



MAXILLARY SINUS AUGMENTATION: A REVIEW

Dental Science

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ABSTRACT

The maxillary sinus pneumatization secondary to loss of maxillary posterior teeth is a common finding. Significant atrophy of the maxilla makes implant placement a challenging clinical situation. Grafting the floor of the maxillary sinus has proven to be the most successful surgical modality for correcting this inadequacy. Various grafting materials and techniques are used for the purpose of maxillary sinus augmentation. The aim of this article is to review the essentials of maxillary sinus anatomy and describe the augmentation materials, techniques, and complications.

KEYWORDS

maxillary sinus, pneumatization, augmentation, dental implant

INTRODUCTION:

The goal of modern dentistry is to restore the patient to normal function, comfort, esthetics, speech and health. Implant dentistry helps in achieving this goal. Predictable success is now a reality for the rehabilitation of many challenging clinical situations.¹ Placement of implants in the posterior part of the maxilla often becomes a challenging clinical situation owing to atrophy of the alveolar process, poor bone quality and maxillary sinus pneumatization. Therefore, vertical alveolar ridge augmentation often becomes necessary before or in conjunction with placement of implants.²

Various regenerative techniques have been advocated in the posterior maxilla, including vertical bone augmentation, distraction osteogenesis and sinus augmentation. Based on clinical evidence sinus augmentation procedure has the most predictable outcome currently.³

Sinus augmentation procedure is a surgical intervention aimed at increasing the height of residual bone in the posterior maxilla by repositioning the floor of maxillary sinus in an upward direction, creating an appropriate bone height that would allow the placement of functional dental implants. Elevation of the maxillary sinus floor was first published by Boyne *et al* in 1980. After these reports, several techniques were reported for successful sinus floor elevation.

The aim of this paper is to review the essentials of maxillary sinus anatomy and describe the augmentation materials, techniques, and complications of sinus augmentation procedure.

ANATOMY OF MAXILLARY SINUS:

Before performing sinus augmentation surgery, it is crucial to understand the anatomy of maxillary sinus.

The maxillary sinus or antrum of Highmore which is the largest of the paranasal sinuses lies within the body of the maxillary bone. It has a pyramidal shape, with an anterior wall corresponding to the facial surface of the maxilla. Its posterior bony wall separates it from the pterygomaxillary fossa medially and from the infratemporal fossa laterally. Its medial wall is formed by the lateral nasal wall and communicates with the nasal cavity *via* the hiatus semilunaris (middle meatus). The Maxillary sinus floor consists of the alveolar process of the maxilla. The sinus floor is convex, with its lowest point around the first and second upper molars. As aging occurs, the sinus floor tends to resorb and form dehiscences around the roots.⁴

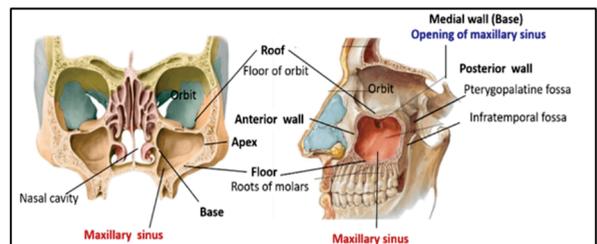


Figure 1: Anatomy of maxillary sinus⁽⁴⁾

The Sinus Membrane

The Schneiderian (mucous) membrane lines the inner walls of the sinus and in turn is covered by pseudo-stratified columnar ciliated epithelium. Thickness of Schneiderian membrane exhibits a wide range (0.16–34.61 mm) with a mean value of 1.68 mm.

Blood supply:

The blood supply of the maxillary sinus is derived from three arteries:⁵

- Infra-orbital artery
- Posterior lateral nasal artery
- posterior superior alveolar artery.

Innervation:

Innervation of the maxillary sinus originates directly from the maxillary nerve, the second branch of the fifth cranial nerve.⁶ The anatomic variations detected are pneumatization (83.2%), antral septa (44.4%), hypoplasia (4.8%) and exostosis (2.6%).

In 1987, Misch developed a classification system based on the amount of residual bone available below the antrum and the treatment options accordingly.⁷

SA 1: Adequate vertical bone for endosteal implants (>12mm) and no surgical intervention required

SA 2: 0-2mm less than ideal height of bone (10-12mm) and may require surgical manipulation

SA 3: 5-10mm of bone below the antrum

SA 4: <5mm of vertical bone below the antrum

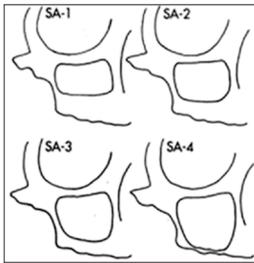


Figure 2: Classification of maxillary sinus based on residual bone height⁽²²⁾

PREOPERATIVE ASSESSMENT:

Careful patient selection based on well defined clinical indications is critical for the long term success of implant therapy in cases requiring sinus floor elevation. The diagnostic process begins with a complete history taking and physical examination.

Radiographic imaging is indispensable to determine anatomical complexity and the most appropriate treatment approach.

Intraoral radiography (paralleling technique): available bone height and trabeculation.

Panoramic Radiographic examination: form of the maxillary sinus, form of the alveolar bone relative to the sinus floor and about any pathological processes that may affect implant treatment. However 3D imaging techniques like Cone beam computed tomography (CBCT) is the radiographic technique preferred as it provides high-quality images in three dimensions using low doses of radiation compared with conventional computed tomography and have become the images of choice for many practitioners⁸

Once all information is gathered during the workup, the case is planned appropriately and educated decisions regarding implant placement are made.

BIOMATERIALS:

Various materials have been used for grafting the floor of the sinus and achieve the desired bone height.⁹ Grafting materials can be categorized based on their source, as: autograft, xenograft, allograft, and alloplast. These different types of grafting materials may be used alone or in any combination. In recent years, L-PRF (because of their constant release of growth factors) has been used in sinus floor elevation either as a sole filling material or in combination with other graft materials. It has been reported that L-PRF can be used to cover the perforations since it has a good intrinsic adherence to the Schneiderian membrane. Tissue-engineered materials¹⁰ like recombinant human protein. RhBMP-2 have also been used for sinus augmentation

Conflicting results concerning the benefit of placing a membrane over a lateral window have been reported. Some studies revealed a tendency for better bone formation and less implant failure when a lateral window was covered with a resorbable membrane (Tawil and Mawla 2001, Choi et al. 2009). A recent review of clinical studies with histomorphometric data following sinus augmentation with autografts alone did not confirm any effect of a barrier membrane on bone formation (Klijn et al 2010).

TREATMENT MODALITIES:

Over the years, several strategies have been advocated to restore the posterior maxilla and address the deficiency of bone volume. The type of sinus floor elevation technique selected is based mainly on residual vertical bone height, marginal bone width, local intrasinus anatomy and the number of teeth to be replaced, although other factors, such as surgical training and experience, may have an impact.

Different techniques that are used for maxillary sinus floor augmentation are:

1. Maxillary sinus floor augmentation applying the lateral window technique
 - With/ without a graft material and simultaneous/delayed implant installation
 - Low window sinus lift technique
2. Crestal approach to sinus grafting
 - Osteotome method of sinus floor elevation

- Combined trephine / osteotome technique
 - Smart lift technique for minimally invasive transcrestal sinus floor elevation
3. Other techniques

1. maxillary Sinus Floor Augmentation Applying The Lateral Window Technique:

Maxillary sinus floor augmentation using the lateral window technique was originally developed by Tatum¹¹ in the mid-seventies and afterwards described by Boyne and James in 1980.¹² This surgical intervention is still the most frequently used method to enhance the vertical alveolar bone height of the posterior maxilla before or in conjunction with installation of implants.

Indications:

The indication for lateral sinus floor elevation with or without grafting materials is a posterior maxilla with inadequate subantral bone height for implant stability (≤ 5 mm).

As yet, there is no consensus on the recommended maximal and/or minimal residual bone crest height for selecting the lateral sinus floor elevation technique.

Surgical technique:

Maxillary sinus floor augmentation applying the lateral window technique is usually performed under local anaesthesia and sedation. The maxillary sinus is exposed intra orally through a horizontal midcrestal, posterior and anterior vertical releasing incisions. A mucoperiosteal flap with a trapezoid base is reflected exposing the lateral wall of the maxillary sinus. The osteotomy should be oval or rectangular which is performed using burs and a high-speed handpiece or piezoelectric surgery avoiding laceration of the Schneiderian membrane (Figure 3A). The bony wall can be removed and retained for later incorporation or tapped into sinus hinging on its superior margin in which case it serves as a new sinus floor. The Schneiderian membrane is carefully dissected and elevated from the maxillary sinus floor as well as the lateral and medial sinus wall and displaced dorsocranially with blunt dissector to create a compartment for placement of the graft material (Figure 3B). Implants are placed simultaneously with the augmentation procedure, if the height of the residual alveolar bone provides insufficient primary implant stability. An implant bed is prepared with burs before the implant placement in the residual alveolar bone where the implant tip remains exposed in the created compartment in the maxillary sinus (Figure 3C). The graft material is densely packed around the exposed implant surface to facilitate bone formation (Figure 3D). The lateral window to the maxillary sinus is usually covered by a resorbable collagen membrane to prevent ingrowth of fibrous tissue before the mucoperiosteum is readapted and sutured. If primary implant stability is compromised, then the implants are inserted 4 to 12 months after the augmentation procedure. Final prosthesis is fabricated three to six months after implant installation.³

Alternatively maxillary sinus elevation using the lateral window technique can also be performed without a graft material and simultaneous installation of implants. This technique was introduced by Lundgren et al. in 2004.¹³ The primary requisite for this technique is sufficient vertical height of the residual alveolar bone to achieve primary implant stability, since immediate implant installation is necessary to preserve and support the elevated Schneiderian membrane, allowing coagulum formation round the exposed implant surface in the sinus cavity.

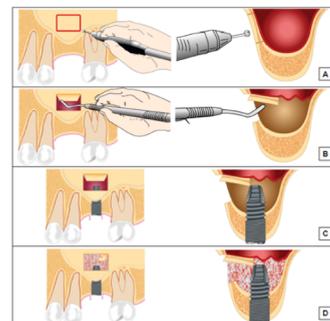


Figure 3: Maxillary sinus floor augmentation using the lateral window technique with a grafting material⁽²³⁾

LOW WINDOW SINUS LIFT TECHNIQUE:¹⁴

This technique uses the guided surgery approach for design and preparation of a lateral window for sinus augmentation. Creating a low window at the most coronal and mesial possible position offers specific surgical advantages such as surgeon-friendly approach, lesser invasiveness, minimizes the chances of encountering the posterior superior alveolar artery.

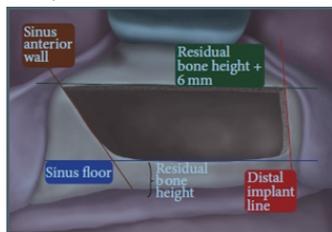


Figure 4 :Low window sinus lift antrostomy⁽²⁴⁾

The Low Window Sinus Lift antrostomy. The lower osteotomy line is positioned flush with the sinus floor. The upper line is 6mm higher (it is placed at a distance from the ridge equal to the residual bone height plus 6 mm.) The mesial line is flush to the sinus anterior wall. The distal one should be placed in correspondence with the position of the most distal implant

2. TRANSCRESTAL APPROACH TO SINUS GRAFTING:

Transcrestal sinus floor elevation (tSFE) represents a surgical option to vertically augment the available bone in the posterior maxilla where an access is gained through the edentulous bone crest. Surgical techniques for tSFE are mainly based on the fracture or perforation of the sinus floor by means of osteotomes or burs. The apical displacement of the Schneiderian membrane obtained by tSFE may be enhanced or better maintained by use of a graft material under the elevated sinus membrane.

This technique is particularly suitable for single tooth replacement with sufficient bone width for implant placement and a minimal residual bone height of 5 mm. The tSFE technique has some advantages over the lateral sinus floor elevation procedure, such as less trauma, shorter operation time and less postoperative morbidity. The implants are commonly placed simultaneously with the tSFE procedure.

Fracture of the sinus floor can be achieved by using osteotomes¹⁵ as described by Summers or a combined trephine osteotome approach as described by Cosci and Luccioli.¹⁶

Another technique Smart lift technique for minimally invasivetranscrestal sinus floor elevation uses specially designed drills and osteotomes that have adjustable stopdevices, thus restricting the working action of burs and osteotomes to the vertical amount of residual bone. This is aimed to prevent any accidental penetration of instruments into the sinus cavity.¹⁷

OTHER TECHNIQUES:

A number of minimally invasive surgical procedures have been described for sinus augmentation. The procedure is called minimally invasive when there is minimal damage to the biologic tissues at the point of entrance of the instrument.

Antral membrane balloon elevation (AMBE)¹⁸ which was introduced by Soltan et al in 2005, hydraulic method¹⁹ for lifting the Schneiderian membrane which was first presented by Chen in 2005 and later modified in 2010 as Hydraulic Sinus Lift (HySiLift) are some of the minimally invasive approaches.

Hydropneumatic sinus lift procedure²⁰ that uses piezoelectric bony window osteotomy and sinus membrane elevation In 1988 Tomaso Vercellotti developed the piezoelectric bone surgery, to overcome the limitations of traditional instrumented oral bone surgery. Flemming et al., in 1998, illustrated this method in a study of 15 patients in which 21 piezoelectric osteotomies were performed. The advantage of the piezoelectric osteotomy are:

- Cutting the bony window with great simplicity and precision,
- Avoiding the risk of perforating the membrane

The subsequent use of the piezoelectric elevators lifts the membrane

by hydropneumatic pressure of a physiologic solution subjected to piezoelectric cavitation

COMPLICATIONS:

There is always the possibility of a complication even in the best of surgical hands and the best operative environment.

Complications²¹ that may occur intraoperatively are perforation of the sinus membrane which is the most common complication (incidence of 20% to 44% during lateral wall sinus augmentation), Bleeding (due to accidental severing of posterior superior alveolar artery), Accidental dislodgement of dental implants into the sinus cavity or obliteration of sinus cavity.

Complications that may occur during post operative period are infection or acute sinusitis, nose bleeding, wound dehiscence or oro antral fistula.

These complications may influence the outcome of therapy. Therefore proper planning and management of these complications will minimize the negative effects on therapy and can increase the long-term success of the implant prosthesis.

CONCLUSION:

The status of the maxillary sinus is an important consideration while planning implant therapy in posterior maxilla. Several surgical approaches aimed at increasing bone height in the posterior maxilla for the insertion and integration of dental implants have been proposed in last 4 decades. Recent anatomical and surgical advancements in the understanding and conduct of sinus augmentation surgery are numerous. These advancements remain the main sources of inspiration that help clinicians to innovate, develop, and maintain a high standard of implant practice outcome and expectations as well as patient satisfaction.

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