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Review Article

Principles and Techniques of Sinus Augmentation

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ABSTRACT

Implants in the posterior region of the atrophic maxilla having a pneumatized sinus often pose a challenge for the clinician. In order to make the implant site viable sinus augmentation needs to be conducted in the posterior atrophic maxilla. Being a technique sensitive procedure, proper knowledge on the anatomy of maxillary sinus is a must. This ensures proper implant placement and sinus augmentation as well as no post-operative complications. This review article explains the basic techniques involved, i.e., direct and indirect techniques along with their various adaptations used specifically for maxillary sinus elevation along with augmentation.

Keywords: Maxillary sinus, Sinus augmentation, Sinus lift technique, Crestal approach, Osteotome

INTRODUCTION

Paranasal Sinuses are very important anatomical structures inside the human body and has great importance in both medicine and dentistry. Dental surgeons are always required to make a proper diagnosis concerning the pain related to oral cavity that may originate from *"sinus[1]"*. Communication between the maxillary sinus and oral cavity (oroantral) or between the nasal cavity and oral cavity (oronasal), has often been considered as a challenge among clinicians. This complication is often encountered after maxillary posterior teeth extraction or any other surgical procedure in the posterior part of the maxillary region. *Egyptians* were the first who identified the paranasal sinuses inside the bones of the *"skull[2]"*. A few years later in the history, Nathaniel Highmore, Born in 1613 was specially connected with the anatomy of the maxillary sinus and which is why, the maxillary sinus was named as *"Highmore's antrum[3]"*. Schneider in 1660, was the first scientist who identified that the mucus was not produced by the brain, but was a product of the *"paranasal sinuses themselves[4]"*.

The development of maxillary sinus begins as early as the 10th week of intra uterine life. It is the largest sinus among all the paranasal sinuses. It is pyramidal in shape in which anterior wall is limited to the facial surface of the maxilla, posterior wall of sinus is limited to the infratemporal surface of the maxilla, superior wall is limited to the fragile, triangular floor of the *"orbit[5,6]"*. and the medial wall separates the sinus from the nasal *"cavity[7]"*. The maxillary sinus derives its blood supply from the 3 branches of the maxillary

artery namely posterior superior alveolar artery, infraorbital artery and the posterior lateral *"nasal artery[5,8]"*. Maxillary sinus receives the nerve supply from infraorbital nerve and branches of maxillary nerve: anterior, middle and posterior *"superior alveolar nerve[5]"*.

CLASSIFICATION FOR TREATMENT OF POSTERIOR MAXILLA

"Misch (1987)" introduced a classification on the basis of amount of residual alveolar ridge height (>5 mm) and width (2.5-5 mm) below the sinus floor for the treatment of posterior edentulous maxillary region. Categories for the treatment extended from sub antral augmentation category *"SA1 to SA4"[9]*.

SA1: Adequate height of the alveolar bone for placing implants (12 mm) and sinus lift is not required.

SA 2: 10 mm of bone below the sinus floor and sinus lift may require.

SA 3: 5-10 mm of bone below the sinus floor.

SA 4: Less than 5 mm of bone below the sinus floor.

To place an implant, there are two main techniques for the elevation of maxillary sinus floor: 1) *"Lateral window approach"* (two-stage technique), 2) *"Transalveolar approach"* (one-stage technique). The decision to use lateral window and transalveolar techniques depends on the availability of height and width of residual alveolar ridge.

DIRECT/LATERAL WINDOW TECHNIQUE

"Tatum[10]," *"Boyne and James[11]"* were the authors who published the studies on elevation of the maxillary sinus floor in patients with pneumatization. They emphasized two-stage sinus lift procedure, where the floor was packed with autogenous particulate bone graft taken from the iliac bone in the first surgery. 3 months later, implants were placed in second surgery and later the prosthetic constructions were done.

Surgical Technique- Direct/lateral window technique[12].

Step 1. Anesthesia– Nerve block will be given to anesthetise Infraorbital, posterior superior alveolar, greater palatine nerve followed by slow infiltration of *"subperiosteal anesthesia."*

Step 2. Incision– An anterior vertical incision will be given at least 10-15 mm anterior to the maxillary sinus wall. Next, a palatal incision is made with blade-15C connecting the vertical incision. To facilitate the suturing, horizontal incision should be made in keratinized tissue. Full thickness flap reflection in order to gain the access for canine fossa located just below the posterior lateral maxillary wall and buttress of the zygomatic arch. Elevator must be adherent to the bone surface while elevating full thickness flap, to make periosteum remains unchanged.

Step 3. Lateral window– A sterile pencil is used to locate the boundaries of the lateral wall window on the buccal surface of bone. Coronal boundary of the lateral window will depend on the location of PSA artery and the implant length. *"Apical"* boundary should be approximately 3 mm above the sinus floor. *"Mesial"* boundary should remain close to anterior wall of sinus and distal boundary would vary according to the number of implants to be placed. Size of the lateral window would be 15 millimeter apicocoronally and 20 millimeter mesiodistally.

Lateral window outline will be made with the help of high speed handpiece and diamond bur (no. 8) with gentle brushing or paintbrush stroke until bluish hue is visible. Lateral window shape is usually oval and it should have smooth edges that prevent the perforation of the sinus membrane. To fracture the sinus bony lateral window, Bone tampers can be used.

Step 4. Elevation of Sinus membrane – Blunt instrument is used to detach the *"sinus membrane.[13]"* The elevation is done with the help of sinus curettes and should start from the sinus floor and extending to the anterior and posterior walls. It should be elevated up to the full height of the expected graft placement. The integrity sinus membrane lining can be checked by

asking the patient to breathe in from nose deeply while observing the membrane lifting.

Step 5. Preparation of implant site– If the bone quality is good and the residual alveolar bone height is 3-4 mm, it becomes possible to place implants in the same visit or else place the implant after 4–6 months. The posterior maxillary bone is a porous bone and has low mineral density, so the implant osteotomy site should be undersize. The sinus membrane lining should be protected with periosteal elevator so as to avoid trauma from *"drills"*.

Step 6. Graft placement– Collagen membrane provides the protection to the sinus membrane. Implants are placed in the prepared implant osteotomy sites. Bone grafts are placed in the anterior and posterior recesses first followed by the medial sinus wall area. Bone graft should not be compacted too tightly as it prevents vascularization. Some researchers showed that sinus augmentation with simultaneous implant placement in lateral approach can be performed with platelet rich fibrin as the sole filling material with promising *"results*[14-16]*"*.

Step 7. Membrane placement– Resorbable barrier membrane is placed over the lateral window (collagen membrane adheres well over the bone which does not require fixation screws and does not require second surgery for its removal).

Step 8. Suturing– Non resorbable monofilament suture and horizontal mattress sutures are used to approximate the flap.

The major disadvantages associated with lateral window approach are that it requires the raising of a large flap to get the surgical access, technique sensitive and time consuming. Success rate is mainly relies on the availability of residual *"bone height*[12]*"*.

One-stage sinus lift versus two-stage lateral sinus lift techniques

The single stage implant placement procedure has an advantage which includes: reduced healing time by 50% as it is a one surgical procedure; but the disadvantage includes the difficulty in stabilizing the implant with minimal bone support, which develops the risk of failure of implant osseointegration. Therefore, if the primary implant stability is not achieved, then it is always prefer to postpone the implant placement till the healing of bone graft takes place and opt for a two-stage procedure. *"Felice et al.*[17]*"* conducted a study with an objective to know out of two which technique, one stage or two-stage sinus lift technique, could be advantageous in sinus floor augmentation with alveolar ridge heights ranges from 1 to 3 mm, in case of lateral window sinus lift technique for implant rehabilitation and they concluded that both the techniques (one stage and two stage) had no statistically significant differences and the planned goals were achieved.

Piezoelectric technique was introduced in 2001 by *"Vercellotti*[18]*"* *et al.* Piezoelectric is used to cut the bony lateral window precisely while maintaining the integrity of sinus membrane and when the piezo surgery tips come in contact with non-mineralized *tissue,* termination of the surgical action takes *"place*[19,20]*"*.

INDIRECT / TRANSALVEOLAR APPROACH

Dr. O. Hilt *"Tatum*[10]*"* was the first who performed the Transalveolar technique and he also proposed osteotome sinus floor elevation (OSFE) by crestal technique. From the side walls of the osteotomy, bone is removed then the bone is pushed toward the maxillary sinus floor. To carry out this procedure, a variety of instruments are required including burs, curettes, channel formers and socket formers, to shave the bone between the alveolar ridge crest and maxillary sinus floor. After the exposure of sinus bony floor, a small osteotome or socket former is used to break the remaining sinus floor and elevate the schneiderian membrane of sinus. The membrane was elevated directly with the help of antral curettes to make a space into which the biomaterial can be placed. The crestal approach as envisioned by Tatum proved technique sensitive procedure, and then the Caldwell-Luc operation became the most accepted procedure for maxillary sinus grafting.

Robert Summers (1994), used a set of tapered osteotomes of increasing diameters for lifting the sinus floor. He proposed a technique for placing an implant in the posterior edentulous maxillary region. In cases where the residual bone height is equal to or *">6 mm*, the Indirect osteotome maxillary sinus floor elevation *"(OMSFE) technique is generally indicated*[21-22]*"* and whereas, in cases with complex atrophied ridges, the direct sinus lift technique is *"used*[23]*"*. This technique has many advantages: a conservative approach, a low rate of postoperative morbidity, shorter implant loading as compared with the direct sinus lift technique and the survival rates are *"high*[24]*"*. Reported complications in this technique are few in which one case report mentioned the benign paroxysmal vertigo as a clinical complication *"(4 cases)*[25]*"*. Few study reports showed the sinus membrane perforations around 2.2%-25[26]. The success of implant survival decreases as the length of the implant and height of preoperative crestal bone decreases. The survival rates for 12mm implant length were 100%, for 10mm implant length were 98.75%, for 8 mm implant length were 98.7% and for 6 mm implant length were only 47.6%. If preoperative alveolar ridge height is more than 5 mm, then the success rate of implant ranges from 96-100%. Whereas, if alveolar bone height is less than 5 mm, the success rate of implant ranges from 85.7-91.3%[27]. This reports indicates that for optimum osseointegration, if the preoperative alveolar ridge height is not more than 5 mm, then sinus augmentation is preferred.

Following are the steps of osteotome *"technique through transalveolar approach*[28]*":*

Step 1. Anesthesia

Step 2. Incision– Mid crestal incision should be made in the edentulous site.

Step 3. Flap– Mucoperiosteal flap is elevated to expose the underlying alveolar ridge, Flap elevation should be done with periosteal elevator.

Step 4. Drilling– Osteotomy site preparation is initiated with a pilot drill (2 mm diameter). A confirmatory radiograph is advised post insertion of pilot drill into the desired site. Further wider diameter set of osteotomes is used to widen the site. Care should be taken to make it 2 mm short of the sinus floor. In low density bone (D3 and D4), osteotomes are used for the condensation of the bone laterally, if needed.

Step 5. Grafting– post the insertion of the largest diameter of osteotome in the implant site, particulated bone grafts are packed to the prepared osteotomy site as the biomaterial. Bone Graft is placed in the osteotome site, before fracturing of the maxillary sinus floor.

Step 6. Fracture– To fracture the maxillary sinus floor, a smaller diameter osteotome is inserted in the osteotomy site. Osteotome should be smaller than the implant body diameter and should be tapped gently. Different pitch of sound can be heard while fracturing the sinus floor.

Step 7. Sinus floor lift– Reinsert the largest diameter osteotome in the prepared implant osteotomy site with the bone graft in place. The bone graft exerts the pressure onto the schneiderian membrane which lifts it further. Biomaterial is placed in the space and tapped gently to an extent to get the desired amount of schneiderian membrane elevation. It should not be extending beyond the stretching limit of the membrane.

Step 8. Placement of implant– The implant diameter to be used should be slightly larger than the osteotomy site prepared.

"MODIFICATIONS*[29]*"

Modified Osteotome Technique

Initially, the osteotome technique was used for congesting the maxillary jaw which is relatively a soft bone. This increases the primary stability as well as success rate of the implants. Subsequently, by using the elasticity or resiliency of the bone *"Summers*[28]*"* introduced maxillary sinus floor dilatation. But the disadvantages of this technique are that it has limited

indications which includes the lack of accessibility to the state of sinus lining. Summers introduced this technique of sinus lift, by fracturing sinus floor with an osteotome and pushing bone graft through prepared osteotome hole.

This technique is a less invasive and less traumatic method of lifing the scheinderian membrane. Later, *"Summer's[28]"* modified this technique, replacing the original concave, osteotomes with cutting edges with convex and rounded osteotomes. The main difference in this technique, the fracture of sinus floor is avoided. The round end of the osteotomes allows the compaction of maxillary bone after preparing with the pilot drill. Osteotome expands the osteotomy, bone graft is in the sinus cavity and *"implant* placement is done[30]*."*

Balloon Sinuslift Technique

The balloon sinus lift technique is based on the osteotome technique. The advantage is that it can be performed with 3 mm or more height of alveolar bone, while the conventional osteotomes technique requires a minimum of 6 mm height of alveolar bone. *"Muronoi et al. (2003)[25]"*, and Soltan *et al.* (2005)[25] demonstrated the use of the sinus balloon while performing the direct sinus lift technique by placing it through a lateral window in sinus wall. *"Kfir et al. (2006)[31]"* demonstrated the transcrestal sinus lift technique using the sinus balloon technique, in which they placed bone graft and implants in single surgery. Other authors such as *"Hu et al.[32]"* have also described this technique as a single stage implant procedure with transcrestal sinus floor lift technique, and they found excellent results. This is a minimally invasive technique in which an elastic catheter is used to force the saline due to which the balloon swells and pushes out the sinus membrane. The disadvantage is that it is cost effective mothed.

"Surgical protocol[32]"

First, local anesthesia will be given then the full thickness mucoperiosteal flap will be raised and osteotomy will be prepared using pilot drills and osteotomes. An osteotome tip will be inserted and tapped gently to allow fracture of the cortical layer of sinus wall. The schneiderian membrane integrity will be checked by using a *"Medi Pack Pal endoscope (Farol Store and Co., Tuttlingen, Germany)"* inserted through the prepared osteotomy. The latex balloon will be attached to a catheter which is used to inflate the balloon. After placing the balloon in the subantral space, progressive, slow and controlled inflations will be performed with saline solution. Inflations will be repeated many times. Do not introduce more than 4 ml of saline each time. During the inflation sequence use the endoscope to evaluate the sinus membrane integrity. The sinus membrane will then be elevated to the desired height, and autologous bone shavings can be used as autograft obtained from drilling. Implants will be placed in the same surgical. In cases, where the implants cannot be placed in the single surgical step, it is preferred to wait for three months to allow the graft consolidation before implant placement.

The hydropneumatic sinuslift *"technique[33]"*

The hydropneumatic sinuslift introduced in 2008 by *"Troedhan et al.[33]"* and is based on transcrestal technique. In this technique, after the preparing the implant osteotomy with the pilot drill by maintaining the 2 mm distance from the sinus floor, then osteotomy is extended till the floor with the help of calibrated diamond tips. The final last diamond tip is called "Trumpet" which has the diameter equal to the last instrument diameter used to extend the osteotomy. A coolant is released from the piezosurgery device and its pressure pushes out the sinus membrane. The bone graft is packed in the space with the help of the "trumpet" and then implant is placed.

Following is the drill sequence used during the implant surgery:

1. **'Pilot drilling':** diamond tip is conical (TKW 1-Ø 1.35mm)
2. **'Preliminary drilling':** diamond tip is cylindrical (TKW 2-Ø 2.1mm)
3. **'Preliminary drilling':** diamond tip is cylindrical (TKW 3-Ø 2.35mm)

4. '**Secondary drilling':** diamond tip is cylindrical (TKW 4-Ø 2.80mm)
5. '**Trumpet':** It is a non-diamond and non-cutting tip (TKW 5). It sprays sterile irrigation which elevates internal sinus membrane by microcavitation. It can be used as a manual instrument in nonactivated mode to compact the bone graft in sinus floor. Haemostatic collagen sponges should be inserted to protect the schneiderian membrane so as to avoid the direct contact of tip to the sinus membrane. The first 4 drills/tips are only used to extend the osteotomy, and trumpet is only used to lift the sinus membrane.

PIEZOSURGERY UNIT IN SINUS LIFT

For three decades, ultrasonic vibrations have been used to cut the tissue. Piezo word is derived from 'piezein', which means pressure. Piezoelectric devices were introduced in dentistry to get the greater precision, simplicity and safety in hard tissue surgery. Jean and Marie Curie (1880), described the effect of piezoelectric on bone. An electric current passes across the present ceramics and crystals which further leads to oscillations of these crystals. A frequency of 25–29 kHz is used to cut only mineralised tissue whereas the frequencies higher than *50 kHz* are used to cut the neurovascular tissue and other soft tissues[34-36]".

"Piezoelectric" unit comprises of a foot switch and hand-piece, connected to the main power unit. The fluids used for irrigation can be adjusted via an adjustable peristaltic pump. It ensures precise cutting by removing the debris from the cutting area. It also maintains a blood-less field and gives better visibility particularly in *areas* where the accessibility is compromised[36]". Piezosurgery tips should be moved continuously at a high speed with minimum pressure forwardly and backwardly[37]". Various types of tips are available that vary in size, shape and *"material*[38]".

Sinus-floor elevation

The surgical technique includes the removal of a lateral bony window through the maxillary sinus wall. *"Al-Dajani*[39]" in his study found that a perforation of the sinus membrane increases the risk for the sinusitis. Therefore, it is important that perforation of schneiderian membrane should be avoided during elevation. *"Seoane et al.*[40]" found that the use of the piezoelectric device reduces the frequency of schneiderian membrane perforation among clinicians with limited experience. Use of specific piezoelectric tips can decrease the risk of accidental or iatrogenic perforations of sinus membrane.

Another advantage piezoelectric device is the thin cut of the bony wall[41]. Piezoelectric device in sinus lift has gained approval; whereas, a few authors are of the opinion that this device does not give a clear *"benefit*[42]". Piezoelectric device can also be used during the same surgical session for harvesting the bone while preparing the osteotomy. *"Stacchi et al.*[43]" described a scraping-pulling technique, in which they shaved the bone chips and used as the autograft for the sinus augmentation. The bony chips can also be mixed with various non autologous biomaterials and placed in the space created in sinus.

DISCUSSION

The maxillary sinus lift procedure is a surgical intervention that seek to maximize the height of remnant alveolar bone in the posterior maxilla by elevating the "schneiderian membrane" in an upward direction, accompanied by biomaterial placement to fill in the gap created between the maxillary sinus floor and the schneiderian membrane, offering an optimum alveolar bone height where dental implants can be placed. Proper knowledge of the anatomical structure and recent advancements of surgical techniques is necessary to perform maxillary sinus lift surgery. The advancements in sinus lift techniques inspires the surgeons to innovate, develop and maintain a high standard of implant practice in dentistry.

CONCLUSION

Excellent results in implant success can be achieved if the post-operative complications are minimal. The

complications can be prevented by a proper case selection and good surgical technique. Increase in implant survival rates can be achieved by proper decision making in regard to implant textured, biomaterial, and the application of a barrier membrane over the lateral bony window of sinus wall.

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