

MAXILLARY SINUS AUGMENTATION PROCEDURES: A HIERARCHIAL REVIEW

Bushra K Quazi*, Manohar.Laxmanrao Bhongade., Prasad V Dhadse and Pranav S Patil

Sharad Pawar Dental College and Hospital, Department of Periodontology & Implantology
Sawangi (M), Wardha, Maharashtra – 442005 (INDIA)

ARTICLE INFO

Article History:

Received 19th May, 2017

Received in revised form 12th

June, 2017 Accepted 6th July, 2017

Published online 28th August, 2017

Key words:

Maxillary Sinus Lift, Surgical Procedures,
Grafting Materials, Dental Implants.

ABSTRACT

Maxillary sinus pneumatization secondary to posterior maxillary tooth loss is an extremely common finding. Significant atrophy of the maxilla prevents dental implant placement in this region. Grafting the floor of the maxillary sinus has emerged as the most common surgical modality for correcting this inadequacy. Graft material is introduced into the space created inferior to the sinus membrane. Various grafting materials and techniques might be used in this procedure. The aim of this article is to review the anatomy and essentials of maxillary sinus augmentation, explain its function, describe the augmentation materials, techniques, and complications. Literature is reviewed that discusses treatment results following Caldwell Luc approach sinus augmentation therapy or osteotome sinus augmentation therapy, with and without simultaneous implant placement. A hierarchy of treatment selection for the augmentation of the posterior maxilla, based upon quantity and position of residual alveolar bone crestal to the floor of the sinus, is proposed.

Copyright©2017 Bushra K Quazi et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

The ideal placement and restoration of dental implants are dependent on the presence of adequate bone volume and quality at the edentulous site. The posterior maxilla is a challenging site for dental implant rehabilitation. Bone quantity in the maxillary posterior edentulous area may be insufficient for dental implant placement because of the presence of the maxillary sinus. When teeth are extracted in the posterior maxilla, bone in that area is lost due to inferior expansion of the sinus involving the residual ridge area (Esposito *et al* 2010, Smiler *et al* 1992, Summers 1994, Jensen *et al* 1998)^{1,2,3,4}. This process is known as pneumatization of the maxillary sinus. Moreover, bone density in this area also decreases rapidly and is the least dense area of the maxilla. To obviate these problems, several techniques have been proposed to lift the maxillary sinus and augment with bone graft. The bone volume augmentation is expected to result in primary implant stability, promote osseointegration, prevent overloading, and provide long-term implant success (Jensen *et al* 1998)⁴. These techniques are called sinus lift procedures.

The maxillary posterior quadrant offers special challenges to the successful use of implant prostheses to restore dental function. Dental implant placement in the posterior edentulous maxilla could potentially be compromised by the lack of adequate vertical dimension of alveolar bone. This

occurs due to the proximity of the maxillary sinus to the alveolar crest as a result of sinus pneumatization, as well as resorption of the alveolar ridge owing to tooth extraction, trauma or pathology. Thus, in turn, prevents placement of implants of adequate length (Smiler *et al* 1992, Truhlar *et al* 1997)^{2,5}. Grafting the floor of the maxillary sinus has emerged as the most common surgical modality for correcting this inadequacy. This technique, first published in 1980 by Boyne and James⁶ and subsequently modified by other clinicians, can result in an increase in bone height that allows the placement of implants of conventional length in the grafted sites. To date, two main techniques of sinus floor elevation for dental implant placement are in use: lateral approach and crestal approach followed by implant placement using either two-stage or one-stage protocol. The aim of this article is to review the anatomy and essentials of maxillary sinus augmentation, explain its function, describe the augmentation materials, techniques, and complications.

Anatomy of Maxillary Sinus

The anatomy of the maxillary sinuses was first illustrated and described by Leonardo da Vinci in 1489 and later documented by the English anatomist Nathaniel Highmore in 1651 (Williams *et al* 1980)⁷. The maxillary sinus (or antrum of Highmore) lies within the body of the maxillary bone and is the largest of the paranasal sinuses, as well as the first to develop. They are paired structures that are mirror images of one another and are approximately pyramidal in shape. The sinus begins to form in early childhood (about two to three years of age), and its formation is nearly complete by

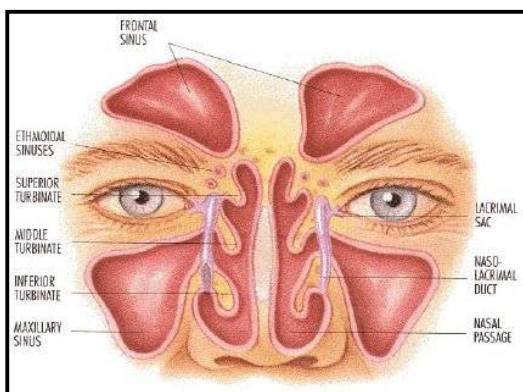
*Corresponding author: Bushra K Quazi

Sharad Pawar Dental College and Hospital, Department of Periodontology & Implantology Sawangi (M), Wardha, Maharashtra – 442005 (INDIA)

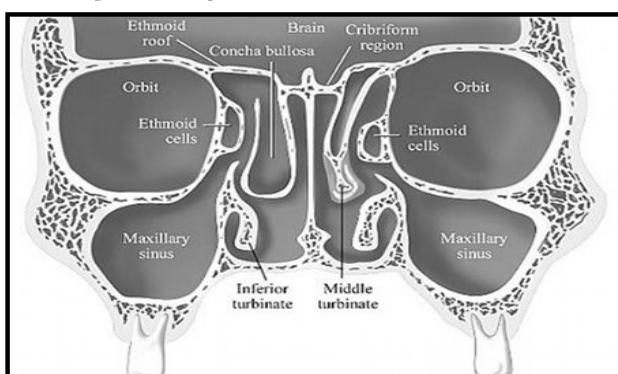
eight years of age. In the adult, the sinus floor is centered over the upper permanent first or second molar and extends to involve the premolar and possibly the canine roots, and posteriorly to involve the second and possibly the third molar roots. Facial size and shape reflect sinus dimensions (Neivert 1930)⁸. In adults, the sinus appears as a pyramid of five thin, bony walls. The base of this pyramid faces the lateral nasal wall and often measures 33 X 33mm; its apex extends approximately 23 mm towards the zygomatic bone (Stammberger 1989, Anon *et al* 1996)^{9,10}. The size of the adult sinus varies from person to person and even between sides in the same individual but is approximately 35 mm in height opposite the first molar, 32 mm anteroposteriorly and 25 mm in width (Turner 1902)¹¹. The dentate maxillary sinus has an average volume of 15 ml, although the range is 9.5 to 20 mL (Kaufman 2003)¹². The floor of the maxillary sinus cavity is reinforced by bony or membranous septa joining obliquely or transversely from the medial and /or lateral walls with buttress like webs. These elements are present from canine to the molar region, and Misch (Misch 1999)¹³ has observed that they tend to disappear in the maxilla of the long term edentulous patients, when the stresses to the bone are reduced.

Although the adult maxillary sinus maintains its overall size, while the teeth are present, in the edentulous maxilla, the antrum expands in both inferior and lateral dimensions and may even invade the canine eminence region and proceed to the lateral piriform rim of the nose. In an older edentulous maxilla, alveolar process resorption with continued sinus pneumatization may leave only a very thin layer of cortical bone separating the sinus mucosa from the oral mucosa. Six bony walls that contain many structures of concern during sinus graft surgery surround the maxillary sinus. Knowledge of these structures is crucial for both preoperative assessment & postsurgical complications

Maxillary Sinus Anatomy



Location of Maxillary Sinus



Clinical and Radiographic Evaluation of Maxillary Sinus

Clinical Evaluation

Before undertaking sinus lift and grafting procedures, a thorough medical history must be obtained as certain diseases and conditions may influence the outcome. Smokers are known to have higher incidence of postoperative problems and graft failure than non smokers (Bergstrom *et al* 1991)¹⁴. Diabetes, heart disease, thyroid disease and immunosuppression may greatly influence the patient's response to surgery, as well as the ultimate outcome including graft viability, but these conditions are not necessarily absolute contraindications to sinus-lift surgery. However, in these cases, working closely with the patient's physician to maximize his or her medical status is crucial for a good result. Complete sinus evaluation by an otolaryngologist, including nasal endoscopy, is recommended for all patients with a history of sinus disease. It may also be useful to fully evaluate patients with asthma, acid reflux and severe allergies, as these conditions are often associated with chronic sinusitis and may predispose these patients to infection and possible graft failure.

A physical examination of the maxillary sinus should include evaluation of the middle third of the face for the presence of asymmetry, deformity, swelling, erythema, ecchymosis, hematoma, or facial tenderness. Nasal congestion or obstruction, prevalent nasal discharge, epistaxis (bleeding from nose), anosmia (the loss of the sense of smell), and halitosis should be noted.

A good understanding of the prospective patient's sinus health status should also be developed. The symptoms of acute sinusitis include severe facial pain and tenderness, while the symptoms of chronic sinusitis include facial pressure, chronic nasal congestion, diminished sense of taste and smell, coughing, maxillary dental pain, discolored nasal discharge, and a history of frequent prolonged cold that may require antibiotics to clear. The clinical examination of maxillary sinusitis concerns the regions surrounding the maxillary antrum. The examination is conducted to assess each wall surrounding the maxillary sinus separately. The infraorbital foramen on the facial wall of the antrum is palpated through the soft tissue of the cheeks or intraorally to determine whether tenderness or discomfort is present. The intraoral examination should include assessment of the floor of the antrum for presence of alveolar ulceration, expansion, tenderness, paresthesia, and oroantral fistulae. The eyes are examined to evaluate the superior wall of the sinus for proptosis, papillary level, lack of eye movement, and diplopia. The nasal fluids may be used to evaluate the medial wall of the sinus by asking the patient to blow the nose in a waxed paper. The mucus should be clear and thin in nature. A yellow or greenish tint or thickened discharge indicates infection.

Radiographic Evaluation

The maxillary sinus is often pneumatized in partial or complete edentulous patients and requires grafting. Therefore visualization of the maxillary sinus and surrounding structures are crucial for the proper diagnosis and treatment. Numerous preoperative radiographic modalities are available to evaluate maxillary sinus and posterior maxilla.

Maxillary sinus augmentation

Procedures

The placement of dental implants requires a sufficient quality and quantity of alveolar bone to support implantation. Osseointegration of dental implants is highly predictable, when implants are completely embedded in bone (Branemark *et al* 1977)¹⁵. The edentulous posterior maxilla generally provides insufficient bone height because of atrophy of the alveolar ridge and extension of the maxillary sinus (Boyne and James 1980, Garg 1999 and Woo and le 2004)^{6,16,17}. Several treatment options have been used in the posterior maxilla to overcome the problem of inadequate bone quantity. The most conservative treatment option would be to place short implants to avoid entering the sinus cavity. Another way of avoiding grafting the maxillary sinus would be to place tilted implants in a position mesial or distal to the sinus cavity if these areas have adequate bone. Furthermore, extra-long zygomatic implants can be placed in the lateral part of the zygomatic bone. Out of all these techniques, grafting the floor of the maxillary sinus has emerged as the most common surgical modality for correcting this inadequacy. The procedure has been referred to in literature as maxillary sinus augmentation, maxillary sinus lift, subantral augmentation or maxillary sinus floor elevation. To date, two main techniques of sinus floor elevation for dental implant placement are in use: lateral approach and crestal approach followed by implant placement using either two-stage or one-stage protocol.

Maxillary Sinus Elevation Using Lateral Approach

The main indication for maxillary sinus floor elevation utilizing a lateral approach is reduced bone height due to alveolar bone resorption and pneumatization of the sinus cavity with or without horizontal bone augmentation. Contraindications for sinus floor elevation using lateral approach can be divided into three groups: intraoral contraindications, medical conditions, and local contraindications. The *medical* contraindications include: chemotherapy or radiotherapy of the head and neck area at the time of sinus floor elevation or in the preceding 6 months depending on the field of radiation; immunocompromised patients; medical conditions affecting bone metabolism; uncontrolled diabetes; drug or alcohol abuse; patient non-compliance; and psychiatric conditions. Whether or not smoking is an absolute contraindication for maxillary sinus floor elevation remains controversial.

Local contraindication include alteration of the nasal-maxillary complex that interferes with normal ventilation as well as the mucociliary clearance of the maxillary sinus, may be a contraindication for sinus floor elevation.

Surgical Procedure

The original Caldwell-Luc technique, commonly referred to as the lateral window or lateral approach, describes an osteotomy preparation in a superior position just anterior to the zygomatic buttress. Two other positions have also been described: a mid-maxillary position between the alveolar crest and zygomatic buttress area, and a low anterior position near the level of the existing alveolar ridge (Lazzara 1996; Zitzmann and Schärer 1998)^{18,19}.

Preoperative preparation

Premedications

Compared with routine dental implant surgery, sinus augmentation has greater chance of morbidity because of the possible additional routes of infection. Bacterial invasion may originate from different sources: 1) transoral surgery, 2) bone graft material, and 3) bacteria from the sinus cavity. Additionally, it has been documented that the inclusion of foreign bodies (eg. implants, alloplasts, allografts) increases infection rates (Peterson 1990, Olson *et al* 1984)^{20,21}. Because a greater chance of infection and morbidity exists with this type of surgical procedure, a strict antibiotic protocol is of benefit. Antibiotic medications have been shown to significantly reduce the number of sinus graft or implant failures caused by infection (Dent *et al* 1997)²².

Procedure

Anesthesia

A local anesthesia with a vasoconstrictor for haemostasis is infiltrated into the maxillary surgical site and any intraoral graft donor site. The surgery can also be performed with local anesthesia, posteriosuperior alveolar, and greater palatine nerve blocks combined with infiltration. A second-division nerve block, entered from the greater palatine canal, can also be used. Local anesthesia is delivered buccal and palatal to the surgical area.

Incision and Flap Reflection

The initial horizontal incision is made either midcrestal or slightly palatal to the edentulous ridge, with mesial and distal extensions 8-10 mm beyond the planned extension of the osteotomy and with consideration of the amount of attached gingiva on the alveolar crest. The incision is carried on forward beyond the anterior border of the maxillary sinus. Buccal vertical releasing incisions are made anteriorly extending into the buccal vestibulum at the mesial and distal extents of the horizontal incision to facilitate reflection of a full thickness mucoperiosteal flap. A mucoperiosteal flap is raised slightly superior to the anticipated height of the lateral window i.e. at least 8-10mm beyond the area of the planned osteotomy to provide soft tissue closure over a bed of bone with little or no chance of exposure of the underlying bone graft or barrier membrane. The lateral wall of the maxilla is exposed by reflecting the mucoperiosteal flap superiorly to the level of the malar buttress. Elevation of the periosteum adjacent to the implant site should be minimized to preserve the blood supply to the alveolar crest. The periosteum should be reflected superiorly just beyond the height of the superior aspect of the anticipated opening into the maxillary sinus (approximately at the level of the zygoma). The facial full thickness mucoperiosteal flap is reflected to provide complete vision and access to maxillary lateral wall.

Access Window Design

The overall design of the lateral-access window is determined after the review of the CT scan, to assess the thickness of the lateral wall of the antrum, the position of the antral floor from the crest of the ridge, the posterior of the anterior wall in relationship to the teeth (if present), and the presence of septa on the floor and/or walls of the sinus. Also transillumination applied beneath the palatal soft tissues or directly to the bone surface of the ridge will help to identify the demarcation of

the residual alveolar process and the sinus and establishing the location of the inferior bone incision 2 or 3 mm superior to it. The inferior bone incision of the access window on the lateral wall of the maxilla is placed approximately 2 to 5 mm above the level of the antral floor (which is 5 to 10 mm from the crest). If the inferior bone incision is made at or below the level of the antral floor, then infraction of the lateral wall will be very difficult, leading to possible membrane perforation. If the inferior bone incision is made too high (>5mm) above the sinus floor, then a ledge above the sinus floor will result in a blind dissection of the membrane on the floor. The most superior aspect of the lateral access window should be approximately 8 to 10 mm above the inferior bone incision. The anterior vertical line of the access window is made approximately 5mm distal to the anterior vertical wall of the antrum. The distal vertical line on the lateral maxilla is approximately 15mm in the edentulous posterior maxilla from the anterior limit of the window and is usually in the region of the first molar, which is within direct vision of the operator.

When the maxillary antroplasty procedure is first devised, the antral window is typically created in a very sharply delineated rectangular configuration. A round bur or disk is used to cut the anterior, posterior and inferior walls; then a series of holes along the superior aspect of the rectangle are made with a no. 2 round bur to serve as a hinge. However, the sharp angles incorporated in this design, as well as the action of punching the drill through the bone to create the holes, tended to tear the sinus membrane. Another difficulty is fracture of the bone of the window, which is often encountered in the postmenopausal female patient with osteoporosis. As a result, the antral window design continued to be refined. A semicircular approach with a superior hinge still proved unsatisfactory (Kent and Block 1989)²³. Some authors advocated making of a trapezoid-shaped osteotomy with a no.1701 fissure cut bur (Smiler *et al* 1992)²⁴. Consequently, in 1993 an oval or round access window configuration with no hinge was developed. An oval shaped osteotomy is recommended to avoid sharp edges that may tear the schneiderian membrane (Garg 1997)²⁵. An osteotomy is prepared in the lateral aspect of the buccal alveolus in one of two ways:

1. By using handpiece and bur
2. By using peizosurgery

By using handpiece and bur

The outline of the Tatum lateral-access window is made on the bone with a rotary hand piece using no. 6 or no.8 round carbide bur under copious cooled sterile saline. A straight handpiece is employed, at a speed of 25,000-50,000 RPM, depending upon the quality and thickness of the residual buccal alveolar ridge. A carbide bur is only used in presence of denser buccal alveolar bone. The carbide bur can be used to initiate the osteotomy to cut more quickly and then exchanged for a diamond bur of the same size and shape when approaching the schneiderian membrane in order to minimize the risk of perforating the membrane with the bur. A no. 8 or 10 round diamond bur is utilized to outline the complete extent of the osteotomy. The osteotomy is deepened with the no. 10 or 8 round bur in smooth sweeping motions with a paint brush stroke type of touch. Care must be taken not to utilize a swaging or pushing motion with the bur. When joining the apical and crestal borders of the osteotomy with

the mesial and distal borders of the osteotomy, a fluid motion must be employed as the bur comes around the "corner" from one side of the osteotomy to the other. Failure to do so will result in a jagged osteotomy edge and increase the incidence of membrane perforation during osteotomy preparation and subsequent membrane reflection. When the bone has been trimmed down to a thin bony plate, the preparation is continued with a no.4 round diamond bur in a straight hand piece until a bluish hue of the sinus membrane is observed. To ensure that the bone has been penetrated all the way around the oval osteotomy, it should be gently tapped and any movement should be noted.

By using peizosurgery

The initial osteotomy in the lateral wall of the alveolus can be prepared with the help of piezosurgery in place of handpiece and burs. Piezosurgery offers a number of advantages which include: greater control of bone preparation than with burs, with precise and minimal bone cutting, lesser chance of soft tissue damage and membrane perforation (Vercellotti *et al* 2001)²⁶ and a more superior osseous response, including a lesser degree of necrosis and decreased morbidity (Vercellotti *et al* 2005)²⁷.

The access window in the lateral wall of the maxilla can be prepared using the peizosurgery device. An OP3 tip is first utilized to outline the osteotomy window and begin to thin the bone, much as the large diameter diamond bur was previously employed. Once the graying membrane is visible along the complete course of the outlined osteotomy, an OT1 tip is employed to complete the osteotomy window. Its use is analogous to that of the smaller diameter diamond bur. The initial reflection, achieved by applying some pressure to the osteotomy window, is carried out utilizing the EL1 insert. The osteotomy must not damage the lining membrane of the sinus. This can be recognized as a gray line that appears as the bone is gently removed with a diamond bur. It is wise to stop periodically and test the membrane to identify those sites that are soft and require no further osteotomy.

Sinus Membrane Elevation

If the buccal wall is separated, the sinus membrane will be exposed and elevated directly with blunt instruments. Meticulous care should be taken to reflect the membrane superiorly without perforating it. On the other hand, gentle tapping is continued until movement of the bony plate is observed if the "trap-door" technique is used. Then, in combination with the elevation of the sinus membrane in the inferior part of the sinus, the bony plate is rotated inwards and upwards to provide adequate space for grafting material.

A flat ended metal punch and mallet are used to gently infracture the lateral access window from the surrounding bone, while still attached to the sinus membrane. The flat ended punch is first positioned at the center of the window. If light tapping does not cause greenstick fracture of the bone, the flat-ended punch is placed along the periphery of the access window and tapped again. A short bladed soft tissue curette designed with two right-angle bends is introduced along the margin of the window (Sinus Curette No.1). The curved portion is placed against the window, whereas the sharp edge is placed between the sinus membrane and the margin of the inner wall of the antrum for a depth of 2-4mm. The curette is slid along the bone margin 360 degrees around

the access window. This ensures the release of the membrane from the surrounding walls of the sinus without tearing from the sharp bony access margins. A larger curved periosteal or sinus membrane elevator is then introduced through the lateral access window along the inferior border (Sinus Curette No.2). The schneiderian membrane is carefully elevated from the floor inferiorly, anteriorly and posteriorly through the osteotomy sites. The curette should always be maintained on the bony floor to avoid a membrane perforation. After the membrane is disengaged from the osseous walls, it will pulsate with patient respiration. This will not occur when there is membrane perforation and is a good clinical test of membrane continuity.

Grafting of the sinus cavity

Grafting material is placed in the compartment made by the elevation of the sinus membrane. It is important that the graft is in contact with the medial osseous wall. Graft is added until the cavity is loosely filled, reconstituting the buccal wall. The grafting material should not be densely packed, because this reduces the space needed for ingrowth of newly forming bone. In addition, pressurizing the thin sinus membrane may result in a late perforation. After the compartment has been filled with grafting material, the lateral window may be closed by covering it with a resorbable or a non-resorbable barrier membrane. Subsequently, the flap is closed free of tension. In most conditions, there is a need for deep periosteal incisions to achieve tension-free closure.

Implant placement

Depending on the clinical condition and the surgeon's preference, sinus floor elevation simultaneously with the implant installation either delayed or one stage protocol is chosen. The decision to apply the one or the two-stage techniques is based on the amount of residual bone available and the possibility of achieving primary stability for the inserted implants.

The ideal conditions for one stage implant insertion at the time of sinus floor elevation include:

1. Greater than 5 mm bone height
2. Greater than 6 mm bone width
3. D3 bone quality or better
4. No sinus pathology
5. No relative contraindications (smoking, ASA 3 patients with lowered immune response)
6. No or small sinus membrane tear during surgery, completely sealed with collagen
7. No parafunction or removable soft tissue borne prosthesis

The implants should not be inserted at the time of the sinus floor elevation, when the following conditions are exist:

1. Less than 6 mm bone width
2. D4 bone quality
3. Treated sinus pathologic condition within the last few months
4. History of recurrent sinusitis (especially when treated with recurrent antibiotic medications)
5. Relative contraindications (smoking, medically compromised patients)
6. Medium to large tear in the sinus membrane during the graft surgery

7. Parafunction or removable soft tissue borne prosthesis

Two-stage sinus elevation (delayed installation of the implant)

If a two stage surgical procedure is used, adequate graft material is placed in the maxillary sinus to accommodate the length of the implant. After the bone has matured i.e. approximately 4 to 12 months depending on the graft materials used, the graft size, and the patient's systemic health is evaluated to ensure that there is sufficient bone height for implant placement. The implants can then be placed in the mature graft material following the surgical protocol prescribed for that system and allowed to integrate.

One-stage sinus floor elevation with simultaneous implant placement

After the sinus membrane has been elevated, the implant sites are prepared. If rotary instruments are used, the sinus membrane has to be protected using a periosteal elevator. When an implant is to be placed at the time of sinus augmentation therapy, an undersized osteotomy is always prepared. Osteotomes of different diameters may be used to prepare the implant site, and then the membrane can be protected by inserting sterile gauze into the sinus compartment. Whenever possible, the osteotomy site is prepared utilizing osteotomes rather than burs. The approach offers the advantages of both greater control during site preparation, and compacting of bone lateral to the osteotomy site and thus to the inserted implant. Before placing the implant, the grafting material is inserted into the medial part of the sinus compartment. Bone is packed against the anterior and posterior maxillary walls, molding the bone against and over the implant to a height of 10-12mm. After implant placement, the lateral part of the compartment is filled with grafting material. The graft can mature while the implant is integrating. The advantage of the immediate approach is reduced overall healing time between the sinus elevation surgery and the implant uncovering and the elimination of a surgical procedure. However, in the immediate approach, failure of the graft is also likely to result in implant failure.

Postoperative care

In order to minimize post-operative pain and discomfort for the patient, surgical handling should be as atraumatic as possible. Precautions must be taken to avoid perforation of the flap and the sinus membrane. The bone should be kept moist during the surgery, and a tension-free primary flap closure is essential. The pain experienced by patients is mostly limited to the first days after surgery. Swelling and bruising of the area are usually the chief post-operative sequelae. Often, swelling and bruising extend from the inferior border of the orbit to the lower border of the mandible or even to the neck. In order to reduce swelling, it is important to cool the area with cooling pads at least for the first post-operative hours. Occasionally, minor bleeding may arise from the nose. Blowing the nose, sucking liquid through a straw and smoking cigarettes, all of which create negative pressure, should be avoided for at least 2 weeks after surgery. It is important to inform the patients that some irritation in the nasal area may be expected. In the event of the need for sneezing, the nose should not be covered so that air pressure is allowed to escape. After the surgery, patients are placed on

antibiotic therapy. 500 mg Augmentin tid (thrice daily) should be prescribed for 7 to 10 days post-surgically. A nasal decongestant should be prescribed and a nasal spray should be used on an as-needed for nasal congestion. Furthermore, antiseptic rinses with 0.1-0.2% chlorhexidine twice daily are indicated for the first 3 weeks after surgery. Depending on the graft materials and the host osteogenic potential, 3 to 12 months should be allowed for the bone graft and the implants to integrate before the prosthodontic phase begins. During this period, the patient can wear a conventional prosthesis that has been relined with a soft material.

Augmentation of Sinus Using Different Grafting Materials

Since, then numerous articles have been published in this field regarding different grafting materials, modifications of classic technique using lateral approach and comparison between different techniques. Different types of biomaterials have been used by various investigators for sinus lift augmentation procedure using lateral approach, which include autogenous bone, bone allograft, alloplast such as tricalcium phosphate, bovine derived bone minerals, bioactive glass, bioresorbable membranes, combination of membrane and bone graft materials as well as various biomaterials like growth factors, BMP to find out the efficacy of these grafting materials for sinus augmentation using lateral approach.

Maxillary Sinus Elevation Using Crestal Approach

Summers in 1994 introduced elevation of the sinus membrane through a crestal approach using osteotome technique to overcome the limitations of the lateral window approach. In crestal approach, the sinus membrane is lifted through the crestal bone using osteotomes, and implants are inserted directly in the sites prepared with the osteotomes of increasing diameters (Emmerich *et al* 2005)²⁸. If the preoperative bone height is at least 4mm, there is adequate primary stability for an implant to permit simultaneous augmentation and implant placement. If less than 4mm of preoperative bone is present, Summers proposed a two stage osteotome procedure. The first stage procedure elevates the membrane so that at least 4mm of alveolar bone is present after healing (Summers 1995)²⁹. A second osteotome procedure elevates the membrane, as necessary, to insert the selected implant. When compared with the lateral window approach, the crestal approach offers the advantages of a more conservative surgical entry, more localized augmentation of the sinus, less operative time and minimal postoperative discomfort (Emmerich *et al* 2005, Davarpanah *et al* 2001, Zitzmann *et al* 1998)^{28,30,19}. The crestal approach technique has then been modified by Cosci (Cosci and Luccioli 2000)³¹ who introduced a series of atraumatic lifting drills of varying lengths to avoid the perforation of the sinus during drilling of the implant site. Therefore, recently clinical research is focusing on elevation of sinus using crestal approach to facilitate the implant in adequate bone housing.

The bone-added osteotome sinus floor elevation (BAOSFE), today referred to as the *Summers technique*, may be considered to be a more conservative and less invasive approach than the conventional lateral approach of sinus floor elevation. Summers supported a small osteotomy through the crest of the edentulous ridge, at the inferior region of the maxillary sinus. This intrusion osteotomy procedure elevates the sinus membrane, thus creating a "tent". This creates a space for bone graft placement. It should be noted that the

bone grafts are placed blindly into the space below the sinus membrane. Although there is uncertainty of possible perforation of the sinus membrane with this technique, an endoscopic study has shown that the sinus floor can be elevated up to 5 mm without perforating the membrane (Engelke and Deckwer 1997)³². The crestal approach technique of Summer has then been modified by Cosci (Cosci and Luccioli 2000)³¹ who introduced a series of atraumatic lifting drills of varying lengths to avoid the perforation of the sinus during drilling of the implant site.

Surgical Procedure

The transalveolar osteotome technique (crestal approach) has been suggested in case of a flat sinus floor with a residual bone height of at least 5 mm and adequate crestal bone width for implant installation. However, patients with a history of inner ear complications and positional vertigo are not suitable for the osteotome technique. In addition, local contraindications like an oblique sinus floor (>45° inclination) are not suitable for the osteotome technique because the osteotomes first enter the sinus cavity at the lower level of an oblique sinus floor, while still having bone resistance at the higher level. In such situation, there is a high risk of perforating the sinus membrane with the sharp margin of the osteotome.

Prior to the surgical procedure, the patient was advocated to rinse with 0.1% chlorhexidine for a period of 1 minute. After this, local anesthesia was administered into the buccal and palatal regions of the surgical area. A mid-crestal incision with or without releasing incision was made and a full-thickness mucoperiosteal flap was raised. The distance from the crestal floor of the ridge to the floor of the maxillary sinus was measured prior to implant site preparation on the pre-operative radiographs. With a surgical stent or a distance indicator, the implant positions were marked on the alveolar crest with a 2.0 mm small round bur. After confirming the distance to the sinus floor, pilot drills with small diameters (1-1.5 mm smaller than the implant diameter) were used to prepare the implant site to a distance of approximately 1 - 2 mm from the sinus floor.

Summers Osteotome Technique

The implant osteotomy was prepared to the appropriate final diameter, 1 - 2 mm short of the antral floor. The first osteotome used at the implant site was a flat ended small diameter tapered osteotome. With light malleting, the osteotome was pushed towards the compact bone of the sinus floor. By this tapping motion, with 0.5 to 1.0 mm increments, the osteotomy sites was prepared to a vertical distance of up to 2 mm beyond the initial prepared implant site. After reaching the sinus floor, the osteotome was pushed about 1 mm further with the help of a mallet using light force, in order to create a "greenstick" fracture on the compact bone of the sinus floor. A tapered osteotome of small diameter was chosen to minimize the force needed to fracture the compact bone. The second tapered osteotome, with a diameter slightly larger than the first one, was used with the same length as the first osteotome and was used to increase the fracture area of the sinus floor. The third osteotome used was a straight osteotome with a diameter about 1-1.5 mm smaller than the implant to be placed. The last osteotome to be used must have a form and diameter suitable for the implant to be placed. It was important that the last osteotome only entered the

preparation site once. If several attempts were made in sites with soft bone (type III or IV), there was a risk of increasing the diameter of the preparation that might jeopardize achieving good primary stability. On the other hand, if the last osteotome diameter was too small compared to the implant diameter, too much force was used to insert the implant which resulted in more bone trauma and, hence, greater bone resorption, thus delaying the osseointegration process (Abrahamsson *et al.* 2004)³³.

During the entire preparation, it was crucial that precise control of the penetration length was maintained. Before placement of grafting materials, the sinus membrane was tested for any perforations. This was tested with the Valsalva maneuver (nose blowing). The nostrils of the patients were compressed, and the patient was asked to blow against the resistance. If air leaked out of the implant site, the sinus membrane was perforated, and no grafting material was to be placed into the sinus cavity. If the sinus membrane was judged to be intact, the preparation was filled with grafting material. The grafting material was then slowly pushed into the sinus cavity with the same straight third osteotome. This procedure was repeated four to five times until about 0.2–0.3 g of grafting material had been pushed into the sinus cavity below the sinus membrane. Finally, before implant placement, the preparation was again checked for patency, and the Valsalva maneuver was repeated. The implant was then slowly threaded into position so that the membrane was less likely to tear as it was elevated. Ideally, the apical portion of the implant should engage dense bone on the cortical floor, bone over the apex, with an intact sinus membrane. The implant should extend 0–2 mm beyond the sinus floor, with 1mm of compressed bone over the implant apex which results in as much as a 3mm elevation of the sinus mucosa.

Cosci's Osteotome Technique

The crestal approach technique by Summers was modified by Cosci (Cosci and Luccioli 2000)³¹. Cosci advocated the use of a series of atraumatic lifting drills of varying lengths to avoid the perforation of the sinus during drilling of the implant site. In the Cosci technique, when the bone height was 6–7 mm then a trephine drill was used, otherwise the standard 3mm long pilot drill was initially used followed by the 3 mm long intermediate drill and by the atraumatic lifting drill of the actual height of the ridge as measured on the radiograph. Osteotomes were not used. The site was then probed to confirm the integrity of the Schneider membrane and the bone graft was gradually inserted in the osteotomy site to lift the membrane to the desired height and then implants were placed.

Post-surgical care

The post-surgical care after placing implants with the osteotome technique was similar to that after standard implant placement. In addition to the standard oral home care, antiseptic rinsing with 0.1–0.2% chlorhexidine twice daily for the first 3 weeks after surgery was highly recommended. However, if bone substitutes were used, the patients are placed on antibiotic prophylaxis for a period of 1 week.

Several modifications of the Summers technique have been proposed. These include the use of nasal suction technique, piezoelectric ultrasonic osteotome, minimally invasive antral membrane balloon elevation (MIAMBE), rotatory

instruments, hydraulic sinus elevation system and electric mallet for osteotome sinus elevation surgeries. Hence, several clinical studies have been conducted in order to evaluate the efficacy of modification of surgical procedures used for sinus lift via crestal approach.

Complications

A number of intraoperative and postoperative complications have been reported. Complications have been classified as: intraoperative, early postoperative and late postoperative. The most frequent complication- which between 10 percent and 60 percent of patients experience-involves a perforation in the Schneiderian membrane. The literature states that there are many complications, such as sinus-membrane perforation, membrane acute or chronic sinusitis, cyst, mucocele, delayed wound healing, hematoma, and loss and sequestration of bone.

Sinus perforation Factors that can influence the chance of perforation include anatomical variations, the surgeon's level of experience, and previous sinus infection or surgery. Anatomical factors consist of thickness of the lateral maxillary sinus wall, connection between membrane and oral mucosa, narrow and wide sinus maxillary sinus septa, and a longitudinal septum. The presence of the sinus septa can hinder membrane elevation and greatly increase the likelihood of perforation. Previous sinus surgery and absence of alveolar bone are also high risk factors. Therefore, imaging studies such as a CT scan may be required to assist in recognizing possible variations. Dr. Manuel Chanavaz classified complications into several categories, including soft-tissue perforation and sinus infection hemosinus. Dr. Michael Picos described sinus perforations by size: small (5mm–10mm) and large (greater than 10mm). Membrane perforation may cause further complications, such as increased risk of infection due to communication with other sinuses. Graft particles could also migrate into the sinus and induce polyps or other sinus diseases. The clinical significance of perforation is controversial. The success of grafting is dependent primarily on the neovascularization of the graft mass, which is reported to derive mainly from the sinus floor. Consequently, it is assumed that the regenerative result of the bone grafting is inferior following membrane perforations. It is recommended by some that simultaneous implant placement not be carried out following severe perforations. However, some researchers propose that membrane perforation played an insignificant role in bone-graft complications. While some studies recommend abandoning the procedure in case of a perforation, many studies suggest that a wide perforation is not an absolute indication for abandoning unless the membrane is largely destroyed. One such study has reported that perforations can occur with any technique, but are more likely to occur when the membrane is raised past the 10mm mark from the alveolar crest.³⁴⁻³⁵

CONCLUSION

A clinically based hierarchical review has been presented which allows the clinician to choose the appropriate modality for augmentation of the posterior maxilla based upon measurable preoperative clinical parameters.

References

1. Esposito *et al* 2010, Esposito M, Piattelli M, Pistilli R, Pellegrino G, Felice P. Sinus lift with guided bone regeneration or anorganic bovine bone: 1-year post-loading results of a pilot randomised clinical trial. *Eur J Oral Implantol* 2010; 3(4):297-305.
2. Smiler *et al* 1992, Smiler DG, Johnson PW, Lozada JL, Misch C, Rosenlicht JL, Tatum OH, Wagner JR. Sinus lift grafts and endosseous implants: Treatment of the atrophic posterior maxilla. *Dent Clin North Am* 1992;36(1); 151-186.
3. Summers RB. A new concept in maxillary implant surgery: the osteotome technique. *Compend Contin Educ Dent* 1994; 15:152-162.
4. Jensen *et al* 1998 Jensen OT, Shulman LB, Block MS, Iacono VJ. Report of the sinus consensus conference of 1996. *Int J Oral Maxillofac Implants* 1998; 13 (suppl):11-45.
5. Truhlar RS, Farish SE, Scheitler LE, Morris HF, Ochi S. Bone quality and implant design-related outcomes through stage II surgical uncovering of Spectra-System root form implants. *J Oral Maxillofac Surg.* 1997; 55(12 Suppl 5):46-54.
6. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autologous marrow and bone. *J Oral Surg* 1980; 38:613-616.
7. Williams PI, Warwick R. WB Saunders.Gray's anatomy, 36. Philadelphia, 1980.
8. Neivert H. Surgical anatomy of the maxillary sinus. *Laryngoscope* 1930;40:1-4
9. Stammberger H. History of rhinology: anatomy of the paranasal sinuses, *Rhinology* 1989; 27:197-210.
10. Anon JB, Rontal M, Zinreich SJ. Anatomy of the paranasal sinuses, New York, 1996.
11. Turner AL. Some points in the anatomy of the antrum of Highmore. *Dental Record* 1902; 22:255-260.
12. Kaufman E. Maxillary sinus elevation surgery: an overview. *J Esthet Restor Dent* 2003; 15:272-282.
13. Misch CE. Treatment planning for the edentulous posterior maxilla. In Misch CE: Contemporary implant dentistry, ed 2, St Louis, 1999, Mosby.
14. Bergström J, Eliasson S, Preber H. Cigarette smoking and periodontal bone loss. *J Periodontol.* 1991; 62(4):242-6.
15. Brånemark PI, Hansson BO, Adell R, Breine U, Lindström J, Hallén O, Ohman A. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand J Plast Reconstr Surg Suppl* 1977; 16:1-132.
16. Garg AK. Augmentation grafting of the maxillary sinus for placement of dental implants: anatomy, physiology, and procedures. *Implant Dent* 1999; 8: 36-46.
17. Woo I, Le BT. Maxillary sinus floor elevation: review of anatomy and two techniques. *Clin Oral Implants Res* 2004; 15: 158-166.
18. Lazzara RJ. The sinus elevation procedure in endosseous implant therapy. *Curr Opin Periodontol.* 1996; 3:178-83.
19. Zitzmann NU, Schärer P. Sinus elevation procedures in the resorbed posterior maxilla. Comparison of the crestal and lateral approaches. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998; 85(1):8-17.
20. Peterson LJ. Antibiotic prophylaxis against wound infections in oral and maxillofacial surgery. *J Oral Maxillofac Surg* 1990; 48:617-620.
21. Olson M, O'Connor M, Schwartz ML. Surgical wounds infection: a 5 year prospective study of 10,193 wounds at the Minneapolis VA Medical Center, *Ann Surg* 1984; 199:253.
22. Dent CD, Olson JW, Farish SE *et al.* The influence of preoperative antibiotics on the success of endosseous implants up to and including stage II surgery: a study of 2641 implants, *J Oral Maxillofac Surg* 1997; 55(Suppl 115):19-24.
23. Kent JN, Block MS. Simultaneous maxillary sinus floor bone grafting and placement of hydroxyapatite coated implants. *J Oral Maxillofac Surg* 1989; 47(3):238-242.
24. Smiler DG, Johnson PW, Lozada JL, Misch C, Rosenlicht JL, Tatum OH, Wagner JR. Sinus lift grafts and endosseous implants: Treatment of the atrophic posterior maxilla. *Dent Clin North Am* 1992:36(1); 151-186.
25. Garg AK, Quinones CR. Augmentation of the maxillary sinus: A surgical technique. *Pract Periodontics Aesthet Dent* 1997; 9:211-219.
26. Vercellotti T, De Paoli S, Nevins M. The piezoelectric bony window osteotomy and sinus membrane elevation: introduction of a new technique for simplification of the sinus augmentation procedure. *Int J Periodontics Restorative Dent* 2001 Dec; 21(6):561-7.
27. Vercellotti T, Nevins ML, Kim DM, Nevins M, Wada K, Schenk RK, Fiorellini JP. Osseous response following resective therapy with piezosurgery. *Int J Periodontics Restorative Dent* 2005 Dec; 25(6):543-549.
28. Emmerich D, Att W, Stappert C. Sinus floor elevation using osteotomes: A systematic review and metaanalysis. *J Periodontol* 2005; 76:1237-1251.
29. Summers RB. The osteotome technique: Part 4-Future site development. *Compend Contin Educ Dent Nov* 1995; 16(11):1080-92.
30. Davarpanah M, Martinez H, Tecucianu JF, Hage G, Lazzara R. The modified osteotome technique. *Int J Periodontics Restorative Dent* 2001; 21:599-607.
31. Cosci F, Luccioli M. A new sinus lift technique in conjunction with placement of 265 implants: a 6-year retrospective study. *Implant Dent* 2000; 9:363-368.
32. Engelke, W. & Deckwer, I. Endoscopically controlled sinus floor augmentation. A preliminary report. *Clinical Oral Implants Research* 1997; 8: 527-531.
33. Abrahamsson, I., Berglundh, T., Linder, E., Lang, N.P. & Lindhe, J. Early bone formation adjacent to rough and turned endosseous implant surfaces. An experimental study in the dog. *Clinical Oral Implants Research* 2004;15(4):381-392
34. Kim, Young Kyun. Hwang, Jung-Won. Yun, Pil Young. "Closure of large perforation of sinus membrane using pedicled buccal fat pad graft: A case report." *The International Journal of Oral & Maxillofacial Implants.* 2008 November-December: 23(6):1139-42.
35. Oh, Eric. Kraut, Richard A. "Effects of Sinus Membrane Perforation on Dental Implant Integration: A Retrospective Study on 128 Patients." *Implant Dentistry.* Vol. 20, No. 1, 2011:13-16.