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Review Article

Different techniques of maxillary sinus augmentation

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Abstract

Tooth loss, primarily due to periodontal disease and dental caries, leads to bone resorption in the absence of occlusal force stimuli. In the maxillary posterior region, implant placement is often challenged by anatomical limitations such as reduced bone quality and height, thinning or absence of cortical bone, and the presence of the maxillary sinus—the largest paranasal sinus.

Maxillary sinus augmentation aims to restore sufficient bone volume for implant placement by lifting the Schneiderian membrane and inserting a bone graft. First introduced by Dr. Hilt Tatum in the 1970s and later detailed by Boyne and James in 1980, this procedure has become a reliable solution for posterior maxillary edentulism.

The augmentation process involves elevating a mucoperiosteal flap to expose the sinus wall, creating a lateral window to access the sinus cavity, and gently lifting the Schneiderian membrane to place graft material. This helps increase alveolar bone height to support dental implants.

Various graft materials are used, including autografts, allografts, xenografts, alloplasts, and growth factors. Autogenous grafts are considered the gold standard due to their osteogenic properties, although donor site morbidity has prompted the development of alternative biologic and synthetic grafts.

Clinical evidence supports the sinus lift as a highly effective treatment for enabling implant placement in atrophic posterior maxillae when executed properly.

Keywords: *Maxillary sinus augmentation, Sinus lift, Posterior maxilla, Dental implants, Bone grafting, Schneiderian membrane, Alveolar bone resorption, Autograft, Allograft, Xenograft, Bone regeneration, Atrophic maxilla, Implant placement, Maxillary sinus, Mucoperiosteal flap, Lateral window technique, Sinus floor elevation, Paranasal sinus, Osseointegration.*

INTRODUCTION

Periodontal disease and dental caries are the main reasons for tooth loss. In the area of lost tooth, as a process of repair bone resorption occurs, due to the absence of stimuli generated by occlusal forces, if this situation remains the osteoclastic activity becomes continuous causing decrease in thickness of bone, a decrease in bone height presenting the different patterns of bone loss in maxilla and mandible.[1,2]When patients lost their maxillary posterior teeth, two types of resorptions occur. The first type is, centripetal resorption which is a result of bone remodelling process following the tooth loss. The second type of resorption caused by pneumatization of maxillary sinus towards the alveolar crest.[3]

Both types of resorption results in decreased amount of bone required for placement implant, which necessitate a regenerative procedure called maxillary sinus floor augmentation (also known as sinus floor elevation).[1,3]

The use of implants significantly increased as an option for oral rehabilitation. However, implant placement in maxillary posterior region is often compromised by anatomical considerations which includes poor bone quality, decreased vertical dimension of bone, thinning or missing of cortex and presence of most important anatomic structure called maxillary sinus. Maxillary sinus is the largest one among all of the paranasal sinuses.[4]

The main objective of maxillary sinus augmentation procedure is to create enough bone height and width, by lifting the lower Schneiderian membrane and placing a bone graft, which facilitate the placement of dental implant.[2,4]

Maxillary sinus augmentation was first developed by Dr. Hilt Tatum in the 1970's and later described by Boyne and James in 1980.[2]

Maxillary sinus floor augmentation procedure includes following steps: elevation of flap which exposes the outer wall of sinus, osteotomy (window) was done in lateral wall of bone which give access to the Schneiderian membrane and sinus cavity. Schneiderian membrane elevation was done to create space for the placement of graft material to increase the alveolar bone height.[5]

Various types of graft materials have been used for maxillary sinus augmentation which includes autografts, allografts, xenografts, alloplastic materials and growth factors.[6]

Autogenous bone grafts considered as gold standard because of its osteoinductive, osteogenic and osteoconductive characteristics. However, because of certain disadvantages like donor site morbidity leads the development and usage of different types of bone grafts of biologic or synthetic origin have been increased.[1,6]

Although sinus grafting is considered to be a relatively invasive surgical procedure, the incidence of reported surgical and postsurgical complications is relatively low. In fact, reported perforation rates vary from as low as 7% to as high as 58%.

The literature has indicated the maxillary sinus lift procedure as an excellent treatment option for maxillary posterior edentulism and when performed well with adequate sinus graft placement produce a significant amount of bone which allows the installation of dental implants.

HISTORY

1974 - A sinus-lift procedure was first performed by Dr. Hilt Tatum Jr.[1,4]

1974 - Tatum developed a modified Caldwell–Luc procedure by infracturing the crest of the alveolus.[2]

1975 - The first sinus graft was done by Tatum in February, in Lee County Hospital in Opelika, Alabama. This was followed by the placement and successful restoration of two endosteal implants. [2]

Between 1975 and 1979 - much of the sinus lining elevation was done using inflatable catheters. [5]

After this, suitable instruments had been developed to manage the lining elevation from the different anatomical surfaces encountered in sinuses.

1976 - Tatum first presented the concept at The Alabama Implant Congress in Birmingham, Alabama and presented the evolution of technique during multiple podium presentations each year until 1986 when he published an article describing the procedure. [2]

1977 or 1978 - Dr. Philip Boyne was introduced to the procedure when he was invited, by Tatum, to be "The Discusser" of a presentation on sinus grafting given by Tatum at the annual meeting of The American Academy of Implant Dentistry.

1980 - Boyne and James authored the first publication on the technique when they published case reports of autogenous grafts placed into the sinus and allowed to heal for 6 months, which was followed by the placement of blade implants. This sequence was confirmed by Boyne before the attendees at The Alabama Implant Congress in 1994.[1]

1986 - Tatum modified his own procedure to lift the membrane via a lateral approach.[2]

1986 - The osteotome-mediated transcrestal sinus lift approach was first proposed by Tatum.[2]

1988 – Wood and Moore reposted the hinge osteotomy technique.[7]

1994 – Summers described a modification of this technique using a set of tapered osteotomes with increasing diameters intended to increase the density of the soft bone and create an up-fracture of the maxillary sinus floor.

Summers introduced a less invasive procedure for sinus membrane elevation along with dental implant placement. The 'Summers technique,' often referred to as 'osteotome/crestal sinus membrane elevation,' or OCSME, is recommended for patients with at least 5.0–6.0 mm of adequate residual alveolar bone below the sinus floor.[2]

1996 – Chen gave the hydraulic sinus condensing technique. This technique uses an osteotomy on the lateral aspect of the ridge of the maxilla.[6]

2000 - The crestal approach technique has been also modified by Cosci and Luccioli.

Cosci technique is a one stage crestal SFE approach using a specific sequence of atraumatic drills of varying lengths.[7]

2001 – Piezosurgery in maxillary sinus elevation, a surgical technique invented by Dr. Tomaso Vercellotti, and first published in the United States.[8]

2002 - Fugazzotto presented a technique in which a trephine with a 3.0 mm external diameter is utilized instead of a drill (or an osteotome) as a first step, followed by an osteotome to implode a core of residual alveolar bone before simultaneous implant placement.[2,8]

2004 - Lundgren et al. introduced maxillary sinus membrane elevation using the lateral window technique without a graft material and simultaneous installation of implants.

2005 - The sinus lift balloon was created to reduce the chance of sinus membrane perforation originally described by Soltan and Smiler and they introduced the antral membrane ballon elevation.

2005 - Minimally invasive hydraulic condensation, a new internal crestal approach was introduced by Leon Chen.

2008 - Computer-guided antral wall elevation was first introduced by Manderales and Rosenfeld.

2009 - Pommer and Watzek provided the gel pressure elevation sinus lift technique.[17]

2011 – Lozada er al. described the Dentium Advanced Sinus Kit technique (Dentium).[7]

2012 - Ahn, Park, and Kim described the reamer-mediated trans alveolar sinus floor elevation.[8,9]

2013 - Andreasi et al. introduce a new method with the advancement of hydraulic pressure exercised on a semisolid graft material to detach the sinus membrane and simultaneously fill the augmented space created this way.[10]

2013 - Indirect sinus elevation with Osseo densification is a technique introduced by Huwais.[19]

2014 - Another novel technique as documented by Kher et al. evaluated a simplified minimally invasive trans alveolar sinus elevation technique utilizing calcium phosphosilicate (CPS) putty for hydraulic sinus membrane elevation. [6,9]

2014 - Pozzi and Moy described a new procedure for sinus elevation using computer-guided planning and a guided surgical approach through the use of CAD/CAM-generated surgical template in combination with expander-condensing osteotomes, thus ensuring a minimally invasive surgical technique.[10,16]

SINUS AUGMENTATION

Maxillary sinus floor augmentation (also termed sinus lift, sinus graft, sinus augmentation or sinus procedure) is a surgical procedure which aims to increase the amount of bone in the posterior maxilla (upper jaw bone), in the area of the premolar and molar teeth, by lifting the lower Schneiderian membrane (sinus membrane) and placing a bone graft. [2,7]

Insufficient bone volume is a common problem encountered in the rehabilitation of the edentulous posterior maxillae with implant-supported prostheses. Bone volume is limited by the presence of the maxillary sinus together with loss of alveolar bone height. Sinus lift procedures increase bone volume by augmenting the sinus cavity with autogenous bone or commercially available biomaterials, or both.[1,6]

There are many techniques that are available for sinus lifting. Basically, they can be divided into two broad categories as
1. The direct method: with lateral antrostomy as a one or two-step procedure
   a. The one-stage technique inserts dental implants simultaneously with the sinus augmentation procedure.
   b. The two-stage technique, bone augmentation is performed during the initial surgical procedure, and the dental implants are placed later once the necessary bone volume has been established

2. The indirect method: With the osteotome technique with a crestal approach. The indirect sinus lift is also called as subantral sinus augmentation, subcrestal augmentation, sinus floor elevation or transcrestal approach.[3]

Indications:

- Inadequate residual bone height (less than 10 mm of bone height).
- Atrophic posterior maxillary alveolus.
- No history of sinus pathosis.[4]
- Oro-antral fistula treatment.
- Reconstruction of palate clefts.
- Interpositional graft with Le Fort I fractures.[5]

Contraindications:

Local Contraindications:[5]

- Maxillary sinus infections and pathological lesions.
- Chronic sinusitis.
- Alveolar scar possibility.
- Odontogenic infections.
- Allergic rhinitis.
- The presence of an irregular alveolar crest.

General Contraindications:[5]

- High doses of radiation in the head and neck region
- Sepsis
- Advanced medical conditions and psychological problem.
- Uncontrolled systemic diseases such as diabetes mellitus.[4]
- Excessive smoking, alcohol or substance consumption

Pre surgical evaluation:

- A comprehensive history and physical examination should be performed before initiating surgical treatment. Pertinent positives in the history such as recent upper respiratory infection, chronic sinus disease, chronic sinus/facial pain, otitis media, history of nasal/sinus surgery, history of prior attempts at maxillary reconstruction, and history of smoking are important to note.[16]
- Preoperative evaluation should have a set of study models, a bite registration, and ideally, a face bow transfer for accurate mounting. This evaluation helps to determine the final tooth position, crown to root(implant) ratio: if >2:1, then sinus augmentation alone is not recommended.[6]
- The occlusion should be preferably canine guided with a minimum interarch distance of 5-7mm.[6]
- Pre surgical CBCT helps in improving accuracy regarding the location, width of the sinus, window access to the sinus cavity. This technique sensitive procedure requires presurgical assessment to know the health status of sinus to reduce any operative complications.[7]

Features other than the height and the width of lingering alveolar edge that can generally be seen in CBCT are:[7]

a) Thickness of the sidelong maxillary sinus divider.
b) Presence of alveolar antral course and its diameter.
c) Maxillary sinus floor width.
d) Abnormality of sinus floor.
e) Any connection of Schneiderian layer with the foundations of the contiguous teeth.
f) Maxillary sinus septum.
g) e) Assessment of the bone/biomaterial volume required for sinus lifting.
h) Assessment of the nature of subantral bone.

CLASSIFICATION FOR TREATMENT APPROACH:[4]

- In 1987, Misch developed a classification for the treatment of edentulous posterior maxilla based on the amount of bone available below the antrum and the ridge width. Treatment categories ranged from subantral augmentation category 1 (SA1) to SA4 based on bone height A (>5 mm) and B (2.5-5 mm) based on ridge width.
- **SA1:** It has an adequate vertical bone for implants, that is, 12 mm. No manipulation of sinus is required.
  SA2: It has 0-2 mm less than the ideal height of bone and may require surgical correction.
  SA3: It has just 5-10 mm of bone height with sufficient width (around 6mm) below the sinus.
  SA4: It has less than 5 mm of crestal bone height and width below sinus.

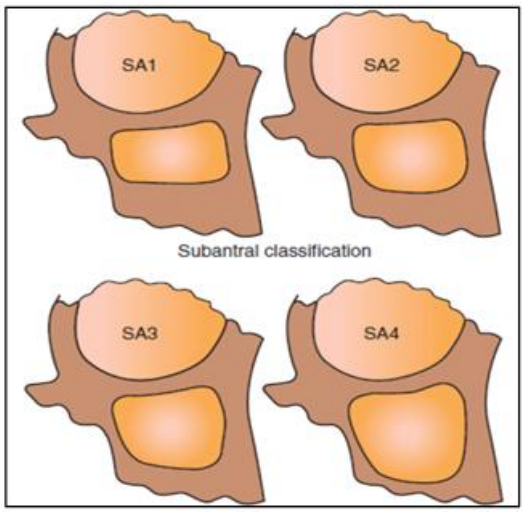


Figure.1 Maxillary Sinus Classified on the Basis of Residual Bone Height[8]

Different Techniques of Sinus Floor Elevation (SFE):[8]

The technique for sinus floor elevation usually depends upon the surgeon's preference and anatomy of the patient such as residual bone height, the thickness of the membrane, and the amount of lift desired. There are two major techniques of augmentation of the sinus floor for dental implant placement:

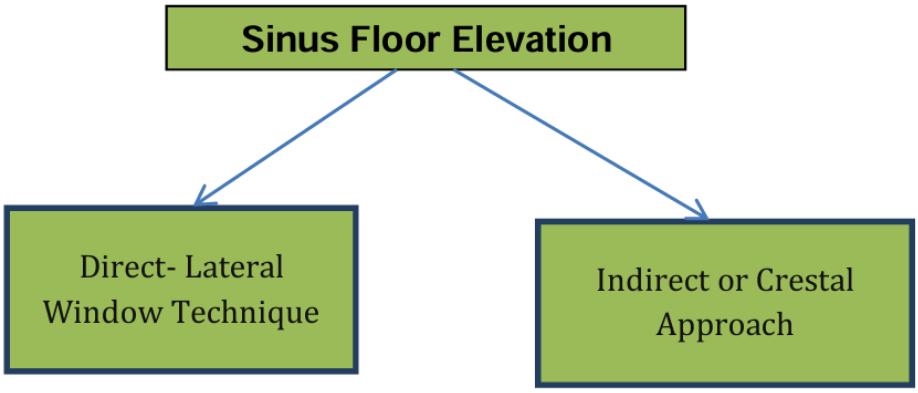


Table 1: Direct versus indirect sinus lift indication criteria.[18]

Sinus lift procedure	Bone dimension
Remaining bone height ≤3 mm	Maxillary sinus floor augmentation with a lateral window approach and delayed standard implant insertion
Remaining bone height of >3 to ≤5 mm	Maxillary sinus floor elevation utilizing a lateral window technique with immediate implant insertion or transalveolar maxillary sinus floor elevation with simultaneous placement of short implants
Remaining vertical bone height of >5 to ≤9 mm	Transalveolar maxillary sinus floor augmentation and simultaneous standard implant placement

Direct sinus lift procedure:

Maxillary sinus floor augmentation using the lateral window technique was originally developed by Tatum in the mid-seventies and afterwards described by Boyne and James in 1980.[2]

A popular augmentation technique that allows for the placement of an implant of the proper length in the posterior region of the maxilla, where bone quality is frequently low, is lateral window sinus elevation. This method uses a window in the maxillary sinus's lateral wall to directly see the sinus membrane.[10]

Steps in the direct/lateral window technique of maxillary sinus floor elevation are as follows: [11]

- **Anaesthesia:** Local anaesthesia with epinephrine (articaine, lidocaine) is usually administrated- posterior superior nerve block, infraorbital nerve block palatal infiltration, or a greater palatine nerve block can be given.
- **Incision:** The initial incision is midcrestal extending well beyond the planned extension of the osteotomy. The incision line should not cross the planned area of the lateral window. In the case of the presence of neighbouring teeth, the incision starts from the mesial area of the anterior tooth and extends until the distal portion of the posterior tooth. Mesial and distal releasing incisions are made avoiding the infraorbital plexus below the infraorbital foramen.
- **Flap Elevation:** A mucoperiosteal full-thickness flap is raised slightly superior to the anticipated height of the lateral window (antral wall). The flap reflection should reach the zygoma buttress to visualize the lateral side of the maxilla. The reflection should be extended beyond the borders of the future osteotomy (window).
- **Window Preparation:** The window outline is prepared in the lateral aspect of the buccal alveolus. The size of the window is determined by the area to be grafted in the lateral aspect of the buccal alveolus. The osteotomy (window) can be oval or rectangular. A high-speed handpiece can be used depending upon the quality and thickness of the buccal wall with copious saline irrigation is utilized to outline the complete extension of the osteotomy (window). Lateral SFE approach today involve numerous antrostomy designs: three different methods are described here for handling the buccal cortical bone plate to introduce the selected bone substitutes.

A. Top-Hinge or Trap Door Techniques.

This technique is similar to the Caldwell-Luc approach creating an infracture of the cortical bony plate like a trapdoor. This is then used as the superior border of the sinus compartment leaving it attached to the underlying Schneiderian membrane.

The first to be done is the inferior horizontal segment of the rectangle, which is made as close as possible to the floor of the sinus and around 2–3 mm above the floor. The superior horizontal segment of the rectangle is performed by drilling closely positioned holes. This creates a trapdoor, which will be fractured inward and displaced medially while hinging on its superior margin (along the superior aspect of the rectangle).[8]

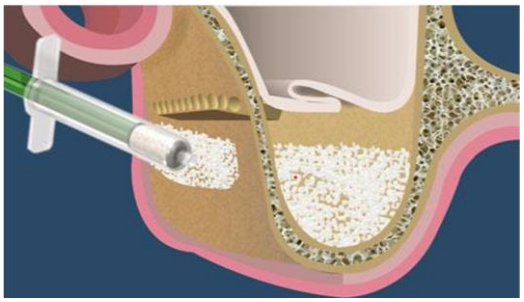


Figure.2 Top-Hinge or Trap Door Technique of SFE[8]

B. Repositioned Bony Window: [12]

In this technique, following the preparation of a rectangular osteotomy using lateral window is gently mobilized.

i) A small periosteal elevator or a Freer elevator is carefully inserted into the osteotomy line and the bony window is easily detached from the underlying sinus membrane and stored in saline.
ii) The sinus membrane is dissected around the margins of the window and extended inferiorly to expose the floor of the sinus in the edentulous area. The bony plate will then be repositioned in place on the lateral aspect of the graft material without rigid fixation.
iii) It not only stabilizes the graft material but also promotes early healing.

C. Complete Osteotomy:

i) The third and most common surgical technique is the preparation of an access hole by removing the entire buccal bone plate (thinning of the buccal bone to a paper-thin bone lamella before the elevation of the sinus membrane).
ii) The preparation is continued until a bluish hue of the sinus membrane is observed. The osteotomy border should be as smooth as possible, avoiding cutting edge to reduce the risk of membrane tearing.

- Lifting the Schneiderian Membrane: Usually, membrane elevation starts at the edges, using a short curette, increasing gradually the amount of membrane elevation from the superior border of the osteotomy, proceeding approximately 2–3 mm mesially, toward the mesio-superior line angle and along the mesial part of the window. Surgical curettes should be permanently in tight contact with the underlying bony walls to minimize membrane tearing. Moreover, the membrane must be elevated higher than the superior osteotomy to prevent excessive pressure on the bone graft material.

- **Introduction of the Grafting Material into the Sinus:** It is possible to place implants immediately if there is a good quality of 3-4 mm of crestal bone available else implant should be placed after 4-6 months of grafting.

  The grafting material should be pushed through the window in all directions: mesially and distally with the help of instruments such as pluggers, periosteal elevators, or even osteotomes. Most importantly, it must reach the medial wall of the maxillary sinus. It should be placed in the cavity loosely, avoiding overpacking. Sinus augmentation with platelet-rich-fibrin as a sole grafting material has also shown promising results with simultaneous implant placement.

- **Barrier Membrane Placement:** The membrane barrier is used to cover the osteotomy site extending 2–3 mm beyond its borders, promoting haemostasis, and preventing graft disruption at the time of suturing. Membrane placed to prevent ingrowth of fibrous tissue[68]. Collagen membrane does not require fixation screw as it adheres to the bone and resorbs by itself.

- **Suturing Technique**: Single interrupted sutures (non-resorbable monofilament 5/0 or 4/0 sutures) are mainly used for the releasing Incisions. Uninterrupted or mattress sutures are used specifically on the top of the ridge in case of delayed or submerged implant placement. Sutures should be removed 10 days to 2 weeks following the SFE procedure.[8]

If primary implant stability is compromised, then the implants are inserted 4 to 12 months after the augmentation procedure. Final prosthetic solution is performed three to six months after implant installation.

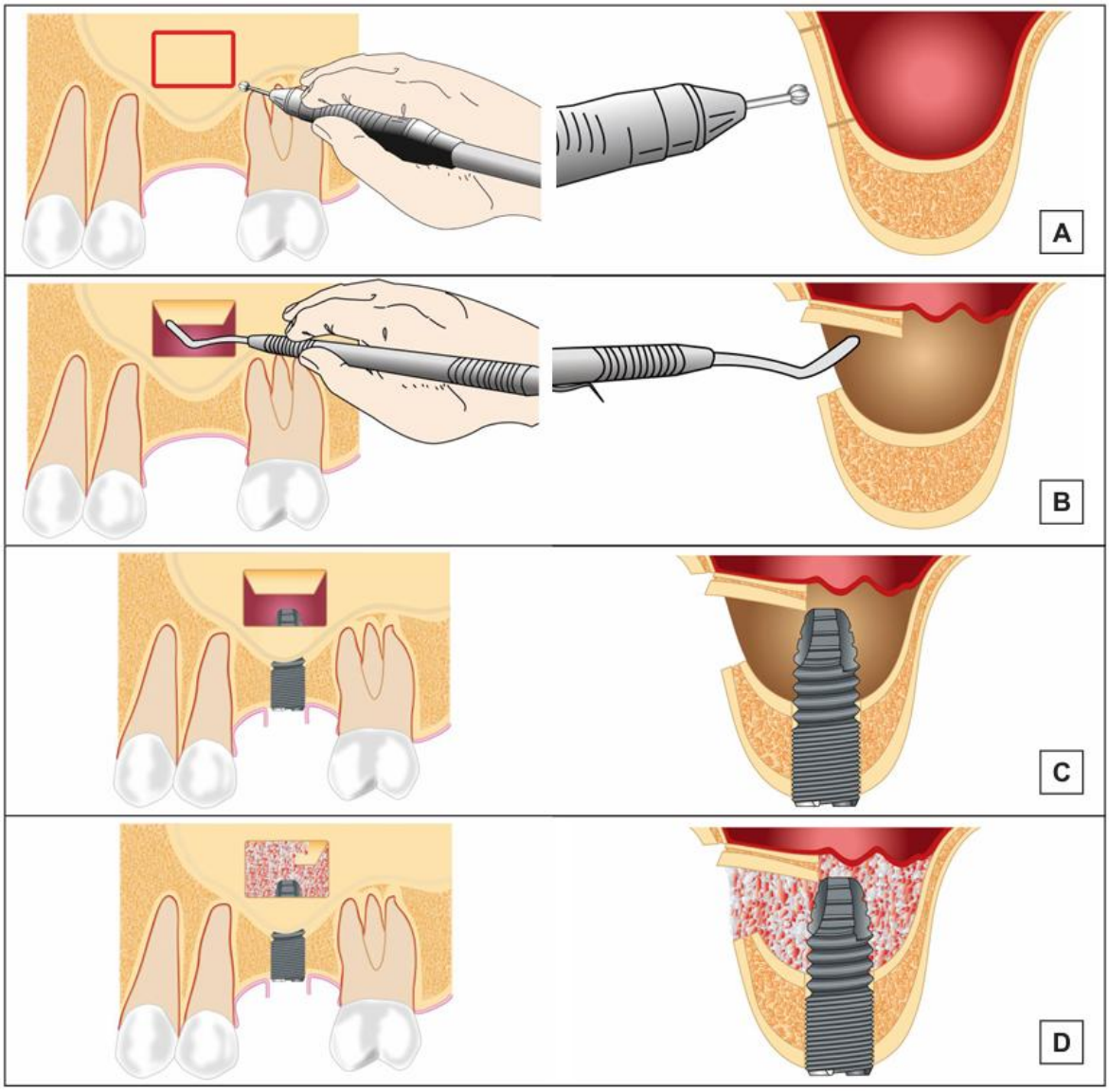


Figure 3: Maxillary sinus floor augmentation applying the lateral window technique with a grafting material. A = a trapdoor osteotomy is performed on the lateral wall of the maxillary sinus. B = the trapdoor is infractured and the Schneiderian membrane is carefully dissected and elevated from the maxillary sinus floor to create a compartment for

placement of the graft material. C = the implant is inserted simultaneously with the augmentation procedure. D = the graft material is densely packed around the exposed implant surface in the created compartment.[9]

Maxillary sinus membrane elevation applying the lateral window technique without a graft material and simultaneous implant installation:

- Maxillary sinus membrane elevation using the lateral window technique without a graft material and simultaneous installation of implants was introduced by Lundgren et al. in 2004.[9]
- This surgical intervention requires sufficient vertical height of the residual alveolar bone in the posterior part of the maxilla to achieve primary implant stability, since immediate implant installation is necessary to preserve and support the elevated Schneiderian membrane, allowing coagulum formation round the exposed implant surface in the sinus cavity.[13]

Surgical technique:

The formation of the lateral window, elevation of the Schneiderian membrane and implant installation is similar to the surgical technique described above for maxillary sinus floor augmentation with a grafting material and simultaneous implant installation, although the implant bed is usually prepared with an undersized drilling protocol and the lateral cortical bony window is often dissected free and removed from the underlying Schneiderian membrane (Figure A). A blood coagulum is formed around the exposed implant tip in the secluded compartment between the elevated Schneiderian membrane and the original floor of the maxillary sinus (Figure B). The lateral window to the maxillary sinus is covered by a resorbable collagen membrane or the dissected lateral cortical bony window. The mucoperiosteum is readapted and sutured (Figure C).[9]

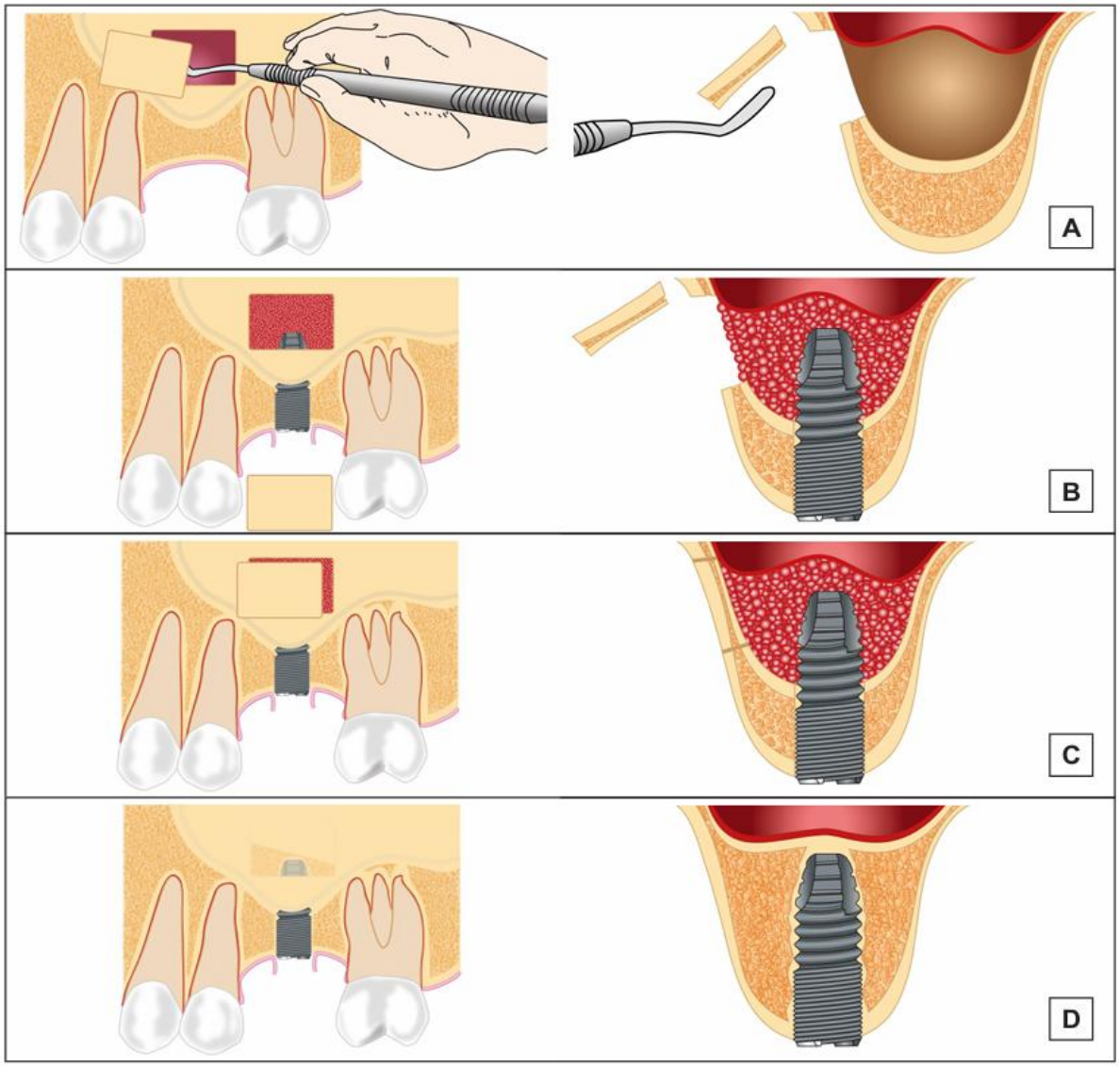


Figure 4: Maxillary sinus membrane elevation applying the lateral window technique without a graft material and simultaneous implant installation. A = the lateral cortical bony window is dissected free and removed from the underlying Schneiderian membrane, which is carefully elevated from the maxillary sinus floor to create a compartment for placement of the graft material. B = a blood coagulum is formed around the exposed implant tip in the secluded compartment between the elevated Schneiderian membrane and the original floor of the maxillary sinus. C = the window to the maxillary sinus is covered by the dissected lateral cortical bony window. D = new bone formation around the implant tip in the previous created compartment.[9]

Indirect sinus lift procedure:

Also called as osteotome technique / crestal approach / transalveolar approach.

The osteotome-mediated transcrestal sinus lift approach was first proposed by Tatum in 1986. In 1994, Summers described a modification of this technique using a set of tapered osteotomes with increasing diameters intended to increase the density of the soft bone and create an up-fracture of the maxillary sinus floor. A special instrument known as "socket former" (for a selected implant size) was used to prepare the implant site leading to a controlled "greenstick fracture" of the sinus floor, moving it in a more apical direction.[8] Root-formed implants were then placed and allowed to heal in a submerged manner. Osteotome-mediated sinus floor elevation is most suitable for installation of a single implant but can be used for multiple implants.

Osteotome-mediated sinus floor elevation with simultaneous installation of implants with or without the use of a grafting material are considered less invasive and time-consuming than maxillary sinus floor augmentation applying the lateral window technique.[9]

Indirect osteotome maxillary sinus floor elevation is generally indicated where the residual bone height is equal to or >6 mm.[10]

Surgical technique:[9]

1. Osteotome-mediated sinus floor elevation and simultaneous installation of implants with or without the use of a graft material is performed under local anaesthesia and sedation.
2. Midcrestal incision where buccal and palatal mucoperiosteal flaps are reflected in a full-thickness approach exposing the crestal part of the alveolar ridge.
3. The implant sites are marked with a 2.0 mm round drill and then prepared with a drill to a depth of 0.5–1.5 mm from the sinus floor (Figure 5A).
4. The Concave tipped tapered osteotomes with increasing diameters are then selected to expand the preparation area both horizontally and vertically. The osteotome itself should never penetrate the maxillary sinus. With each insertion of a larger osteotome, bone is compressed, pushed laterally and apically. A mallet is used, when needed, on the osteotome to expand the bone.
5. The sinus elevation is delayed until the osteotome with the final apical diameter is used at the desired working depth. Once the largest osteotome has expanded the implant site Graft is inserted in the osteotomy site, before the in-fracture of the sinus floor.
6. The sinus floor fracture is obtained with the final osteotome, punching out the cortical plate of the sinus floor with the adherent sinus membrane (Figure 5B). A different pitch of tapping sound can be a sign that a portion of the sinus floor has been fractured upward and inward into the sinus cavity. A bone graft can be added and tapped to achieve the desired amount of sinus membrane elevation. This intrusion procedure produces a fracture in the least traumatic way possible. Furthermore, it allows more implants to be inserted in a greater variety of sites during a routine office procedure.
7. The integrity of the membrane is controlled with Valsalva maneuver, before grafting material may be added to the lifted area underneath the elevated Schneiderian membrane with the original maxillary sinus floor.
8. The implant is inserted in the residual alveolar bone with the implant tip exposed in the lifted area (Figure 5C). Mucoperiosteum is readapted and sutured.

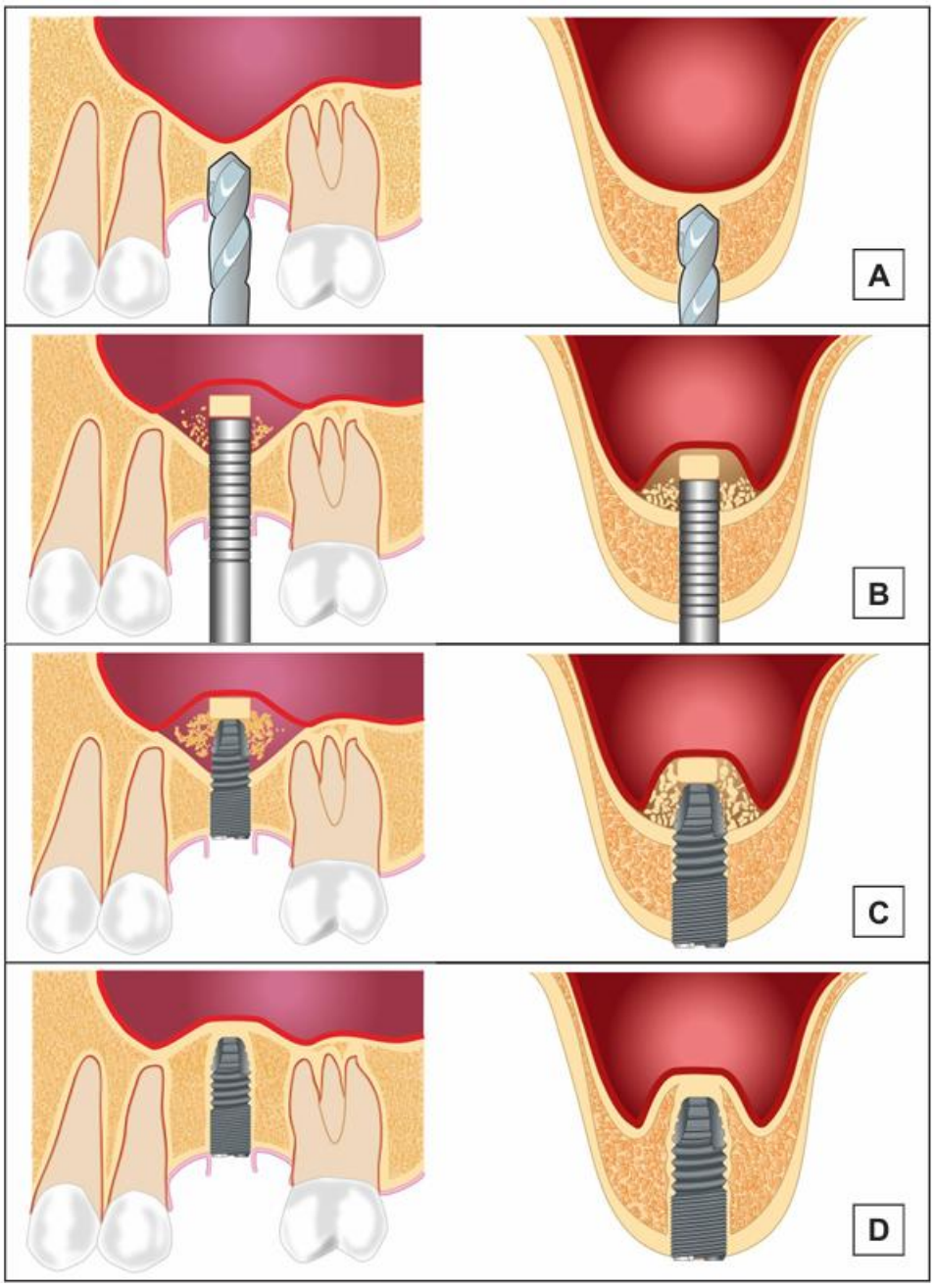


Figure 5: Osteotome-mediated sinus floor elevation and simultaneous installation of implants with or without the use of a graft material. A = the implant bed is prepared with a series of osteotomes with increasing diameter or in combination with burrs to a depth approximately 1-2 mm away from the maxillary sinus floor boundary. B = an up-fracture of the maxillary sinus floor is made with a mallet under light tapping and the Schneiderian membrane with the maxillary sinus floor is carefully elevated with the osteotome or a blunt instrument. C = the implant is inserted in the residual alveolar bone with the implant tip exposed in the lifted area. D = new bone formation around the implant tip in the previous created compartment.[9]

Final prosthetic solution is performed three to six months after osteotome-mediated sinus floor elevation with simultaneously implant installation, when de novo bone is formed around the implant (Figure 5D).[9]

The indirect osteotome technique offers a number of advantages: The surgery is more conservative, sinus augmentation is localized, there is a low rate of postoperative morbidity, a shorter time to implant loading is possible than with the direct technique, and high survival rates of around 90% are obtained.[3]

Modified osteotome technique utilizing drills:[9]

In the presence of dense bone quality, with no need to improve it further, the use of the osteotomes following Summers technique would not be recommended.

In which case safe-ended drills are used till 1 mm of the sinus floor following which grafting material is introduced into the surgical site to partly absorb the shock from osteotomes. This 'modified technique' eliminated unnecessary malleting in the presence of a dense residual bone and therefore proved to be more tolerable to patient.

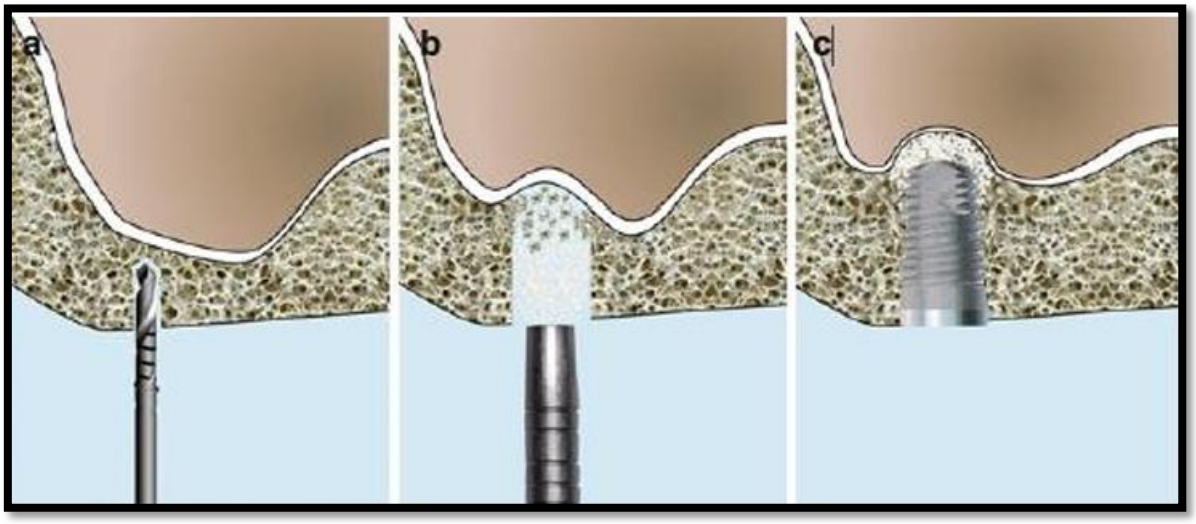


Figure 6: Schematic Drawings Illustrating the Modified Osteotome Technique.[8]

Instruments used for sinus floor elevation:

Sinus Lift Kit (Sinus Lift Instrument, Bone Packer, Sinus Lift Curettes, Bone Graft Instrument)

- Bone Packing Instrument- One end is flattened to separate the Schneiderian membrane from maxillary bone and other end to pack bone graft.
- Sinus Lift Instrument- One end to reflect Schneiderian membrane and other end to separate and elevate the reflected membrane.
- Bone Graft Instrument- One end is flat to elevate membrane and transfer bone graft and other end is spoon shaped to pack graft.
- Sinus Lift Curette- Mirror image ends with spoon shaped tips to reflect membranous lining of sinus cavity. Available in two sizes- Small and Medium.

Figure 7: Instruments used for sinus floor elevation.

Figure 8: Instruments used for direct sinus lift procedure

Figure 9: osteotomes and mallet for osteotome mediated sinus lift procedure

Minimally invasive surgery:

A minimally invasive surgical procedure has been defined in general surgery as a procedure that is carried out with the least damage possible to the patient. The procedure is called "minimally invasive" when there is minimal damage to biological tissues at the point of entrance of the instrument.[9,11]

Today, minimally invasive surgeons continue to determine and redefine how much can be achieved through smaller incisions and with minimal surgical stress. There are some obvious advantages with a less invasive surgical approach for the patient, such as quicker recovery, less postoperative pain, and economic gain due to shorter recuperation.

Various minimally invasive sinus lift devices on the market can be clustered according to the drilling speed.

Low-speed drilling is recommended for:

i) Hatch Reamer (Sinustech America, Calabasas, CA, USA).
ii) Bone Compression Kit (MIS, Tel Aviv, Israel).
iii) Cowellmedi Sinus Lift Kit (Cowellmedi Co., Busan, South Korea).
iv) Sinu-Lift System (Innovative Implant Technology, Aventura, FL, USA).
v) Disc-up Sinus Reamer (Dentimate Co., Seoul, South Korea).
vi) Sinus Master (Mr. Curette Tech., Seongnam, South Korea).

High-speed drilling is to be applied when using:

I. Sinus Crestal Approach (SCA) Kit (NeoBiotech, Seoul, South Korea).
II. Dentium Advanced Sinus Kit (Dentium, Suwon, South Korea).
III. Sinus Lateral Approach (SLA) Kit (NeoBiotech, Seoul, South Korea) [Figures 10 and 11]
IV. Samuel Lee's Internal Sinus Grafting System (MegaGen, Daegu, South Korea).
V. Santa System (Dentis, Daegu, South Korea).

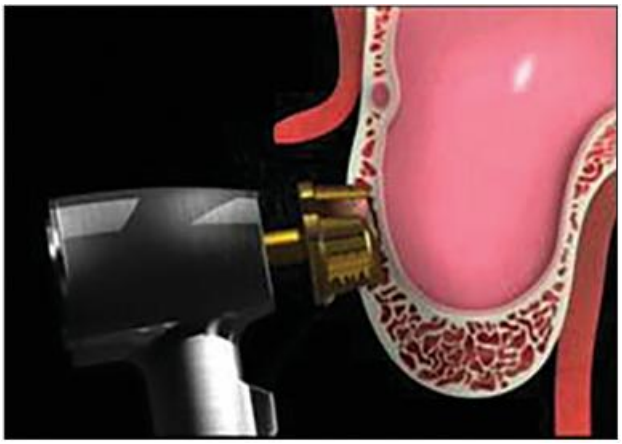


Figure 10: LS reamer for sinus lateral approach (SLA, NeoBiotech, Seoul, South Korea).[4]

Figure 11: LS reamer[4]

Devices that allow for both high- and low-speed drilling are:

i) Dr. Cosci drill (Dentech Co., Tokyo, Japan).
ii) Sinus Lift Drill (SSI, Seongnam, South Korea).[4]

Minimal invasive techniques include:

The antral membrane balloon elevation (AMBE) technique.

The piezoelectric minimally invasive system.

The Hydraulic Sinus Lift Procedure.

The Minimally Invasive Transcrestal (MITSA) Approach.

Advanced Techniques of Lateral Window Technique for Sinus Floor Elevation:

1. Piezoelectric Surgery in Sinus Lift Procedures:

Piezosurgery, a surgical technique invented by Dr. Tomaso Vercellotti, and first published in the United States in 2001, uses low-frequency ultrasonic vibration to create the lateral window and elevate the sinus membrane.[4,7]

Piezosurgery can be particularly useful for the preparation of the bony window (diamond coated square or bell-shaped tips) and in atraumatic dissection of the thin and delicate sinus membrane with specially designed tips (rounded, dull, bell-shaped, or curette-shaped tips).

Troedhan and colleagues have developed the Intralift technique to elevate the sinus floor by using piezoelectric surgery based on a specific set of tips for the application of ultrasound. The high-power ultrasonic instruments allow the osteotomies to be made even, in thicker compact cortical bone.[3]

The piezoelectric surgical sets consist of many different inserts from osteotomies, to diamond-cutting inserts. The inserts were used with a vibration 60 - 210 mm with power exceeding 5W. The advantage of this system is that it does not cut the soft tissues. Therefore, this surgical instrument can be used to elevate the sinus membrane without perforating it.

Figure.12: Piezoelectric Kit Including Various Tips.[8]

The advantages of SFE using piezoelectric techniques are:

i) Reduced membrane perforation rate.
ii) Improved intraoperative visibility.
iii) Reduced intraoperative bleeding.
iv) Reduced surgical trauma.

2. Computer Guided Sinus Floor Elevation:

Computer-guided antral wall elevation was first introduced by Manderales and Rosenfeld in 2008.[9]

- The digitally printed surgical guide is adapted tightly to the maxilla and fixated in place using titanium mini-screws and verified for stability.
- After accurate fixation, a round diamond bur is used to create the outlines of the osteotomy following the contours of the surgical guide. The surgical guide is then removed and the sinus membrane is carefully elevated along the lateral, inferior, and medial walls.
- The surgical stent is reinserted and fixed in its place again and pilot drills are used to initiate implants drilling. The stent is finally removed and drilling of the implants osteotomies is completed.
- No graft material is used to augment the created volume. A collagen membrane (Hypersorb) is used to cover the bony window and wound closure is achieved using 4-0 vicryl sutures.

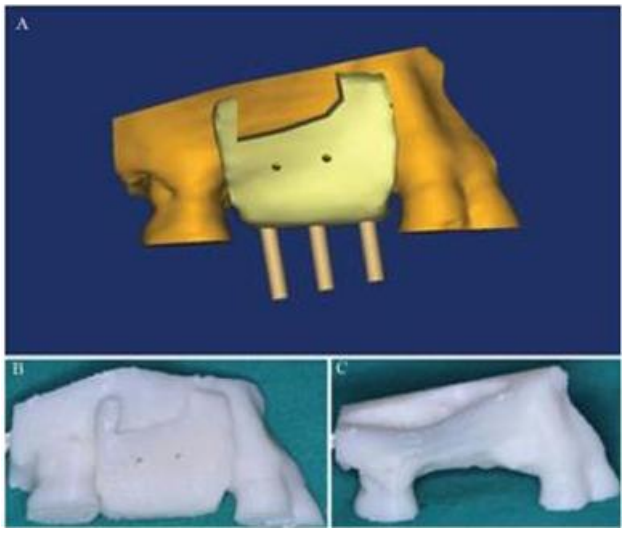
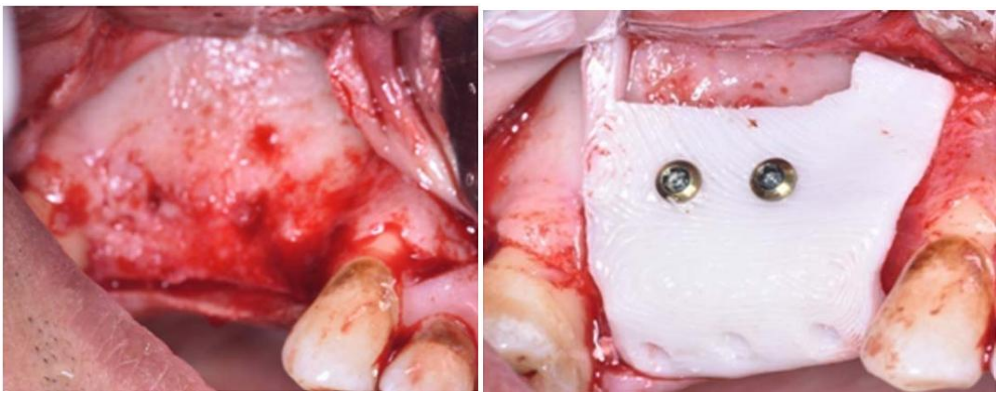


Figure.13: Digitally Printed Surgical Guide[11]

A, 3D reconstruction of the maxilla and virtual planning and designing of the surgical guide. B, Digital printing of the cutting guide and maxilla using FDM. C, Digital printing of the maxilla using FDM



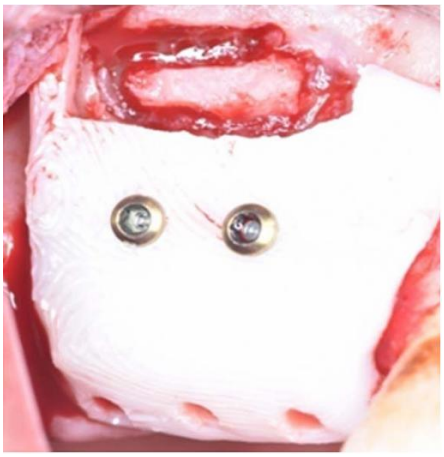


FIGURE 14: Incision and flap elevation.

FIGURE 15: Adaptation and fixation of the surgical guide.

FIGURE 16: Completing the lateral window osteotomy.[11]

Advancements in Crestal Sinus Lift Procedure:

1. Modified Trephine/Osteotome Approach (Simultaneous Implant Placement):

Fugazzotto (2002) presented a technique in which a trephine with a 3.0 mm external diameter is utilized instead of a drill (or an osteotome) as a first step, followed by an osteotome to implode a core of residual alveolar bone before simultaneous implant placement.[8,10]

- This technique could be utilized either following a flap reflection or using a flapless approach.
- A calibrated trephine bur with a 3.0 mm external diameter is used to prepare the site within approximately 1–2 mm of the sinus membrane at reduced cutting speed.
- Following removal of the trephine bur, a calibrated osteotome corresponding to the diameter of the trephine preparation is used under gentle malleting forces, to implode the trephine bone core to a depth approximately 1 mm less than that of the prepared site.
- The widest osteotome utilized will be one drill size narrower than the normal implant site preparation.
- Implant placement induces a lateral dispersion of the imploded alveolar core with gentle and controlled displacement.

This technique lessens the patient's trauma and preserves a maximum amount of alveolar bone at the precise site of anticipated implant placement.[8]

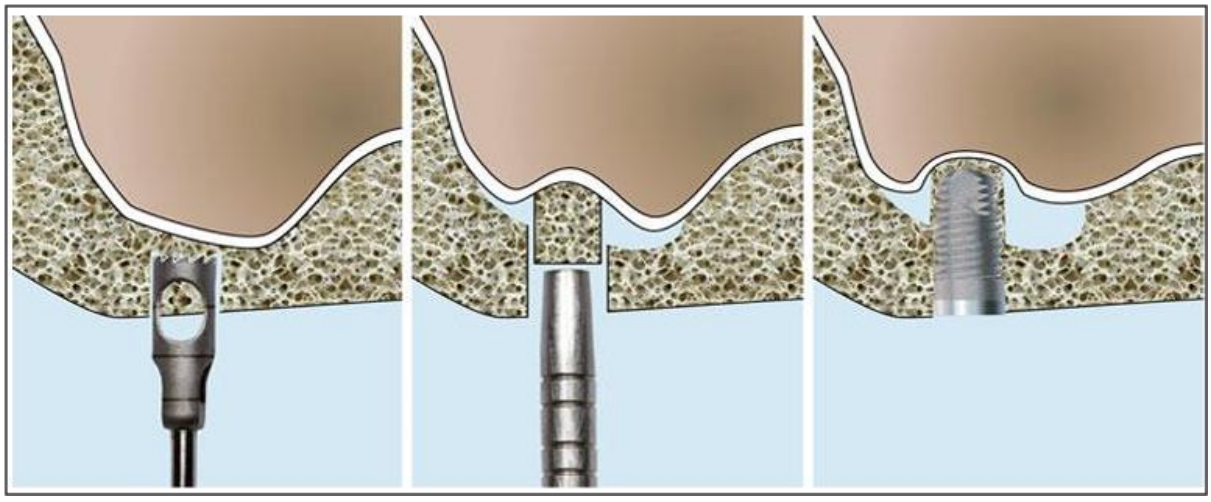


Figure.17: Schematic Drawings of Modified Trephine/Osteotome Approach.[8]

2. Cosci Technique:

The crestal approach technique has been also modified by Cosci and Luccioli (2000).

Cosci technique is a one stage crestal SFE approach using a specific sequence of atraumatic drills of varying lengths.[8,12]

The shape of the drill tip prevents perforation of the sinus membrane and permits gentle abrasive removal of the cortical bone of the sinus floor without fracture. Description of Cosci technique.

❖ **If the RBH is 6–7 mm:**

- A dedicated trephine drill of a 3 mm diameter is initially used for the starting 2–4 mm of the depth of osteotomy site.
- The dedicated 3 mm long and 2 mm diameter pilot drill is then used.
- Followed by the 3 mm long intermediate and 3.1 mm diameter drill and by one or more atraumatic lifting drills for the actual height of the ridge as measured on the radiograph.

❖ **If the residual bone height is 4–5 mm:**

- The trephine drill is not used, and the site is initially prepared with the dedicated 3 mm long and 2 mm diameter pilot drill, the rest of the preparation procedure being identical.

❖ After using the first atraumatic lifting drill, the site is probed with a blunt instrument to feel the presence of the Schneiderian membrane. If the presence of bone is felt, a 1 mm longer atraumatic lifting drill is used, and so on, until the sinus lining is felt. Then, the graft is gently pushed into the site using a particular instrument called "body lifting"; this step is repeated until the site is filled with the graft.[12]

❖ According to the Cosci technique, eight atraumatic SFE drills are available in the kit with incremental lengths of 1 mm starting from 5 mm to12 mm.[8]

Figure 18: Dr. Cosci's Non-Invasive Sinus Lift Kit.[8]

3. Antral Membrane Balloon Elevation (AMBE):

The sinus lift balloon was created to reduce the chance of sinus membrane perforation originally described by Soltan and Smiler (2005). [14]

This technique utilizes an inflatable balloon designed by Zimmer to evenly elevate the membrane when connected to a latex balloon that can inflate up to 5 cm. The balloon instrument can also be used to anticipate the required bone graft material, such as 1 cc of saline, which is used to inflate the balloon, equal to 1 cc of grafting material. On average, with 1 cc of saline, the sinus lift balloon may elevate the sinus membrane by 6 mm.[8,9]

There are three types of design:

- Angled design can be used in the lateral window/Caldwell-Luc approach.
- Straight design can be used in the crestal / Summer's approach.
- Micro-mini design can be also used in the crestal / Summer's approach with a small diameter opening (1.9 mm).

Technique:

1. The initial osteotomy (a pilot drill of 2 mm in diameter) after a flap or flapless procedure is performed to a depth 1–2 mm short of the floor. A small diameter osteotome can be used to penetrate the sinus floor.
2. It is recommended to inflate and deflate the balloon extraorally several times with normal saline before inserting it into the sinus cavity.

3. Once the balloon is inserted into the sinus cavity, the balloon can be pumped with normal saline.
4. A bone graft can then be inserted through the osteotomy site. The dome-shaped bone grafting material can be seen via radiograph.
5. A dental implant may be placed during the same procedure.[8]

Figure 19: antral membrane balloon.[4]

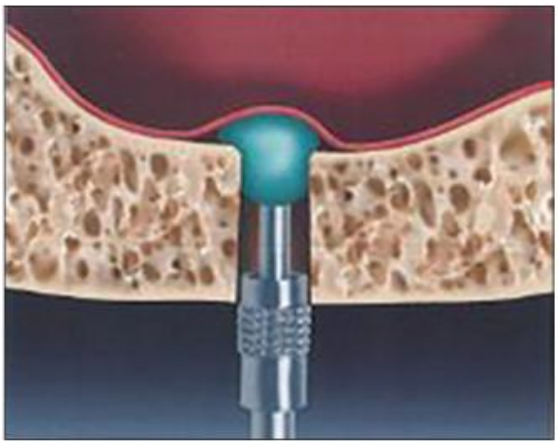


Figure 20: A minimally invasive ambe. adapted from the percrestal sinuslift .[4]

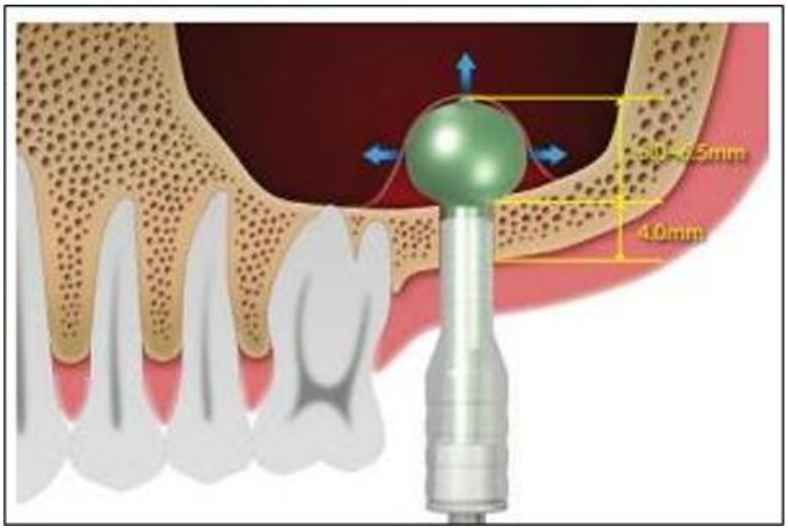


Figure.21: Sinus Floor Elevation Using Baloon Technique[8]

4. Hydraulic Sinus Lift Procedure:

Besides balloon sinus lift, other surgical techniques have been proposed to minimize the tapping motion by using hydraulic pressure, the so-called “hydraulic sinus lift” procedure.[15]

Minimally invasive hydraulic condensation, a new internal crestal approach was introduced by Leon Chen in 2005. Using a 2mm round bur a pinhole is created on the sinus floor and the membrane is separated through hydraulic pressure of the high-speed handpiece.[6]

The unregulated hydraulic pressure is applied into the osteotomy site by means of air/water exhaust spray from a high-speed dental handpiece or an uncontrolled water jet from a plastic syringe, to detach the Schneiderian membrane from the sinus floor. The applied hydraulic pressure is designed to loosen the membrane. In order to provide suitable equal distribution of hydrostatic pressure, the concept of "controlled hydrostatic sinus elevation" was introduced. This controlled hydrostatic sinus lift procedure is accomplished by using a calibrated, hand-controlled pump and pressure sensor meter.[8,15]

Furthermore, during this conventional method, a single-use syringe is used which it is not possible to check exactly the progression of the membrane position.

In 2013, Andreasi et al. introduce a new method with the advancement of hydraulic pressure exercised on a semisolid graft material to detach the sinus membrane and simultaneously fill the augmented space created this way. This technique is called as HySiLift. There were three components of instruments have used this purpose:[16]

i) a titanium syringe equipped with a micrometric control piston on which it is possible to assemble disposable syringes of various volumes;
ii) a surgical steel dispenser available in two forms (conical and cylindrical) and four diameters (two cylindrical of ø 3.2 and 4.0 mm and two conical of ø 2.8–4.0 and 3.5–4.6 mm) and;
iii) a needle in surgical steel, with a Luer lock attachment, complementary to that of the single-use syringe.

The single-use syringes can be pre-loaded with the desired amount of graft material.

The tip of the titanium injector is semi-spherical shaped so that to penetrate nearly 3 mm in the sub-Schneiderian space without damaging the overlying mucosa while the lateral openings allow uniform distribution of the paste-like graft material while forming a dome precisely in correspondence to the future implant site. The threaded portion of the dispenser extends for an about 6 mm length, thus indicated for ridges of 3-6 mm thickness to ensure the sufficient stability of the tool during the injection maneuver.[3]

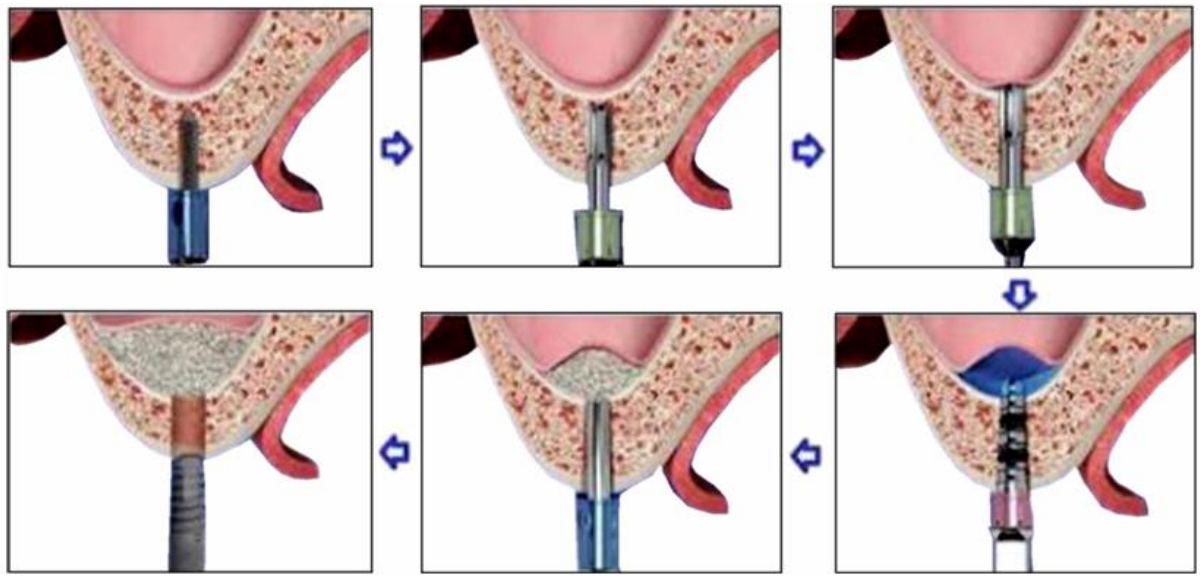


Figure 22: Diagrammatic representation of safe-ended drills to remove the cortical floor, insertion of fluid for a hydraulic lift, thereafter insertion of particulate graft and the implant.[5]

5. Minimally Invasive Transcrestal (MITSA) Approach Using CPS Putty to Elevate the Sinus Membrane:

Another novel technique as documented by Kher et al. 2014 evaluated a simplified minimally invasive transalveolar sinus elevation technique utilizing calcium phosphosilicate (CPS) putty for hydraulic sinus membrane elevation. [13,17]

a) In this technique, transcrestal SFEs are performed using a modification of Summers' technique.
b) Full-thickness mucoperiosteal flaps are elevated in order to gain access to the alveolar crest.

c) An osteotomy is initiated at the ridge crest using a 2.0 mm pilot drill. The drill is stopped 1 mm short of the estimated height of the sinus floor, following which a periapical x-ray is obtained to verify the exact position of the drill in proximity to the sinus floor.
d) The osteotomy is then further widened using the drilling sequence.
e) A small quantity of approximately 0.2 cm of CPS putty is delivered in the osteotomy via a narrow-tipped cartridge delivery system to act as a cushion prior to tapping the sinus floor, and a 3 mm concave osteotome with depth markings and a mallet are used to carefully fracture the floor of the sinus.
f) Following the green-stick fracture of the floor of the sinus, the bone substitute is directly injected into the prepared sinus cavity via the cartridge delivery system.
g) Once the cartridge tip fits tightly in the osteotomy, allowing the insertion pressure to be delivered directly to the fractured inferior border of the sinus floor, 0.5 cm of CPS putty is carefully injected into the osteotomy.[19]
h) The hydrostatic pressure exerted by the putty results in an atraumatic elevation of the sinus floor.
i) CPS putty can be added in increments until adequate elevation of the Schneiderian membrane is seen on intraoperative radiographs.
j) An appropriately sized implant is subsequently placed at the level of the osseous crest using a manual torque wrench for enhanced tactile sensation. The implants are initially engaged into the remaining native bone at the crest of the ridge and then slowly twisted in to engage in the viscous CPS putty at the apical aspect of the osteotomy. Cover screws are later placed and flap closure achieved.[4,16]

Figure 23: MITSA hydraulic membrane elevation using CPS putty4

The most significant benefit from the use of this technique is that it can achieve a gain in bone height comparable with that achieved with the use of the lateral window approach.

Advantages:

1. Less invasive transalveolar approach.
2. It also overcomes the need to purchase the specialized equipment required to apply hydraulic pressure for the elevation of the Schneiderian membrane, while simultaneously placing an adequate volume of the graft material in the site to allow for placement of the implants.
3. Its atraumatic nature.
4. Reduced chairside times.
5. Reduced overall treatment duration.
6. Improved patient comfort, and minimal graft wastage are additionally beneficial.

- The limitations of the technique proposed are the operator skill and experience necessary for success, and the minimum 3 mm of available bone height needed for achieving primary stability for the implant.[4]

6. Transcrestal Guided Sinus Lift Technique (TGSL):

Pozzi and Moy (2014) described a new procedure for sinus elevation using computer-guided planning and a guided surgical approach through the use of CAD/CAM-generated surgical template in combination with expander-condensing osteotomes, thus ensuring a minimally invasive surgical technique.[8,9]
Recommended for a residual alveolar crest of at least 5 mm in height and 5 mm in width distal to the canine.[8]

Technique:

a. The virtual tri-dimensional implant positions and angulations and available bone height is determined with the help of a three-dimensional software planning program (NobelClinician, Nobel Biocare AG). The working length of each drill is equal to the ABH minus 1.0 mm.

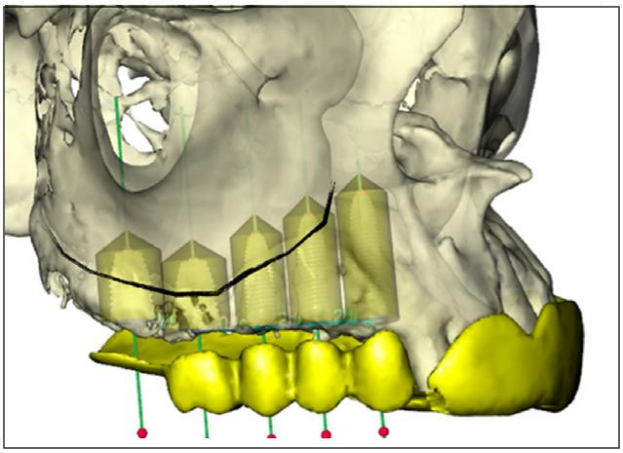


Figure 24: Preoperative three-dimensional planning and virtual implant placement[12]

b. The data is sent digitally to a central production workstation (Nobel Biocare AB, Kloten, Switzerland) for the fabrication of the stereolithographic-generated surgical template, which registers the planned implant locations.
c. A surgical occlusion index (Exabite II NDS, GC America, Inc.) is fabricated to register the vertical dimension of occlusion between the surgical template and the opposing dentition to enable accurate seating and positioning of the surgical template during surgery.
d. A flapless technique is used through the stereolithographic template (Nobel Biocare AB).
e. A partial-thickness mini-flap is reflected and each drill is used through the surgical template under copious irrigation to avoid overheating until the desired depth is achieved.
f. Expanding-condensing osteotomes with a calibrated working length up to 26 mm, compatible with the Nobel Guide tooling are used through the sleeves of the surgical template.

Figure 25: Osteotome carefully tapping performed throughout the sleeve of the surgical template.[12]

g. Careful, gentle tapping on the expanding-condensing osteotomes is performed to infracture the bony sinus floor.[8,12]
h. An average of 500 mg of grafting material mixed with an antibiotic solution is formed in the shape of the root and placed into the implant site using the final osteotome to act as a plugger.

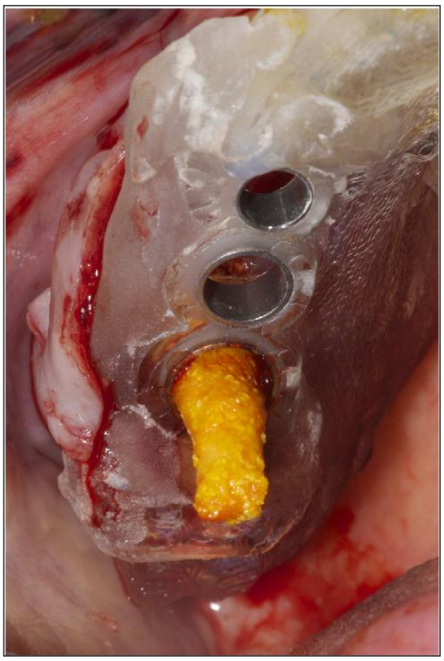


Figure 26: The grafting material reshaped as a root form and handled into each implant site throughout the sleeve of the surgical template.[12]

i. The implant placement is done through the guide sleeve of the surgical template.[8]

7. Reamer mediated sinus floor elevation:

Ahn and colleagues introduced the technique of reamer mediated sinus floor elevation. They used reamers with a single cutting edge angled at 85 degrees to prepare the osteotomy site. The reamers were operated at a lower speed of 30-50 rpm, creating a gentle vertical pushing force on the sinus floor, facilitating the membrane's separation and elevation.[6.13]

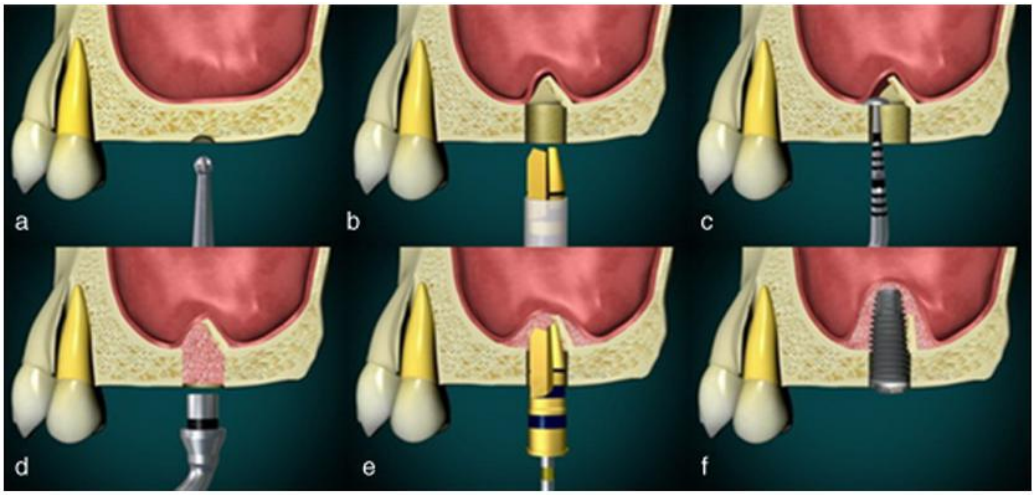


Figure 27: Illustrations of the reamer-mediated transalveolar sinus floor elevation procedure. (a) Two mm round bur marking. (b) Cutting and lifting of the sinus floor by the reamer acts like a trapdoor. (c) Confirming sinus floor elevation and intact Schneiderian membrane using a round-tip probe. (d) Packing the osteotomy with graft material. (e) Elevating the Schneiderian membrane via augmentation of the graft with the reamer (at 30r.p.m.). (f) Implant placement.[13]

8. Indirect sinus elevation with Osseo densification:

This technique introduced by Huwais in 2013. The technique involves using a specially designed bur called a Densah bur in a counterclockwise direction at 800-1500 rpm. This technique is used to achieve Osseo densification, which is the apical condensation of bone, resulting in an indirect sinus elevation with reduced chances of perforation.[6] The modified transcrestal approach using Densah burs is suggested when the RBH is less than 5 mm instead of the lateral approach.[16]

The importance of this can be explained in the following:

1. Indirect sinus floor elevation by Densah burs can be used when the RBH is less than 5 mm.
2. It is proposed as an alternative procedure to the direct (lateral window) sinus floor elevation procedure.

3. In some cases, the amount of vertical bone gain obtained by Densah burs in the indirect sinus lifting can be the same as the lateral approach.

Procedure:

- A midcrestal incision was performed, and a full-thickness flap was raised along the alveolar ridge.
- Drilling was started using the 1.8 mm pilot drill to determine the two implant sites. Then, drilling was changed into reverse (densifying) mode, which was CCW, and the drill speed was 1000 rpm with copious irrigation.

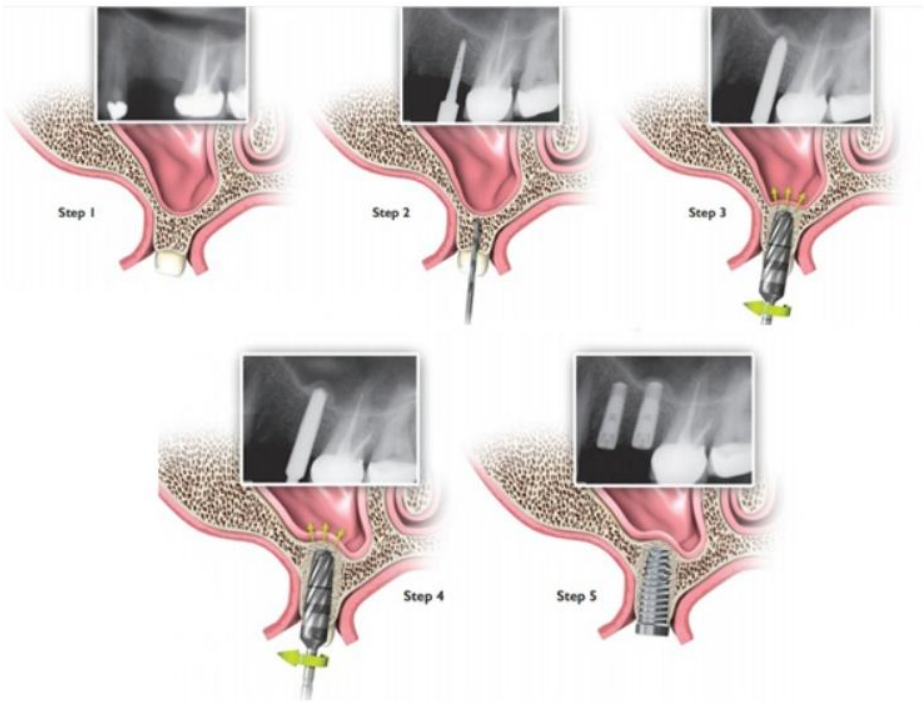


Figure 28: Demonstrating sinus elevation using Densah burs[18]

- The OD was started with a 3-mm-diameter Densah bur, and a gentle pressure with a pumping motion was applied to reach the sinus floor. When reaching the sinus floor, the bur started a vibrating motion. This is a result of the unique design of the Densah bur, which allows it to compress and densify the bone in all directions, preserving and autografting the bone until the sinus floor was penetrated.[16]
- The densification was continued using the Densah burs with the following sequence: 3.5 mm – 4.0 mm – 4.5 mm – 5.0 mm – 5.5 mm. Furthermore, the sinus membrane was visible and intact in all densifying stages, and all the drills did not exceed the sinus floor by more than 3 mm.[20]

Figure 29: Densah kit

9. Subantroscopic laterobasal sinus floor (SALSA) technique:

Engelke and Deckwer described a new endoscopically controlled technique for sinus floor augmentation. This technique involved transalveolar mobilization of the sinus membrane controlled by sinuscopy, transalveolar augmentation, and simultaneous implant placement and has been indicated for moderately reduced alveolar sites.[18]

- A crestal incision was made with a vestibular relief incision in the first premolar region. A full-thickness mucoperiosteal flap was then elevated, exposing the anterobasal aspect of the sinus wall, including the inferior third of the zygomatic buttress and the alveolar crest with the planned implant sites.
- *Microsurgical access:* A 5-mm-diameter laterobasal osteotomy was made directly anterior to the zygomatic buttress at the inferior aspect of the anterior sinus wall.
- The osteotomy was performed with a 4-mm diamond round bur under magnification with the support video endoscope technique.
- The sinus membrane was displaced with the help of microsurgical elevators of 2 to 4 mm in diameter around the trepanation.
- The bony access was opened just enough to allow introduction of 4-mm-diameter angulated mucosal elevators into the subantral space. The circular dissection of the sinus membrane was performed under continuous microendoscopic observation on a monitor. After circular detachment, the access hole was rounded and extended to a diameter of 5 mm. Its position was always located at the most inferior aspect of the alveolar recess to facilitate the laterobasal tunnelling.
- *Creation of SAS:* The SAS was created by tunnelling the sinus membrane with elevators of 0-, 45-, and 90-degree angulation under tactile control with the osseous basal floor.
- *Endoscopic Control of the SAS:* After detachment of the sinus membrane, the subantral space was examined via the access-trepanation using the 70- degree and 30-degree endoscopes.
- *Endoscopically Controlled Stepwise Augmentation:* The first portion of the augmentation was placed at the most distal part of the SAS. The desired "tenting up" of the membrane was checked endoscopically before covering the mesial aspect of the most distal implant with augmentation material.

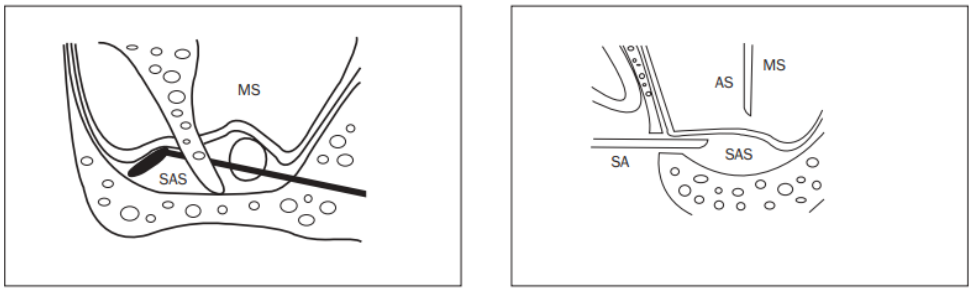


Figure 30a and 30b: Schematic representation of the SALSA technique. (Left) Preparation of the subantral space through the keyhole approach (panoramic view). (Right) Endoscopic control during SALSA (cross-sectional view). MS = maxillary sinus; SAS = subantral space; AS = antroscopy; SA = subantroscopy.[18]

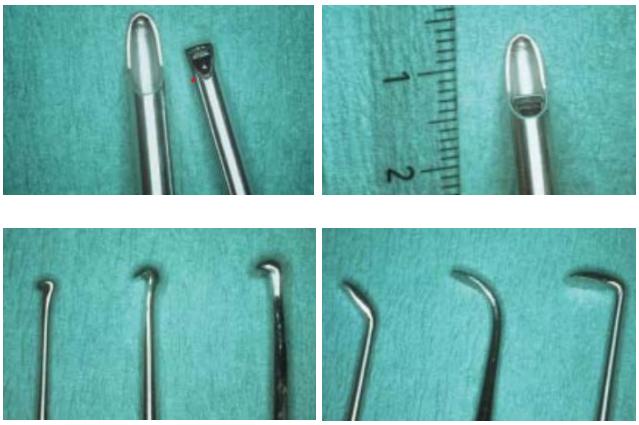


Figure 31: Instruments for SALSA technique.
The 2.7-mm endoscope tip and SPS working end.
Endoscope with SPS mounted.
Microsurgical sinus elevators: type O "dish-knives" for opening.
Microsurgical elevators: type T for tunnel preparation.[18]

10. Sinus/alveolar crest tenting (SACT) technique:

In the 1980s, a method was devised that employed osteotomes to elevate the sinus membrane, eliminating the requirement for any form of graft material. In the study conducted by Summers, a trephine was employed to excise the osteotomy site. Subsequently, osteotomes were utilized to insert bone beneath the sinus membrane, ensuring that an optimal amount of 7 mm of bone was available.[19]This technique, known as localized management of the sinus floor (LMSF), aimed to elevate the sinus floor while simultaneously positioning a dental implant. The current SACT technique is derived from the principles of the LMSF technique. In contrast, the SACT technique allows for the placement of implants with a bone thickness of 1 to 3 mm, without the need for graft material or membranes to cover the surgical site.[20]

11. Boyne's distraction osteogenesis technique:

Distraction osteogenesis (DO) refers to a biomechanical phenomenon in which bone tissue is formed through the application of distraction stresses between bone segments. These forces influence the biological potential of the bone, resulting in the production of a callus with specific dimensions in terms of length and height. Distraction osteogenesis is initiated by performing a corticotomy or sub-periosteal osteotomy, and subsequently, the distractor is fixed to the segments, resulting in their gradual elongation.[19,20]

Bone grafting materials:

Bone grafts can be used to promote bone formation and maxillary sinus augmentation can be accomplished through the use of autografts, allografts, xenografts, alloplastic material, and growth factors.[1,21]

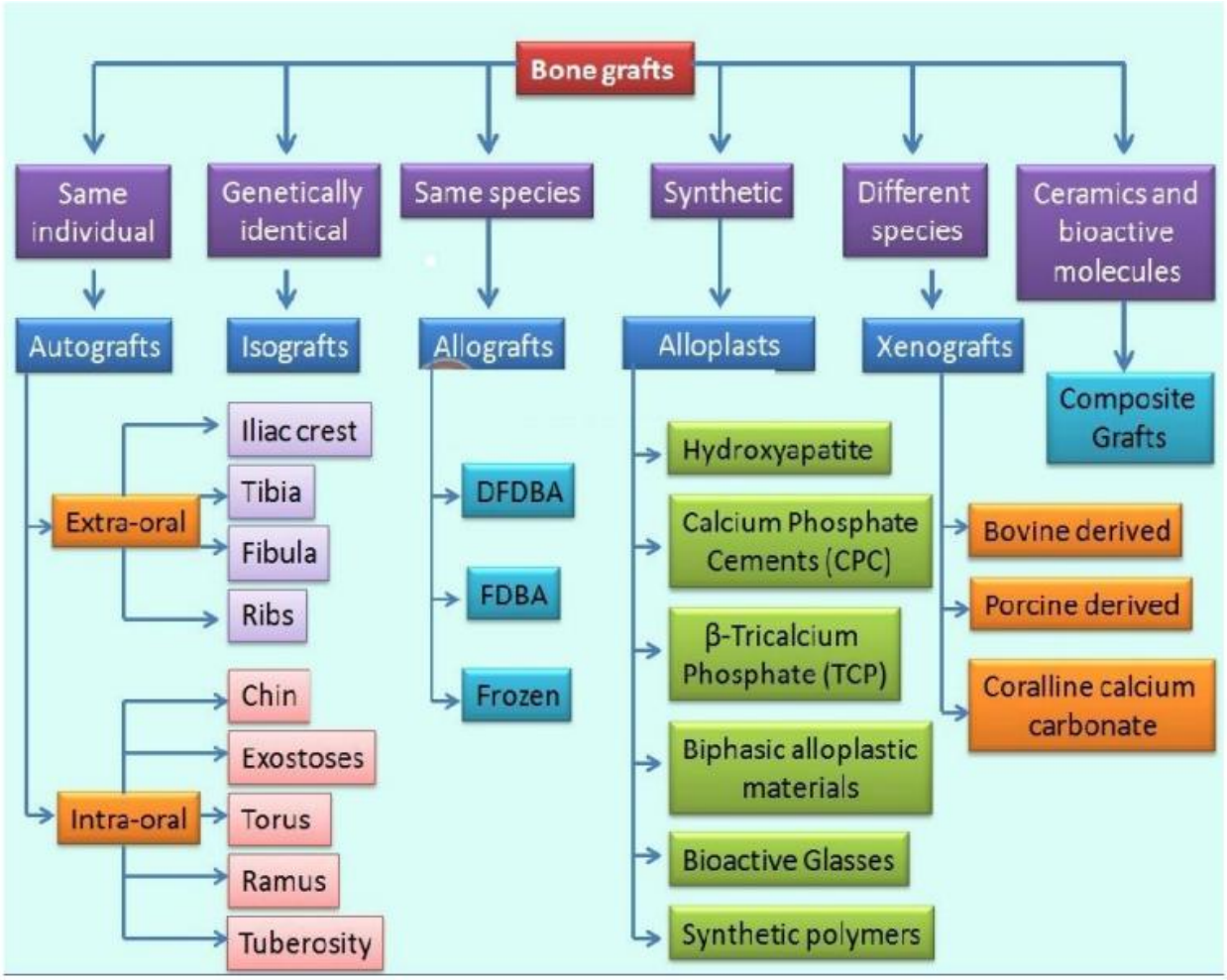


Figure 32: Flow chart of classification of bone grafts[21]

Fundamental consideration on bone substitute:

There are four main characteristics considered ideal in bone regeneration, those of which at least one bone substitute must present.[22]

a. The first main feature is the osteogenesis or osteogenic activity (ability of bone formation from viable osteoblasts or pre-osteoblasts derived from the graft donor area, which are capable of generating cellular proliferation and producing new bone).

b. The second property is the osteoconduction (the capacity of the graft for support or allow cell migration, formation of blood vessels and the bone growth in surface).

c. The osteoinductivity (refers to the ability of a graft to induce nondifferentiated stem cells or osteoprogenitor cells to differentiate into osteoblasts).

d. Finally, the osseointegration, which is the ability of chemical contact between the bone surfaces without the fibrous tissue's presence.

It is fundamental the presence of at least one of the characteristics described above and only autogenous bone presents them all.

Other characteristics considered ideal include: the remodelling of the bone initially formed in mature lamellar bone as a function of time passing, ability to stabilize implants when installed simultaneously to the grafting procedure, low risk of infection, good availability, low antigenicity and physiologically stable, not cause rejection and be ideally be absorbed after the regeneration. [22]

Autogenous grafts obtained from the same individual are considered the gold standard because of their osteogenic capacity and osteoconductive and osteoinductive properties. Autogenous grafts also heal quickly and have strong resistance to infections. However, the increased morbidity and unpredictable reabsorption associated with autografts have led to the development and use of synthetic substitutes.[21]

Allogenic grafts, obtained from another individual in the same species, have only osteoconductive and osteoinductive capabilities.

Xenografts, obtained from different species, possess only osteoconductive capability.

Alloplastic grafts, whether natural or synthetic, are solely osteoconductive biomaterials.

Adding xenografts to autogenous grafts improves volumetric stability in the sinus augmentation procedure. All graft types can be prepared in different forms, such as large blocks or streaky gels.

The bone substitutes made of ceramic are widely used associated or no with another biomaterial. There are many types of calcium phosphate (CaP) obtained by different methods of synthesis and nowadays, tricalcium phosphate (TCP) and hydroxyapatite (HA) are highly sought. Compounds of the base of calcium phosphate (CaP) have excellent biocompatibility, osteoconductive activity, and they are biodegradable. HA is an inorganic compound which is very similar to the structure of the mineral phase of bone, but shows weak and slow degradation (1-2%/year). However, TCP presents a very fast biodegradation rate, and is not always concurrently with the bone deposition.

The BoneCeramic® (Straumann®, Basel, Zwitzerland) is a completely synthetic biomaterial with osteoconductive property which favors the formation of vital bone.27 It is composed of biphasic CaP (BCP), a combination of HA (60 wt% and 40% TCP-B).[22]

The use of biodegradable polymers as a scaffold for cell culture has emerged as an alternative in bone regenerative therapy. Several natural and synthetic polymers are being studied and biodegradable polymers are considered as the best candidates for the construction of scaffolds for the tissue repair. Polylactic acid (PLA), polyglycolic acid (PGA) of polycaprolactone (PCL) and their copolymers are widely used in manufacturing scaffolds. The choice of the biopolymer as a bone substitute is due to biocompatibility, reproducibility, porosity, cell adhesion ability, besides being easily manipulated.

Some authors have suggested performing sinus lift procedures without grafting materials by utilizing coagulated blood as a scaffold to form new bone. However, this technique was not evaluated alongside appropriate control procedures, and the results were not reproducible.

A different approach was introduced in managing cases using platelet rich plasma or plasma rich in growth factors, with or without grafting biomaterials. The preparation of platelet-rich plasma involves the use of citrate in blood samples to prevent coagulation and maintain a liquid form. To prepare the gel form, thrombin and/or calcium chloride are added to induce fibrin polymerization.[21,7]

Platelet-rich fibrin is considered a second-generation platelet concentrate, offering additional advantages such as enhanced healing capabilities, low cost, and ease of handling. Platelet-rich fibrin can improve new bone formation, and significant results can be obtained after a sinus lift procedure. The use of platelet-rich fibrin can also improve implant stability and the osseointegration process. Platelet-rich fibrin is currently a trend in the management of sinus lift procedures and is considered superior to first-generation concentrates.

Postoperative instructions and care:

Following postoperative instructions should be provided to the patient with both verbal and written form:

1. On first night after surgery, head should be elevated on 2 or more pillows.
2. Liquid diet for 2 days and then soft diet for 2 weeks.
3. Some nasal bleeding may occur during first day.
4. Medications – Amoxicillin with clavulanate potassium 625 mg BID for 10 days; ibuprofen 600 mg and acetaminophen 500 mg QID for 3 days; oxymetazoline nasal spray for 7 days; 1.2% chlorhexidine mouth 30 cc BID for 14 days.[18]
5. Avoid chewing from the surgical site, blowing the nose for 2 weeks, smoking, balloon blowing, sucking liquid with straw, lying in pressured aircraft or scuba diving, carbonated drinks (minimum 3 days), heavy lifting of weights, and playing musical instrument that require blowing. Actions that create negative pressure (blowing of nose or sucking through straw) must be avoided by the patient during the first week after surgery. If the patient does sneeze, he or she must keep the mouth open, so that the pressure is not exerted within the sinus.[19]
6. Swelling – some bruising, facial swelling expected underneath the eye. Apply ice packs over the face; 10 min on and 10 min off.[14]

Complications and management:

Although sinus augmentation of the posterior maxilla is considered as a reliable and safe technique, it is still subject to some complications.[23]

Common complications that can occur during maxillary sinus graft surgery are the perforation of the Schneiderian membrane, penetration into the sinus or nasal cavity, bleeding, damage to the adjacent teeth, bone fracture, perforation of the alveolar bone, inadequate initial implant stability, incorrect placement or alignment of the implant, blockage of the opening to the maxillary sinus, and accidental swallowing of surgical instruments.[15]

Open sinus lifting (lateral window technique)
Schneiderian membrane perforation
Chronic rhinosinusitis
Hemorrhage
Overfilling (ostium blockage)
Closed sinus lifting (osteotome technique)
Schneiderian membrane perforation
Benign paroxysmal positional vertigo
Implant displacement

TABLE 2: Complications of associated with sinus lift procedures[23]

Sinus Membrane Perforations:

The most common complication involving sinus elevation is membrane perforation. The incidence of this occurrence has been reported to range 10-56%. Verified by inspecting visually, elevated membrane movement while nasal breathing, radiographically visible leakage, and cautiously done Valsalva maneuver. Risk factors are bony septa, thin membrane, sinus pathology, over drilling, or overfilling of graft materials.[23]

Perforation management done by suturing with Vicryl 6/0, collagen wound dressing, absorbable collagen membrane or platelet-rich fibrin sealants based on the extent of perforations. It is sometimes necessary to stabilize this membrane on the surrounding bone using fixing pins or resorbable sutures.[8]

Haemorrhage/Bleeding:

The maxillary sinus region contains a network of blood vessels, with the primary vessel being the maxillary artery. This artery gives rise to multiple branches, including the infraorbital artery, the anterior superior palatine artery, and the posterior superior alveolar artery, that supply blood to the sinus cavity and the adjacent tissues and structures. Numerous connections (anastomoses) are typically observed between the posterior superior alveolar artery and the infraorbital artery within the lateral bony wall of the sinus. These connections play a crucial role in ensuring adequate blood circulation in this region. Bleeding can occur if arteries are damaged during the preparation of the lateral window. To mitigate this risk, it is advisable to identify the location of the artery prior to surgery using CBCT.[15]

In case of bleeding, head elevation and direct firm pressure must be applied with a compress soaked with tranexamic acid for 15 min, Bone wax or grafting material into the AAA canal stops the bleeding. Electro cauterization or direct ligation is helpful in case of significant Haemorrhage.[8]

Buccal Bone Fracture:

In these cases, the mobilized buccal bone can be resorbed, exposing the implant surface; it is recommended to cover it with biomaterial and a membrane to let it heal properly. There is also a risk of losing the implant's primary stability. The implant should be removed and replaced after healing.[8]

Infectious Complications:

Acute sinusitis is often related to perioperative anaerobic contamination, favoured by superinfection of an insufficiently drained hematoma, or inadequate antibiotic coverage. Its prevention is based on strict aseptic conditions, use of bone grafts impregnated with metronidazole, and on appropriate antibiotic coverage, to begin in the preoperative phase or immediately postoperative.[8]

Overfilling (ostium blockage):

Due to its elevated position in the cranium, the occurrence of iatrogenic ostium blockage resulting from overfilling with bone grafts is infrequent. This blockage can interfere with normal sinus functioning leading to additional complications, such as chronic rhinosinusitis.

The incidence of chronic rhinosinusitis following sinus lift surgery ranges from 4.2% to 8.4%. The causes of rhinosinusitis could be secondary to contamination of the sinus space during surgery, due to ostium blockage caused by graft overfilling or mucosal swelling, or due to a reduction in airflow owing to low sinus volume, altered mucosal activity as a result of mucosal lacerations and implant protrusion or lacerations of the membrane. The Signs and symptoms of which present as Muco-Purulence (89%), Facial Pain or Pressure (78%), Nasal Congestion (56%), Foul Smell (45%), Cough (18%), Purulent Drainage Around the Implants (18%), Ocular Pruritus (9%), Postnasal Drip (9%).[23]

Management: Medical management for sinusitis may include prescribing systemic antibiotics, additionally nasal douching with saline solutions, nasal steroid sprays, and oral antihistamine medication may be recommended21. If the initial treatment fails a conventional Cadwell-Luc osteotomy, either through the oral cavity or via endoscopy through the nasal or oral cavities is carried out. This procedure may include sinus irrigation to remove any contaminants, and sometimes the contaminated graft and/or implant removal as well.

Displacement of the implant:

A dental implant can get displaced in the following situations: when it is placed in the posterior maxilla without undergoing sinus lift, if the surgeon lacks experience with the anatomical landmarks of the maxillary sinus and if the dental implant is excessively tapped during internal sinus osteotomy. To avoid such migration of an implant into the sinus, the use of tapered implants with smaller apical diameters placed over a cone shape-configured implant bed is advisable. This will help to prevent the displacement of the entire device into the sinus.[8,23]

Benign paroxysmal positional vertigo:

A highly prevalent Oto-neurological disorder characterized by brief episodes of vertigo and nausea precipitated by a rapid change in head posture. It is that the trauma is caused by the osteotome and surgical hammer mallet during the closed sinus lift procedure. Symptoms typically manifest within 1 to 2 days after the operation and affect the opposite side of the treated area. However, this condition can be treated successfully using the Epley repositioning technique and show full recovery within 2 days.[6]

Alternative to Sinus Lift Surgery:

Several therapeutic options such as short implants, Tilted implants, and Distal cantilevers are available. Short implants are indicated in edentulous sites with subantral residual bone height [RBH] >5 to ≥9 mm. Though the implant placement reduces the demand for the regeneration of bone, limited evidence is available on long-term biological and prosthetic complications. Distal cantilevers and tilted implants are given in edentulous patients with subantral RBH ≤5 mm. Though bone regeneration may not be required, if not properly designed may lead to potential prosthetic complications.[6]

RECENT ADVANCES IN SINUS LIFT SURGERY

1. Smart lift technique:

This procedure was introduced by Franceschetti et al. The implementation of the Smart Lift technique, combined with graft biomaterials, resulted in a uniform displacement of the sinus floor towards the apex and a low occurrence of postoperative morbidity. The implant site's vertical growth is achieved by utilizing the Smart Lift technique, which involves relocating the compressed trephined bone core into the sinus.[24]

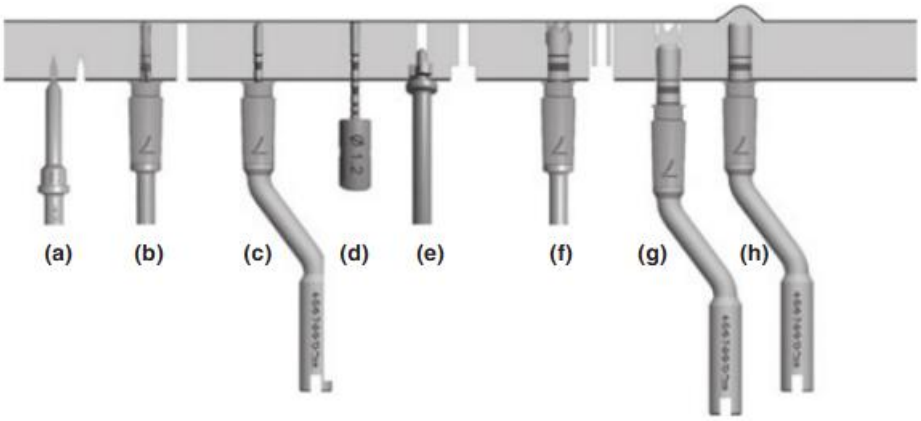


Figure 33: Smart lift procedure: sequence of rotating and manual instruments.[24]

(a) The Locator Drill is used to perforate the cortical bone at the site where the implant has to be placed.
(b) The Probe Drill is used to define the orientation of the implant, with an adjustable stop device set at least 1 mm shorter than the radiographic working length.
(c) The Probe Osteotome is gently forced in an apical direction until the cortical bone resistance of the sinus floor is met, thus providing the "surgical working length" (sWL). The working action of all instruments included in the succeeding surgical steps is set at the sWL using the proper adjustable stop device.
(d) A radiographic pin may be used to check the orientation of the prepared site by means of a periapical radio-graph.
(e) The "Guide Drill" is used to create a crestal countersink.
(f) The Smart Lift Drill produces a bone core up to the sinus floor.
(g, h) The bone core is condensed and malleted to fracture the sinus floor by means of the Smart Lift Elevator. A graft biomaterial may be placed into the sinus cavity by gradual increments with the Smart Lift Elevator.

2. Autologous platelet concentrates in sinus lifting:[25]

PRP is a form of autologous fibrin adhesive that may be easily generated from whole blood by centrifugation, leading to a significant concentration of platelets. Furthermore, it is worth noting that PRP demonstrates a significant presence of mitogenic and angiogenic growth factors, which are recognized for their pivotal involvement in the bone healing mechanism. The factors encompassed in this category consist of platelet-derived growth factor (PDGF), transforming growth factor (TGF), & insulin-like growth factor. In contemporary times, PRP has been utilized for the purpose of elevating sinus floor.

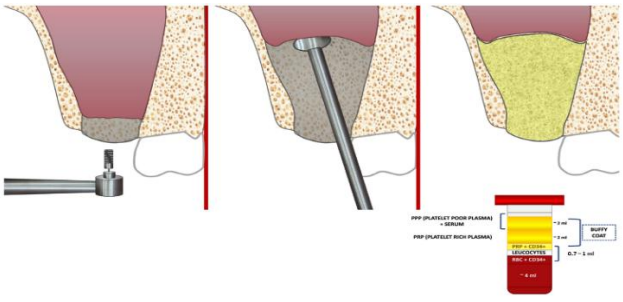


Figure 34: Summer's technique using CGF graft for sinus lift.[25]

Research studies examining the concentration of growth factors and the kinetics of their release have indicated that platelet-rich fibrin (PRF) exhibits superiority compared to alternative platelet concentrates. PRF is considered a therapeutically beneficial substitute for conventional PRP owing to the incorporation of fibrin, a notable auxiliary molecule that serves as an effective carrier in tissue regeneration. The implementation of the PESS procedure, which combines PRF endoscope, simultaneous placement of implant, and elevation of sinus floor, has considerable potential as a treatment approach for individuals with less than 4 mm of remaining alveolar crest height. By combining PRF with endoscopic-guided trans-crestal elevation to the sinus floor and implanting it at the same time, it is feasible to finish fitting the final prosthesis in a considerably shorter duration of 3 months, in contrast to the usual 12-month timeframe linked to conventional treatment approaches.[24, 25]

CGF is considered a new generation of platelet products that have dense fibrin networks and a high concentration of GF and are important in cell proliferation. The CD34+ cells have been discovered at both levels (CGF-RBC) and are entrapped in the CGF matrix in large numbers. Due to its promotion of osteogenic cell differentiation and proliferation, the CGF seems to have more promise for tissue regeneration. As a result, the CGF greatly boosts alkaline phosphatase (ALP) activity.[25]

According to Chen et al., in patients with a residual bone height of 4–6 mm before surgery, the osteotome sinus floor elevation with a CGF approach is safe and dependable, whether bone grafting is used or not.[25]

3. Augmentation of maxillary sinus with tissue-engineered bone: The utilization of cultivated periosteal cells for tissue-engineered bone and cartilage regeneration was initially documented by Rich et al in 1994. Breitbart et al. cultivated cell cultures in osteogenic environments using periosteal tissue obtained from an adult New Zealand white rabbit's proximal tibia. In a rabbit model, critical-sized calvarial injuries were successfully repaired achieved through the utilization of a polyglycolic acid scaffold.[26]

SUMMARY AND CONCLUSION:

Sinus augmentation is crucial in restoring the posterior edentulous maxilla. To ensure the successful placement of an implant in this desired area, the clinician must have meticulous knowledge of anatomical factors such as sinus characteristics and the remaining alveolar bone for implant placement. Accurate diagnosis will help choose the appropriate treatment plan and technique. Although sinus lift procedures have high predictability, they may cause discomfort and increase patient Comorbidities. In selecting the treatment approach lateral window or trans alveolar crestal technique to perform maxillary sinus floor elevation, the clinician needs to consider the following factors.

1. It is commonly accepted that a residual bone height of less than 4 mm warrants a lateral window sinus elevation approach without simultaneous implant placement.
2. The length of the implant planned also influences the treatment approach. A disadvantage of the trans alveolar crestal technique is its limitations in elevating the Schneiderian membrane. Often, it is difficult to elevate the membrane more than 4–5 mm apically.

Sinus lift procedure with grafting material is more successful with better long term survival rates than those without grafts.

Finally, it is difficult to provide clear indications with respect to whether the crestal or lateral SFE procedure should be adopted first. Ultimately, the decision is determined by the surgeon's judgment based on his experience and each clinical situation, with priority given to surgical interventions that are simpler, less invasive, with less risk of complications, and ultimately attaining goals within the shortest time frame.

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