

Maxillary Sinus Elevation Difficulty Score with Lateral Wall Technique

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Maxillary sinus augmentation is a procedure commonly performed in patients in need of posterior maxillary implants with limited vertical ridge height and sinus pneumatization. However, minimal information has been presented to evaluate the complexity of the sinus elevation procedure via a lateral window approach based on patient examination, including extraoral findings, anatomical factors, and the possible influence from the surgeon's experience. Therefore, this article presents a new scheme of maxillary sinus floor elevation difficulty score based on comprehensive patient- and surgical-related factors. The proposed scoring tool aims to aid surgeons in performing a comprehensive presurgical evaluation prior to the lateral wall sinus augmentation surgery and also enhance communication between clinicians and patients regarding the complexity of the case. *Int J Oral Maxillofac Implants* 2020;35:631–638. doi: 10.11607/jomi.8034

Keywords: intraoperative complications, maxillary sinus, postoperative complications, risk factors, sinus floor augmentation

Severe bone resorption following tooth loss in the posterior maxilla is a common finding. This challenging scenario can further be complicated by the pneumatization of the maxillary sinus and make rehabilitation of dental implants very difficult. Maxillary sinus floor elevation (MSFE), either via a lateral or transalveolar approach, is a common and effective procedure to address bone deficiency prior to implant placement in the posterior maxilla.^{1–5} The predictability of maxillary sinus floor elevation via a lateral window sinus floor elevation (LSFE) approach to increase bone height has been well documented,¹ and clinical studies have shown long-term success of the implants placed in the augmented sites.² Nevertheless, intraoperative and postoperative complications have often been described, including membrane perforation, sinusitis, cyst formation, wound dehiscence, sequestration, loss of bone grafts, excessive bleeding, and even future implant failure.^{1,6} Among all complications, perforation of

the sinus membrane during surgery is considered one of the most common problems encountered, with the incidence ranging from 0% to 58.3%.^{2,7} Membrane perforation may result (but not necessarily) in acute sinusitis or dislodgment of bone graft into the sinus cavity.⁸ Although the effect of membrane laceration on postoperative complications and implant survival remains controversial,^{1,8,9} a recent article showed the detrimental effect of membrane perforation on graft success.⁹ Similarly, a recent systematic review concluded that intraoperative membrane laceration could result in increased risk of implant failure.¹⁰ The large variability of the incidence of membrane tearing reported in the literature can be explained by the fact that several anatomical and patient-related factors contributed to an increased risk of perforation.

The use of difficulty score systems has been more common in the medical field than the dentistry field.^{11–15} Among all the advantages of proposing a difficulty score system for the LSFE, evaluating the complexity of the surgery before the procedure, matching a specific case to the clinician's expertise, and facilitating the communication between clinicians and/or patients may be the most important. Therefore, the aim of this article is to present a comprehensive presurgical maxillary sinus elevation difficulty (MSED) score based on the literature and the authors' own experience.

MATERIALS AND METHODS

To support the proposal of the MSED score for the lateral wall sinus augmentation technique, a review of all the available literature (until January 2019) was performed across the National Library of Medicine (MEDLINE by

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Submitted August 27, 2019; accepted January 3, 2020.

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Table 1 Factors Associated with Maxillary Sinus Elevation Difficulty (MSED) and the MSED Scoring System

Risk factors for perforation	Difficulty score (points)		
	0	1	2
Anatomical-related factors			
(1) Sinus membrane thickness	1.5–2.0 mm	0.8–1.49, 2.01–2.99 mm	< 0.8, > 3 mm
(2) Presence of sinus septa	Absence of septa	One septum	Multiple septa
(3) Direction of sinus septa	Absence of septa	Mediolateral (transverse)	Anteroposterior (sagittal)
(4) Height of sinus septa	Absence of septa	Height < 6 mm	Height ≥ 6 mm
(5) Type of edentulism and root position relative to the sinus cavity	Totally missing teeth (from second premolar to second molar)	Two adjacent missing teeth (between first premolar and second molar)	Single missing tooth (between second premolar and second molar)/Presence of teeth at the sinus elevation area and root into/close to the sinus elevation area
(6) Residual bone height	> 4 mm		< 4 mm
(7) Sinus width (angle between the lateral and the medial sinus walls)	Wide (angle > 60 deg)	Angle within 30–60 deg	Narrow (angle < 30 deg)
(8) Palatonasal recess angle	Obtuse (≥ 90 deg)		Acute (< 90 deg)
(9) Alveolar antral artery	Diameter < 1 mm	Diameter 1–2 mm	Diameter > 2 mm
(10) Buccal wall thickness	< 1 mm	1–2 mm	> 2 mm
(11) Zygomatic arch location	Apically positioned		Coronally positioned
(12) Bone dehiscence	Absent	Presented at the buccal wall	Presented at the ridge level or the medial wall
Patient-related factors			
(1) Smoking habit	No		Yes
(2) Preoperative chronic sinusitis	No		Yes
(3) Gingival phenotype	Thick (≥ 1 mm)		Thin (< 1 mm)
(4) Surgical access	Wide		Narrow
(5) Surgical access—elevation site relative to the surgeon's dominant hand	Left side for left-handed surgeon or right side for right-handed surgeon	Left side for right-handed surgeon or right side for left-handed surgeon	

PubMed), EMBASE, the Cochrane Library, and the Grey Literature, using the following keywords: “sinus augmentation OR floor elevation,” “sinus complication,” and “sinus perforation.” In addition, a manual search of related articles, including a complete search of *The International Journal of Oral & Maxillofacial Implants*, *The International Journal of Periodontics & Restorative Dentistry*, *Journal of Clinical Periodontology*, *Journal of Periodontology*, *International Journal of Oral Implantology*, and *Journal of Oral and Maxillofacial Surgery* was performed.

MAXILLARY SINUS ELEVATION DIFFICULTY SCORE WITH LATERAL WALL TECHNIQUE

Several articles have discussed the impact of sinus membrane thickness, presence and location of sinus septa, residual bone height, sinus width, and location of the alveolar antral artery on the risk of membrane

perforation.^{7,9,16,17} Based on the literature and authors' experience, the anatomical- and patient-related factors that might affect the intrasurgical difficulty of sinus elevation via the lateral wall technique were identified. For each factor, 0 points can be assigned when normal anatomy is presented or in the absence of a structure that may inject difficulty into the case, while 2 points can be given for challenging anatomy structure or situations. For some factors, an intermediate scenario with moderate intraoperative difficulty was also identified, and 1 point can be assigned (Table 1). The rationale of this difficulty score is to “anticipate” the level of difficulty during the surgical procedure based on scientific evidence as well as clinicians' experience. Difficulty scores have been extensively used in the medical field for predicting the complexity of the surgery, the risk of intraoperative and postoperative complications, matching a particular case to the clinician's expertise, and encouraging thorough presurgical evaluation and planning.^{18–22} In dentistry, difficulty scores have been introduced for the extraction of impacted wisdom

teeth^{11–13} and for classifying the complexity of orthodontic cases.^{14,15} Recently, Tavelli and coworkers proposed a sinus classification based on: (1) factors associated with the risk of perforation; (2) bone condition; and (3) other parameters, including the visibility and mouth opening.⁷ The proposed MSED score presents an update of this previous sinus classification by combining the evidence from the literature with the clinical experience of the authors. The endpoint is to provide guidelines for surgeons to comprehensively evaluate cases and rank each case based on the expected level of difficulty for better clinical outcomes.

Anatomy-Related Risk Factors

Sinus Membrane Thickness. Sinus membrane perforation remains one of the most common complications during sinus floor augmentation.^{2,7,23} It has been suggested that among all the factors that might affect the sinus membrane perforation, membrane thickness plays a major role.^{24–26} Lum and coworkers found that patients who experienced membrane perforation during sinus floor elevation had a thinner membrane compared to patients without membrane perforation (0.84 mm vs 2.65 mm, respectively).²⁷ However, it is worth mentioning that cone beam computed tomography (CBCT) might not be the most accurate method to evaluate the thickness of the sinus membrane, as a systematic review concluded that CBCT tends to overestimate 2.5 times membrane thickness compared with histologic findings. One should also keep in mind that membrane thickness can be affected by the gingival phenotype²⁸ and by age, but not by sex or the weather at the time the scan was taken,²⁹ and an excessive thickness may represent a pathologic condition that might result in a higher chance of perforation (eg, sinusitis or inflammation).³⁰ According to Shanbhag et al, increased membrane thickness (> 5 mm) is positively associated with a higher risk of ostium obstruction, which is a contraindication of sinus floor augmentation.³¹ In line with a previous review paper,⁷ a membrane 1.5 to 2.0 mm thick can be considered favorable for sinus floor elevation, while thickness < 0.8 mm and > 3 mm may be associated with a higher risk of perforation (Table 1). Figure 1 shows a lateral window approach with a thin membrane.

Presence of Sinus Septum. According to a systematic review, presence of sinus septum was associated with an increased incidence of membrane laceration during lateral sinus elevation.²³ Sinus septa (or Underwood's septa) can be divided into primary/congenital or secondary (following tooth loss), with an average frequency ranging from 28.4% to 44.8%.³² These anatomical structures are more often encountered in the molar area,³³ with a single septum more commonly observed

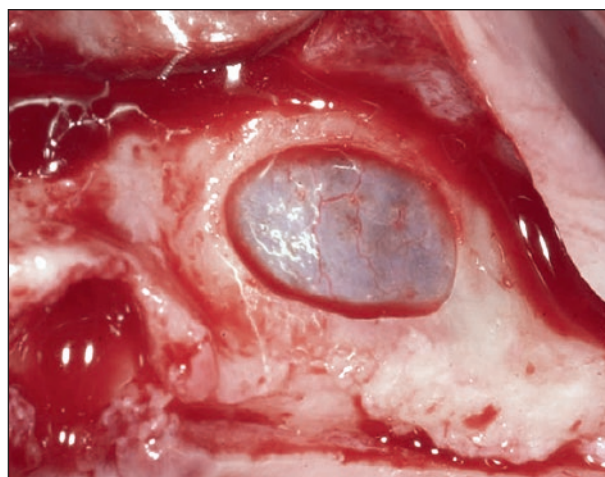


Fig 1 Lateral window approach showing a thin sinus membrane

than multiple septa³² (Fig 2). Cakur and coworkers found that the presence of sinus septa is related to the thinning of the sinus membrane, which may account for a higher perforation rate when performing LSFE.³⁴ The presence of sinus septa adds additional challenges during the surgery, by affecting the design of the osteotomy window and the elevation of the membrane.³³ Although several techniques have been proposed for managing sinus septa,³³ it is generally accepted that absence of this anatomical structure is a more favorable condition than the presence of one or more septa.

The 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% and 87.6%, while fewer patients present with septa running in the anteroposterior (sagittal) direction.³² While transverse septa can be bypassed by creating two separate bony windows, the presence of sagittal septa represents a more challenging situation in LSFE, increasing the risk of membrane perforation. The authors' clinical experience also suggested that sagittal septa usually extend toward the medial wall. The absence of septa is considered to be the most favorable condition, while the presence of mediolateral (transverse) septa and anteroposterior (sagittal) septa are moderate- and high-difficulty cases, respectively (Table 1).

Height of Sinus Septa. The height of sinus septa seems to be related to their location (anterior, middle, and posterior region) and direction.³⁵ A radiographic study found that anterior and medium septa are significantly higher than septa located in the posterior region. Interestingly, the presence of the septa would also affect the membrane thickness; at the locations closer to the septa, there was an increase of 1 mm in the sinus membrane thickness.³⁶ Wen and coworkers identified

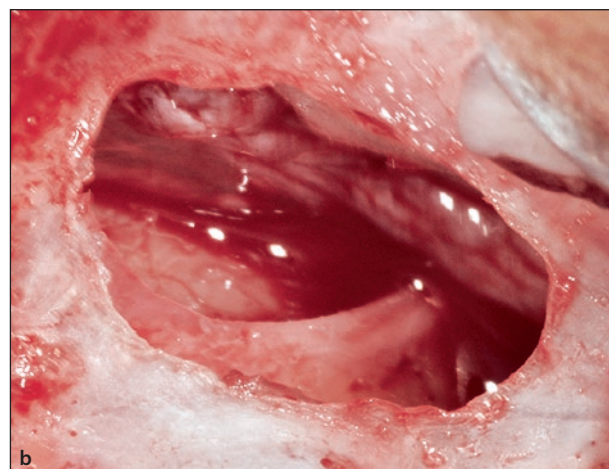
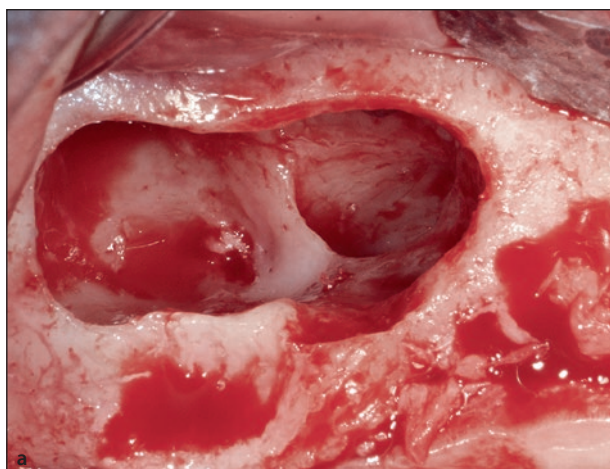


Fig 2 Maxillary sinus floor elevation in presence of sinus septa.

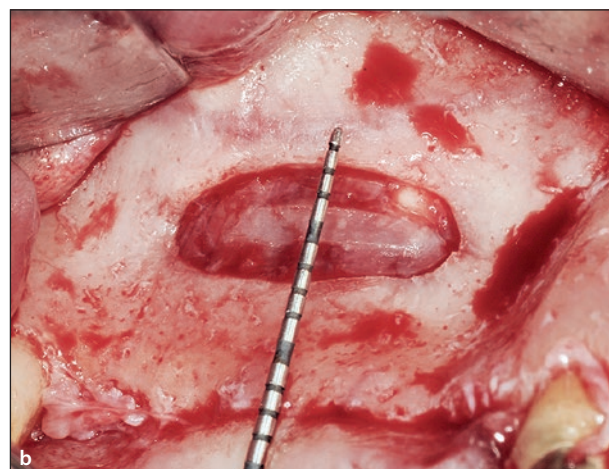
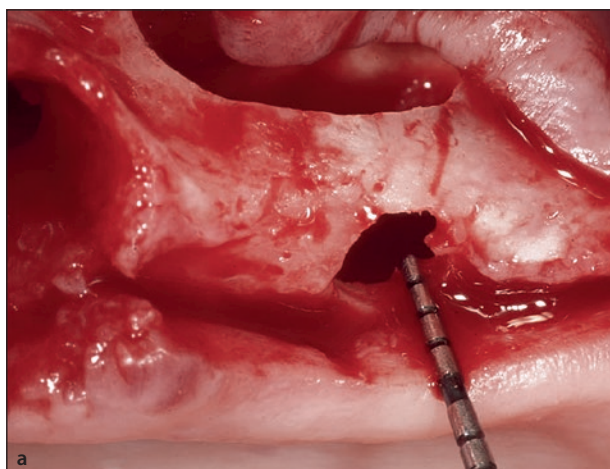


Fig 3 Clinical scenarios with (a) minimal or (b) 6-mm residual bone height.

6 mm as the cutoff point for the septa height that is associated with an increased perforation rate and therefore complicates the LSFE.³³

Type of Edentulism and Root Position Relative to the Sinus Cavity. The type of edentulism and the location of the edentulous area can also play a role in the difficulty of the LSFE. It has been reported that mixed premolar-molar sites have a relatively higher perforation rate (41.2%) than premolar sites (16.7%) or molar sites (26.2%).³⁷ In addition, a single missing tooth possesses a higher membrane perforation risk than multiple missing teeth since the membrane can be closer to adjacent teeth roots and its elevation from the floor of the sinus is more challenging.⁷

Residual Bone Height. Two retrospective studies reported an increased risk of membrane perforation when the patients presented with a residual ridge height of

less than 4 mm.^{16,37} However, a perforation risk of seven times higher has been shown in patients with a residual bone height of 3 to 6 mm compared to patients with less than 3 mm of bone height⁹ (Fig 3). Despite these conflicting results, 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 the LSFE.^{7,17} In addition, limited residual bone height (< 3 mm) was found to be associated with a lower long-term survival rate for implants placed simultaneously with lateral maxillary sinus floor augmentation.³⁸

Sinus Width. Cho et al showed that narrow sinus anatomy could be related to increased perforation risk. In particular, 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%),

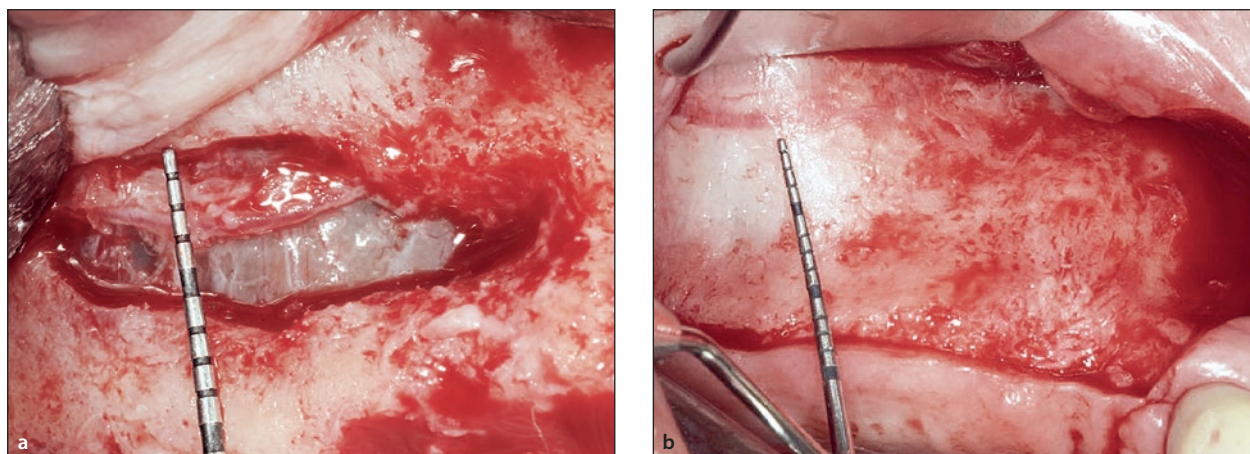


Fig 4 (a) Large and (b) small alveolar antral artery running in the area of the osteotomy window.

compared to sinuses with angles between 30 and 60 degrees or even wider sinuses (> 60 degrees), where the perforation rate decreased to 28.6% and to 0%, respectively.³⁹ In addition, it has been shown that narrow sinus morphology is more often found in the second premolar area, where the elevation may be more prone to perforation.⁴⁰

Palatonasal Recess Angle. The palatonasal recess is defined as the angle between the roof of the hard palate and the lateral wall of the nasal cavity.⁴¹ An acute angle of the palatonasal recess could add to the complexity and difficulty when performing LSFE and limit the height of elevation, especially if the acute recess angle is presented less than 15 mm away from the alveolar ridge. In a cone beam computed tomography (CBCT) study, the incidence of an acute palatonasal recess was found to be 15%, 8.2%, and 2.4% at the second premolar, first molar, and second molar sites, respectively.⁴¹

Alveolar Antral Artery. Excessive bleeding during the LSFE procedure can complicate the creation of the antrostomy by reducing the visibility of the field and therefore increasing the risk of membrane laceration. Injuries to large blood vessels running in close proximity to the lateral wall can result in this complication. The relationship between the lateral wall of the maxillary sinus and the course of the anastomosis between the posterior superior alveolar artery and the infraorbital artery (alveolar antral artery [AAA]) has been extensively investigated in the literature. Solar et al reported that AAA is mostly present as an intraosseous anastomosis, while in 44% of cases, it can also be extraosseous.⁴² Rosano et al showed that the AAA can display three different patterns (completely intraosseous, partially intraosseous, or under the periosteum of the lateral sinus wall) and that posteriorly from the second premolar area, the artery is commonly found to be adjacent to the sinus membrane with no bony layer interposed between the

vessel and the membrane.⁴³ AAA has been estimated to be located 11.25 to 26.9 mm from the alveolar crest and 5.8 to 10.4 mm from the sinus floor.⁴⁴ However, these data have to be interpreted with caution since AAA has high variability in its course. Therefore, a thorough preoperative evaluation using CBCT is recommended. CBCT studies reported that the diameter of AAA is usually less than 1 mm (62.2%),⁴⁵ and an AAA of a diameter ≥ 2 mm is not a common finding (4.3%).⁴³ According to Ella et al, AAA with a diameter between 0.5 and 1 mm accounts for intraoperative bleeding in approximately 10% of the cases, while the likelihood of hemorrhage is approximately 57% when the AAA diameter is 1 to 2 mm.⁴⁶ Therefore, the diameter of the vessel, when located in close proximity to the designated area of the antrostomy, can affect the complexity of the LSFE (Fig 4).

Buccal Wall Thickness of the Maxillary Sinus. CBCT studies showed that buccal wall thickness progressively increased from the second premolar to the second molar, with a thickness ranging from 1.5 to 1.9 mm.^{47,48} An excessive thickness in the buccal bone (> 2 mm) requires more time for completing the antrostomy and might increase the risk of membrane perforation when using rotating instruments or having limited access to the membrane due to the instrument shank limitations, while a thin buccal bone (≤ 1 mm) usually allows surgeons to identify the blue color of the membrane below the cortical wall more easily.⁴⁹

Zygomatic Arch Location. The anatomy of the zygomatic arch can also affect the surgical access to perform the antrostomy and influence the complexity of the LSFE. From the authors' clinical experience, the zygomatic process of the maxilla could be classified as relatively apical (≤ 15 mm from the crest) or more coronal to the ridge (> 15 mm from the crest). If the bony process is more apically located, therefore allowing a wider

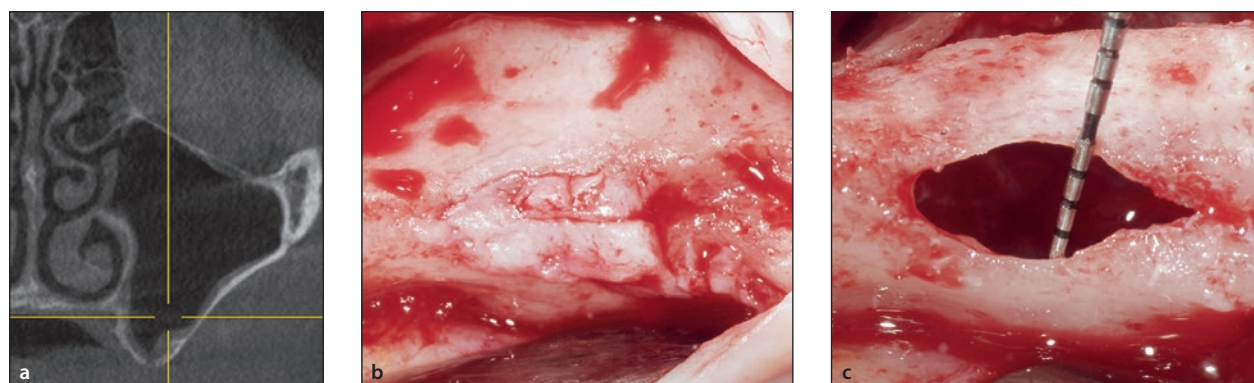


Fig 5 Clinical scenario with crestal bony dehiscence.

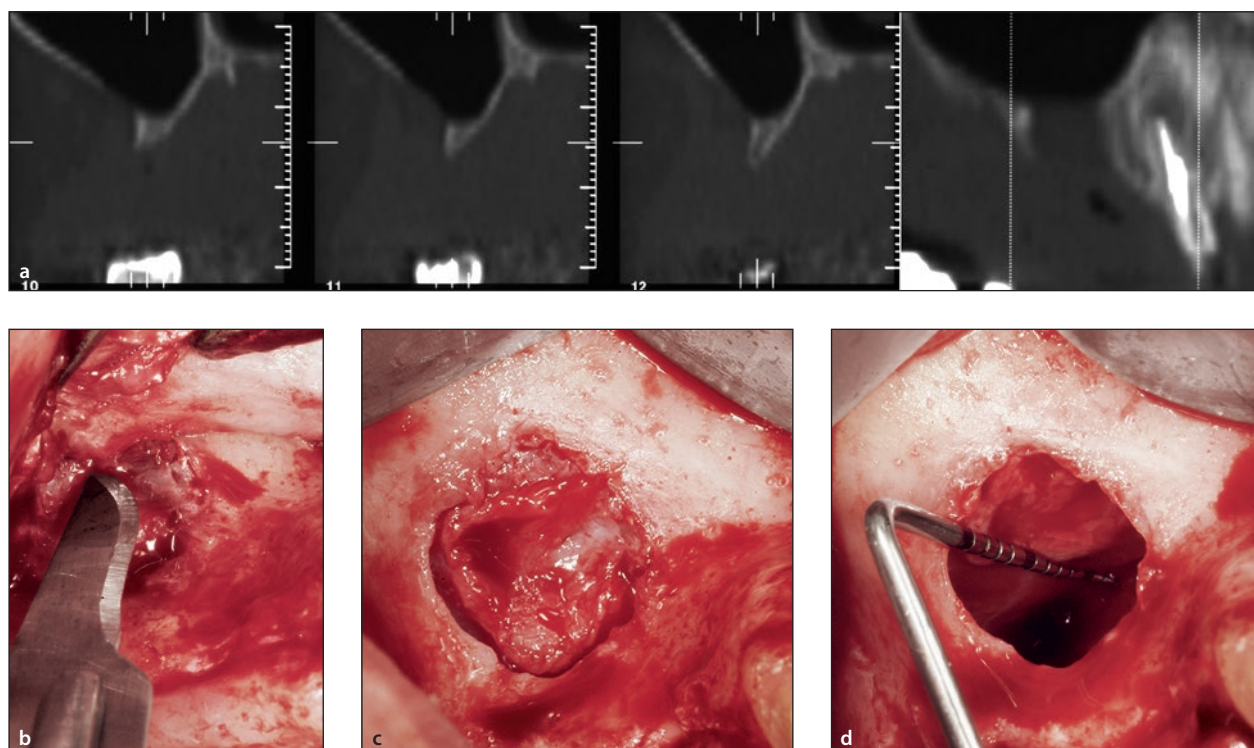


Fig 6 Clinical scenario with facial bony dehiscence.

vertical wall, it is easier for the clinician to perform the antrostomy. Patients with a long face usually have a thinner buccal wall and a zygomatic process positioned more apically to the alveolar ridge. On the other hand, patients with a short face tend to have thicker sinus walls and a zygomatic process more coronally positioned, which may limit the surgical access for creating the window and therefore poses additional challenges during the surgery.⁴⁹

Bone Dehiscence. The presence of a bony dehiscence may also affect the difficulty of the surgery, especially when the discontinuity of bone is at the level of the ridge or the mesial wall of the sinus (Figs 5 and 6).^{7,49}

Patient-Related Factors

It has been reported that smoking is associated with a higher incidence of perforation⁵⁰ and postoperative complications, such as sinusitis wound dehiscence.¹⁶ However, the effect of smoking on implant survival rate in augmented sinuses remains controversial.⁵¹ In addition, preoperative chronic sinusitis has been shown to affect the surgical outcomes, thus often leading to postoperative infection and even implant loss.⁵² Therefore, it is highly recommended to treat any sinus pathology before LSFE to prevent complications. In addition, a strong correlation between gingival phenotype and membrane thickness and a moderate correlation

between gingival phenotype and membrane perforation were found.¹⁷

Surgical access is another patient-related factor that can influence the difficulty of performing an LSFE.⁴⁹ Wide surgical access was defined as when the patient's mouth is partially open and the clinician is able to have a perpendicular view to the surgical site, whereas narrow surgical access occurs in cases in which the clinician has restricted access and visibility from the sides.⁴⁹ Lastly, the elevation site relative to the surgeon's dominant hand may also play a role in the surgical complexity⁴⁹ (Table 1).

MAXILLARY SINUS ELEVATION DIFFICULTY ASSESSMENT

Based on the reviewed literature and the expertise of the authors (Table 1), an assessment tool can be used to classify the complexity of an LSFE procedure into "simple," "moderate," and "difficult" categories (Table 2). An LSFE can be considered easy and lower risk when the sum of the points related to every single parameter is between 0 and 8, moderate risk and difficulty when points are between 9 and 16, and a difficult, challenging case when the sum is ≥ 17 . The proposed difficulty score represents an attempt to classify the cases based on the expected level of difficulty. Cases with difficulty scores of ≥ 17 points pose a higher chance of intraoperative complications linked to sinus septa, unfavorable sinus anatomy, large AAA, etc. Conversely, cases with a lower score are less likely to encounter intraoperative complications. The present assessment system also aims to promote a comprehensive preoperative evaluation of the factors that might increase the risk of membrane perforation during the procedure. Lastly, with the understanding of the estimated risk for complications in advance, this may allow the clinicians to select/match the appropriate cases according to their own expertise. Despite these advantages of the proposed evaluation scheme for a sinus augmentation procedure, further clinical studies are necessary to validate the LSFE score in predicting the complexity of the case and the likelihood of intraoperative complications.

CONCLUSIONS

The presented difficulty score offers a systematic and comprehensive method of assessing the complexity of maxillary sinus augmentation via a lateral approach and the risk of possible intraoperative complications. Prospective clinical studies are necessary to validate the proposed difficulty score system.

Table 2 Maxillary Sinus Floor Elevation Difficulty Assessment

Difficulty assessment	Definition
Simple	0–8 points in the MSED Scoring System
Moderate	9–16 points in the MSED Scoring System
Difficult	≥ 17 points in the MSED Scoring System

ACKNOWLEDGMENTS

This article was partially supported by the University of Michigan Periodontal Graduate Student Research Fund. The authors do not have any financial interests, either directly or indirectly, in the products or information listed in the article.

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