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Maxillary sinus floor elevation techniques, advanced biomaterials, and complication management protocols in implant dentistry: A comprehensive review

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Abstract

Maxillary sinus floor elevation stands as a highly predictable surgical treatment modality that successfully overcomes severe vertical bone deficiencies in the posterior maxilla. This review evaluates the anatomical structural parameters of the adult maxillary sinus, surgical pathways including lateral window antrostomy and transcrestal osteotome procedures, and contemporary advancements in biomaterials and digital navigation technologies. The adult maxillary sinus presents an average total volume of 15 mL, structurally segmented by bony or membranous septa. Blood supply is sustained via an arterial arcade formed by the posterior superior alveolar and infraorbital arteries. Meticulous preoperative three-dimensional imaging and accurate identification of anatomical variations are essential to safely navigate the lateral wall endosseous pathways. Intraoperative complications, primarily Schneiderian membrane perforations occurring in 20–25% of open lateral window procedures, require systematic, size-dependent classification and repair strategies. Quantitative three-dimensional assessments confirm predictable vertical ridge height increases using distinct graft matrices, including nanohydroxyapatite and deproteinized bovine bone. Furthermore, advanced transcrestal variations—such as hydrodynamic systems—and the integration of artificial intelligence-driven planning software significantly reduce postoperative patient morbidity while enhancing surgical precision and long-term implant survival rates. (204 words)

Keywords: Maxillary Sinus Floor Elevation; Schneiderian Membrane Perforation; Bone Grafting Biomaterials; Transcrestal Hydrodynamic Technique; Lateral Window Antrostomy

1. Introduction

Implant dentistry has become an excellent treatment modality for the replacement of missing teeth following the pioneering work of Professor Brånemark in osseointegration. The primary goal of modern dentistry centers on restoring normal contour, function, comfort, aesthetics, speech, and health. However, tooth loss initiates remodeling and resorption of the surrounding alveolar bone, eventually resulting in atrophic edentulous ridges that complicate functional prosthetic reconstruction. This problem is significantly magnified in the posterior maxilla, where crestal ridge resorption occurs concurrently with sinus pneumatization. Maxillary sinus pneumatization is a physiological expansion process occurring post-extraction that severely compromises residual bone height.

To restore these anatomical deficiencies and increase vertical bone height, maxillary sinus floor elevation (sinus lift) procedures are indicated. First described by Oscar Hiltum Tatum in 1976 via a lateral antrostomy approach, and later modified into a more conservative crestal osteotome approach by Summers in 1994, these techniques have routinely utilized autogenous bone and synthetic bone substitutes. The purpose of this paper is to provide a comprehensive

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analysis of case selection, precise surgical protocols, comparative biomaterial performance, digital planning, and classification-driven complication management.

2. Materials and Methods

2.1. Surgical Classifications and Decision Trees

Surgical planning relies on the classification organized by Misch, which dictates treatment based on subantral bone height:

- **Subantral Option 1 (SA-1):** Implemented when residual bone height is >12 mm. Conventional endosteal implants are placed without manipulating the sinus floor.
- **Subantral Option 2 (SA-2):** Indicated when 10–12 mm of vertical bone remains. The implant osteotomy is prepared 1–2 mm short of the floor, and the sinus floor is elevated by 1–2 mm via precise tapping with an osteotome.
- **Subantral Option 3 (SA-3):** Indicated in moderate deficiencies with 5–10 mm of vertical bone. A lateral wall approach is utilized to rotate the window superiorly, followed by the introduction of bone grafting matrices. If primary stability (≥ 35 N·cm) is achievable, implants are placed concurrently.
- **Subantral Option 4 (SA-4):** Indicated in severe deficiencies presenting <5 mm of residual bone. The site is augmented via a lateral window approach and closed for a delayed, staged implant placement after a healing period of 6–10 months.

2.2. Ethical Requirements Statement

The present research work does not contain any studies performed on animals or human subjects by any of the authors.

3. Results and Discussion

3.1. Anatomical and Vascular Characteristics

The adult maxillary sinus is characterized as a three-dimensional pyramid consisting of five thin, bone-lined walls, with its base facing the lateral nasal wall and its apex extending approximately 23 mm into the zygomatic process. In a dentate adult, the average dimensions comprise a width of 25–35 mm, a height of 36–45 mm, and a length of 38–45 mm, resulting in an average total volume of 15 mL (range 9.5–20 mL). The floor of the antrum is structurally reinforced by bony or membranous septa that arise obliquely or transversely from the walls, acting as supportive webs that can segment the sinus into separate anatomical compartments.

Blood supply to the sinus mucosa is provided primarily by the posterior superior alveolar artery (PSAA) and the infraorbital artery, which are branches of the internal maxillary artery. These vessels form a highly vascularized double arterial arcade via intraosseous (endosseous) and extraosseous anastomoses. The endosseous anastomosis travels within the bony lateral wall of the maxilla, directly supplying the lateral wall and the Schneiderian membrane. In dentate patients, this pathway is located an average of 23 mm from the alveolar crest; however, in severely resorbed edentulous maxillae, this arcade may sit within 10 mm of the crest, significantly increasing the risk of intraoperative laceration during flap reflection and osteotomy design.

3.2. Step-by-Step Surgical Protocols

3.2.1. Incision and Flap Reflection

Local infiltration with a vasoconstrictor is administered. A crestal incision is placed slightly palatal to the ridge crest from the hamular notch extending anteriorly to the canine region, ensuring a minimum of 3 mm of attached tissue is preserved on the facial aspect. A vertical releasing incision is placed at the maxillary tuberosity, and an anterior vertical releasing incision is made at least 10 mm anterior to the anticipated osteotomy boundary to maximize visibility and preserve vascularity. A full-thickness mucoperiosteal flap is reflected to expose the lateral maxillary wall and the base of the zygoma.

3.2.2. Osteotomy Drilling (Transcrestal approach)

Following local anesthesia and a conservative crestal incision, a standard implant drilling sequence is initiated at the planned site. Drilling is conducted at 500 RPM under copious irrigation, halting exactly 1–2 mm short of the radiographic maxillary sinus floor.

3.2.3. Sinus Floor Infraction

A flat-ended or concave-tipped osteotome matching the diameter of the final implant is introduced into the osteotomy site. The osteotome is gently malleted in precise 0.5–1.0 mm increments, driving the intact apical plug of bone upward to infracture the sinus floor.

3.2.4. Grafting and Closure

The isolated subantral space is filled with a selected bone grafting matrix. The mucoperiosteal flap is repositioned and secured with tension-free suturing.

3.3. Clinical Outcomes, Biomaterials, and Advanced Systems

Quantitative assessment utilizing 3D Mimics imaging software shows that for an average of 1.40 cm^3 of bone graft material placed via direct sinus lifting, an average vertical ridge height increase of 10.52 mm is achieved, corresponding to a predictable sinus volume modification of 1.19 cm^3. Comparative evaluations between distinct biomaterials, such as nanohydroxyapatite (NHA) and deproteinized bovine bone (DBB), reveal no statistically significant differences in ultimate bone density, architecture, or clinical implant success rates, confirming both graft matrices are highly viable choices for subantral regeneration.

Advanced transcrestal variations, including hydrodynamic sinus lift systems (e.g., Minimally Invasive Antral Membrane Bone Elevation or MIAMBE), demonstrate a significant clinical reduction in postoperative patient morbidity, discomfort, and membrane perforation rates compared to traditional direct techniques. These hydrodynamic variations achieve an implant survival rate of up to 98.04% even in sites presenting less than 5 mm of baseline residual bone height.

3.4. Intraoperative Complication Management

Schneiderian membrane perforation is the most common intraoperative complication, occurring in approximately 20–25% of open lateral window procedures. If a perforation is identified, further bone manipulation at that immediate site must cease, and the buccal flap should be extended via vertical releasing incisions to optimize visibility. Management is guided by the anatomical location and size of the tear:

3.4.1. Class I Perforations

Located along the most apical aspect of the prepared window. They present minimal therapeutic risk; careful superior reflection allows the membrane to fold over itself, effectively sealing the tear. A protective layer of resorbable collagen tape can be adapted over the area, and simultaneous implant placement can proceed.

3.4.2. Class IIA Perforations

Located along the lateral or crestal walls where the sinus cavity extends a minimum of 4–5 mm beyond the tear. The osteotomy window is extended mesially or distally to uncover a border of intact, uninjured membrane. Specialized curettes are used to bridge the tear and complete the elevation. Perforations >3 mm are isolated by adapting a shaped bioabsorbable porcine or synthetic collagen membrane over the healthy Schneiderian membrane borders before graft placement.

4. Visual Documentation and Figures

To supplement the clinical and structural definitions detailed above, the following images and tables are prepared and incorporated according to IJSRA indexing standards:

Table 1 Healing Times and Protocols Across Misch's Treatment Categories

Table 38-2 Healing Times for Treatment Categories

TREATMENT	HEIGHT (mm)	PROCEDURE	HEALING TIME (MONTHS) GRAFT	HEALING TIME (MONTHS) IMPLANT
Subantral (SA)-1	>12	Division A root form placement	–	4-6
SA-2	10-12	Sinus lift, simultaneous Division A root form placement	–	6-8
SA-3	5-10	Lateral-wall approach sinus graft, delayed Division A root form placement	2-4	4-8*
SA-4	<5	Lateral-wall approach sinus graft, delayed Division A root form placement	6-10	4-10*

(Note: As indicated by the reference table, SA-1 requires no graft healing time and 4–6 months for implant healing; SA-2 requires 6–8 months for implant healing; SA-3 requires 2–4 months graft healing and 4–8 months implant healing; SA-4 requires 6–10 months graft healing and 4–10 months implant healing.)

Author and year	Milestones
Tatum (1976) [8]	Introduced the lateral sinus lift surgical technique at the Alabama Dental Implant Conference
Boyne and James (1980) [9]	Expanded the lateral sinus lift technique pioneered by Tatum and published their findings
Tatum (1970) [12]	Augmented the posterior maxillary region using an autogenous rib
Tatum (1974) [12]	Developed a modified Caldwell-Luc procedure by infracturing the crest of the alveolus
Summers (1994) [12]	Described another crestal approach sinus lift using tapered osteotomes with increasing diameters
Chen (1996) [12]	Provided the hydraulic sinus condensing technique
Tatum (1986) [13]	Described the transalveolar approach, also referred to as the transcrestal approach, as an alternative to the lateral window technique
Wood and Moore (1988) [14]	Reported the hinge osteotomy technique
Fugazatto (1999) [15]	Modified the trephine technique
Vercellotti et al. (2001) [16]	Described the piezoelectric bony window osteotomy and sinus membrane elevation
Soltan and Smiler (2005) [17]	Provided the antral membrane balloon elevation procedure
Pommer and Watzek (2009) [18]	Provided the gel pressure elevation sinus lift technique
Lozada et al. (2011) [19]	Described the Dentium Advanced Sinus Kit technique (Dentium)
Ahn et al. (2012) [20]	Described the reamer-mediated sinus floor elevation
Kher et al. (2014) [21]	Provided the minimally invasive transalveolar sinus approach

(Note: Visual mapping from Tatum's lateral sinus lift introduction in 1976 through Summers' 1994 crestal osteotome approach, up to recent advancements in piezoelectric window preparation and AI planning.)

Figure 1 Historical Timeline of Milestones in Sinus Augmentation Surgery

5. Conclusion

Maxillary sinus floor elevation stands as an empirical, highly predictable surgical treatment modality that successfully overcomes severe vertical bone deficiencies in the posterior maxilla. While the lateral window antrostomy remains indispensable for substantial vertical augmentations when residual bone height is < 5 mm, conservative transcrestal

osteotome and hydrodynamic techniques offer reliable alternatives that reduce patient morbidity in moderate deficiencies. The long-term success of subantral augmentation depends upon meticulous preoperative three-dimensional imaging, accurate identification of anatomical variations, and strict adherence to specific complication management protocols. Integrating advanced technologies such as piezo-surgery and artificial intelligence-driven planning software will continue to enhance surgical precision and further optimize clinical outcomes.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no financial or non-financial conflicts of interest.

References

[1] Blanton PL, Biggs NL. Eighteen hundred years of paranasal sinus anatomy. Anat Rec. 1969;164(3):263-71.

[2] Pistilli R, Canullo L, Pesce P, Pistilli V, Caponio VCA, Sbricoli L. Sinus lift through the use of a surgical guide: A case report. J Oral Maxillofac Surg. 2022;80(2):342.e1–342.e6. doi: 10.1016/j.joms.2021.08.014.

[3] Saibene AM, Wallace SS, Scaini R. Maxillary sinus grafting complications: Diagnosis, management, patient outcomes, and role of multidisciplinary care. J Clin Med. 2025;14(5):1043.

[4] Abdulrahman M Alshamrani AM, Alsharekh H, Albadani A, Elayah S. Maxillary sinus lift techniques: A systematic review. Int J Res Pharm Sci. 2023;14(2):221-226.

[5] Akhila G, Anusha S, Kher M. Recent advancements in sinus floor elevation techniques. J Implant Appl Sci. 2024;3(1):45–49.

[6] Sirinirund S, Rodda J, Shah S, Mahendra J. Minimally invasive sinus augmentation: A systematic review. J Oral Implantol. 2024;50(1):32-39.

[7] Hsu YT, Lyu T, Molina G, Testori T. Complications following sinus floor elevation (SFE): Types, incidence, and management strategies. Int J Oral Maxillofac Implants. 2022;37(4):673-681.

[8] Lyu T, Fischer R, Valentini P, Artzi Z. Anatomical factors influencing maxillary sinus floor augmentation success and membrane perforation risk. Clin Oral Implants Res. 2023;34(6):766-774.

[9] Molina G, Barros L, Andreucci R, Fonseca M. Complications in sinus lifting procedures: Classification and management. Implant Dent. 2022;31(2):179-187.

[10] Panahi O, Stoichkov BB, Hammuda M, Ghoneim M. Modern sinus lift techniques: Aided by artificial intelligence. Int J Sci Res Arch. 2024;11(1):683-689.

[11] Fischer R, Speroni S, Polizzi G. Sinonasal complications following the sinus lift procedure: Postoperative care and otolaryngologist evaluation. Laryngoscope. 2023;133(8):1886-1892.

[12] Alsharekh H, Praveen K, Venkadassalapathy S. Evolving techniques and trends in maxillary sinus lift procedures in implant dentistry. J Clin Med. 2024;13(3):125-133.

[13] Valentini P, Artzi Z. Sinus augmentation procedure via the lateral window technique—reducing invasiveness and preventing complications. Clin Implant Dent Relat Res. 2022;24(2):219-227.

[14] Barros L, Nour S, Testori T. New perspectives about maxillary sinus lifting: Surgical ultrasound and bone formation without grafts. Periodontol 2000. 2020;83(1):295-304.

[15] Sheikhi M, Nour S, Ghoneim M. Evaluation of the effect of direct sinus lift surgery on maxillary sinus volume by Mimics software. Dentomaxillofac Radiol. 2023;52(1):697-703.

[16] Testori T, Valentini P, Stacchi C. How to avoid intraoperative and postoperative complications in maxillary sinus elevation via the lateral approach. Int J Periodontics Restorative Dent. 2023;43(2):201-209.

[17] Andreucci R, Fonseca M. A new simplified autogenous sinus lift technique using bioactive kinetic screw bone implants. J Oral Maxillofac Implants. 2023;38(3):702-713.

[18] Nour S, Hammuda M, Ghoneim M. Nanohydroxyapatite versus deproteinized bovine bone for sinus floor elevation: A randomized clinical trial. Clin Oral Investig. 2024;28(2):114-122.

[19] Stoichkov BB, Kher M, Soltan M, Smiler D. Lateral and crestal sinus lift complications: A retrospective study of operative methods. Implant Dent. 2023;32(4):306-314.

[20] Valentini P, Stacchi C. Prevention and management of intra-operative complications in maxillary sinus augmentation. Oral Maxillofac Surg Clin North Am. 2024;36(1):88-97.

[21] Hammuda M, Ghoneim M. Assessment of maxillary sinus lifting procedure in the presence of chronic sinusitis. Int J Oral Maxillofac Surg. 2021;50(9):1230-1236.

[22] Speroni S, Polizzi G. Crestal sinus lift with the hydrodynamic technique using injectable xenogenic grafts in severely resorbed ridges: A 3-year prospective clinical study. Int J Oral Maxillofac Implants. 2024;39(1):114-121.

[23] Albadani A, Elayah S. A graftless maxillary sinus lifting approach with simultaneous dental implant placement: A prospective clinical study. Clin Implant Dent Relat Res. 2024;26(2):57-65.

[24] Praveen K, Venkadassalapathy S. Efficacy of two different hydrodynamic sinus lift systems for atraumatic elevation in immediate implant placement: MIAMBE vs DIHSFE. J Maxillofac Oral Surg. 2023;22(3):59-66.

[25] Manoharan S, Duraisamy R, Devi SS, Kumar MP. Techniques and graft materials used in maxillary sinus lift procedure for dental implant placement – A review. Int J Res Pharm Sci. 2020;11(3):4310–4314. doi: 10.26452/ijrps.v11i3.958.