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Review Article

Cutting-edge methods and new frontiers in maxillary sinus lifting for enhanced dental restoration and implants: An analytical review

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ABSTRACT:
Maxillary sinus lifting stands as a cornerstone in dental implantology, vital for overcoming insufficient bone volume in the posterior maxilla. This article delves into the forefront of advancements and pioneering techniques in sinus lift surgery, spotlighting state-of-the-art methods that significantly bolster the success of dental restorations. It explores the evolution of sinus elevation strategies, including the lateral window approach and the osteotome technique, and underscores recent innovations that enhance outcomes and minimize complications. Moreover, the article synthesizes the impact of cutting-edge diagnostic imaging in refining treatment planning and execution. Key anatomical nuances, including the intricate structure and variability of the maxillary sinus, is examined to contextualize these advancements. By incorporating recent breakthroughs and emerging methodologies, this review aspires to provide a thorough overview of how contemporary approaches in maxillary sinus lifting facilitate more effective and aesthetically superior dental implant outcomes.
Key words: Maxillary sinus, Maxillary sinus augmentation, Crestal approach, Direct lateral window, Osteotomebone graft, Dental implants, Success, Survival

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INTRODUCTION

Maxillary sinus augmentation, also known as sinus floor elevation, is frequently performed to prepare the posterior maxilla for dental implants, especially when there is significant bone loss due to sinus expansion, alveolar bone deterioration, or injury.[1] Before the 20th century, although knowledge of bone and sinus anatomy was present, there were no systematic techniques for bone augmentation or sinus lifting.[2] Dental practices were more rudimentary, focusing primarily on extraction and basic restoration.[3] The concept of using bone grafts to augment bone for dental implants began to take shape in the mid-20th century, during the 1960s-1970s.[4] Pioneering work by researchers and clinicians highlighted the importance of bone volume for implant stability.[5] Early techniques were primarily experimental and involved a lot of trial and error.[6] In the 1970s, Dr. Bernhard T. D. Schulte and Dr. Willi M. K. Zahradnik played a crucial role in developing and refining the sinus augmentation procedure.[7] Their work focused on understanding the biological processes involved in bone grafting and the interaction between graft material and surrounding bone.[8] In the modern era, during the 1980s and 1990s, the sinus lift technique saw significant advancement through Dr. J. C. Tatum's introduction of the "lateral window approach."[9] This technique involved creating a small window in the lateral wall of the maxillary sinus to place the bone graft, which became a widely accepted method.[10] At the same time, autogenous bone taken from the patient became more popular because of its compatibility and effectiveness.[11] Methods for performing a sinus lift include the lateral window approach, where a hole is created in the sinus cavity to insert the graft material, and the osteotome technique, which uses a specialized tool to gently lift the sinus floor.[12] Additionally, the osteotome technique provides a more conservative approach.[13] Recovery generally involves managing swelling and discomfort with medications such as antibiotics, painkillers, decongestants, and anti-inflammatory drugs.[14] Graft materials may include autogenous bone from the patient's own body, allogeneic grafts from human donors, alloplastic materials that are synthetic substances, and xenogeneic grafts from animal sources.[15] These materials can be used individually or in combination. Implants can be placed during the same procedure or after a healing period of 6 to 9 months.[16] Indications for sinus augmentation include inadequate residual bone height of less than 10 mm vertically and atrophic posterior maxillary alveolus.[17] Contraindications for the procedure include: acute active sinusitis, recurrent chronic sinusitis, severe allergic rhinitis, neoplasms or sizable cysts within the sinus, a history of previous sinus surgery such as the Caldwell-Luc procedure, past radiation therapy to the maxilla, presence of Underwood's septa or pronounced sinus floor convolutions, uncontrolled diabetes, alcoholism, heavy smoking, and psychosis.[18] Normal pneumatization of the maxillary sinus, particularly when combined with tooth loss, often results in inadequate bone volume, specifically related to height, to accommodate an implant.[19]This challenge is compounded by the necessity to extract failed posterior teeth.[20] To address this, the maxillary sinus must be augmented to provide sufficient bone height for implant placement.[21]When adequate height is available for implant stability but additional height is necessary, sinus augmentation can be performed via the alveolar ridge approach.[22] However, in scenarios where minimal bone is present and increased height is needed to support the implant, a sinus approach is required.[23] The maxillary sinus is the largest of the paranasal sinuses, having a pyramidal shape.[24] Its average dimensions are approximately 36-45 mm in height, 23-25 mm in width, and 38-45 mm in length along the anteroposterior axis, with a volume of 15 ml.[25] Key anatomical characteristics of the maxillary sinus include several distinct features.[26] The anterior wall stretches from the infraorbital rim to the alveolar ridge of the maxilla and houses the infraorbital neurovascular bundle.[27] The superior walls constitute the base of the sinus and are relatively fragile. Meanwhile, the posterior wall demarcates the maxillary sinus from the pterygopalatine fossa, encompassing vital structures such as the posterior superior alveolar nerve, various veins, the pterygoid venous plexus, and the internal maxillary artery.[28]The inner wall constitutes the outer aspect of the nasal cavity and includes the primary ostium, which serves as the main drainage route for the nasal cavity.[29] The lateral wall forms the anterior face of the nose, affects the posterior section of the palate, and the malar region, and is involved in lateral wall sinus grafting procedures.[30] The maxillary sinus septum, as described by Underwood in 1910, is classified into primary and secondary types.[31] Primary septa develop during the formation of the palate and teeth, while secondary septa arise from sinus expansion following tooth loss.[32] These septa, usually found between the first and second molars, may obstruct nasal surgeries and might require multiple external access points to navigate through them.[33] The maxillary sinus is lined with Schneider's membrane, a pseudo stratified columnar respiratory epithelium comprising basal cells, columnar cells, and goblet cells adhering to the basal lamina.[34] It contains 100-150 cilia, which beat up to 1000 times per minute.[35] The membrane thickness ranges from 0.13 to 0.5 mm, with an average of 0.8 mm.[36] For sinus lifting procedures, it is crucial to fully detach the membrane from the caudal region.[37] The risk of membrane perforation varies with the angle between the sinus walls: less than 30° (62.5% risk), between 30° and 60° (28.6% risk), and greater than 60° (0% risk).[38]Excessive filling of the sinus with bone graft material can lead to membrane necrosis, sinusitis, and graft failure.[39] Anatomical considerations include the proximity of the roots of maxillary premolars and molars to the maxillary sinus, with molar roots being closer to the sinus.[40] The mesio buccal root apex of the second molar is nearest to the sinus wall, with an average distance of 0.83 mm, while the lingual root apex of the first premolar is the farthest from the sinus wall.[41]Blood supply to the sinus comes from branches of the maxillary artery, including the infraorbital artery, posterior lateral nasal artery, and posterior superior alveolar artery.[42] The greater palatine artery may also supply the lower portion of the sinus. The infraorbital and posterior superior alveolar arteries supply the lateral wall, while the posterior lateral nasal artery supplies the medial wall.[43]

Extra osseous anastomoses in the buccal tissues, located 23–26 mm from the ridge, and intraosseous anastomoses within the buccal bone plate, found 16–19 mm from the ridge, may lead to haemorrhage during flap preparation.[44] Radiolucency observed on Cone Beam Computed tomography (CBCT) scans indicates intraosseous blood vessels that may need careful management.[45] Advancements in Sinus Augmentation: 1990s Developments: Dr. Carl E.

Misch and Dr. Paul D. Johnson advanced sinus augmentation techniques by exploring various graft materials; including synthetic alternatives and bone substitutes.[46]Their work significantly expanded the options available and enhanced the overall effectiveness of the procedure.[47]Advances in imaging technology, from the 2000s to the present, have refined sinus lift planning by offering detailed 3D views of the sinus and surrounding anatomy.[48] New biomaterials, such as synthetic bone grafts and growth factors, have improved graft integration and shortened recovery times.[49] There has been a shift towards minimally invasive techniques, including endoscopic approaches and advanced surgical tools. Ongoing research continues to enhance these materials and techniques, improving success rates and patient outcomes.[50] This review article delves into the surgical method, emphasizing anatomical considerations, preoperative assessments, indications and contraindications, as well as potential risks and complications.[51]

DISCUSSION

In the posterior maxilla, the placement of dental implants is often complicated by reduced vertical bone height. This reduction can result from sinus pneumatization, aging, or premature tooth loss. Moreover, the bone quality in this region is frequently classified as D4, characterized by low density, which exacerbates the difficulty of implant placement.[52] The ideal surgical strategy for managing anatomically challenging conditions includes utilizing a sophisticated technique called maxillary sinus floor elevation with bone grafting. This procedure, often referred to as sinus augmentation, aims to enhance the implant site within the sinus cavity by elevating the sinus floor and augmenting the bone volume.[53] Sinus augmentation procedures are well-established techniques used to address deficiencies in vertical bone height in the posterior maxilla.[54] These procedures are performed using two principal methods: the lateral window technique and the osteotome sinus floor elevation technique. The lateral approach for maxillary sinus floor elevation is the most frequently employed surgical technique to augment bone volume in the posterior maxilla.[55] Numerous earlier studies indicate that implant placement in conjunction with sinus augmentation demonstrates a predictable long-term success rate and survival outcomes.[56] The standard technique entails the manual elevation of the membrane using hand instruments following osteotomy performed with rotary tools. While this method poses a risk of membrane perforation, it remains advantageous due to its cost-effectiveness.[57] Alternatively, the recommendation by Torella et al. and Vercelotti et al. for the utilization of piezoelectric devices in osteotomy and membrane preparation may be considered.[58] Piezoelectric instruments are specifically designed for bone surgery, employing low-frequency ultrasonic vibrations that enable precise cutting of bone structures while minimizing the risk of soft tissue injury.[59]

Direct sinus lift/Lateral window approach using piezoelectric device: A No. 15 surgical blade will be used to make an incision, beginning at the distal aspect of the first premolar region and extending to the mesial aspect of the second molar. An additional vertical releasing incision will be made anteriorly in the upper vestibule.[60] The periosteal elevator is utilized to reflect the full thickness mucoperiosteal flap and expose the lateral aspect of the maxillary bone. A piezoelectric device will then outline a bony window on the lateral wall of the maxilla (Figure 1).[61]

Figure 1: Piezoelectric unit and tips

Using sterile isotonic saline irrigation, an osteotomy is performed to create a rectangular window in the lateral maxillary sinus wall, allowing visualization of the Schneiderian membrane relative to the adjacent bony structures and sinus floor. Sinus lift curettes will be utilized to gently separate the Schneiderian membrane from the adjacent bony structures and sinus floor (Figure 2). [62]

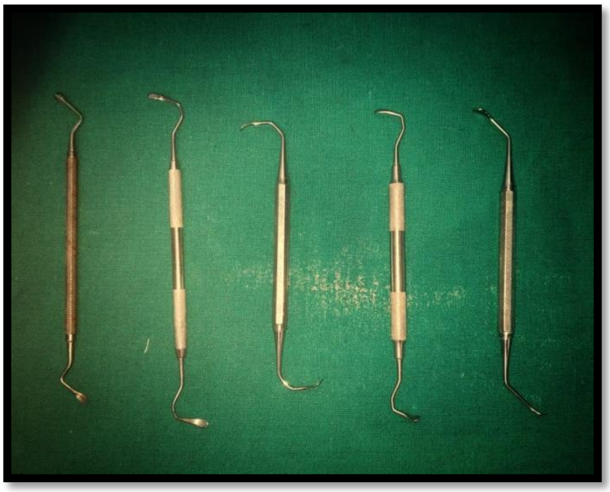

Figure 2: Sinus lift elevators

The membrane's integrity is confirmed through the Valsalva maneuver, observing sinus expansion and contraction to verify the absence of perforations. A bellows effect will be observed upon the patient’s breathing. The bony window, together with the membrane, will be elevated within the sinus cavity to establish a bony roof for the graft material.[63]Post-operative instructions include keeping the head elevated, maintaining a soft diet, and avoiding activities that create negative pressure in the sinus. Medications such as amoxicillin, ibuprofen, and acetaminophen are prescribed, along with chlorhexidine mouthwash and oxymetazoline nasal spray. Activities that may impact the sinus, such as nose blowing, smoking, or heavy lifting, should be avoided to ensure proper healing. [64]

Indirect sinus lift/Osteotome mediated sinus floor elevation: In 1994, Summers introduced a minimally invasive technique for sinus floor elevation via a crestal approach, utilizing an instrument known as an osteotome.[65] This method also enabled the simultaneous placement of dental implants, offering a more efficient and less invasive option for patients requiring sinus augmentation. In this technique, after achieving adequate anesthesia, a mid crestal incision is made intraorally, with or without the addition of a vertical releasing incision.[66] The mucoperiosteal flap is elevated along the residual alveolar ridge, and the intended implant site is marked on the alveolar crest using a small round bur. The implant bed is then prepared using a series of osteotomes with progressively increasing diameters or in combination with burs, stopping approximately 1 to 2 mm short of the maxillary sinus floor.[67] An up-fracture of the maxillary sinus floor is performed using a mallet with gentle tapping. Subsequently, the Schneiderian membrane and the maxillary sinus floor are carefully elevated using an osteotome or a blunt instrument (Figure 3).[68]

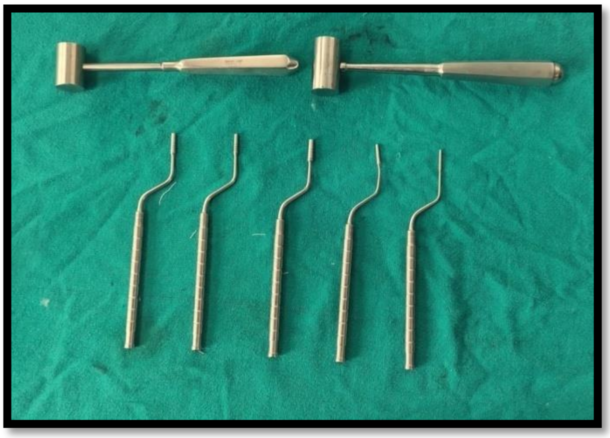

Figure 3: Osteotomy Sinus kit

Indirect sinus lift using densah: The Osseodensification technique, a relatively recent advancement, utilizes rotary densifying drills to enhance bone density at the surgical site. This method not only preserves existing bone structure but also compacts the bone, improving the stability and success of procedures such as dental implant placement.[69]Osseodensification burs, commonly referred to as Densah burs, are employed in this technique. By rotating in a non-cutting, counterclockwise direction, these burs are used to compact the alveolar bone and elevate the sinus membrane (Figure 4).[70]

Figure 4: Densah sinus lift kit

These approaches vary in invasiveness and technique, offering alternatives based on patient needs and anatomical considerations.[71]

Complications and Management: Sinus Membrane Perforation: This is a common intraoperative complication, occurring in 7%–35% of sinus augmentation procedures.[72] Factors influencing perforation risk include vigorous instrumentation and membrane thickness.[73] Membrane perforation can lead to increased postoperative sinusitis and graft failure rates. Small defects <2 mm may heal on their own, but larger perforations should be patched with a hydrated resorbable collagen barrier.[74] If perforation occurs while creating the lateral window, extend the osteotomy several millimeters beyond the original window to reestablish contact with the intact membrane.[75]Bleeding from the sinus membrane can be managed by placing gauze soaked in an anesthetic solution containing 1:80,000 epinephrine directly onto the membrane.[76] Bone bleeding can be controlled with direct pressure or cautery, and an intraosseous arterial bleeder can be managed by displacing the membrane and compressing the bone with a mosquito hemostat.[77] Dislodgement of Implant into Sinus: This complication can occur several days post-implantation, at abutment connection surgery, or even years later. Causes include incorrect implant positioning, excessive pressure during placement, or ridge widening due to overdrilling.[78] Careful treatment planning, patient selection, and the appropriate sinus augmentation technique are essential to minimize implant displacement risk.[79] Once displacement is diagnosed and located via imaging, the implant must be removed promptly. Other complications include preexisting antral pathologies like rhinosinusitis, odontogenic sinus diseases, pseudocysts, retention cysts, and mucoceles.[80] Pneumatization of the maxillary sinus due to posterior maxillary tooth loss may prevent implant placement in this region.[81] Tools used in nasal surgery include high-performance hand tools with diamond burs for creating a window in the nose by removing bone.[82] Osteotomes of various sizes cut back bone and enlarge the core, especially in smaller areas. A sinus curette is used to gently lift the sinus membrane and separate it from the sinus floor. Periosteal strippers help disrupt and protect the central sinus membrane. A collagen membrane is placed over the sinus window to cover and protect the graft without the need for fixation screws.[83] Bone tampers aid in bone and window expansion. Sutures include nonabsorbable monofilament and horizontal mattress types for securing the flap. Surgical aspirators clear debris to enhance visibility of the surgical site. After graft placement, the implantation hole is opened to prepare the implant site.[84] Graft instruments are used to pack and hold the bone grafting materials to ensure proper placement and coverage.[85] Indications for nasal augmentation include the need for sinus augmentation when the alveolar height is insufficient in the posterior palate, often due to tooth loss or extraction. Surgeons not experienced in orthopedic surgery may avoid external perspectives on nasal augmentation. The outlined method simplifies internal nasal augmentation, making it easier and safer for implanting in the posterior maxilla when alveolar height is insufficient and when alternative methods are not feasible.[86] Sinus floor grafting has become the most common surgery to increase alveolar bone height before placement of endosseous dental implants in the back of the palate.[87] The results of this procedure may be affected by specific surgical procedures, simultaneous prevention of slow implantation, use of external window guards, choice of graft material and characteristics of the location, length and width of the plant.[88] Continuous advancements in Cone Beam Computed Tomography (CBCT) technology are expected to improve the precision of preoperative assessments, offering enhanced visualization of sinus anatomy, septa, and other critical structures.[89] Future advancements may include higher resolution imaging and faster scanning times, reducing patient discomfort and radiation exposure.[90] Integrating real-time 3D scanning technology can improve accuracy in sinus lift surgery and graft placement.[91] Innovations in biodegradable and bioactive materials, like stents and ceramics, aim to enhance integration, improve function, and reduce complications in bone health.[92] The use of autologous stem cells or platelet-rich plasma could increase integration and improve outcomes, reduce patient recovery time, and enhance surgical accuracy. The integration of robotic systems into sinus lift surgery may enhance graft placement precision and decrease variability in surgical outcomes. Applying machine learning and artificial intelligence to analyze patient data can improve predictive models of surgical outcomes, leading to more accurate risk assessment and tailored treatment plans.[93]

CONCLUSION

This analytical review article has explored cutting-edge methods and new frontiers in maxillary sinus lifting, highlighting significant advancements that enhance dental restoration and implant success. Modern techniques, including advanced imaging technologies, innovative biomaterials, and minimally invasive approaches, have revolutionized sinus augmentation procedures. These developments offer improved precision, reduced recovery times, and higher success rates for dental implants in cases with limited upper jaw bone height. The integration of synthetic bone grafts, growth factors, and refined surgical tools has expanded the possibilities for effective sinus lifting, allowing for more predictable and successful outcomes. Additionally, advances in classification systems for managing complications, such as sinus membrane perforation, have provided clearer guidelines for handling intraoperative challenges. As research continues to evolve, ongoing innovations promise to further refine these techniques, ensuring even better outcomes for patients. The future of maxillary sinus lifting is poised to benefit from these cutting-edge advancements, driving continued progress in dental restoration and implantology.

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