Management of the Posterior Maxilla With Sinus Lift: Review of Techniques

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Purpose: The posterior maxilla presents several challenges to the implant dentist. The pneumatization of the maxillary sinus is one such problem. The management of this problem in the most atraumatic way is important for long-term success of implants placed in this region.

Materials and Methods: Articles presenting different techniques of sinus lift are reviewed and presented.

Results: Each technique presented has its own advantages; however, selection of technique should be done cautiously based on long-term results.

Conclusion: This article reviews techniques and presents advantages, disadvantages and success rates where available.

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The success rate of dental implants for both function and esthetics has been reviewed in several studies. An essential condition for successful implant therapy is the presence of an adequate quantity and quality of bone. The posterior edentulous maxilla presents special challenges to the implant surgeon that are unique to this region compared with the other areas of the mouth. Most important among these is the presence of the maxillary sinus. The maxillary sinus is an air cavity located in the maxilla. It is pyramidal in shape and is frequently reinforced with internal vertical septa, creating further intrasinus cavities. The size of the sinus varies from individual to individual. In the adult the mean width is 35 mm at the base and the mean height is 25 mm.[1] The sinus communicates with the middle meatus through the ostium. The schneiderian membrane, which lines the sinus, is adherent to the underlying bone. This membrane is very thin and is lined by pseudostratified, ciliated epithelium. This ciliated epithelium allows the passage of fluids toward the nasal meatus. The structures beneath the sinus consist of the alveolar ridge and the maxillary posterior teeth. The alveolar bone has an external cortex, an internal cortex in intimate contact with any teeth that are present, and a cortex beneath the sinus. Spongy bone is situated between the cortical plates.[2]

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After tooth extraction, the initial decrease in bone width is due to the resorption of the buccal bone plate. As the edentulous area continues to atrophy, there is a continuing loss of bone height and density and an increase in antral pneumatization.[3,4] It is therefore common to find the sinus floor close to the alveolar crest. This finding is related to 2 phenomena: *1*) the enlargement of the sinus at the expense of the alveolus after tooth extraction because of the increased osteoclastic activity of the periosteum of the schneiderian membrane[5] and *2*) increased pneumatization of the sinus simply because of the increase in positive intra-antral pressure.[6] In addition, the maxilla is made of primarily spongy bone and is composed of the least dense bone in the oral environment. The amount of bone beneath the sinus is often very limited. The treatment of the posterior maxilla depends on the amount of bone present in the subsinus region. Several classifications have been proposed to categorize the amount of bone present below the sinus. A useful classification that assesses the volume of bone in the subsinus area in 3 dimensions has been presented by Davarpanah et al.[2] The subsinus bone loss classification includes 4 categories:

1. Vertical bone loss from within the sinus: This bone loss results from significant pneumatization of the sinus. The residual distance from the floor of the sinus to the crest of the ridge is reduced. However, the interocclusal distance is not altered. Methods to increase the intrasinus volume of bone such as sinus elevation and graft are used in these cases.
2. Vertical bone loss (apicocoronal) of the alveolar ridge: This is loss of the alveolar ridge below the sinus. The interocclusal distance is increased.

This type of loss can compromise placement of implants, restrict the length of the implants being used, and result in an unfavorable crown-implant ratio. The volume of the crestal bone needs to be increased in these cases by use of techniques such as onlay graft and guided bone regeneration (GBR).

3. Horizontal bone loss (buccopalatal) of the alveolar ridge: This is a centripetal type of resorption that could lead to an unsatisfactory emergence profile of the implant. The surgical correction of this situation should restore the buccopalatal volume of bone by use of appositional bone grafts or by GBR.
4. Combination subsinus bone loss: This type of bone loss, both vertical and horizontal, is the most frequent. Saddle-shaped bone grafts are used to correct the bone loss in these situations. If this bone loss is combined with intrasinus loss of bone volume, sinus grafts should also be combined with the previously mentioned surgical technique.

Materials and Methods

Techniques used for management of the posterior maxilla with sinus lift have been reviewed and presented in this article. The techniques are discussed broadly under lateral window and osteotome techniques. The various modifications of these 2 techniques and the success rates reported by the authors are presented.

LATERAL WINDOW TECHNIQUES

Surgical lift of the maxillary sinus floor is currently an accepted technique in implant surgery in the rehabilitation of the posterior area of the edentulous maxilla. It is a relatively simple and predictable surgical technique. Tatum[7] was the first to report penetration of the maxillary sinus with a modified Caldwell-Luc approach, which makes use of an unfinished fenestration osteotomy in the maxilla's external face to raise the sinus membrane, creating an empty hole in the floor of the antral cavity. This area is then filled with different grafting materials. However, one of the most common complications of this technique is perforation of the schneiderian membrane while separating it or when making the osseous window for reaching the sinus.[8,9]

To avoid the complications of perforation, Torella et al[10] have proposed using an ultrasonic ostectomy to obtain access to the sinus. The method is similar to the original technique proposed by Tatum.[7] The operative technique involves elevation of a full-thickness flap, and access to the cavity is provided by ultrasonic ostectomy with the tip of the generator placed perpendicular to the osseous level and with abundant sterile irrigation. A complete ostectomy along the perimeter of the osseous window is initiated and deepened until tactile sensation of the schneiderian membrane, which is resected by the ultrasonic tip, is obtained. Once the fenestration is completed, the osseous window is dislocated with an instrument. The schneiderian membrane in the sinus floor is separated until the membrane, together with the osseous window, is raised, and in this way empty space is obtained to place an implant. This space is then filled with a bone graft. The authors report the advantages of this technique as follows:

1. Reduced risk of perforating the schneiderian membrane
2. Better view and hygiene of the operative area during ostectomy because of the mechanical cleaning effect of the irrigation liquid under the action of the ultrasound
3. A thinner and more conservative osseous incision

The disadvantages of the ultrasonic ostectomy compared with the rotary ostectomy used in the traditional lateral window are relatively unimportant and outweighed by its advantages.

Vercellotti et al[11] have advocated a piezoelectric bony window osteotomy and piezoelectric sinus membrane elevation (PSME). They performed 21 piezoelectric bony window osteotomy and PSME procedures in 15 patients. The Mectron Piezosurgery System (Mectron Medical Technology, Mectron SPA, Carasco, Italy) was used. The inserts move with a linear vibration of between 60 and 210 μm, providing the handpiece with power exceeding 5 W and a high-powered pump that emits the physiologic solution. After flap elevation, the procedure involves making a bony window with the No. 1 piezoelectric scalpel. Thereafter, the PSME is done using an overturned cone compressor tip. The compressor is inserted into the frame of the window, separating the borders by approximately 2 mm. The second phase of the PSME involves using the elevator tip with which membrane elevation is achieved, beginning first at the apical position, then in the mesial and distal aspects. Once the membrane is elevated on 3 sides, it is possible to separate it from the floor of the sinus, where adhesions are very common, therefore avoiding the risk of perforation. The sinus augmentation was done with autogenous bone graft mixed with autogenous platelet-rich plasma gel. The authors report a success rate of 95% for this technique. Of the 21 cases, 1 resulted in perforation of the membrane. The difference between using normal ultrasonic instruments and the piezoelectric method is that the insufficient power does not allow the use of inserts capable of making a linear cut. The instrument therefore does

not cut bone, and continued attempts to perform the osteotomy cause an excessive increase in temperature that can lead to bone necrosis.

Piezoelectric surgery uses specifically engineered surgical instruments characterized by a surgical power that is 3 times higher than that of normal ultrasonic instruments. This means that there is a higher working level, and therefore osteotomy can be performed even when the bone is highly mineralized. However, ultrasonic instruments have the advantage of not working once they touch soft tissues. Piezosurgical instruments allow the elevation of the sinus membrane, the most difficult part of the sinus lift surgery, especially in the molar-sinus depression. The separation of the endosteum from the flat bone is achieved by the specifically designed inserts working on the internal part of the sinus bone walls and by the hydropneumatic pressure of the physiologic saline solution subjected to piezoelectric cavitation.

A novel approach to the lateral wall method has been proposed by Emtiaz et al.[12] An incision, either a midline or palatal crestal incision, is made along the alveolar ridge, starting from the tuberosity area to the anterior border of the sinus. After the crestal incision, a buccal vertical incision anterior to the planned osteotomy is made to ease tissue release. A mucoperiosteal flap is elevated. Anatomic variations of the sinus, the number of implants to be placed, and the length of the implants determine the location of the osteotomy. A measurement is taken from the most coronal aspect of the crestal bone to a superior position at least 2 to 4 mm higher than the planned implant position/height. By use of a trephine on a straight implant handpiece (at approximately 1,800 rpm), with copious irrigation to avoid overheating the bone, a round bone cut is made 4 to 5 mm above the crest of the alveolar ridge. The trephine is positioned perpendicular to the lateral wall. The outer bony cortex is removed gently to avoid tearing the membrane. The bony segment is placed in saline solution and is used for eventual repositioning over the graft. The exposed membrane is then lifted from the sinus floor. Additional graft material is placed until the lateral wall of the maxilla is reconstituted. The round bony window is then repositioned exactly over the osteotomy. The mucoperiosteal flap is repositioned and sutured. The authors have used this technique successfully since 1991. The advantages of this technique are as follows:

1. The time required to prepare the lateral window is decreased.
2. A more precise osteotomy can be performed.
3. Depending on the size and anatomy of the sinus, smaller or larger preparation with the various sizes of trephines available can be made.
4. There is no need for a barrier membrane because the bony segment acts as a barrier.

The disadvantages of the technique are as follows:

1. A limitation in approach in some patients is caused by angulation of the trephine.
2. The approach is technique sensitive, but the authors believe that all existing approaches for sinus elevation are also technique sensitive.

The antral membrane balloon elevation technique has been proposed by Soltan and Smiler.[13] In this technique a mucoperiosteal flap is elevated at the site, and an osteotomy of the buccal bone is performed by copious irrigation. The resulting bony fenestration is pressed inward, carrying the underlying membrane along with it. The dissection of the membrane for the sinus wall should be carried up to the medial wall. At this point, a balloon made out of latex is used. It should be inflated with 3 to 4 mL of sterile saline solution to check for leaks. The balloon is then emptied and placed against the sinus floor midway between the lateral and medial walls. The balloon is gently inflated with 2 to 4 mL of sterile saline solution, and as it expands, the membrane is elevated. After the required amount of elevation of the membrane, the balloon is deflated and removed. A resorbable collagen membrane soaked in platelet-rich plasma is placed under the elevated sinus membrane, and the space created by the balloon is grafted with a bone graft material. Loose compaction of the material is carried out until the lateral wall of the sinus is rebuilt. A second GBR membrane is trimmed, moistened with platelet-rich plasma or aqueous antibiotic, and placed over the lateral wall window. The mucoperiosteal flap is repositioned and sutured. The advantages offered by this technique are as follows:

1. The technique is said to offer optimal assurance that the fragile epithelium will be subjected to minimal trauma.
2. Postoperative pain, bleeding, and possibilities of infection are reduced.
3. The technique is said to be completed within 30 minutes.
4. It is beneficial especially in difficult-to-access areas when adjacent teeth are present.

The disadvantages are as follows:

1. The antral membrane balloon elevation technique requires a buccal fenestration and is not as conservative as the crestal approach.

2. If the balloon is inflated too quickly or with more than 4 mL of saline solution, it may burst. This could rupture the antral lining.

OTHER VARIATIONS

Other than the instruments used for performing the osteotomy, 3 other variations have been described. The first is the hinge osteotomy, where a hinge bony rectangle is created in the lateral wall of the maxilla, approximating the malar buttress. This bony rectangle is then pushed inward, along with the schneiderian membrane, to function as a new sinus floor, reinforced with graft material.[8,14] The range of motion of the bone flap is limited in this case because it can be moved inward only until the height of the hinge.

However, in cases of compromised anatomy of the lateral wall of the maxilla, the use of the elevated osteotomy is advocated. In the elevated osteotomy an uninterrupted bone cut replaces the hinge along the superior horizontal aspect of the quadrilateral. In this technique the bone and schneiderian membrane can be elevated higher than the aperture from which they were cut.

In cases of advanced alveolar resorption, the malar buttress may approximate the alveolar crest. In such cases the complete osteotomy technique can be used. A quadrilateral cut is first made; a molt curette is then used to peel the schneiderian membrane carefully from the entire surface of the bone window. Once the bone segment is removed, it is placed in saline solution and safeguarded for subsequent repositioning.

The final variation is the crestal osteotomy, in which a rectangular-shaped osteotomy is prepared on the crest of the alveolar ridge. The detached window is then elevated apically while the sinus membrane is simultaneously reflected. As in the hinge osteotomy technique, the rectangular bony segment will act as the new sinus floor. This technique can only be used when less than 2 mm of bone is evident between the floor of the sinus and crest of the residual ridge.[12]

CRESTAL APPROACH TECHNIQUES

Summers[15] in 1994 developed a surgical technique using osteotomes that is indicated when the subsinus residual bone height is 5 to 6 mm and the bone is of low density. After progressive preparation of the bone, elevation of the floor of the sinus by several millimeters is obtained. In this technique bone is compacted laterally and apically around the implant site by use of osteotomes of progressively increasing diameter. A success rate of 96% over a period of up to 5 years was reported by Summers for 143 implants placed in 46 patients. However, the type of implant and the criteria for success were not described.

Horowitz[16] has reported a 97% success rate in a study in which 34 implants were placed in 18 patients using the osteotome technique. However, this study was a short-term study ranging from 2 to 15 months, with a mean of 5 months. In addition, the number of implants placed was small.

Coatoam and Krieger[17] have reported a success rate of 92% for 89 implants that were followed up for 6 to 42 months. The method uses osteotomes to lift the sinus floor and is referred to as the indirect sinus graft. They also used demineralized lyophilized bone with or without autogenous bone. Implants were placed simultaneously with the sinus grafting procedure during the same surgical visit.

Zitzmann and Scharer[18] reported the results of 3 different methods of subsinus grafting and implant placement: 2-stage appositional, 1-stage appositional, and osteotome technique. The volume of residual subsinus bone is the determining factor for the choice of technique. They placed 59 implants in 20 patients using the osteotome technique. A success rate of 95% (3 failures) was reported after a mean follow-up of 16.5 months (range, 6-24 months). A radiographic gain of 3.5 mm was obtained with the osteotome technique. The authors consider this technique to be contraindicated in cases where there is bone height of less than 6 mm.

Komarnyckyj and London[19] reported a 95.3% success rate for 43 implants placed in 16 patients with a follow-up of 9 to 47 months. A mean bone gain of 3.25 mm was noted after autogenous bone grafting.

Bruschi et al[20] described a technique where osteotomes were used to elevate the sinus floor. However, bone grafting biomaterials were not used to graft the sinus floor. Five to 7 mm of subsinus bone should be available for this technique. In this study 499 implants—317 IMZ (IMZ Implant System, San Bruno, CA) and 182 Frialit-2 (Dentsply Inc, Mannheim, Germany)—were placed in 303 patients. The success rate 2 to 5 years after exposure was 97.5%.

The modified osteotome technique was proposed by Davarpanah et al[2] in 1996. This technique is indicated when the height of subsinus bone is greater than 5 mm. Once the site is drilled up to 1 mm below the sinus floor, a resorbable graft material is introduced into the surgical site before using the osteotomes. The material serves as a shock absorber to gently fracture the sinus floor. The advantages of this technique have been reported as follows: it is more conservative, it enables placement of implants measuring 10 mm or longer, implants can be placed at the same surgical visit, and the operative time is reduced compared with other sinus graft procedures.

Sotirakis and Gonshor[21] proposed an elevation of the maxillary sinus floor with hydraulic pressure. This technique is similar to the technique of Summers[16] in

that it uses osteotomes in a specific sequence to both deepen and widen the osteotomy site and in-fracture the sinus floor. Elevation of the sinus floor is achieved by injecting normal saline solution under hydraulic pressure beneath the schneiderian membrane with a suitably fitted syringe. This procedure achieves simultaneous detachment and elevation of the sinus membrane. The technique was first used on hen's eggs, then on human cadavers, and, finally, on patients. Twenty detachments and elevations were performed on ten cadavers. The membrane ruptured in 2 cases. The authors determined the cause of the rupture to be excessive irrigation pressure with the normal saline solution. The clinical cases were performed after determination of the required hydraulic force for membrane elevation. Eleven clinical cases were performed. The mean preoperative residual ridge height was 4 mm, and the mean postoperative height elevation into the sinus was 6 mm. Elevation with additional bone grafting was performed in 7 cases. Sixteen implants were placed, of which thirteen were in elevated and grafted sinuses. Except for 2 cases, the remaining cases have been loaded for 2- to 30-month periods. The authors have reported no implant loss in any of the clinical cases.

The studies reviewed here all describe different techniques that have been used to elevate the sinus membrane. However, most of the studies reviewed have presented their technique but not the clinical results of the technique. Most of the studies have indicated that the technique used is technique sensitive, which leads us to believe that a learning curve could be associated with increased success rates for any type of sinus lift procedure. A well-structured training program under an experienced mentor would be of great benefit to the novice implant dentist. This article is an attempt to describe the various techniques available to manipulate the sinus membrane to achieve additional space for implant placement in the posterior maxilla. An exhaustive review of techniques and, where applicable, the success rates have been presented. Several of the techniques presented require more long-term studies with a larger study population.

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