Maxillary sinus augmentation procedures: a narrative clinical review
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An edentulous posterior maxilla can present a challenge for placement of dental implants due to the proximity of the maxillary sinus. Sinus augmentation is a surgical bone grafting procedure aimed to increase the bone height for implant support. A number of sinus augmentation techniques have been presented and the outcomes show good implant success rates. In order to achieve the desirable outcomes, it is important to gain knowledge of the maxillary sinus anatomy and complete a thorough preoperative evaluation. Being aware of the location of vasculature, nerves, and the presence of septa will help reduce the risk of intraoperative and postoperative complications. This review provides a narrative clinical overview related to the anatomy, preoperative evaluation, contraindications, techniques, postoperative care, outcome measures, and complications of sinus augmentation procedures. (Quintessence Int 2020;51:578–584; doi: 10.3290/j.qi.a44632)

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The aim of maxillary sinus augmentation surgery is to increase the vertical height of the residual alveolar bone in order to achieve proper dimensions for dental implant placement. Bone loss in the posterior maxilla might occur due to tooth extraction, aging, or pneumatization of air-filled cavities. Sinus augmentation surgery can increase bone height by elevating the maxillary sinus floor to create a space between the sinus membrane and the osseous floor; a space that could then be filled with bone graft materials. Ultimately, the end goal is to increase bone height enough to achieve dental implant stability and bone support in the long term.

Anatomy

Maxillary sinus

The maxillary sinuses are the largest of the paranasal sinuses. They are filled with air and lie within the maxillae. The paired sinuses are lateral to the nasal cavity, superior to the dentition, inferior to the floor of the orbit, and anterior to the infratemporal fossa. The apex of each maxillary sinus is neighboring the zygomatic bone. The lateral wall of the sinus is made of thin bone and is the location of access when utilizing the lateral approach of the sinus augmentation procedure. The medial wall contains the sinus ostium, which is located superiorly allowing for graft material to be inserted without jeopardizing the sinus drainage. The ostium opens into the ethmoid infundibulum within the middle meatus of the lateral nasal wall. The function of the maxillary sinus is not completely understood but it is assumed to take part in warming aspirated air and reducing the weight of the craniofacial structures. The sinus floor in relation to the dentition extends from the premolar or canine area to the back adjacent to the maxillary tuberosity.

Sinus membrane

The maxillary sinuses are lined with a bilaminar mucoperiosteal membrane. The sinus membrane has three layers: periosteum, connective tissue, and ciliated pseudostratified columnar epithelium (respiratory epithelium). The presence of sinus membrane pathology prior to the surgery can increase the risk for complications and implant failure later.
**Maxillary sinus septa**

Maxillary sinus septa are thin bony structures that can span from the lateral to the medial sinus wall. It can present in up to 37% of patients and is commonly located between the first molar and second premolar. There is a great variability in the location and shape of the septa and it is important to take proper imaging before any surgery involving this area to reduce the risk of complications.

**Vasculature**

The posterior superior alveolar artery, inferior orbital artery, greater palatine artery, and sphenopalatine artery are the main branches of the maxillary artery that provide blood supply to the bony walls and membrane of the sinus. The inferior orbital and posterior superior alveolar arteries supply the lateral part of the maxillary sinus while the posterior lateral nasal artery supplies the medial part of the sinus. The posterior superior alveolar artery travels on the lateral wall of the sinus and takes on a variable course. This artery is one to be cautious of during the lateral window approach because it can be the cause of intraoperative and postoperative bleeding. In order to prevent injury to any of the arteries, it is important to evaluate the anatomical locations by using cone beam computed tomography (CBCT) preoperatively.

**Innervation**

The infraorbital, superior alveolar, and palatine nerves of the second division of the trigeminal nerve innervate the maxillary sinus. The posterior and middle superior alveolar nerves supply the posterior wall of the sinus. The anterior superior alveolar nerve supplies the anterior wall. The infraorbital nerve runs in a posterior-anterior direction in the middle of the maxillary roof to supply the superior and part of the medial wall. Lastly, the greater palatine nerve supplies the ostium and inferior wall of the sinus.

**Preoperative evaluation**

**Bone height**

Sinus augmentation might be indicated when the distance from the residual bone to the sinus floor is less than required for implant placement, typically 10 mm. It is a common practice that in case the bone height is above 5 mm, osteotome transcrestal approach can be used. If the bone height is 5 mm or less then, usually, lateral window approach is preferred.

**Interarch distance**

The interarch distance is the distance between the mandibular occlusal plane and the maxillary ridge. The maxillomandibular ridge relationship should also be determined in a buccolingual dimension. If this distance is less than 5 mm it could compromise the treatment plan as there is not enough room for the restoration. An increased interarch distance might be observed as a result of resorption of the alveolar ridge. This could lead to the creation of long abutments and crowns, which result in compromised esthetics, an unfavorable crown-to-implant ratio, and increased mechanical forces on the implants.

**Radiography**

Radiographic evaluation is necessary to determine the height of the residual ridge, the location and anatomy of the maxillary sinus floor, the height of the sinus, and the presence of pathology or septa. Computed tomography is preferred over two-dimensional radiography because it is more accurate in identifying the relevant anatomical structures and provides information about the dimensions of the alveolar ridge, the width of the maxillary sinus, and the thickness of the sinus lateral wall. CBCT is also helpful to rule out preexisting diseases or malformations in the sinus.

**Contraindications**

Contraindications for sinus augmentation include active sinus infection, recurrent chronic sinusitis, recurrent fungal sinusitis, uncontrolled diabetes, cystic fibrosis, maxillary sinus hypoplasia, neoplasms, and history of radiation therapy to the site. Medical conditions and medications that would prevent implant placement are also contraindicated. Lastly, the use of inhaled steroids and cocaine dependency contraindicate the procedure.

**Prophylaxis**

Prophylactic antibiotics and steroids are occasionally given prior to sinus augmentation procedures. However, the choice to use them is ultimately in the hands of the surgeon. There is no evidence to suggest that the use of these medications is required prior to the procedure and there is some controversy as to their effect on the outcomes of the surgery.
Types and techniques of sinus augmentation

The two most common approaches taken for completing a sinus graft procedure are the lateral window/direct approach and the osteotome transcrestal/indirect approach. The technique chosen for the procedure is based, mainly, on the residual alveolar bone height. If the height is 4 mm or less then the lateral window approach is generally recommended with delayed implant placement. However, if the implant is to be placed simultaneously with the sinus augmentation, the residual bone height should be adequate to ensure implant stability. It has been suggested that when transcrestal approach was used with a residual bone height of less than 4 mm, implant survival rates decreased. Therefore, the osteotome transcrestal approach is usually indicated when the residual bone height is more than 5 mm.

Lateral window/direct approach

The lateral window approach (Fig 1) was first conducted by Oscar Hilt Tatum Jr in the 1970s. In this technique, the sinus membrane is elevated, following a window creation in the lateral wall of the sinus, to allow the insertion of graft material if the bone height is insufficient for implant placement. It has been shown that the bone height can be increased by 9 mm or more using the lateral approach sinus augmentation. In this approach, a full-thickness flap is elevated to reveal the lateral sinus wall of the maxilla and a bony window is made on the lateral wall. The inferior aspect of the window should be 2 to 3 mm from the floor of the sinus and usually extends distally to the first or second molar. To prevent perforation of the sinus membrane, the operator should stop drilling once the bluish-purple color of the membrane is visible. It is also important to prevent damage to...
the roots of the remaining teeth if they are present.\(^5\)\(^6\) The osteotomy can be prepared with a high-speed handpiece or piezoelectric instruments.\(^2\)\(^6\)\(^21\) The bone that is adherent to the window can either be kept attached to the superior margin of the sinus membrane as a roof over the graft materials or it can be removed completely.\(^2\)\(^5\)\(^2\) Once the bone is fractured off to create the window, the sinus membrane is elevated with a curette to open up a space for the bone grafting material.\(^1\)\(^6\) A dental implant can be placed in the residual alveolar bone if there is sufficient bone height to achieve implant stability.\(^9\)\(^2\)\(^0\) A collagen membrane may be placed over the window site, especially if the window is large.\(^6\)\(^2\)\(^0\) Finally, the flap is repositioned and sutured.\(^5\)\(^9\)\(^2\)\(^2\) It is then recommended to allow 9 months for the consolidation and remodeling of the grafted bone.\(^5\)\(^9\)\(^2\)\(^0\) In cases where the implant cannot be stabilized in the residual alveolar bone, implant placement should be performed after 6 to 9 months.\(^5\)\(^9\)\(^2\)\(^0\)

**Osteotome transcrestal/indirect approach**

The osteotome transcrestal approach (Fig 2) was first conducted by Robert B Summers in the 1990s.\(^4\) The transalveolar floor elevation was intended for easier intervention, shorter procedural time, and fewer complications and risks.\(^2\)\(^0\)\(^2\)\(^1\) It is indicated when there is more than 5 mm of residual bone height.\(^2\)\(^1\) The osteotome transcrestal approach enables adding bone height from 4 to 8 mm with the use of graft materials.\(^1\) A full-thickness flap is raised at the crestal area; the surgical site is then marked with a round bur and a pilot osteotomy is created.\(^5\)\(^9\)\(^2\)\(^6\)\(^2\) The space created is smaller than the size of the implant.\(^2\)\(^6\) During this part of the procedure, apical and lateral bone is compacted as sequential osteotomies of increasing diameter are used.\(^5\)\(^9\)\(^2\)\(^7\) An osteotome is used to elevate the sinus membrane.\(^5\)\(^9\)\(^2\)\(^0\) The pressure from the osteotomes and trapped fluids against the sinus membrane causes it to elevate over an area that is wider than the osteotomy.\(^9\) At this point, bone graft materials can be inserted at the apical portion of the surgical site prior to placing the implant.\(^9\) The placement of a dental implant usually occurs simultaneously.\(^2\)\(^1\) It is important to ensure the stability of the implant at the time of placement.\(^9\) Restoration of the implant is advised after 6 months following the procedure.

The antral membrane balloon elevation is a modification of the osteotome transcrestal technique that raises the sinus membrane with a latex balloon.\(^1\) The balloon is filled with saline and the amount is dependent on how much elevation is required.\(^6\) Another approach is the intralift technique. In this technique, hydrodynamic pressure is used to elevate the sinus membrane.\(^2\)\(^8\) The risk for perforation is minimized and the patient experiences less discomfort following the procedure. The Dentium Advances Sinus Kit is another approach designed to decrease the risk of membrane perforation.\(^6\) The use of this kit has also been claimed to reduce surgical time by allowing for easy access to the sinus cavity.

**Grafting materials**

There are several different types of graft materials available for sinus augmentation. It has been demonstrated that the survival of implants is similar when different bone grafting materials are used alone or in combination with other biologic agents and growth factors.\(^2\)\(^9\)\(^3\)\(^1\) Furthermore, a study that compared sinus elevation surgery with and without grafting, reported no significant difference when compared to using graft materials.\(^2\)\(^7\)\(^3\)\(^2\) The decision of what grafting materials to use is ultimately based on the case and the operator’s judgement.

**Postoperative care**

**Medications**

The presence of a foreign material, along with the sinus flora and the oral flora, all pose a risk for infection.\(^4\)\(^3\) Therefore, antimicrobials might be prescribed for 1 to 2 weeks following the procedure.\(^5\)\(^3\)\(^1\) The antimicrobials of choice are amoxicillin, augmentin, or clindamycin. In order to reduce swelling, pain, and inflammation following the surgery, steroids are also prescribed occasionally; however, their use is controversial following sinus augmentation.\(^6\) Systemic and topical anti-congestants can be used to prevent blockage of the ostia, enabling proper drainage of the sinus space.\(^9\) Lastly, analgesics (as needed) and chlorhexidine mouth rinse should be prescribed to the patient.\(^9\)

**Postoperative instructions**

It is important to inform the patient that soreness is normal and expected following sinus surgery.\(^9\) The patient should avoid strenuous activity and smoking.\(^6\) Also, the patient should have a soft diet to avoid any potential trauma to the surgical area.\(^3\)\(^4\) Good oral hygiene is key and will help to facilitate healing and lower the risk for infection.\(^6\) Chlorhexidine rinses should be used daily after 24 hours post-surgery. To avoid excessive pressure, the following sinus precautions need to be considered: no blowing nose, no using straws or smoking, no exhalation against pressure, such as inflating balloons or blowing into instruments, limit bending over, and sneeze and cough with mouth open.\(^3\)\(^4\)
Outcome measures

Overall, sinus elevation procedures present with very high reported success rates. In a meta-analysis that collected data over 3 years, post sinus elevation surgery using the osteotome transcrestal approach, Tan et al found that the implant success rate was 92.8%. Similarly, Pjetursson et al found that the implant success rate was 90.1% using the lateral window technique. In a systematic review by Del Fabbro et al, the survival rates for simultaneous and delayed implant placement using the lateral window technique was compared. The survival rate for the simultaneous procedure was 92.2% and for the delayed procedure it was 92.9%. Implant success rate based on vertical bone loss was also evaluated and reported to range between 92.7%, when the residual bone height was less than 5 mm, and 96.9%, when it was greater than 5 mm.

Complications

Intraoperative complications

Sinus membrane perforation One of the common complications of sinus augmentations is perforation of the sinus membrane, which can negatively affect sinus integrity and graft survival. The reported incidence of perforations ranges between 10% and 44% during the surgery when the lateral window approach is used. The presence of septa and a residual bone height less than 3.5 cm were reported to increase the risk for perforation. This complication was shown to be associated with postoperative acute sinusitis, infection, and graft failure. If the perforation is small, a collagen membrane can be used to cover the perforation. When the perforation is large, it might require sutures or fibrin adhesive. In severe cases, the procedure may be aborted and reattempted after 4 to 6 months.

Septa Septa in the sinus make it more difficult to create the bony window and dissect the sinus membrane. The presence of septa increases the risk for sinus membrane perforation. If the septum is anteriorly located then two lateral windows may need to be created on either side of the septum to avoid complications.

Bleeding The presence of bleeding during the operation can come from the blood vessels of the mucoperiosteal flap, sinus membrane, or bone. It is uncommon for heavy bleeding to occur since the blood vessels in the surgical site are mostly thin and peripheral. To minimize the risk of bleeding, piezosurgery should be considered as an alternative instrument to prepare the window in the lateral approach. If bleeding does occur, measures for stopping it include firm pressure, local vasoconstrictors, cautery, cellulose, and sutures.

Postoperative complications

Infection Contamination of the operative site by oral or sinus bacteria will likely lead to an infection. Antibiotics should be
prescribed as a first line to suppress the pathogens. Drainage might be indicated in some cases. If the infection is within the sinus and there is no response to the antibiotics, then a re-entry with graft material removal and debridement is indicated.⁹¹

Conclusion

Sinus augmentation is a viable option when considering the placement of an implant in an atrophied posterior maxilla. The procedure has high success rates when planned and performed carefully. Proper training, thorough preparation, and clinical experience are of paramount importance when performing these procedures.

References


Declaration

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