

Maxillary Sinus Augmentation – A Comprehensive Review

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Abstract

Implant dentistry is the most successful treatment option available to replace missing maxillary posterior teeth caused by atrophy of the maxilla and the pneumatization of the maxillary sinus. However, the availability of bone is the most critical factor that determines the success of the implant. To increase residual bone height, several approaches have been proposed, including the transalveolar or lateral window approach. These procedures involve entering the sinus, elevating the membrane, placing a bone graft, and eventually increasing the bone height. Maxillary sinus augmentation has proved to be a groundbreaking procedure that has made the placement of implants in the posterior maxilla feasible. As traditional techniques can be cumbersome for patients, minimally invasive procedures are gaining popularity. This literature review

provides a comprehensive insight into various surgical approaches, modifications, biomaterials used, and alternative rehabilitation options.

Keywords: Atropic Posterior Maxilla, Crestal Approach, Dental Implants, Lateral Window Technique, Maxillary Sinus, Maxillary Sinus Augmentation, Osteotomy.

Introduction

Dental implants have revolutionized the field of dentistry in edentulous situations, however, inevitable anatomical changes that take place over time following dental extractions pose a challenge to clinicians when substituting natural teeth. Of utmost concern is the inadequacy of the vertical height of bone in the posterior maxilla, jeopardized by the presence of the maxillary sinus which poses a significant obstacle. Therefore, sinus augmentation also referred to as sinus floor

elevation can provide a favorable outcome for dental implant placement in such situations. Tatum introduced this technique in 1977, which could be performed employing two different ways, the direct approach called lateral window technique, and the indirect approach called osteotome^[1]. Different biomaterials used during the procedure range from autologous bone grafts from either intraoral or extraoral sites to synthetic materials like allografts and xenografts. A sinus lift is considered one of the safest and most effective treatment modality with a low complication rate. However, some patients may experience complications such as Schneiderian membrane perforation, chronic rhinosinusitis, bleeding, and implant displacement.

This review elaborates on the various surgical approaches, their modifications, biomaterials used, and the therapeutic alternatives for posterior maxillary rehabilitation.

Discussion

A. Indications And Contraindications of Maxillary

Sinus Augmentation [MSA]

The indications are pneumatization of the sinus, resorption of the alveolar ridge, or a combination of both. Contraindications include the presence of any sinus pathologies such as cysts, mucoceles, tumors, acute, chronic, or allergic sinusitis, oroantral fistula, odontogenic infections, interarch distance >2:1. Patients who smoke or consume alcohol and have any underlying systemic illness are also contraindicated.

Patient Evaluation: Preoperative evaluation should have a set of study models, a bite registration, and ideally, a face bow transfer for accurate mounting. This evaluation helps to determine the final tooth position, crown to root(implant) ratio: if >2:1, then sinus augmentation alone is not recommended. The occlusion should be preferably canine guided with a minimum

interarch distance of 5-7mm. Implant failure is more likely with periodontal disease due to thickened mucosa owing to the root proximity of the sinus.

Panoramic radiographs may miss certain findings like a bone between crest and the floor, bony septa, and any pathologies due to a distortion error of up to 25-30%. CT scan is highly recommended for presurgical evaluation as it provides information on anatomy, residual bone height, septa, and surrounding structures^[1].

B. Subantral Classification:

Depending upon the available bone height between the floor of the antrum and the crest of the alveolar ridge, Misch has classified the treatment options for ideal implant placement into four categories:

SA-1: Where there is a 12mm height from the crest to the floor of the sinus, plan for conventional implant placement. If the bone width is inadequate, bone augmentation or ridge splitting is recommended before implant placement. The implant is then left to heal for 4-6 months.

SA-2: 10-12mm of remaining bone is present wherein indirect sinus lift with osteotome is performed and the implant is placed and loaded after 6-8 months.

SA-3: At least 5mm of vertical bone is present, direct sinus lift with lateral window technique is implemented and the implant placement is delayed for 2-4 months.

SA-4: Less than 5mm of residual alveolar bone is available. A direct osteotome technique followed by implant placement after 4-6 months is advocated^[2].

Boyne & James, and later Kent & Block, were the first to perform lateral sinus floor elevation using autogenous bone from the iliac crest and implant placement. In 1986, Tatum reported on his initial outcomes using a crestal approach for maxillary sinus and simultaneous implant placement. Wood & Moore later reported on

lateral sinus augmentation using bone harvested from an intraoral site.

C. Classification of Sinus Lift Procedures

There are two types of techniques: graft and non-graft techniques. Additionally, there are different methods for performing a sinus lift. The first method involves using an osteotome and includes Modified Summer's and Fugazzotto's techniques. The second method does not use an osteotome and includes Hydraulic sinus condensation, Antral membrane balloon, and Piezoelectric bony window osteotomy.

Direct/ Lateral Window Technique: This technique involves the visualization and instrumentation of the sinus membrane through a window created on the lateral aspect of the sinus.

Technique: After adequate anesthesia, a vertical incision is placed 10-15mm anterior to the sinus wall followed by the elevation of a mucoperiosteal trapezoid base flap to access the canine fossa. The lateral window, often rectangular or oval in shape, is outlined using a no.8 diamond bur with a size of approximately 10 mm * 20 mm until a bluish tint is visible, applying gentle paintbrush strokes. Bone tampers are instruments used to elevate or completely fracture the bony access window of the sinus. The membrane detachment begins at the floor by carefully using the sinus curettes. The membrane integrity can be checked by asking the patient to take a deep breath while observing it lifting^[3]. When placing bone grafts, beginning with the anterior and posterior recesses, it is crucial not to compact the bone graft too tightly, as this can prevent vascularization. Incision closure is done with non-resorbable monofilament sutures. Achieved encouraging outcomes. In 2003, researchers analyzed the impact of maxillary sinus floor elevations on dental implant survival rates after at least one year of functional loading. The study

found the average survival rate of implants placed with the lateral window technique ranges from 61.7% to 100%, with a mean of 91.8%^[4]. The need for a large flap elevation is time-consuming and technique-sensitive and the success of this technique relies on the remaining vertical height which is the major drawback. However, with the introduction of piezoelectric surgery by Vercellotti in 2001, the procedure could be performed effortlessly and with precision to ensure membrane integrity.

Indirect/ Crestal/Trans Alveolar Approach: When the remaining bone height [RBH] is equal to or >6mm, an indirect approach is indicated. This approach is less invasive than the direct technique as the sinus membrane is not directly manipulated, and the sinus cavity is not directly visualized. As a result, perforations in the membrane can be harder to detect.

Technique: After local anesthesia, a mid-crestal incision is made with vertical releasing incisions on the palate. A full-thickness flap is raised to expose the ridge crest. A pilot hole is made with a drill, followed by a widening of the osteotomy site. Single-site preparation carries a higher risk of sinus perforation. Sinus membrane elevation is achieved by tapping and adding bone graft, followed by implant placement. Drawbacks include benign paroxysmal vertigo and no control over the force generated by a mallet.

Pjetursson et al. compared implant installation outcomes with and without deproteinized bone material. They found that implants installed with the material had a greater radiographic bone height gain (4.1 mm) compared to those installed without it (1.7 mm)^[6]. Another review conducted by Esposito et al., using a crestal approach to lift the sinus lining and place 8mm implants stated that the indirect crestal approach may result in fewer complications than the lateral window

approach to place implants 10mm long if the residual alveolar bone height is between 3 to 6 mm [7].

Modified Summer's Technique: The antral floor can be raised by intruding the existing bone in the site using osteotomes of similar sizes with a concave tip, also known as osteotome sinus floor elevation (OSFE). However, inadvertently puncturing the membrane may be a risk. To avoid this, bone grafts are added to the osteotomy, known as bone-added osteotome sinus floor elevation (BAOSFE). During BAOSFE, the grafted bone and trapped fluids create a hydraulic plug that gently raises the membrane. BAOSFE reduces the risk of membrane perforation and eliminates the need for a donor site for procuring the graft [8]. The advantages of this technique therefore include less trauma and invasiveness however, tapping by the osteotome may cause benign paroxysmal positional vertigo, with a lack of tactile discrimination.

Fugazzotto's Technique: Fugazzotto used trephines of varying diameters and an osteotome to implode maxillary posterior alveolar bone before regenerative material placement, to prepare for future implantation. The site was prepared using a trephine guided by preoperative radiographs and residual ridge morphology. The cutting speed was limited to 500 rpm and the depth of the osteotomy site was 1-2mm from the sinus membrane. The osteotome was used with gentle mallet forces to compress the trephine bone core to a depth of approximately 1 mm less than the prepared site. The prepared site was packed with graft followed by Bio-Guide membrane, securing it with fixation tacks. 4 to 5 months after the surgery, the sites were re-entered for placing the implants. This technique was less traumatic, minimizing membrane perforations and placing longer implants with ease. [8]

A case report described by Umesh Pai et al [9] employed a technique using a minimal armamentarium along with an autogenous core and calcium phosphor silicate putty to lift the membrane. The approach aims to avoid the complications associated with a direct sinus lift procedure.

D. Minimally Invasive Techniques:

Antral Membrane Balloon Elevation (AMBE): Soltan et al. introduced the AMBE procedure in 2012. This technique utilizes an inflatable balloon designed by Zimmer to evenly elevate the membrane when connected to a latex balloon that can inflate up to 5 cm. To progressively inflate the balloon, the saline is slowly injected through the balloon sleeve inserted 1mm beyond the floor. The height desired is achieved by deflating the balloon and repeating the process until the desired sinus elevation is reached. It is expected that a single cubic centimeter of saline will raise the membrane by 6mm. Studies have demonstrated that utilizing this method can lower the risk of perforating the sinus membrane when adjacent teeth are present, is less time-consuming, and reduces post-operative bleeding, infection, and pain. However, AMBE requires a buccal fenestration and a larger incision than other alternative operations [10]. Huda Moutaz in a systematic review in 2018 [11] compared the minimally invasive antral membrane balloon elevation technique with the traditional trans-alveolar technique for sinus floor elevation: They concluded that antral membrane balloon elevation can produce over 10mm of bone gain in a minimally invasive manner.

Hydraulic Sinus Condensation: Minimally invasive hydraulic condensation, a new internal crestal approach was introduced by Leon Chen in 2005. Using a 2mm round bur a pinhole is created on the sinus floor and the

membrane is separated through hydraulic pressure of the high-speed handpiece^[12].

This technique is advantageous as there is minimal risk of traumatizing the sinus membrane, good tactile control, permits implant placement in complex nasal cavities with multiple septae. However, there is a lot of debate surrounding the risk of air embolism when using this technique. The efficacy of two hydrodynamic sinus lift elevations, Minimally Invasive Antral Membrane Balloon Elevation (MIAMBE) and Drill Integrated Hydrodynamics Sinus Floor Elevation (DIHSFE) was evaluated in a study by Praveen et al^[13] for immediate implant placement in the posterior maxilla. The study found that MIAMBE causes fewer post-operative complications and patient morbidities compared to DIHSFE.

Kher and others pioneered the minimally invasive trans-alveolar sinus approach (MITSA) in 2014, which involves using calcium phosphor silicate putty to elevate the sinus membrane hydraulically. Once the final drill is done, the Nova bone cannula should fit snugly in the prepared site. Due to the consistency of this material, the membrane is lifted gently and an implant is placed. As the procedure involves using the osteotome only once, it is considered less traumatizing for the patients. A gel pressure transcresal sinus lift procedure by Pommer and Watzek on 10 atrophic maxillae of human cadavers revealed that the gel minimizes the risk of membrane perforation by acting as a cushioning agent for the sinus membrane^[14].

As a new minimally invasive approach, Pozzi and Moy used a computer-aided surgical template along with an expander condensing osteotomes to lift the sinus membrane^[15].

Ahn and colleagues introduced the technique of reamer-mediated sinus floor elevation. They used reamers with a

single cutting edge angled at 85 degrees to prepare the osteotomy site. The reamers were operated at a lower speed of 30-50 rpm, creating a gentle vertical pushing force on the sinus floor, facilitating the membrane's separation and elevation^[16]. Indirect sinus elevation with Osseo densification is a technique introduced by Huwais in 2013. The technique involves using a specially designed bur called a Densah bur in a counterclockwise direction at 800-1500 rpm. This technique is used to achieve Osseo densification, which is the apical condensation of bone, resulting in an indirect sinus elevation with reduced chances of perforation^[17].

E. Graft Vs Non-Graft:

Various biomaterials like autologous bone, xenogenic bone, demineralized or mineralized allogeneic bone, and alloplasts have been used in sinus lift surgeries. These materials have the potential for osteogenesis, osteoconduction, and osteoinduction.

Chen et al reported that the maxillary sinus bone formation is not dependent on the biomaterial but the space maintenance for the blood clot formation along with the resorption and deposition of bone cells from the cancellous bone Silva DeF et al conducted a comparative analysis in 2016 on the use of grafts in sinus augmentation procedures. They found a 96% survival rate without grafts and 99% with biomaterials after 48-60 months. The study concluded that the use of biomaterials reduces surgical time and total costs compared to using a graft.

According to Esposito et al. in 2015^[19], bone substitutes like Bio-Oss and Cera sorb seem to be equally effective as autogenous bone grafts for augmenting atrophic maxillary sinuses. This means that they could be used as a substitute for autogenous bone grafting. No evidence suggests PRP treatment improves sinus lift outcomes for implant rehabilitation.

E. Post-Operative Care:

The patient is advised to apply pressure to the surgical site by biting down on the gauze for at least 20 minutes and preferably for 3-4 hours. Additionally, patients should follow all prescribed medication and instructions. Based on the doctor's advice, the patient should consume only a liquid diet for the next 2 days, and a soft diet for the next 2 weeks. Patient is advised to stay upright, rinse with chlorhexidine 1.2% 3-4 times daily, take calcium supplements, rest and take prescribed medication. Including Analgesics needed, amoxicillin 500mg thrice daily for 10 days. [2].

Restrictions: After surgery, smoking should be avoided for a minimum of two weeks, but ideally six weeks. Additionally, for the first 48 hours, the patient should refrain from consuming alcohol or engaging in activities such as blowing nose, sneezing, bending forward, using a straw, spitting, or rinsing the mouth vigorously. It is also recommended to remove any removable dentures or night guards during recovery and to avoid playing musical instruments [20].

G. Postoperative Complications: Despite having highly predictable implant survival rates, complications can still occur both during and after the surgery. The complications include Schneiderian membrane perforation, haemorrhage, ostium blockage due to graft overfilling, benign paroxysmal positional vertigo, and Implant displacement.

Schneiderian membrane perforation: This is the most common complication that occurs during open sinus lift surgery. In a review article, Vina-Alumina and colleagues reported that the implant survival rate in procedures with membrane perforations was 88.6%, which rose to 98% with intact membranes. Sinus perforations during sinus lift procedures have been linked to specific anatomical characteristics, such as

minimum alveolar height, narrow sinus cavity, and bony septa within the sinus. Other factors that can contribute to sinus perforations include the thickness of the Schneiderian membrane and the surgical technique used, including the surgeon's expertise, surgical design, and the instruments employed [21]. A technique called the "Loma Linda pouch" was introduced for the repair of perforations in the sinus membrane during sinus grafting with the use of a resorbable collagen membrane. The "Hammock" approach immobilizes the collagen membrane as much as possible and promotes increased blood supply, which in turn stimulates vital bone formation [22].

Hemorrhage: Thorough analysis using a computed tomography scan before performing a procedure can significantly help to avoid bleeding complications during surgery. During surgery, if the sinus artery gets accidentally damaged, immediate hemostasis measures must be taken by clamping and suturing at the distal end. However, if the vessel is damaged close to the window borders, it might retract and become inaccessible for clamping. In such instances, hemostatic agents such as aminocaproic acid or bone wax can be applied to the bone until hemostasis is achieved.

Overfilling (ostium blockage): Due to its elevated position in the cranium, the occurrence of iatrogenic ostium blockage resulting from overfilling with bone grafts is infrequent. This blockage can interfere with normal sinus functioning leading to additional complications, such as chronic rhinosinusitis.

4. Chronic rhinosinusitis: The incidence of chronic rhinosinusitis following sinus lift surgery ranges from 4.2% to 8.4%. The causes of rhinosinusitis could be secondary to contamination of the sinus space during surgery, due to ostium blockage caused by graft overfilling or mucosal swelling, or due to a reduction in

airflow owing to low sinus volume, altered mucosal activity as a result of mucosal lacerations and implant protrusion or lacerations of the membrane. The Signs and symptoms of which present as Muco-Purulence (89%), Facial Pain or Pressure (78%), Nasal Congestion (56%), Foul Smell (45%), Cough (18%), Purulent Drainage Around the Implants (18%), Ocular Pruritus (9%), Postnasal Drip (9%) [23].

Management: Medical management for sinusitis may include prescribing systemic antibiotics, additionally nasal douching with saline solutions, nasal steroid sprays, and oral antihistamine medication may be recommended²¹. If the initial treatment fails a conventional Cadwell-Luc osteotomy, either through the oral cavity or via endoscopy through the nasal or oral cavities is carried out. This procedure may include sinus irrigation to remove any contaminants, and sometimes the contaminated graft and/or implant removal as well.

Benign paroxysmal positional vertigo: A highly prevalent oto-neurological disorder characterized by brief episodes of vertigo and nausea precipitated by a rapid change in head posture. It is that the trauma is caused by the osteotome and surgical hammer mallet during the closed sinus lift procedure. Symptoms typically manifest within 1 to 2 days after the operation and affect the opposite side of the treated area. However, this condition can be treated successfully using the Epley repositioning technique and show full recovery within 2 days.

In 2016, Samartino et al [24] conducted a randomized clinical trial to compare the use of conventional mallet osteotomes with screwable ones that do not require hammering. The study demonstrated that the incidence of this complication was 3.06% and 0% in the conventional mallet and screwable osteotomes groups, respectively. This supports the hypothesis that reducing

percussive and vibratory trauma on the head may decrease its incidence.

Displacement of the implant: A dental implant can get displaced in the following situations: when it is placed in the posterior maxilla without undergoing sinus lift, if the surgeon lacks experience with the anatomical landmarks of the maxillary sinus and if the dental implant is excessively tapped during internal sinus osteotomy. To avoid such migration of an implant into the sinus, the use of tapered implants with smaller apical diameters placed over a cone shape-configured implant bed is advisable. This will help to prevent the displacement of the entire device into the sinus.

H. Alternative to Sinus Lift Surgery

Several therapeutic options such as short implants, Tilted implants, and Distal cantilevers are available. Short implants are indicated in edentulous sites with subantral residual bone height [RBH] >5 to ≥ 9 mm. Though the implant placement reduces the demand for the regeneration of bone, limited evidence is available on long-term biological and prosthetic complications. Distal cantilevers and tilted implants are given in edentulous patients with subantral RBH ≤ 5 mm. Though bone regeneration may not be required, if not properly designed may lead to potential prosthetic complications [25].

Conclusion

This review discusses various techniques, modifications, complications, and alternative treatments for sinus lift surgery. Sinus augmentation is crucial in restoring the posterior edentulous maxilla. To ensure the successful placement of an implant in this desired area, the clinician must have meticulous knowledge of anatomical factors such as sinus characteristics and the remaining alveolar bone for implant placement. Accurate diagnosis will help choose the appropriate treatment plan and

technique. Although sinus lift procedures have high predictability, they may cause discomfort and increase patient Comorbidities.

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