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Maxillary Sinus Floor Elevation: A Review of the Pertinent Anatomy and Surgical Techniques

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INTRODUCTION

The maxillary sinus is the first of all the paranasal sinuses to develop and ends its growth at approximately 20 years of age with the eruption of the third molars.[1]The Maxillary sinus is described as being pyramidal in shape, the pyramid being turned on its side with the apex pointing laterally into the zygomatic process of maxilla, and occasionally extending into the zygomatic bone and the base lying vertically on the medial surface and forming the lateral nasal wall. Its four sides are described as anterior, posterior, superior and inferior.[2] The anterior wall forms the facial portion of the maxillary bone. The posterior and lateral walls blend together to form the posterolateral wall of the sinus, which separates it from the infra temporal fossa and forms the maxillary tuberosity and pterygoid fossa. The superior wall makes up the roof of the sinus, which is also the floor of the orbit. The inferior wall is formed by the alveolar process and the palatine process of the maxilla.[1]

Key Words: Maxillary sinus, Sinus lift, Window approach, Crestal approach

DISCUSSION

1. ANATOMY AND APPLIED ASPECT

1.1 Adult Maxillary Sinus: The average dimensions of the adult sinus are 2.5 to 3.5 cm wide, 3.6 to 4.5 cm tall, and 3.8 to 4.5 cm deep. It has an estimated volume of approximately 12 to 15 cm^3. [3]Anteriorly, it extends to the canine and premolar area. The sinusfloor usually has its most inferior pointnear the first molar region. The size ofthe sinus will increase with age if thearea is edentulous. Nonetheless, this process often leaves the bonylateral and occlusal alveolus paper thin in the posterior maxilla[4].

In the final stage of its pneumatization, its floor moves 4–5 mm below the level of the nasal cavity wall. Normally, it presents asymmetry in size and shape. Partial or complete opacification of the maxillary sinuses in the first year of life is normal.[5] According to **Lawson et al.[6],** the high frequency of variation from the normal anatomy of the maxillary sinus and the tendency of this sinus to preserve its morphology in polyethnic groups, continues to intrigue research workers.

The maxillary sinus includes a medial wall that separates the maxillary sinus from the nasal cavity, a posterior wall facing the maxillary tuberosity, a mesio-vestibular wall containing the neurovascular bundle, an upper wall constituting the orbit floor, and a lower wall next to the alveolar process that is the bottom of the maxillary sinus itself.[7] The maxillary sinus bony cavity is lined with the sinus membrane, also known as the Schneiderian membrane. This membrane consists of ciliated epithelium like the rest of the respiratory tract. It is continuous with, and connects to, the nasal epithelium through the ostium in the middle meatus.[3]

The floor of the sinus is formed by the junction of the anterior sinus wall and the lateral nasal wall. In adults, the floor of the sinus is approximately 1 to 1.25 cm below the level of floor of nasal cavity. It is variable in its extension and extends between adjacent teeth or between individual roots in about half of the population, creating elevations in the antral surface (commonly referred to as "hillocks") or protrusions of root apices into the sinus.[8.9] The roots of the maxillary first and second molars are in intimate relation to the floor of the maxillary sinus in most cases, in some cases the apices of these teeth protrude into the sinus, and the sinus membrane must be raised surgically in order to treat lesions related to them.

Antral mucosa is thinner and less vascular than nasal mucosa. Serum-mucosa (mixed) glands are located in the lamina directly underneath, especially next to the ostium opening. Normally the thickness of the Schneiderian membrane varies from 0.13mm to 0.5mm. However, inflammation or allergic phenomena may cause it to thicken, either generally or locally (in streaks). In such cases, it may be necessary for a surgeon to restore the sinus to a physiologic state before a sinus lift operation can be carried out.[7]

1.2 Maxillary Sinus Ostium

The maxillary ostiumis the communication between the maxillary sinus and nasal cavity, is located in the superior aspect of the medial wall halfway between its anterior and its posterior boundaries (approximately 2cm from the anterior aspect, 2cm from the posterior wall, and 4cm from floor of sinus). This ostium varies widely in shape and size. The mean functional size of the primary maxillary ostium in a living individual is 2.4 mm. The maxillary ostia or hole drains into a slit like opening into the nasal airway and this also aerates the sinus. The uncinate bone is a thin but an important bone as it makes up the medial wall of a slit, the infundibulum, which passes from hiatus semilunaris to the maxillary sinus.[10] The ostium opens into the posterior part of hiatus semilunaris in the middle meatus, mostly in the inferolateral part of the ethmoid infundibulum. The location of ostium is related more to the embryology and development of the sinus than to the configuration of the sinus. Its location is the first site of invagination of nasal mucosa, which later is followed by descent of the floor of the sinus within the maxillary bone to its adult position, leaving the ostium situated close to the roof of the sinus. Because of this location, the ostium is in unfavourable position from the point of view of gravity dependent drainage.[1]

1.3 Maxillary Sinus Septa

The inner surface of the maxillary sinus is rarely smooth, and is often occupied by the bony septa that protrude from the sinus floor and divide the alveolar recess of the sinus into several chambers.[1] Maxillary sinus septa were first described by **Underwood**[11]in 1910. They are the walls of cortical bone within the maxillary sinus. Their shape has been described as an inverted gothic arch arising from inferior or lateral walls of the sinus, and may even divide the sinus into two or more cavities. According to Underwood[11], the maxillary sinus floor is frequently divided into three basins: a small anterior one over the premolar region; a large median one descending between the roots of first an dsecond molars; and a small posterior one corresponding to the third molar region.[12] **Krennmair et al**[13] classified septa into primary and secondary: primary septa corresponding to that arising from the development of maxilla; and secondary septa arising from irregular pneumatization of the sinus floor following tooth loss.[13]

Such septa are of significance when retrieving a root fragment displaced in the sinus and during sinus floor bone grafting procedures. Sinus septa also can interfere with drainage of the sinus.[1] Radiographic identification of these structures is important, since the design of the lateral window during sinus lift procedures is based on presence and size of maxillary sinus septa.

1.4 Vascular Supply and Drainage

Arterial vascularization of the maxillary sinus is supplied by the maxillary artery, the larger terminal branch of the external carotid artery. Within the pterygopalatine fossa, the maxillary artery gives off many branches for the maxillary sinus[14,15,16]

- After entering the pterygopalatine fossa, the maxillary artery gives off the posterior superior alveolar artery (PSAA). This artery enters the posterior superior alveolar foramina on the maxillary tuberosity and gives off dental branches and alveolar branches. The dental branches of this artery supply the pulp tissue of the posterior maxillary teeth by way of each tooth’s apical foramen, and the alveolar branches supply the periodontium of the posterior maxillary teeth. Dental and alveolar branches also supply the maxillary sinus.
- The infraorbital artery (IOA) artery shares a common trunk with PSAA in the pterygopalatine fossa. The IOA enters the orbit through the inferior orbital fissure. The artery travels in the infraorbital canal, provides orbital branches, and gives off the anterior superior alveolar artery (ASAA).
- The ASAA arises from the IOA and gives off dental and alveolar branches. The dental branches supply the pulp tissue of the anterior maxillary teeth. The alveolar branches supply the periodontium of the anterior maxillary teeth.

These vessels anastomose together, with the formation of an intraosseous or intramaxillary and extraosseous or extramaxillary network. Extraosseous anastomoses are made up of the alveolar branches of the PSAA, the inferior branches of the IOA, and the alveolar branches of the ASAA. Intraosseous anastomoses are formed by the dental branches of the ASAA and PSSA. Venous drainage is ensured by the posterior alveolar vein and the inferior alveolar vein. These veins are usually symmetrically located and receive branches from the same areas of the maxillary zone as are supplied by the artery network.

The arterial supply of the buccal part of the maxillary sinus is delivered by two vessels: the posterior superior alveolar artery and the infraorbital artery. The local oral mucosa as well as the mucous membrane of the lateral maxillary sinus are vascularized by these two vessels in a double arterial circle.[17] The rather large diameter of the vessels supplying the lateral antral wall seems to be crucial to the fact that the periosteal supply to local bone can be maintained even in severe maxillary atrophy and after complete disappearance of the centro-medullary vessels. Especially in the severely atrophic maxilla, the alveolar ridge should be denuded from its periosteum as little, as carefully, and as briefly as possible to minimize the impairment of blood flow. Intraoperative bleeding from acompromised vessel in the lateral wall is not threatening because of the small size of the artery. It can make visualization of the schneiderian membrane difficult, thus making membrane elevation more difficult, and it can interfere with placement of the graft material**.** This bleeding can usually be controlled by pressure with a moist gauze pad.[18]

The maxillary blood supply is essential for preserving the vitality of the affected maxillary region, integration of the grafting material, and wound healing, e.g. following sinus floor elevation. Although it is well established that edentulous maxillae demonstrate a decreasing vascularity as bone resorption progresses, the vascular conditions relevant to sinus floor elevation procedures have not been investigated yet**.**

2. SURGICAL TECHNIQUES OF SINUS LIFT

Maxillary sinus floor elevation was initially described by Tatum at an Alabama implant conference in 1976 and subsequently published by Boyne in 1980.[19,20] Its need stemmed from the indispensability to restore the posterior maxilla using implants. The procedure is one of the most common preprosthetic surgeries performed in dentistry today. Since its first description, numerous articles have been published in this field regarding different grafting materials, modifications to the classic technique, and parity between different techniques. Pneumatization of maxillary sinus causes insufficient vertical bone volume on posterior maxilla. So the restoration of edentulous posterior maxilla with dental implants is challenging due to a deficient posterior alveolar ridge, unfavorable bone quality and increased pneumatization of the maxillary sinus.[19] There are two main techniques: the lateral window andthe transalveolar (crestal) approach.

2.1 The lateral window approach

For safe access to the lateral sinus, a full-thickness mucoperiostealflap originating from the midcrestal area or slightly toward the palatal side is preferred, just in case the sinus wall is thin and close to the alveolar crest. A releasing incision at the anterior or posterior edge of this flap should be designed with a slightly flared out characteristic to ensure an appropriate blood supply from the base. On some occasions, a single anterior releasing incision is able to provide sufficient access for the sinus approach. Most importantly, the releasing incisions should be made distant to the proposed window site and the position of the overlapping barrier membrane in casefurther access is necessary.[21,22]Marx and Garg suggested using a cottonoid soaked with a carpule of 2% lidocaine with 1:100,000 epinephrine and left in the space created for 5 minutes so as to limit bleeding and allow for better visualization for further dissection.[16] It is important to free up the sinus membrane in all directions (anteriorly, posteriorly, and medially) before attempting to intrude the trapdoor medially.

In order to open the trap-door window, either the rotary technique or the piezoelectric technique can provide adequate access. Using a piezoelectric tip during preparation of the bony window will considerably reduce the risk of perforation of the membrane.[23,24] The "incomplete fracture" and "wall-off" techniques are two ways to prepare the lateral window osteotomy. The "incomplete fracture" technique includes tapping of the bony island over the graft materials as a roof, which cannot be achieved easily in the narrow sinuses.[19]The "wall-off" technique offers complete removal of the bony island, which results in better access to the sinus. For both techniques, it is important to raise the sinus membrane from the surrounding bony walls, and to be sure to reach the medial wall to obtain adequate horizontal space for grafting materials.[25] Furthermore, this elevation must extend antero-posteriorly to providethe exposed sinus floor to allow for graft and implant placement.

The elevation of sinus space created below the lifted sinus membrane is then grafted with different fillers consisting of autogenous bone, bone substitute, or a mixture of these materials. In general, implants can be placed at the same time with a minimal bone height of 4-5 mm for primary stabilization during the grafting procedure, or can be subsequentlyplaced after a primary healing period of 9-12 months topermit bone regeneration.[21] The initial bone thickness at the alveolar ridge seems to be a reliable indicator in deciding between these two methods. If the bone thickness is 4 mm or less, initial implant stability would be jeopardized. Therefore, a two-stage lateral antrostomy should be carried out. The reverse holds true for a one-stage procedure.[26]A one-stage procedure is less time-consuming for both the clinician and the patient. However, it is more technique-sensitive and its success relies heavily on the amount of residual bone.[27]

The wound is then closed with primary suturing to avoid exposure of the graft orimplants. At the second stage for implant exposure, a partial thickness mucoperiostealflap across the ridge crest to contain a safe zone of palatal keratinized mucosa could be raised andlaterally positioned towards the buccal side in order to preserve a keratinized zone of mucosa on the periphery of implant emergence area.[21]

2.2 The Crestal Approach

One of the drawbacks of the lateral antrostomy is that it requires the raising of a large flap for surgical access. Summers proposed a conservative crestal approach using osteotomes for maxillary sinus floor elevation in 1994.[10]This technique begins with a crestal incision. A full-thickness flap is raised to expose the alveolar ridge. An osteotome of the smallest size is then tapped into place by a mallet or drill into the bone. Preoperative bone height underneath the sinus is measured to determine the desired depth for osteotome extension. The goal is to extend the instruments just shy of the sinus membrane. Osteotomes of increasing sizes are introduced sequentially to expand the alveolus. With each insertion of a larger osteotome, bone is compressed, pushed laterally and apically.[29]Fracture of the sinus floor can be detected by change in the resistance between the osteotome and the bone, or a change in the sound of the tapping. Advancement of the osteotome into the sinus should be avoided, as it increases the risk of perforation of the membrane.30Summers stated that the very nature of this technique improves the bone density of the posterior maxilla where type IV bone is normally found. Once the largest osteotome has expanded the implant site, a prepared bone mix is addedto the osteotomy as the grafting material.[29]

Summers suggested a 25% autogenous bone with 75% hydroxyapatite mix; however, a variety of graft materials have also been used. The final stage of sinus floor elevation is completed by reinserting the largest osteotome to the implantsite with the graft material in place. This causes the added bone mix to exert pressure onto the sinus membrane and to elevate it. Additional grafting material can subsequently be added and tapped in to achieve the desired amount of elevation. Once this height is gained, the implant fixture is inserted. The implant fixture should be slightly larger in diameter than the osteotomy site created by the largest osteotome. It becomes the final osteotome, “tenting” the elevated maxillary sinus membrane.[29]

The main advantage of the crestalosteotome technique is that it is a less invasive procedure. It improves the density of the maxillary bone, which allows greater initial stability of implants. It also has the potential for the use of less autogenous grafting material. Summers suggested the crestal incision to be extended distally to the tuberosity area where autogenous bone can be harvested.[29] The disadvantage of the crestal approach is that the initial implant stability is unproven if the residual bone height is less than 6 mm. The chances of achieving a sufficiently high elevation with the osteotome technique is limited.[26] With this approach, there could also be a higher chance of misaligning the long axis of the osteotome during the sequential osteotomy.

2.3 Complications& their management

Serious complications are very rare, while the occurrence of the other complications corresponds to the character of the procedure. Following are the most commonly encountered complications:

1. By far the most frequently occurring complication is perforation of mucosa of the maxillary sinus during the surgery. If not closed spontaneously, oxycellulose mesh can be used for coverage.
2. Acute sinusitis is the most serious complication. It is most frequently caused by infection of the augmentation material during the surgery. It has dramatic manifestations and requires revision surgery of the maxillary sinus under general anesthesia with the removal of all foreign bodies.
3. Mild purulent exudate from a dehiscent mucosal wound accompanied by swelling, pain and subfebrile conditions, is not a big threat. It can be usually managed by irrigations and antibiotic therapy.
4. From time to time, healing by second intention is seen and it is not a big risk for the effectiveness of the procedure. If the bone window is situated too close to the mucosal incision, or if the augmentation material is too much compressed, the augmentation material can be liberated from the wound. In this case, it is recommended to use antibiotics and apply a secondary suture.
5. Postoperative hematoma is observed mostly in older females. It has an annoying effect in esthetic terms but usually resorbs within two weeks.
6. Primary failure (non-osseointegration) of the implant remains a very rare event in hydroxyapatite-coated implants. Long-term success is not significantly different from that of usual implant procedures.

CONCLUSION

Restoring edentulism with dental implants requires careful treatment planning. This is especially true with the posterior maxilla when pneumatized maxillary sinuses could limit the amount of alveolar bone for implant placement. Maxillary sinus floor elevation offers one of the most common preprosthetic procedures to solve this problem. Lateral antrostomy allows for a greateramount of bone augmentation to the atrophic maxilla but requires a larger surgical access. The crestal approach is minimally invasive but permits only a limited amount of augmentation. Therefore, practitioners should select the type of procedure appropriate to the particular clinical needs. In addition, all relevant anatomic structures in the vicinity should be respected to minimize surgical complications.

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