periodontics Restorative Dent*. 2008;28(1):9-17.
66. Proussaefs P, Lozada J. The "Loma Linda pouch": A technique for repairing the perforated sinus membrane. *Int J Periodontics Restorative Dent*. 2003;23(6):593-597.
67. Valentini P, Eid G, Ferrandi JM, Abensur D, Testori T. Management of sinus membrane perforations. *Eur Dent Impl J*. 2019;15(2):64-65.
68. De Oliveira H, De Moraes R, Limirio P, Dechichi P. Repair of a perforated sinus membrane with an autogenous periosteal graft: a study in 24 patients. *Br J Oral Maxillofac Surg*. 2018;56(4):299-303.
69. Ali S, Bakry SA, Abd-Elhakam H. Platelet-rich fibrin in maxillary sinus augmentation: a systematic review. *J Oral Implantol*. 2015;41(6):746-753.
70. Valentini P, Calciolari E, Monlezun S, Akcalı A, Donos N, Quirynen M. APCs in sinus floor augmentation. *Periodontol 2000*. 2024;1-7. doi:10.1111/prd.12554 Epub ahead of print.
71. Cricchio G, Sennerby L, Lundgren S. Sinus bone formation and implant survival after sinus membrane elevation and implant placement: a 1- to 6-year follow-up study. *Clin Oral Implants Res*. 2011;22(10):1200-1212.
72. Testori T, Yu SH, Scaini R, et al. Split-thickness flap for the management of a maxillary sinus wall bony fenestration during lateral window sinus augmentation: case reports and technical surgical notes. *Int J Periodontics Restorative Dent*. 2022;42(3):311-318.
73. Tavelli L, Borgonovo AE, Saleh MH, Ravidà A, Chan HL, Wang HL. Classification of sinus membrane perforations occurring during transcrestal sinus floor elevation and related treatment. *Int J Periodontics Restorative Dent*. 2020;40(1):111-118.
74. Valentini P. Prevention and management of intraoperative complications in maxillary sinus augmentation using the lateral approach: a review. *Bull Stomatol Maxillofac Surg*. 2023;19(2):16-26.
75. Ella B, Sédarat C, Noble Rda C, et al. Vascular connections of the lateral wall of the sinus: surgical effect in sinus augmentation. *Int J Oral Maxillofac Implants*. 2008;23(6):1047-1052.
76. Rosano G, Taschieri S, Gaudy JF, Weinstein T, Del Fabbro M. Maxillary sinus vascular anatomy and its relation to sinus lift surgery. *Clin Oral Implants Res*. 2011;22(7):711-715.
77. Kim J, Jang H. A review of complications of maxillary sinus augmentation and available treatment methods. *J Korean Assoc Oral Maxillofac Surg*. 2019;45(4):220-224.
78. Scarano A, Lorusso F, Arcangelo M, D'Arcangelo C, Celletti R, de Oliveira PS. Lateral sinus floor elevation performed with trapezoidal and modified triangular flap designs: a randomized pilot study of postoperative pain using thermal infrared imaging. *Int J Environ Res Public Health*. 2018;15(6):1277.
79. Speroni S, Rapani A, Zotti M, Miceli B, Stacchi C. Lateral antrostomy integrated with digital approach (LAIDA): a case report and literature review. *Open Dent J*. 2024;18:e18742106296851.
80. Felisati G, Lozza P, Chiapasco M, Borloni R. Endoscopic removal of an unusual foreign body in the sphenoid sinus: an oral implant. *Clin Oral Implants Res*. 2007;18(6):776-780.
81. Pikos MA, Miron RJ. To drill or to densify? Clinical indications for the use of osseodensification. *Compend Contin Educ Dent*. 2019;40(5):276-281. quiz 282.
82. Baldini N, D'Elia C, Bianco A, Goracci C, de Sanctis M, Ferrari M. Lateral approach for sinus floor elevation: large versus small bone

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

window - a split-mouth randomized clinical trial. *Clin Oral Implants Res*. 2017;28(8):974-981.
83. Lombardi T, Stacchi C, Berton F, Traini T, Torelli L, Di Lenarda R. Influence of maxillary sinus width on new bone formation after transcrestal sinus floor elevation: a proof-of-concept prospective cohort study. *Implant Dent*. 2017;26(2):209-216.
84. Molina A, Sanz-Sánchez I, Sanz-Martín I, Ortiz-Vigón A, Sanz M. Complications in sinus lifting procedures: classification and management. *Periodontol 2000*. 2022;88(1):103-115.
85. Hsu YT, Rosen PS, Choksi K, Shih MC, Ninneman S, Lee CT. Complications of sinus floor elevation procedure and management strategies: a systematic review. *Clin Implant Dent Relat Res*. 2022;24(6):740-765.

How to cite this article: Valentini P, Stacchi C. Prevention and management of intra-operative complications in maxillary sinus augmentation: A review. *Clin Implant Dent Relat Res*. 2025;27(1):e13397. doi:10.1111/cid.13397

17088208, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/cid.13397 by CochraneItalia, Wiley Online Library on [09/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License