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*Review*

# Risk Assessment of Transcrestal Maxillary Sinus Floor Elevation: A Narrative Review

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## Abstract

**Background:** Transcrestal maxillary sinus floor elevation (TSFE) is a key technique for posterior maxillary bone deficiency in implantology, with sinus membrane perforation as the main complication. Accurate risk assessment is critical for improving surgical success and implant survival rates. **Findings:** TSFE surgical risk is determined by six core factors: bone defect type, elevation height, sinus floor morphology, sinus membrane status, ostium patency, and immediate implant placement. Surgical difficulty can be stratified into Easy/Moderate/Difficult, with matching technical strategies to reduce risks. **Conclusions and Relevance:** Multidimensional risk stratification and targeted technique selection effectively control TSFE risks. Surgeons with lateral window technique experience are recommended for TSFE, and multidisciplinary collaboration is advised for high-difficulty cases, providing precise guidance for clinical implant practice.

**Keywords:** transcrestal maxillary sinus floor elevation (TSFE); risk assessment; sinus membrane perforation; dental implants; risk factors

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## 1. Introduction

Transcrestal maxillary sinus floor elevation (TSFE) is the first-line treatment for insufficient bone volume in the posterior maxilla in oral implantology<sup>1-7</sup>. Sinus membrane perforation, the most common adverse complication of TSFE<sup>8</sup>, often leads to surgical failure and poor implant prognosis. Accurate assessment of surgical difficulty and rational clinical strategy selection are the core links to avoid complications and ensure surgical success.

Based on extensive clinical practice and literature review<sup>9-10</sup>, this narrative review systematically sorts out the core risk assessment factors of TSFE, stratifies surgical difficulty, and formulates corresponding clinical technical strategies. The purpose of this review is to construct a standardized TSFE risk assessment framework, provide a professional reference for clinical implantologists, and improve the safety and clinical outcomes of TSFE surgery.

## 2. Materials and Methods

### *Literature Retrieval*

This narrative review collected relevant literature on TSFE risk assessment and clinical application from mainstream databases (PubMed, Embase, Web of Science) up to 2025, with search terms including "transcrestal maxillary sinus floor elevation", "TSFE", "risk assessment", "sinus membrane perforation" and "dental implant". Literature screening was conducted with the following inclusion criteria: (1) original research, narrative reviews and systematic reviews on TSFE risk assessment; (2) studies published in English; (3) studies with complete clinical data and clear outcome indicators. Exclusion criteria: (1) case reports with no risk assessment analysis; (2) non-English language literature; (3) duplicate publications and conference abstracts. The literature was screened

by clinical relevance and evidence level, and the core risk factors and clinical strategies of TSFE were summarized and sorted out.

This narrative review is a literature-based study without human subjects or human tissue involvement. The study protocol has been granted an exemption from the Institutional Review Board (IRB) of Rytime Dental Hospital in accordance with local IRB standards.

### 3. Results

#### 1. Core Risk Assessment Factors of TSFE

Six key factors determine the surgical risk of TSFE, and the risk level of each factor is stratified into Easy/Moderate/Difficult (Table 1), which is the basis for surgical difficulty evaluation.

(1) Bone Defect Type: Bone defect types, encompassing horizontal, vertical, and combined defects,<sup>11</sup> are core elements for assessing baseline surgical conditions. When an edentulous site presents no horizontal or vertical bone deficiency, the surgical procedure is relatively straightforward, requiring only sinus floor elevation. Minor bone defects increase operative difficulty, often necessitating adjunctive guided bone regeneration (GBR) and raising concerns about an increased crown-to-root ratio of the future prosthesis. Severe bone defects significantly elevate surgical complexity, demanding high precision and adaptability from the surgeon, and may require simultaneous or staged grafting protocols, thereby increasing procedural difficulty and patient morbidity.

**Table 1.** Risk Factor Assessment of Transcrestal Maxillary Sinus Floor Elevation.

	Easy	Moderate	Difficult
Bone Defect Type			
Horizontal bone defect	None	Slight	Severe
Vertical bone defect	None	Slight	Severe
Mixed type	-	Slight	Severe
Height to be elevated	≤2mm	3 - 4mm	>4mm
Maxillary sinus floor morphology	Flat	Slope < 30°	Slope > 30° or with septum

Sinus membrane status (imaging)	1 - 3mm	< 1mm; > 3mm	Abnormal status (such as spherical shape, fluid level, bubble shadow, calcification spots, etc.)
Maxillary sinus ostium	Open		Obstructed
Immediate implant placement	No		Yes

(2) **Required Bone Height Augmentation:** In much of the literature, TSFE with a planned augmentation height of less than 4mm is considered safe.<sup>12</sup> However, in clinical practice, surgeons frequently perform TSFE with greater augmentation heights (>4mm) based on considerations of trauma and treatment duration. It must be emphasized that proficiency in the lateral window sinus floor elevation technique is a prerequisite before attempting TSFE with larger augmentation ranges to ensure procedural safety and success.

Elevation heights within 2-3mm carry a relatively low risk of sinus membrane injury. For heights of 3-4mm, requirements for operational precision increase, necessitating careful control of elevation force and extent. Heights exceeding 4mm are associated with a significantly increased risk of membrane stretching and perforation, with surgical difficulty rising exponentially. More refined techniques and instrumentation are required to ensure safety.

(3) **Maxillary Sinus Floor Morphology:** Maxillary sinus floor morphology includes flat, sloped (<30°), sloped (>30°), or presence of septa.<sup>13,14</sup> A flat floor facilitates instrument manipulation and sinus lift. For slopes <30°, adjustment of the operating angle and force is necessary to avoid membrane tearing. Slopes >30° or the presence of septa create complex sinus floor anatomy, greatly increasing the risk of membrane perforation during elevation and adding uncertainty to the procedure.

(4) **Sinus Membrane Status:** Sinus membrane status is assessed radiographically. Mild thickening (1-3mm) has a relatively manageable impact on surgery. Membranes <1mm or >3mm often exhibit altered texture and elasticity, making them prone to rupture during elevation.<sup>15,16</sup> Abnormal states (e.g., spherical, air-fluid levels, air bubbles, calcifications) suggest potential intrasinus pathology such as inflammation or cysts,<sup>17,18</sup> substantially increasing surgical risk and difficulty. Thorough preoperative assessment and contingency planning are essential.

(5) **Maxillary Sinus Ostium:** A patent maxillary sinus ostium facilitates surgical procedures. Obstruction alters the intrasinus pressure environment and postoperative sinus homeostasis, increasing the risk of postoperative infection and lift failure.<sup>19,20</sup> Regardless of the planned lift height, surgeons must preoperatively assess and prepare for challenges posed by ostial obstruction and inform patients of associated risks. Some scholars suggest that radiographic findings of irregular (>5mm), circumferential, or complete mucosal thickening around the ostium are associated with an increased risk of obstruction, warranting ENT consultation. Any grade of spherical mucosal appearance correlates with a relatively lower risk of sinus obstruction, but if accompanied by sinusitis symptoms, ENT consultation is advised.<sup>21</sup>

(6) **Simultaneous Immediate Implant Placement:** Immediate implant placement in the posterior maxilla often requires concomitant TSFE. Compared to TSFE at healed sites, cases involving immediate implantation present increased surgical risks, such as achieving primary stability and ensuring safe membrane elevation. Factors like available apical bone volume, the potential to achieve primary stability, and the planned membrane elevation height must be meticulously evaluated preoperatively to minimize complications.

## 2. TSFE Surgical Difficulty Stratification and Corresponding Technical Strategies

Integrating the six risk factors, TSFE surgical difficulty is divided into three levels, and differentiated technical combinations are adopted for each level to control risks:

(1) Easy: Minimal bone defects, elevation <2mm, flat sinus floor, normal membrane status, patent ostium, no immediate implantation. Drilling/countersink or osteotome technique alone is applicable, with the focus on membrane protection.

(2) Moderate: Mild bone defects, elevation 3-4mm, slope <30° sinus floor, mild membrane thickening, patent ostium. Combined technique (drilling/osteotome + hydraulic pressure assistance) is recommended for precise control of elevation force and range.

(3) Difficult: Severe bone defects, elevation >4mm, slope >30°/septum, abnormal membrane status, ostial obstruction, with immediate implantation. A synergistic approach (drilling + hydraulic pressure + osteotome with cushioning medium) is used to reduce membrane trauma.

#### 4. Discussion

This narrative review constructs a comprehensive TSFE risk assessment framework based on six core factors (bone defect type, elevation height, sinus floor morphology, sinus membrane status, ostium patency, immediate implant placement) and realizes quantitative stratification of surgical difficulty into Easy/Moderate/Difficult. The core contribution of this framework is to link risk factors with technical selection, forming a "risk assessment - difficulty stratification - targeted strategy" clinical decision-making chain, which makes the TSFE clinical operation more standardized and precise, and effectively reduces the occurrence of complications such as sinus membrane perforation.

The technical strategy matching principle proposed in this review is consistent with the clinical experience summarized in existing literature: for low-difficulty cases, a single conventional technique can meet the surgical needs; for moderate-difficulty cases, hydraulic pressure assistance is added to make up for the limitation of a single technique in force control; for high-difficulty cases, a cushioning medium is combined to reduce membrane trauma during blind operation. This layered technical selection idea fully considers the clinical practicability and operability, and is suitable for popularization in clinical implantology.

This review emphasizes that surgeons performing TSFE must have experience in the lateral window sinus floor elevation technique, which is the safety foundation for handling complex situations in TSFE. For high-difficulty TSFE cases, if the surgeon lacks sufficient experience, it is recommended to convert to the lateral window technique or seek ENT multidisciplinary consultation. This view clarifies the application boundary of TSFE: TSFE is not the default option for all maxillary sinus augmentation cases, and patient safety and surgical controllability should be the primary principles of clinical decision-making. The risk assessment framework constructed in this review can serve as a preoperative "filter" to identify cases suitable for TSFE and those that need to be converted to other techniques, which is of great clinical guiding significance.

The limitations of this narrative review are that the risk assessment factors are mainly based on preoperative imaging (Cone-Beam Computed Tomography) and clinical examination, and lack dynamic intraoperative factors (such as real-time hydraulic pressure, membrane biomechanical properties). Future research can further enrich the risk assessment system by incorporating intraoperative dynamic monitoring indicators and conducting large-sample prospective clinical studies to verify the reliability and validity of the framework. In clinical practice, implantologists can flexibly adjust the risk assessment indicators and technical strategies according to their own surgical experience and clinical conditions, and continuously optimize the TSFE clinical decision-making process.

Accurate multidimensional risk assessment and targeted technical selection are the core to the success of TSFE in oral implantology. By stratifying surgical difficulty according to bone defects, elevation height and other six core factors, and matching corresponding surgical techniques, grafting protocols and implant placement plans, the surgical risk of TSFE can be effectively controlled. Emphasizing the surgeon's technical experience and multidisciplinary collaboration can further

improve the safety and clinical outcomes of TSFE, and provide a more reliable theoretical and practical support for implant rehabilitation in the posterior maxilla.

## 5. AI Disclosure Statement

Artificial intelligence (AI)-assisted writing tools were used in the preparation of this manuscript solely for the purpose of optimizing the fluency of American English expression, refining sentence structure, and correcting grammatical errors in the text. The AI tools were not involved in any core intellectual work of this study, including but not limited to research design, identification and analysis of transcrestal maxillary sinus floor elevation (TSFE) risk factors, stratification of surgical difficulty, formulation of clinical strategies, interpretation of clinical case data, and drafting of research conclusions and clinical implications.

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