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Internal Sinus Lifting: Rational, Techniques & Complications

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ABSTRACT

This article explores maxillary sinus floor augmentation, a surgical procedure that increases bone height in the upper jaw to facilitate dental implant placement. It becomes necessary when tooth extraction in the posterior maxilla leads to bone resorption and pneumatization of the maxillary sinus. The article discusses the anatomical considerations of the maxillary sinus, including its walls, blood supply, innervation, and Schneiderian membrane. It emphasizes the importance of pre-operative cone-beam computed tomography (CBCT) for proper surgical planning. Various sinus floor augmentation techniques are reviewed, categorized into two main approaches: direct (lateral window) and indirect (internal). The article details advantages and limitations of techniques like the inflatable catheter, Summers osteotome, intralift (piezoelectric), hydraulic, and Sinu-Lift System. Additionally, a minimally invasive technique utilizing maxillary sinus floor osseodensification is presented. Potential complications associated with these procedures are addressed, including perforation of the Schneiderian membrane, bleeding, and infection. The article concludes by highlighting the importance of careful planning and meticulous surgical technique to minimize these risks and ensure successful implant placement.

Literature Review

Extraction in the maxillary posterior region causes progressing alveolar ridge atrophy and maxillary sinus pneumatization. Furthermore, roots protruding into the sinus, having a thin cortical bone lining which may become fractured and dislodged during the extraction procedure, allow sinus expansion toward the empty socket. Thus, implant placement becomes challenging due to substantial reduction of the residual vertical bone height and inadequate bone quality [1,2]. The treatment options proposed in such cases are either conventional removable partial dentures compromising the patients' esthetic demands, or the use of extra short implants which is not feasible when residual bone height < 6 mm. Other solutions are placing tilted implants mesial or distal to the sinus cavity or the use of zygomatic implants in cases where adequate bone is available [2]. The maxillary sinus augmentation targets increasing the vertical bone height of the alveolar bone; thus, expanding prosthetic options by making implant placement in posterior maxillary atrophic ridges possible.3 The maxillary sinus "antrum of Highmore" is the largest paranasal sinus.

The adult maxillary sinus is a pyramid-like structure with its base lateral to the nasal wall, its superior wall represents the floor of the orbit, and its apex faces the zygomatic process of the maxillary bone. The volume of the maxillary sinus in adults is 12-15ml filled with air. This volume tends to increase with loss of posterior upper molars [3,4]. The anterior wall of the sinus extends from the inferior orbital rim to the maxillary alveolar process. It consists of thin bone, and it serves as the surgical site for the Caldwell-Luc (lateral antrostomy) approach. Furthermore, the canalis sinuous grooves it internally (which accommodates the anterior superior alveolar nerve and vessels.

Three major landmarks in the anterior wall:

1) The thin canine fossa

2) The infraorbital foramen located in the midsuperior region and

3) The infraorbital groove [3,5]

The posterior wall separates the maxillary sinus from the infratemporal fossa. It forms the anterior border of the pterygo-palatine fossa. The medial wall is the lateral wall of the nasal cavity and separates the sinus from the nasal cavity. It is rectangular in shape and is slightly deficient at the maxillary hiatus. Furthermore, it carries the inferior nasal conchae on the nasal side and lodges the primary ostium, which serves as the main route for the drainage of secretions [3,6]. The ostium is an elliptical or slit-like shaped drainage channel serves as an overflow drain and is situated between the middle and posterior thirds of the ethmoidal infundibulum and tends to be situated closer to the roof of the sinus than the floor, which reduces the chances of a blockage during sinus augmentation procedures.

It drains into the ethmoidal infundibulum, and then into the middle meatus of the nasal cavity at the hiatus semilunaris [4,5]. Branches of the maxillary artery: The posterior superior alveolar artery, inferior orbital artery, greater palatine artery, and sphenopalatine artery provide blood supply to the bony walls and membrane of the sinus.4 Locations of the inferior orbital artery and the posterior superior alveolar artery are necessary in surgical planning, as injuring these arteries results in bleeding. The two arteries reunite with each other and form a double arterial arcade, which encompasses the maxillary sinus [3,7]. This anastomosis is either extraosseous (23-26 mm away from alveolar ridge) or end osseous (16.4-19.6 mm from the alveolar margin) [8].

The dental branch of the posterior superior alveolar artery has an end osseous anastomosis with the inferior orbital artery in all dissected anatomical cases, but radiographic detection of this anastomosis is possible in only 50% of cases [4,7]. Branches of the second division of the trigeminal nerve, which include the infraorbital,

superior alveolar, and palatine nerves, provide general sensory innervation to the sinus. the posterior and middle superior alveolar nerves innervate the posterior wall of the sinus, the anterior superior alveolar nerve innervates the anterior portion of the sinus, whereas infraorbital nerve innervates the superior wall and part of the medial wall of the sinus. The greater palatine nerve innervates the ostium of the maxilla. Innervation of the maxillary sinus is important, because there is a particular connection between the maxillary sinus venous system and the cavernous sinus that can be a route for spread of infection from the sinus to the brain [2-9]. The Schneiderian membrane consists of three layers.

Periosteum is the first layer covering the bone of the sinus, the second layer is highly vascular connective tissue covering the periosteum, and the third layer is pseudostratified columnar epithelium (respiratory epithelium) exposed to the sinus cavity. The Schneiderian membrane is continuous with the nasal mucosa as they connect at the ostia. One or more septa "Underwood's septa" would divide the sinus into recesses [3-10]. The use of Cone-beam computed tomography (CBCT) in pre-operative radiographic assessment is mandatory when planning a sinus floor elevation surgery. Features commonly observed in CBCT include measuring the height and width of the residual alveolar ridge, evaluation subantral bone quality, intimate relation of Schneiderian membrane with roots of adjacent teeth, estimation of the graft volume needed for sinus lifting [11,12]. Sticky bone is a fabricated growth factor-enriched bone graft matrix, using autologous fibrinrich blocks either with concentrated growth factors (CGF) (Sohn, et al. [13]) or with liquid injectable platelet-rich fibrin matrices (I-PRF) (Mourão and colleagues in [14,15]) granting the stabilization of the bone graft in bony defects which minimizes bone loss during healing.

Furthermore, promoting healing by the significant release of cytokines and autologous growth factors. Nonetheless, the easy handling of the grafting material reduces the surgical time. All these factors indicate that sticky bone is a promising autologous bone graft material for bone tissue regeneration [13-17]. In the 1960s., Boyne reported a sinus lift procedure then, various sinus lift techniques and procedures were introduced into the implant dentistry field. The aim of these techniques was to elevate the sinus membrane creating a subantral space to increase the vertical height of bone [2-18]. Currently, the available sinus lift techniques used for implant placement in the pneumatized posterior maxillae are divided into two main methods:

1) The direct (open) method: lateral (window) sinus lift either as a one or two-step procedure. The direct sinus lift is also termed as lateral antrostomy or "Caldwell-Luc operation" [3-18].

2) The indirect(closed) method: Internal sinus lift. The indirect sinus lift is also termed as crestal approach, subantral sinus augmentation, osteotome sinus floor elevation, "Summer's technique", subcrestal augmentation, sinus floor elevation or trans alveolar approach [2-18].

The indirect sinus lifting is a conservative less invasive technique, less time consuming and minimizes patient morbidity. In this technique a small osteotomy is executed through the crest of the edentulous ridge at the inferior border of the antrum which raises the Schneiderian membrane creating a "tent" and granting space for graft biomaterial placement and blood clot formation [1,2].

Inflatable Catheter Technique

Executed by Tatum then two endosteal implants were inserted and their restorations. In 1980 Boyne and James authored the first publication on the approach reporting cases of placement of autogenous grafts into the sinus, the grafts were allowed to heal for 6 months then blade implants were placed [18]. Transcrestal sinus lift using the sinus balloon is conservative minimally invasive approach with minimal intraoperative complications. David Peñarrocha Diago et al. stated that they were able to execute transcrestal sinus lift from 3 mm of residual bone, the mean height gain was of up to 8.7 mm, with a 100% implant success rate one year after Implant loading. Nevertheless, it becomes a challenging technique in case of teeth neighboring the edentulous area [18-20].

Summers Osteotome Technique

Internal sinus lift technique using osteotomes to raise the Schneiderian membrane. It eliminated hammering making the technique more convenient for the patient with placement of a graft biomaterial around the implant. Another term for this technique "bone-added osteotome sinus floor elevation technique". The challenge in this technique was the availability of > 5mm residual bone height preventing membrane perforation and low primary stability of the implant [18-22].

Intralift Technique

Torrella and colleagues introduced piezoelectric technology for the lateral osteotomy surgeries. Troedhan et al. invented the Intralift technique to raise the Schneiderian membrane by using piezoelectric surgery consisting of a specific set of tips for the application of ultrasound. The high-power ultrasonic instruments enable osteotomies to be made even, in thicker compact cortical bone. The piezoelectric osteotomy grants a good tactile sense does not injure nonmineralized structures i.e.: does not cut the soft tissues. Hence, it is less likely to perforate the membrane. The piezoelectric surgical sets comprise various inserts from osteotomies to diamond-cutting inserts. The hydropneumatics pressure of the saline solution irrigation is subjected to the piezoelectric cavitation pushing the Schneiderian membrane upwards resulting in its' detachment and floating [18-25].

Hydraulic Sinus Lift Technique

In this approach, the Schneiderian membrane is raised through a crestal approach, characterized by the hydraulic detachment of the mucosa through injecting a liquid by its spontaneous expulsion or aspiration, and simultaneous filling of the sub Schneiderian space, combined with solid or semisolid graft biomaterial. The drawback of this approach is prolonging the surgical time. Additionally, a single-use syringe is used in this procedure thus, it is impossible to check the exact progression of the sinus membrane position. 18,26 Andreasi and colleagues proposed a new technique with the advancement of hydraulic pressure exerted on a semisolid graft material to separate the Schneiderian membrane and simultaneously fill the augmented space created in this manner. He named this technique "HySiLift" [18-27].

Sinu-Lift System

This is a minimally invasive two-staged indirect sinus lift technique named "Sinu-Lift system" which utilizes beta-tricalcium phosphate combined with platelet-rich plasma. The disposable kit consists of starter drill, curettes, and bone packer. The starter drill makes osteotomy towards the sinus membrane which is deactivated upon contact with the Schneiderian membrane to prevent perforation. The yellow and blue curettes gently separate and raise the membrane. The bone packer usage is to fill the subantral space incrementally with pure phase synthetic β-TCP (Tricalcium phosphate) mixed with PRP (Platelet Rich Plasma) [18-28].

Maxillary Sinus Floor Augmentation Through Bone Densification

The sinus lift technique through alveolar crest osseodensification is conservative minimally invasive and minimally traumatic, profiting from of hydropneumatics counterclockwise rotating instruments, allowing the osseodensification by lifting the maxillary sinus floor without touching on the Schneiderian membrane, which allows it to be elevated at a minimum risk of perforation [29-31]. This technique enhances bone quality, thereby providing a larger bone extension surface in contact with the implant and thus, greater possibility of primary torque and long-term implant success. Osseo densification compacts bone and simultaneously autografts it into the osteotomy walls and apex instead of removing it. The use of a Densah® drill bit at high speed counterclockwise, without a cutting edge and with a steady irrigation causes the formation of a layer of strong dense bone along the walls of the base of the osteotomy preparation [30,31].

The main complications of the transcrestal technique are perforation of the Schneiderian membrane. It is common in the direct technique. Careful 3D radiographic assessment of the sinus anatomy should be carried out to minimize the risk of perforation. There is a controversy about the survival of implants after perforation and repair of the Schneiderian membrane [4-32]. In case of a small perforation there is a possibility that it will repair itself by clot formation or fold over of the sinus membrane. In case of a large perforation (>5 mm), coverage with a resorbable membrane serving as a barrier between the sinus and the grafting biomaterial is recommended. In case of extensive perforations (>10 mm), the use of a large resorbable membrane extending over the lateral wall and stabilized by bone tacks or sutures is advisable [4-34]. Bleeding Injury of arteries can be avoided by preoperative radiographic CBCT evaluation. Piezosurgery running on low-frequency ultrasonic vibrations and having a selective cutting action, has a minimal incidence of damaged vessels and membrane. Methods to stop bleeding include raising the head, firm and direct application of pressure, and local vasoconstrictors usage other techniques include, suturing of the vessel or cautious use of electrocautery, as it could perforate the sinus membrane [4-36].

Infection

If the postoperative infection is limited and external to the sinus cavity, incision and drainage is recommended as well as curettage and irrigation but in case of spreading of infection into the sinus, the infected grafting biomaterial should be removed especially when it is loose, mobile, and grayish in color. Systemic antibiotics should be adjusted according to the culture and sensitivity tests results [3-37].

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