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Grado en Odontología

SINUS LIFT: THERAPUETIC OPTIONS TO RESTORE THE POSTERIOR MAXILLA

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Abstract

Background: The posterior maxilla is one of the most challenging areas when considering dental implants as the treatment of choice to restore an edentulous area. Sinus augmentation is a technique which aims to lift the maxillary sinus floor to help achieve ideal and optimal conditions for implant placement.

Objective: The aim of this review is to compare the available techniques of sinus augmentation as well as their indications. It will also achieve an analysis of the effects on residual bone height with the use of different types of biomaterials used as well as identify common complications in sinus augmentation.

Methodology: 23 articles were selected from PubMed, 1 article published on Madridge Journal of dentistry and dental oral surgery and 1 article published on Medknow. The articles were published from the year 2015 to the year 2020 with a total of 37 trials.

Results: 97.3% of the trials were performed on humans while only 2.7% were on animals, with a most common age range between 26-73 years and an average of 27 patients in the trials. The most prevalent technique was the lateral window approach which was done on 618 individuals. 73.7% of the patients presented a residual bone height between 2-7mm and a total of 1187 implants were placed simultaneously, and 667 implants had delayed placement. Most common complication was membrane perforations present in 10 trials. Autogenous bone block showed an average of 12.55mm of residual bone gain and was considered the highest.

Conclusion: The lateral window technique was done when the residual bone height is ≤. 4mm and the transcrestal approach when it was >5mm. Autografts showed highest increase in residual bone height but other materials and graftless techniques are comparable. The most prevalent complication was membrane perforations.

Keywords: sinus augmentation, sinus lift, grafting, bone, implant, maxillary sinus, autologous bone, dental implants, Lateral window, implant stability, sinus elevation, biomaterials and bone substitutes.

Resumen

Introducción: El maxilar posterior es una de las zonas más complicadas cuando se consideran los implantes dentales como tratamiento de elección para restaurar una zona edéntula. El aumento de seno es una técnica cuyo objetivo es elevar el suelo del seno maxilar para ayudar a conseguir las condiciones ideales y óptimas para la colocación de implantes.

Objetivo: El objetivo de esta revisión es comparar las técnicas disponibles de aumento de seno, así como sus indicaciones. También se logrará un análisis de los efectos sobre la altura del hueso residual con el uso de los diferentes tipos de biomateriales utilizados, así como identificar las complicaciones comunes en el aumento de seno.

Metodología: Se seleccionaron 23 artículos de PubMed, 1 artículo publicado en Madridge Journal of dentistry and dental oral surgery y 1 artículo publicado en Medknow. Los artículos fueron publicados desde el año 2015 hasta el año 2020 con un total de 37 ensayos.

Resultados: El 97,3% de los ensayos se realizaron en humanos mientras que solo el 2,7% fueron en animales, con un rango de edad más común entre 26-73 años y una media de 27 pacientes en los ensayos. La técnica más prevalente fue el abordaje por ventana lateral que se realizó en 618 individuos. El 73,7% de los pacientes presentaban una altura ósea residual de entre 2-7mm y se colocaron un total de 1187 implantes de forma simultánea, y 667 implantes tuvieron una colocación retrasada. La complicación más común fue la perforación de la membrana, presente en 10 ensayos. El bloque de hueso autógeno mostró una media de 12,55 mm de ganancia de hueso residual y fue considerado el más alto.

Conclusiones: La técnica de ventana lateral se realizó cuando la altura de hueso residual es ≤ 4mm y el abordaje transcrestal cuando era >5mm. Los autoinjertos mostraron el mayor

aumento de la altura ósea residual, pero otros materiales y las técnicas sin injerto son comparables. La complicación más frecuente fue la perforación de la membrana.

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Anatomical aspect of the maxillary sinus and it’s characteristics

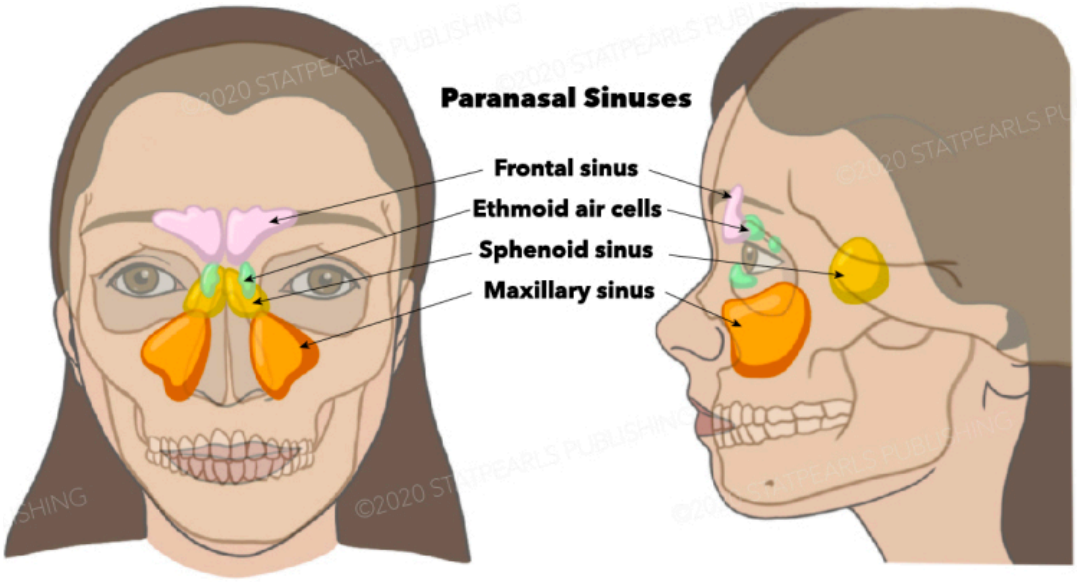
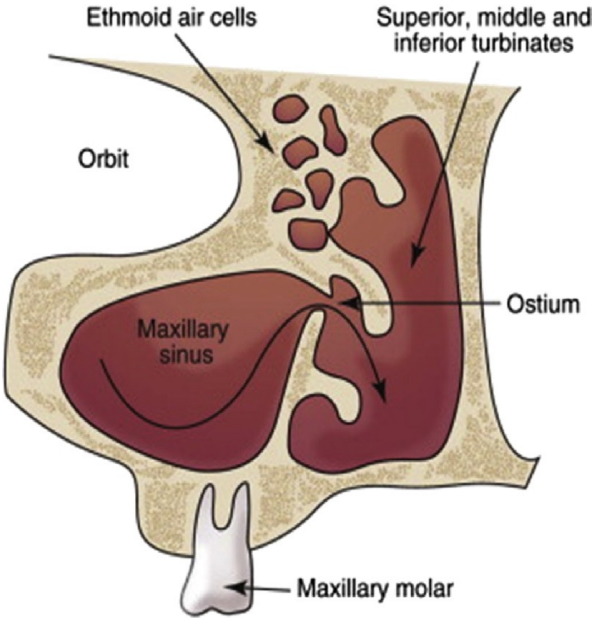


Figure 1. Anatomy, head and neck, nose Paranasal sinuses \(1)

The nasal cavity that we present as humans is surrounded by several anatomical complexities known as the paranasal sinuses. When approaching the nasal cavity from an antero-posterior view, one can identify that the nasal cavity is marked by an anterior limit, known as the ala of the nose and a posterior limit known as the choana (1). The nasal cavity is considered to be divided into 2 indistinguishable sides which are demarcated by the nasal septum in the midline.(1). The paranasal sinuses are present on each side with distinguishable anatomical characteristics. When considering the orbit as a reference, the frontal sinus is considered to be located on the superior aspect of the orbit, the maxillary sinus being in the inferior part of the orbit, the sphenoidal sinus on the posterior aspect of the orbit and the ethmoidal sinus are seen to be located medially to the orbit.

The maxillary sinus presents a unique anatomical aspect which helps us differentiate it from other paranasal sinuses that surround the nasal cavity. The maxillary sinus is considered to be the paranasal sinus with the largest size (2,3). The anatomical boundaries that the maxillary sinus presents gives it a pyramidal shape with distinct limits (4) .

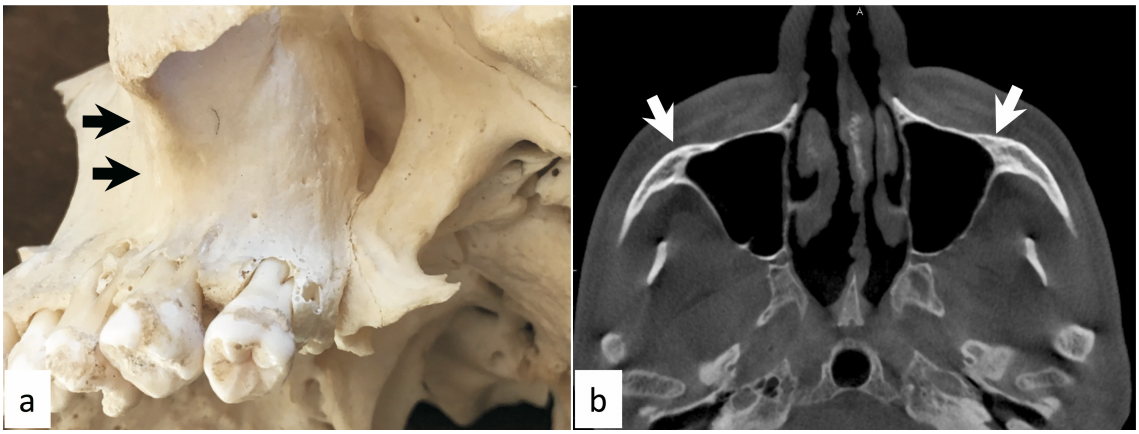


F*igure 2* (2)

Assuming that the maxillary sinus presents a pyramidal shape, the base of the sinus is considered to be the lateral wall of the nasal cavity, this is also known as the medial wall of the maxillary sinus. In the medial wall of the maxillary sinus lies the primary osteum, which presents a significant characteristic of being the main pathway of secretions to be drained (2). The primary osteum has a pathway which is present on the superior aspect of the medial wall and hence allows grafting material to be placed without disturbing the drainage of substances as seen on *figure 2* (2).

Superiorly, the pyramidal shape of the maxillary sinus is marked by the floor of the orbit. The apical portion of the pyramid is considered to be limited by the zygomatic process of the maxillary bone (2,3). As seen on *figure 3a and 3b,* the maxillary sinus presents a direct relationship with the zygomatic process of the maxillary bone. Adult maxillary sinuses vary and present different sizes depending on the individual. However, the average proportions that the maxillary sinus presents are considered to be around 25 to 35mm wide, 36 to 45mm in

height and 38 to 35mm in length (2). Considering the contents of the maxillary sinus, it is seen that the maxillary sinus presents an approximate volume of air of 15 mL, however the volume of air inside the maxillary sinus is variable from one individual to the other, appearing to be slightly increased in patients with partially edentulous areas or in patients with complete edentulism (2,3).



F*igure 3a,3b* (6)

Relationship of the maxillary sinus with dentition:

The sinus floor has an extension towards the anterior aspect with a limit towards the upper canines or premolars and has a posterior extension with a limit of the maxillary tuberosity (3,5).

When taking into account the relationship with teeth and the maxillary sinus, one can identify how close the root tips are to the floor of the maxillary sinus. It has been seen that the maxillary sinus floor presents a closer proximity to the root tips of the

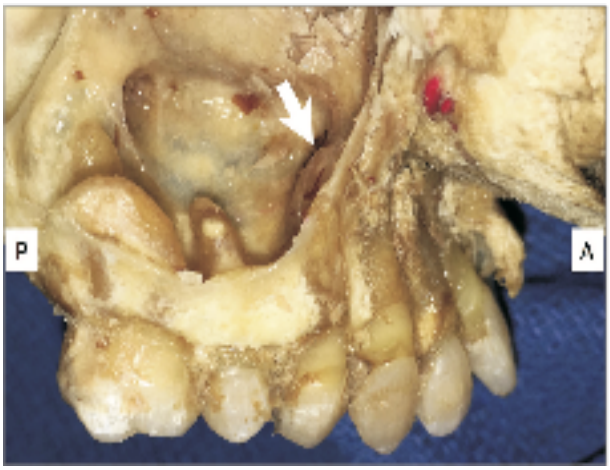


Figure 4 (6)

maxillary molars in comparison with the maxillary premolars (6). This can be seen on *figure 4.*

CT scans of the maxillary sinus have identified that the average distance between the sinus floor and the posterior teeth are to be 1.97mm, with molars having a 40% closer relationship to the sinus floor (6).

Vasculature and Innervation of the maxillary sinus:

1. **Vasculature:**

- The lateral wall of the maxillary sinus is considered to be supplied by several arteries. The main supply of the lateral aspect is considered to be by the main branches of the internal maxillary artery. These branches include the infraorbital and the posterior superior alveolar arteries(2).
- One of the branches of the sphenopalatine artery, known as the posterior lateral nasal artery provides blood supply to the medial part of the sinus. One main advantage of the vascularity in this area, is that it provides an exceptional environment for graft integration (2).
- Along the anterior pathway of the posterior lateral nasal artery the posterior and medial wall of the sinus are supplied with blood (6).

2. **Innervation:**

- The posterior and middle superior alveolar nerves provide sensation to the posterior wall of the maxillary sinus (2).
- The anterior superior alveolar nerve provides sensation to the anterior wall of the maxillary sinus (2).
- The infraorbital nerve provides sensation to the superior and medial wall of the maxillary sinus (2).

- The greater palatine nerve provides sensation to the osteum and the inferior wall of the maxillary sinus (2).

The maxillary sinus presents a unique anatomical complexity that surrounds it known as the Schneiderlin membrane. The Schneiderlin membrane of the maxillary sinus consists of 3 main superficies. The first layer is a bony periosteum which provides coverage of the antrum (2). The second is considered to be a connective tissue which is vascular and is provided with blood supply by the arteries that supply the maxillary sinus (2). The final layer is known as a pseudostratified columnar epithelium, also known as a respiratory epithelium which has a direct exposure to the sinus cavity (2). The Schneiderlin membrane is also seen to have a direct connection to the nasal mucosa, which encounter at the ostia (2). The thickness of the membrane varies slightly, however it is mentioned that the membrane presents an average thickness of 0.8mm in the antrum (2).

Classification of the maxillary sinus contours for establishing a correct treatment protocol of sinus augmentation

1. Misch's classification of the maxillary sinus (7)

In the year 1987, Misch established a classification of the maxillary sinus and it's contours before approaching the procedure of sinus augmentation.(7) As mentioned before, the maxillary sinus presents a pyramidal structure and Misch had an advance to classify the maxillary sinus according to the bone available below the antrum as well as the ridge width (7). This classification was considered to be fundamental before placing an implant, as it determines if the residual bone height would be sufficient or not for implant placement. The residual bone height was measured in millimeters and were split into 4 main categories, taking into account the subantral area:

- **SA1:** A residual bone height of at least 12mm below the antrum, and it is considered to be suitable for implant placement.
- **SA2:** A residual bone height between 10 and 12mm below the antrum, and usually requires s sinus augmentation procedure. (8)
- **SA3:** A residual bone height between 5-10mm below the antrum.
- **SA4:** A residual bone height less than 5mm below the antrum.

According to each of the category mentioned, Misch recommended a specific treatment protocol that should be done when the intended treatment is implant placement. For example, he mentioned that a patient with a category of SA1 would not require sinus augmentation and it is considered clinically suitable for implant placement with a good prognosis. A residual bone height between 10 and 12mm, with a category of SA2 would usually require a sinus augmentation procedure. Both SA3 and SA4 categories were recommended a sinus augmentation procedure using the lateral approach as well as graft placement with a delayed implant placement were recommended (8). As seen on *figure 5*, the maxillary sinus is marked in green and the residual bone height below the antrum is mentioned in red.

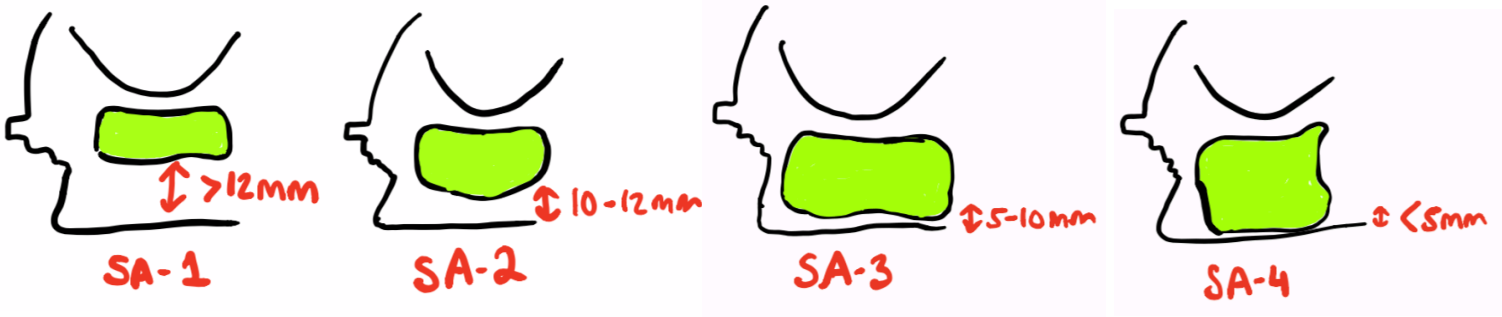


Figure 5. A graphical representation of Misch's classification including the limits of the residual bone height as well as the maxillary sinus marked in green (7).

2. ABC classification of the maxillary sinus contours by Wang and Amar (9)

In November 2008, Hom-Lay Wang and Amar Katranji suggested a new classification to classify to the maxillary sinus, it's contours as well as the bone width and height of the residual bone. They considered this classification as the ABC classification, classifying it into 3 main categories: A,B and C. Categories C and B are then split into divisons respectively named h, v and c. (9)

Wang and Amar approached this classification assuming that all implants will be of specific dimensions. They assumed that implants will be generalized with a fixed diameter of 4mm and a length of 10mm (9).

- **Class A (Abundant bone):** Demonstrates that the floor of the maxillary sinus has a distance of 10mm away from the bone crest, with a width of at least 5mm. It also mentions that the distance from the bone crest to the adjacent cemento-enamel junction is less or equal to 3mm (9). They mentioned that patients that present this class would be ideal for implant placement without grafting.

Class A

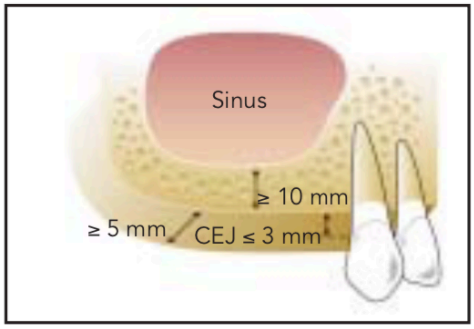


Figure 6 (9)

- **Class B (Barely sufficient bone):** Demonstrates that the floor of the maxillary sinus has a distance of 6 to 9mm away from the bone crest, with a width of at least 5mm. It also mentions that the distance from the bone crest to the adjacent cemento-enamel junction is less than or equal to 3mm (9). They mentioned that patients that present

this class would require a sinus lift procedure using the lateral window approach and may require grafting. As stated before, class B could then be further classified into 3 main subdivisions:

⇒ **Division h:** The letter "h" corresponds to the horizontal defect that it presents. The sinus floor distance is 6-9mm from the crestal bone level, however the width is considered to be lower than 5mm and hence compels a horizontal augmentation procedure with different techniques involving GBR (guided bone regeneration). The bone crest presents a normal value of less than or equal to 3mm from the cemento enamel junction. (9).

⇒ **Divison v:** The letter "v" corresponds to the vertical defect that it presents. The sinus floor distance is 6-9mm from the crestal bone level, with a normal bone width of at least 5mm, however the distance from the bone crest to the cemento-enamel junction is more than 3mm and hence requires a vertical augmentation procedure. The vertical augmentation procedure is approached by lifting the bone crest using bone grafts (9).

⇒ **Division c:** The letter "c" corresponds to the combined defect that it presents. This division is considered to be a combination of both the defects that division v and h present. Here the sinus floor distance is 6-9mm from the crestal bone level, however the width is less than 5mm and the distance from the bone crest to the cemento-enamel junction is more than 3mm (9). Patients presenting these aspects would require a combination of both vertical and horizontal augmentation with the aid of bone grafting materials to increase the bone level (9).

Class B

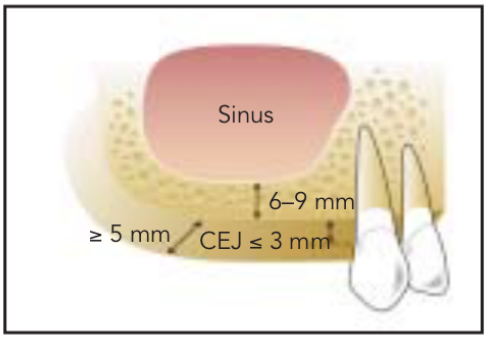


Figure 7a (9)

Class B, division h

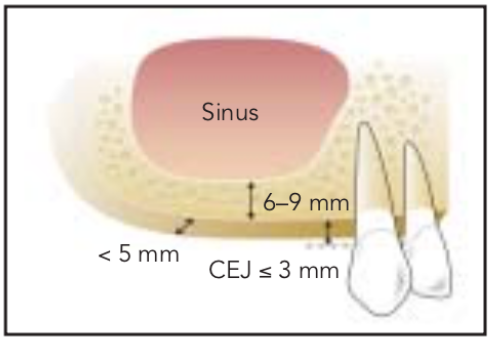


Figure 7b (9)

Class B, division v

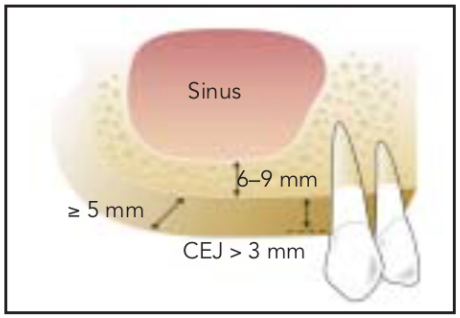


Figure 7c (9)

Class B, division c

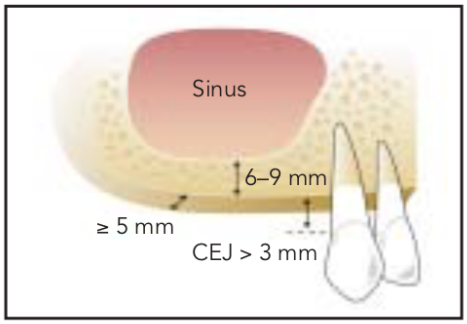


Figure 7d (9)

- **Class C (compromised bone):** Demonstrates that the floor of the maxillary sinus has a distance value equal or lower than 5mm away from the bone crest, with a width of at least 5mm. It also mentions that the distance from the bone crest to the adjacent cemento-enamel junction is less than or equal to 3mm (9). They stated that for a favorable outcome and prognosis, a sinus lift procedure using the lateral approach technique should be used. Class C could then be classified into 3 main subdivisions just like class B:

⇒ **Division h:** The letter “h” corresponds to the horizontal defect that it presents. The sinus floor distance to the crestal bone level is less than or equal to 5mm, however the width is considered to be lower than 5mm. The bone crest presents a distance of 3mm or lower from the adjacent cemento- enamel junction. This division is considered beneficial when approached using the lateral window approach for a sinus lift procedure with graft placement. This procedure also requires horizontal augmentation due to the horizontal defect it presents which could be handled by the use of bone grafts (9).

⇒ **Divison v:** The letter “v” corresponds to the vertical defect that it presents. The sinus floor distance is less than or equal to 5mm from the crestal bone level, with a normal bone width of at least 5mm, however the distance from the bone crest to the cemento-enamel junction is more than 3mm and hence requires a vertical augmentation procedure using bone grafting materials.

⇒ **Division c:** The letter “c” corresponds to the combined defect that it presents. This division is considered to be a combination of both the defects that division v and h present. Here the sinus floor distance is less than or equal to 5mm from the crestal bone level, however the width is less than 5mm and the distance from the bone crest to the cemento-enamel junction is more than 3mm (9). Patients presenting these aspects would require a combination of both vertical and horizontal augmentation with the aid of bone grafting materials to increase the bone level (9).

Class C

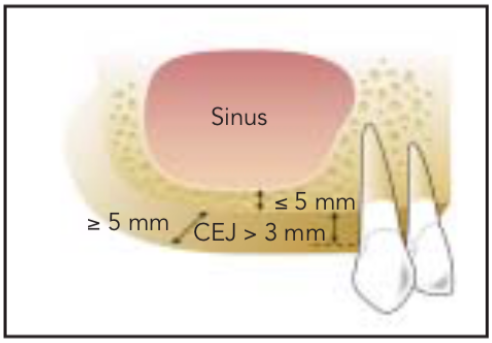


Figure 8a (9)

Class B, division h

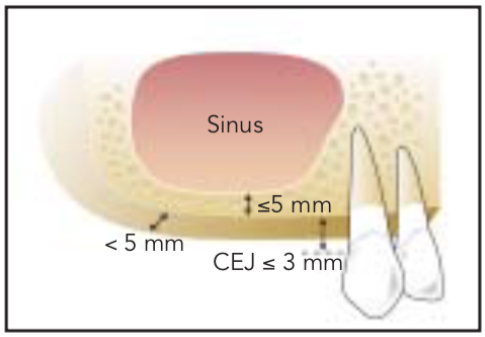


Figure 8b (9)

Class C, division v

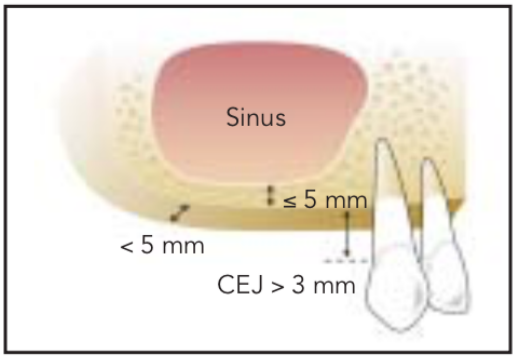


Figure 8c (9)

Class B, division c

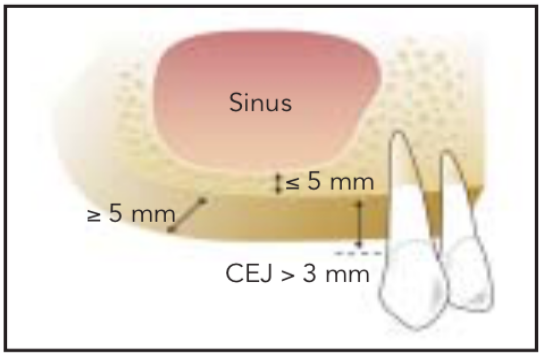


Figure 8d (9)

The ABC classification is supported by illustrated diagrams as seen on *figure 6* which presents class A. *Figures 7a,7b,7c and 7c* represents class B , B division h, B division v and B division C respectively. Finally, *figures 8a,8b,8c,8d* represent class C division h, C division v and C division c respectively.

Surgical techniques and the existing treatment protocols for maxillary sinus lift/augmentation

The posterior maxilla is considered to be one of the most challenging areas when considering dental implants as the treatment of choice to restore the posterior edentulous maxilla. This is mainly due to how close the maxillary sinus could be towards the crestal bone level and hence maxillary sinus augmentation procedures could be performed (7,10)

What is sinus augmentation? Sinus augmentation, also known as a sinus lift procedure is a technique which aims to lift the maxillary sinus floor, as well as the use of bone grafting materials to allow a rise of bone height and hence help achieve the ideal and optimum conditions for implant placement with sufficient support (10).

Currently, there are various sinus augmentation surgical techniques that are available, each of which have a specific indication. The two main techniques that are present are:

1. **The lateral window or the direct approach**
2. **The osteotome/transcrestal or the indirect approach**

Each of the two surgical techniques rely on one fundamental factor which is the distance in bone level from the floor of the maxillary sinus to the crestal bone level, also known as the residual bone height (10). When taking into account the residual bone height, one can establish a correct treatment protocol depending on the case that the patient presents. The lateral window approach, also known as the direct approach, is usually the chosen choice of treatment when the patient presents a residual bone height of 4mm or lower. However, on the other hand the osteotome/transcrestal, also known as the indirect approach is usually approached when the patient presents a residual bone height of 5mm or above (10).

1. The lateral window/ direct approach:

The lateral window technique, also known as the direct approach was first discovered by *Oscar Hilt Tatum jr* in the year 1970 (10). It is also known as the direct approach due to the fact that the dental professional could perform the procedure of sinus augmentation while having a direct visual access to the Schneiderlin membrane of the maxillary sinus (11).

Surgical technique:

The first step of the surgical procedure involves the administration of local anesthesia to the posterior superior alveolar nerve as well as the greater palatine nerve (3). A midcrestal incision is then preformed with the application of 2 vertical relievings towards the anterior and posterior region (12). The relievings could be either one or two, depending on the quantity of flap reflection that will be required. The lateral wall of the maxillary sinus is then accessed through a reflection of a mucoperiosteal flap with a trapezoid base (12). A procedure known as a trapdoor osteotomy is performed with the use of high speed burrs or piezoelectric instruments, in which bone removal is performed on the lateral aspect of the

maxillary sinus (12). The trapdoor osteotomy presents the shape of a window and must be performed taking into account specific factors to eliminate the possibility of perforation of the Schneiderlin membrane. One factor is that must be taken into account is that the inferior border of rectangular window that is preformed must have a distance of 3mm away from the maxillary sinus floor (3,7) This could be clearly seen on *figure 10a*. In addition, the posterior aspect of the window could be present above the maxillary tuberosity, but the anterior wall of the sinus should be at least 3mm away from the anterior border of the rectangular window (3).

Once the trapdoor osteotomy is preformed, a bluish purple appearance could be directly visualized, which is the Schneiderlin membrane(7). After the bone plate has been removed, it could be then used in later procedures for graft placement (7). Once a direct access to the Schneiderlin membrane is achieved, the membrane is lifted from the floor of the maxillary sinus in addition to the lateral and medial sinus walls with the use blunt instruments known as curettes (7,12). Following this procedure, the sinus membrane is now relocated dorsocranially providing an adequate space for bone grafting material to be successfully implemented in that region (12). When this step has been reached, the dental professional could then elect one of two choices: One stage implant procedure, where the implant will be directly placed with or without a bone graft with a subsequent suturing and repositioning of the mucoperiosteal flap. Or a two-stage implant procedure, where the grafting could be performed with subsequent suturing and repositioning of the mucoperiosteal flap and then implant will be placed after a healing time.

One stage or two-stage using Lateral window technique?

Nowadays, many articles have been controversial on whether or not each of the techniques is beneficial over the other. When taking into account the one stage technique, the implant is placed in the same appointment and have seen to have an advantage of a reduction in healing time by 50% (7). However, one major drawback is the possibility of lack of implant stability and hence the implants penetrating the sinus could be a critical complication (7). Therefore, whenever one doubts that implant stability could be affected, then postponing the implant placement using the two-stage technique should be the treatment of election (7).

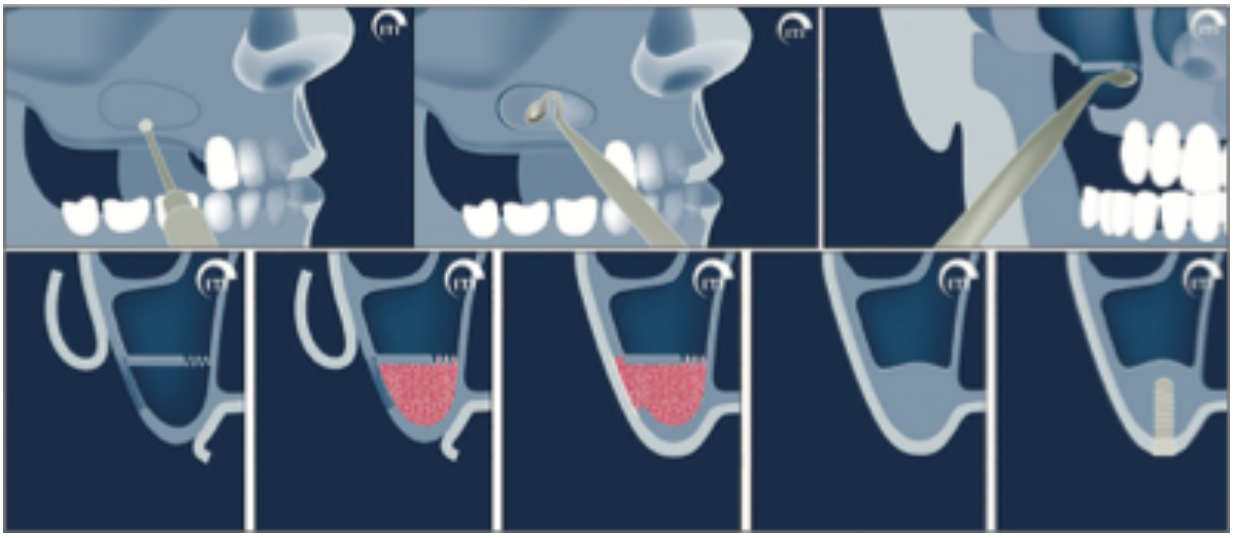


Figure 9. A graphical representation of the steps of the lateral window/ direct technique with subsequent bone graft placement and a two stage implant placement (7).

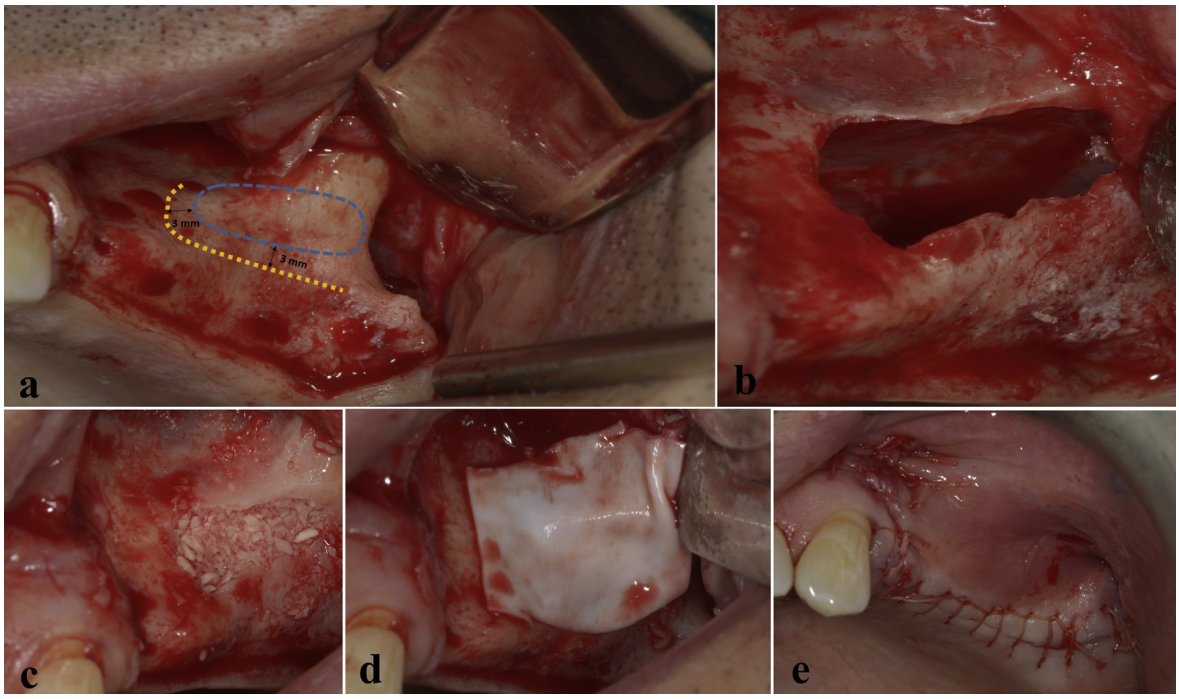


Figure 10. A clinical representation of the steps of the lateral window/ direct technique with subsequent bone graft placement. A- trapdoor osteotomy with a 3mm limit from the sinus floor and the anterior wall of the sinus. B- Direct visualization of the Schneiderlin membrane after osteotomy and trap door removal. C- Bone graft implementation. D- Collagen membrane to seal the window. E- Suturing of the mucoperiosteal flap. (3)

2. The osteotome/transcrestal or indirect approach:

The osteotome/transcrestal, also known as the indirect approach was first discovered by Robert B summers in the year 1990 (10). The indirect approach is considered to differ from the lateral window technique due to the lack of direct visualization of the Schneiderlin membrane when preforming the procedure. In the lateral window procedure, the osteotomy was performed on the lateral aspect of the maxillary sinus however in this indirect approach the maxillary sinus augmentation procedure is preformed directly through the socket. The transcrestal approach is characterized by being a simpler procedure with fewer complications

and less time consuming when compared to the lateral window technique. (10). As stated before, the transcrestal technique is approached when the residual bone height is more than 5mm.

In the year 1994, Summers identified a crestal technique which involves the use of specific tapered osteotomes with rising diameters (7). This technique had one major advantage which was that the use of drilling was eliminated and hence it is very conservative and provided less complications and risks (7).

Surgical technique:

The first step of this surgical procedure involves the use of anesthesia or sedation if required (12). A midcrestal incision is then preformed using a scalpel at the crestal area and a full thickness flap of the mucoperiosteum is reflected allowing direct visualization to the bone at the crestal area (10,12). Following the reflection of the flap, the area where the surgical procedure will be performed will be marked with a round burr on the alveolar crest as seen on *Figure 11a* (10,12). A range of osteotomes with rising diameter will then be used to prepare the area of the implant site, taking into account a fundamental factor which is the distance of the burrs should be around 1 to 2mm away from the floor of the maxillary sinus as seen on *Figure 11b* (10,12).

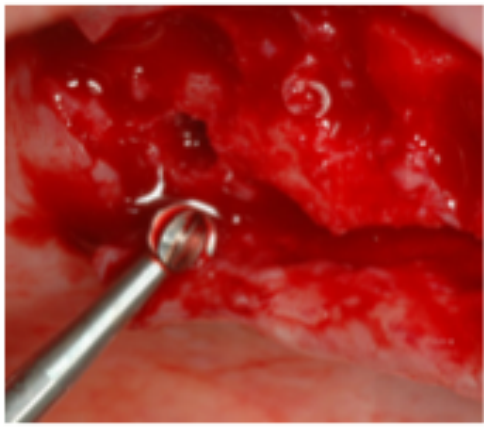


Figure 11a. The implant site is marked using a round burr at the crestal region where the surgical procedure will be performed (13).

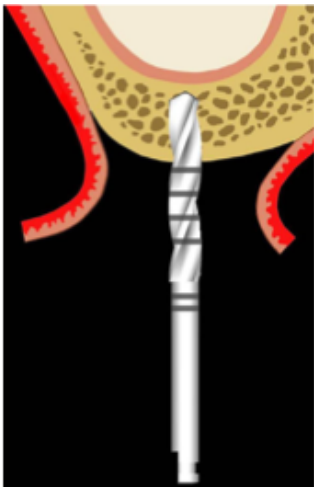


Figure 11b. The burrs present a distance of 1-2mm away from the inferior floor of the maxillary sinus (13).

Light tapping using a specific mallet is then preformed allowing an up-fracture of the floor of the maxillary sinus. The Schneiderlin membrane is then lifted using a blunt instrument (10,12). Several factors contribute to the maxillary sinus lifting which include the pressure produced by the osteotomes as well as the presence of fluids towards the membrane (10). One fundamental aspect that must be taken into account to verify the integrity of the sinus membrane using a vasalva maneuver, allowing the patient to blow while blocking their nose before graft placement (12). Following this procedure, bone grafts could be successfully implemented towards the apical area and the placement of dental implants is usually followed by this procedure. One ultimate aspect that must be taken into account which will have a direct impact on the prognosis of the surgical technique is the presence of implant stability during the placement. (12). The surgical site and flap is then sutured and the final coronal and prosthetic portion of the implant will be placed in a period of 6 months.(12)

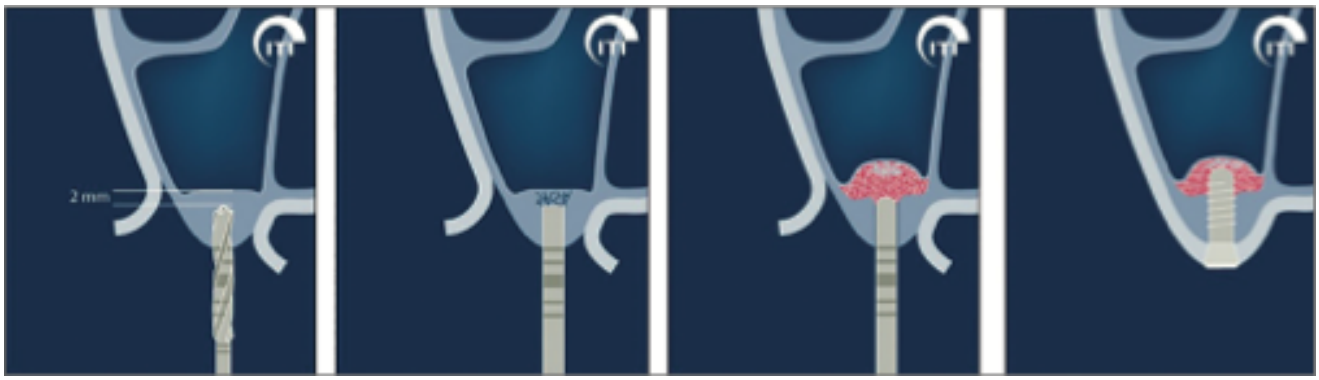


Figure 11c. A graphical representation of the steps of the transcrestal approach, showing a distance of 2mm from the pilot drill and the floor of the maxillary sinus and the placement of grafting material and subsequent implant placement. (7)

Indications and contraindications of Maxillary sinus lift/ Augmentation

Patients with loss of alveolar bone width and height could lead to an unfavorable prognosis when the treatment of choice is implant placement. (8) Posterior edentulous areas as well as periodontal disease are one of the main reasons for bone loss and therefore could require bone grafting to restore these areas. The main indication for sinus augmentation is the presence of maxillary sinus pneumatization (2,8).

What is maxillary sinus pneumatization? When a patient loses posterior teeth in the upper maxilla due to several factors, the maxillary sinus has a tendency to expand and hence achieves a closer proximity to the alveolar crest as well leading to a reduction in the residual bone height below the maxillary sinus floor (2,8). The maxillary sinus has a tendancy to expand both in the lateral direction as well as the inferior direction and hence could possibly lead to invasion till the canine region (8). It has been mentioned that bone loss occurs in edentulous areas due to the lack of occlusal forces that maintain the integrity of the surrounding bone tissue (8).

The major indication of sinus augmentation is the presence of sinus pneumatization which will impede implant placement in the maxillary posterior area. The use of shorter implants is controversial and is not considered to be an adequate solution due to the lack of implant stability which is a fundamental aspect that must be considered when achieving implant

placement with a good prognosis (8,13). The use of short implants would also require 6mm or more of residual bone height which makes it an inadequate solution (13).

On the other hand, several contraindications could impede the procedure of sinus augmentation and must be taken into account when approaching a correct treatment plan. They could be split into 2 major groups:

Medical contraindications: (2,10,13)

- Chemo or radiotherapy of the head and neck during the time of sinus augmentation or in the next 6 months.
- Immunocompromised patients with bone metabolism abnormalities.
- Uncontrolled diabetes
- Psychiatric conditions
- Drug and alcohol abuse
- Nasomaxillary complex alterations that has a direct effect on ventilation
- Allergic sinusitis, odontogenic sinusitis, viral, bacterial and mycotic rhinosinusitis.
- Active sinus infection.
- Cystic fibrosis.

Local contraindications could include smoking however it is controversial on whether smoking has a direct impact on the success of sinus augmentation. Another local contraindication would be the absence of sufficient bone as well as insufficient residual bone height that would allow a suitable environment for implant stability (2,10,13)**.**

Complications of Maxillary sinus lift/ Augmentation and postoperative instructions

When preforming a sinus augmentation procedure, various complications could occur and hence must be taken into account when establishing a correct treatment protocol. Complications that could occur are split into complications that happen during the surgical procedure, also known as intraoperative complications, or complications that happen after the surgical procedure, also known as postoperative complications (10).

Taking into account the intraoperative complications, we can identify the perforation of the Schneiderlin membrane as a critical intraoperative complication (2,3,10,11,13–15). The sinus membrane perforation is seen to have a direct negative affect on the integrity of the maxillary sinus as well as the survival of the graft material and thus must be strictly avoided to obtain a good prognosis of the surgical procedure (10).

Fugazatto and *Vlassis* obtained a classification to classify the extent of the perforation of the Schneiderlin membrane and classified it into 4 main classes (2):

- **Class I:** Perforation of the Schneiderlin membrane bordering the site of osteotomy. Class I perforations have an advantage of being able to be sealed due to the fact that the membrane folds itself when elevated (2).
- **Class II: :** Perforation of the Schneiderlin membrane in the middle and superior part of the site of osteotomy, with a mesiodistal extension of two thirds of the osteotomy site (2).

- **Class III:** Perforation of the Schneiderlin membrane in the lower border of the osteotomy site at the sixth that is present mesially or distally and is usually not common (2).
- **Class IV:** Perforation of the Schneiderlin membrane in the two thirds that are located centrally of the lower border of the site of osteotomy and is usually caused due to lack of experience or care when preforming the procedure (2).

According to an article published by *James Huang, Hui Yu and Yu chang,* the use of platelet rich fibrin allows the formation of a fibrin network as well as the stimulation of osteoblasts, fibroblasts and periodontal ligament cells and therefore could be a fundamental treatment advance in the case of membrane perforations (16).

Another Intraoperative complication is the presence of septa (2,10). Septa are usually found inside the sinus and a preoperative thorough examination must be performed with the use of radiographs such as seen in *figure 12b* to eliminate the difficulty of sinus membrane dissection and creation of the bony window (2,10). The presence of bony septa has seen to have increased the possibility of the perforation of the Schneiderlin membrane (10), therefore the use of radiography such as a CBCT scan should be performed before the procedure to analyze the presence of septa and hence a reduction in membrane perforation (14) . Bleeding present during the surgical procedure after preforming the incision is considered normal due to the presence of blood vessels surrounding the region, however sometimes severe bleeding occurs causing lack of visualization and could be challenging to control during the procedure. Therefore considering the use of piezo surgery as a treatment of choice to minimize bleeding could be taken into account (10,11). The presence of bleeding during the surgical procedure

should be directly treated by lifting the patient's head as well as compression. In the case in which this procedure did not control the bleeding, the use of a hemostat could be used or the implication of a bone rongeur to crush the bone at the bleeding sight (17).

Postoperative complications after the surgery include the presence of infection due to bacterial contamination at the site and therefore the use of antibiotics is a fundamental aspect that must be considered when these types of surgeries are performed (2,3,10). Another postoperative complication includes graft resorption (11). Several studies have been performed on evaluating which ideal grafting material should be used to prevent this complication and is still considered to be a controversial topic. For sinus lift procedures, grafting material usually takes a period of around 6 months to allow correct solidification and modeling (11). Hence, when placing the graft the time of implant placement must be considered as the graft has the tendency of being resorbed when it is not stabilized by means of an implant (11).

Postoperative instructions and care: (10)

- As mentioned before, the presence of an infection could be a postoperative complication that could occur. Therefore patients are usually prescribed antibiotics in the form of amoxicillin, amoxicillin-clavulanic acid or even clindamycin (10). If the patient is not allergic to amoxicillin, the prescription of 1g Amoxicillin/ clavulanic acid 3 times a day for a period of 1 week is usually provided (18). However, if the patient is allergic to amoxicillin, the prescription of clarithromycin 250mg and Metronizadole 500 mg 3 times a day for a period of 1 week is usually advised (18).

- To decrease the amount inflammation and pain, steroids could be prescribed as well (10).
- Patients are advised to avoid smoking as well as active activities (10).
- Patients are also advised to have a good oral hygiene and chlorhexidine mouthwashes should be provided and used on a daily basis 24 hours after the surgical procedure (10).
- In order to prevent trauma as well as an increase in sinus pressure, patients are advised to avoid nose blowing or exhalation with a lot of pressure. This is due to the fact that the membrane is still fragile and perforation or movement of the grafted material could be a complication if this activity is preformed (10,11)

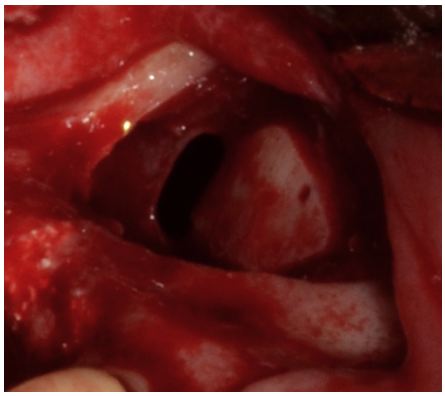


Figure 12a. A clinical representation of a perforation of the Schneiderlin membrane (11)

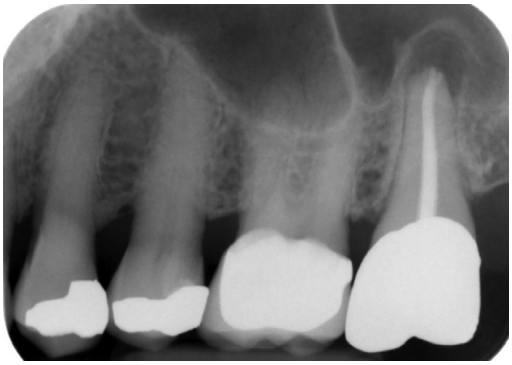


Figure 12b. A radiographic representation the presence of septa in the maxillary sinus (11)

Available biomaterials as well as grafting materials in sinus augmentation procedures

Nowadays it is considered a controversial topic on whether bone grafting procedures should be indicated in cases of sinus augmentation. It has been mentioned that the main indicator that provides dental professionals with the use of grafts is the necessity of gaining alveolar height and allowing correct implant placement ensuring stability (11). Bone grafting is considered to be a dynamic process which involves several processes including osteogenesis, osteoinduction and/or osteoconduction (19). Osteoinduction involves a process in which pluripotent cells are used to develop into preosteoblasts and allow bone formation, while Osteoconduction refers to the bone growth on the surface of the material (20). There are several different types of materials which could be used to allow bone generation when sinus lift procedures are executed, those include:

- Xenografts: which are considered to be grafts from different species (11).
- Allografts: which are considered to be grafts from the same species (11).
- Autografts: which are considered to be grafts from the same patient (11).
- Alloplast: which are considered to be graft material obtained from non-animal species for example specifically fabricated or engineered (11).

Each of these types of grafts could be obtained from different origins and hence present different characteristics. Whether which material is considered beneficial is still controversial and still requires more studies with comparison of the prognosis of each of the materials used after sinus augmentation.

The characteristics of each of the materials used could be seen below on *Table 1.*

Grafting material	***Origin***	***Desired characteristics***	***Undesired characteristics***
Xenograft	• Calcifying corals • Calcifying algae • Animal bone mineral	• Limited osteoconductive effect • Biocompatible	
Allograft	• Humans: FDBA/DFDBA	• Limited osteoconductive effect • Biocompatible • Rapid bone formation (DFDBA)	• Resorption • Bone formation takes a long time (FDBA)
Autograft	• Tibia • Illium • Symphysis • Ramus • Tuberosity • Platelet rich fibrin	• No disease transmission • Cortical and cancellous	• Requires another surgical site • Resorption
Alloplast	• Polymers • Calcium phosphate • Bioactive glass • Bone morphogenic protein	• Osteogenic, biocompatible • Bonds to bone (bioactive glass) • Osteoinductive (Bone Morphogenic Protein)	• Expensive

Table 1. comparison of the different characteristics each of the graft material presents. DFDBA: Demineralized freeze-dried bone allograft, FDBA: Freeze-dried bone allograft. (11)

The gold standard for sinus augmentation procedures are considered to be Autografts which are obtained from intra or extraoral sources (3,21). This is due to the fact that they present a very high osteogenic potential however, they present some resorption potential and are

therefore becoming less considered (3). The ideal material for grafting when doing a maxillary sinus augmentation should be able to provide biologic firmness and therefore is characterized by keeping the volume of the graft maintained and hence allowing bone remodeling and permeation of new bone (19). From a biological point of view, the ultimate and perfect grafting material should be non- toxic, with no carcinogenic potential, easy to obtain, able to withstand forces and inflammation and not expensive with a good adhesion potential (19).

2. Objectives

Recently, maxillary sinus augmentation is considered to be a very well pondered topic due to the wide range of techniques as well as materials that are available. It has been considered to be a controversial matter when electing which treatment technique or modality depending on each case the patient presents. In addition, the use of bone grafting materials when sinus augmentation is indicated is also considered to be debatable on whether it actually affects implant prognosis in the long term. Many new techniques with minimally invasive procedures are now being discovered and are considered to be alternative options to the main techniques of sinus augmentation such as the lateral window or the transcrestal technique.

This literature review will focus on 3 main objectives that will be analyzed and taken into account when reviewing the articles:

- Comparing the different techniques of sinus augmentation, as well as if the residual bone height has an influence on the chosen technique.
- Obtain a thorough analysis of the effects on residual bone height with the use of different types of grafts as well as a comparison graftless techniques to identify whether bone grafting is a fundamental aspect when a sinus lift procedure is applied.
- Identifying whether or not complications are common during sinus augmentation procedures and whether or not they affect the long-term prognosis.

Recent studies have been made in order to obtain a valid answer to which treatment election protocol is considered to be best when doing a sinus lift procedure but is still considered to be an argued topic due to many factors that should be taken into account. Therefore, this review will provide emphasis on these 3 main objectives to achieve a thorough comparison

3. Methodology

In order to conduct a thorough analysis of the chosen topic, a series of scientific articles as well as journals were searched on Medline using specific keywords including “sinus augmentation, sinus lift, grafting, bone, implant, maxillary sinus, autologous bone, dental implants, Lateral window, implant stability, sinus elevation, biomaterials and bone substitutes”. The search for these articles included full text articles which were primarily written in English. 23 articles were selected as they were published on PubMed, as well as 1 article published on Madridge Journal of dentistry and dental oral surgery and 1 article published on Medknow. The articles were published over a 5-year period from the year 2015 to the year 2020, ensuring that they are relevant and up to date.

The articles had inclusion criteria of being recent (in the last 5 years), they also included clinical as well has radiologic studies and trials on both humans and animals, randomized clinical trials and treatment outcomes of implant placement and bone grafting after a follow up period.

On the other hand, articles that were published earlier than the year 2015 were not taken into consideration. Articles that used other techniques other than the lateral window or the transcrestal approach for sinus augmentation were not considered as well as articles with the lack of clinical trials or radiographic analysis of the outcomes.

The 23 articles were analyzed taking into account specific factors and were classified into different criteria as seen on *Table 2*. Some of the studies presented multiple trials and hence a total of 37 trials were compared. The articles were classified according to the following factors:

- The author
- The Year in which they were published
- Whether the trials were made on humans or animals
- The age range as well as the mean/average age
- The number of patients included in each of the study
- The sinus augmentation technique (either transcrestal or lateral window)
- How much residual bone height the patients presented before the trial was preformed?
- Which grafting material was used?
- How many implants were placed?
- The change in bone height, implant stability quotient (ISQ) or implant survival rate
- Any complications that occurred during the trial

Author	Year	Trials on	Age range/ mean	Number of patients	Technique of Augmentation	Residual bone height	Grafting material	Implant placement time	Number of implants placed	Change in bone Height, implant stability quotient (ISQ) or survival	Complications
Waleed Fouad et al (22)	2017	Humans	21-61 (37.1)	17	Lateral window	4-6mm	Deproteinized bovine bone (Xenograft)	Simultaneous	34	8.59mm gain	2 cases with membrane perforation
Waleed Fouad et al (22)	2017	Humans	21-61 (37.1)	17	Lateral window	4-6mm	Graftless	Simultaneous	34	4.85mm gain	2 cases with membrane perforation
Pohl et al(23)	2018	Sheep	Adults	12	Lateral window	2-3 mm	Autogenous hip bone	Simultaneous	2	0.5-1mm gain in crestal area	-
Horia et al (24)	2018	Humans	32-65 (49.5)	14	Lateral window	4-5 mm	Bovine bone substitute with platelet rich fibrin	Simultaneous	40	10.12mm gain	2 cases with membrane perforation
Lobna Aly et al (25)	2017	Humans	49-68	12	Lateral window	4-6mm	Putty form of demineralized bone matrix	Simultaneous	36	Marginal bone level gain 0.56mm	-
Lobna Aly et al (25)	2017	Humans	49-68	12	Lateral window	4-6mm	Powder form of demineralized bone matrix	Simultaneous	36	Marginal bone level gain 0.40mm	-
Sherif Ali et al (26)	2015	Humans	-	46	Lateral window	Average of 2.67 mm	Platelet rich fibrin	Simultaneous	110	9.8 mm gain	3 cases with membrane perforation

Túlio Pignaton et al (27)	2018	Humans	47-73 (59.7)	20	Lateral window	<2mm	Anorganic bovine bone	8 months after (Delayed)	146	26.2% ± 9.10 gain	-
Túlio Pignaton et al (27)	2018	Humans	47-73 (59.7)	20	Lateral window	>2mm	Anorganic bovine bone	8 months after (Delayed)	146	29.8% ± 8.67 gain	-
Silvio Meloni et al (28)	2017	Humans	>18	16	Lateral window	0-4mm	100% Anorganic bovine bone	7 months after (Delayed)	24	Marginal bone loss of 1.28mm	No complications
Silvio Meloni et al (28)	2017	Humans	>18	16	Lateral window	0-4mm	50% Inorganic bovine bone + 50% autologous bone	7 months after (Delayed)	22	Marginal bone loss of 1.18mm	1 Membrane perforation, 2 chipping of the ceramic
Mamit kumar et al (29)	2018	Humans	-	14	Lateral window	3-5mm	Platelet rich fibrin with bovine bone	Immediate	-	11.6mm bone gain after 12 months	No complications
Rakshith Hegde et al (30)	2016	Humans	-	14	Lateral window	-	Grafting and non-grafting	-	24	2.37-10mm gain	-
Roni Kolerman et al (31)	2017	Humans	43-68 (58)	13	Lateral window	<5mm	Freeze dried bone allograft	9 months after (delayed)	-	27.5% ± 8.1 gain	-
Roni Kolerman et al (31)	2017	Humans	43-68 (58)	13	Lateral window	<5mm	Biphasic calcium phosphate	9 months after (delayed)	-	24% ± 6.8 gain	-
Marcello Maddalone et al (32)	2017	Humans	46-68 (56)	33	Lateral window	4-9mm	Intraoral autologous bone from ramus	Simultaneous	58	Marginal bone loss 1.22mm ± 1.6mm	2 soft tissue inflammation, few membrane perforations

Hanchi Wang et al (33)	2019	Humans	25	1	Transcrestal	<1mm	Platelet rich fibrin	Simultaneous	1	ISQ 77.2	No complications
Luca pisoni et al (34)	2016	Humans	39-72 (53.2)	22	Lateral window	1-5mm	Autogenous bone block with or without particulate bone	Delayed	-	12.55mm bone gain	6 small membrane tears, 3 hemorrhage, 3 slight wound dehiscence, 1 partial graft loss, 1 temporary alteration due to inferior alveolar nerve injury
Luca pisoni et al (34)	2016	Humans	39-72 (53.2)	19	Lateral window	1-5mm	Particulated autogenous bone	Delayed	-	10.63mm bone gain	6 small membrane tears, 3 hemorrhage, 3 slight wound dehiscence, 1 partial graft loss, 1 temporary alteration due to inferior alveolar nerve injury

Kornel Krasney (35)	2015	Humans	29-66 (44)	26	Transcrestal	>3mm	Allogenic granulate	6 months after (delayed)	26	3.38mm mean increase in ridge height with 100% implant survival	Membrane perforation
M. Falah et al (36)	2016	Humans	38-60 (52)	18	Lateral window	4-7mm	No graft	Simultaneous	72	6.14 ± 1.34mm bone gain with 94% implant survival	-
Gerrardo La monaca et al (37)	2018	Humans	50-72	6	Lateral window	0-4mm	Mineralized solvent dehydrated bone (MCBA)	6 months after (Delayed)	13	20.1 % bone gain	-
Gerrardo La monaca et al (37)	2018	Humans	50-72	6	Lateral window	0-4mm	Freeze dried mineralized bone graft (FDBA)	6 months after (Delayed)	13	32.1 % bone gain	-
Gerrardo La monaca et al (37)	2018	Humans	50-72	6	Lateral window	0-4mm	Anorganic bovine bone (ABB)	6 months after (Delayed)	13	16.1 % bone gain	-
Gerrardo La monaca et al (37)	2018	Humans	50-72	6	Lateral window	0-4mm	Equine- derived bone (EB)	6 months after (Delayed)	13	22.8 % bone gain	-

Gerrardo La monaca et al (37)	2018	Humans	50-72	6	Lateral window	0-4mm	Bicalcium phosphate	6 months after (Delayed)	13	20.3 % bone gain	-
Gerrardo La monaca et al (37)	2018	Humans	50-72	6	Lateral window	0-4mm	Bioapetite-collagen (BC)	6 months after (Delayed)	13	21.4 % bone gain	-
Huda asmael (38)	2018	Humans	-	302	Transcrestal	5mm	All different grafts	Simultaneous	514	Average bone gain of 6.96mm and 96.62 % implant survival	No complications
Radek Mounajjed (39)	2020	Humans	Mean 54.7	54	Lateral window	4.07 ± 1.87 mm	Autologous bone from mandibular ramus and β tricalcium phosphate	After 6-9 months (Delayed)	119	11.91 ± 2.80 mm bone gain	14 membrane perforations
Javier Romero Millán et al (40)	2018	Humans	54.5	62	Lateral window	4.4 ± 1 mm	β -tricalcium phosphate	Simultaneous	113	7 ± 2 mm vertical bone gain	-

Javier Romero Millán et al (40)	2018	Humans	55	48	Lateral window	3.3 ± 0.9 mm	β -tricalcium phosphate	Delayed	106	8.7 ± 2.7 mm vertical bone gain	-
Sebastian Stefanski et al (41)	2016	Humans	38-78 (58)	19	Lateral Window	5.25 mm	No grafting	Simultaneous	28	100% implant survival, 4.75mm bone height gain	6 membrane perforations
Manuel Cara fuentes et al (42)	2016	Humans	32-71	26	Lateral window	4-7 mm	No grafting	Simultaneous	38	97 % implant survival	No complications
Manuel Cara fuentes et al (42)	2016	Humans	31-69	25	Lateral window	4-7 mm	Hydroxyapatite of bovine origin	Simultaneous	38	93 % implant survival	No complications
Dong kang et al (43)	2019	Humans	54.2	15	Transcrestal	-	Bone graft placed but not mentioned what material was used	Simultaneous	33	81.8% implant survival	Ecchymosis, hematoma, periimplantitis, numbness
Adrián Millán et al (44)	2020	Humans	>18	24	Transcrestal	≥ 5mm	Bovine bone graft	Simultaneous	-	1.12 mm vertical bone gain	No complications
Adrián Millán et al (44)	2020	Humans	>18	25	Transcrestal	≥ 5mm	No grafting	Simultaneous	-	0.63 mm vertical bone gain	No complications

Table 2. Articles used in the analysis including each of the factors to differentiate between them

4. Results

1. Trials on:

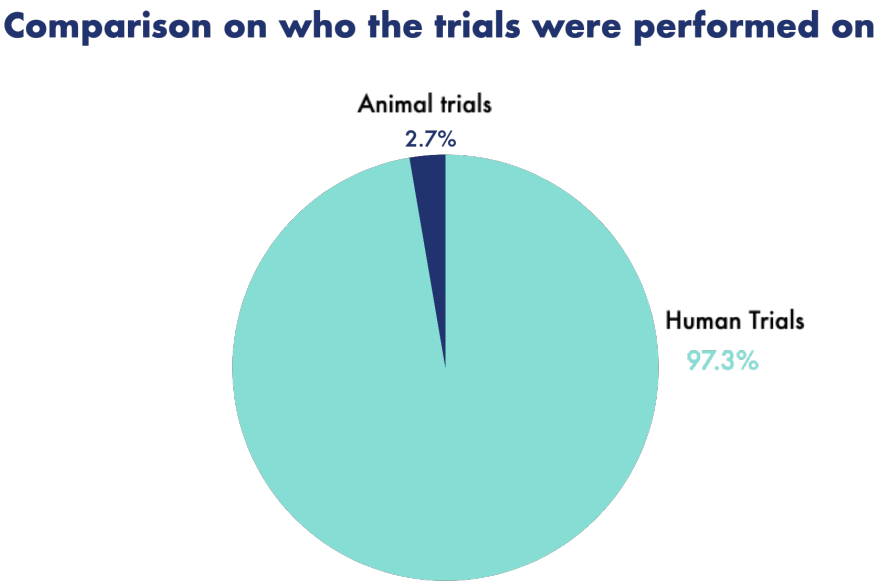


Figure 13. Comparison on who the trials were performed on in all the studies

2. Age range:

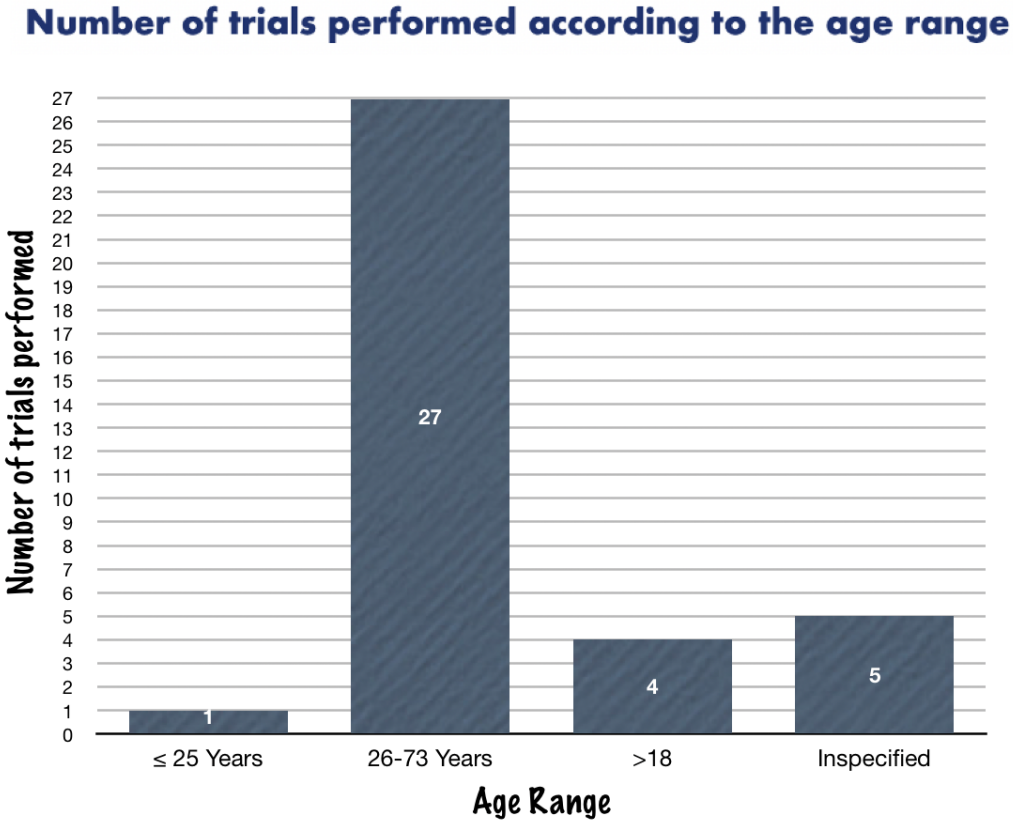


Figure 14. Comparison of how many trials were performed according to different age groups

3. Average number of patients:

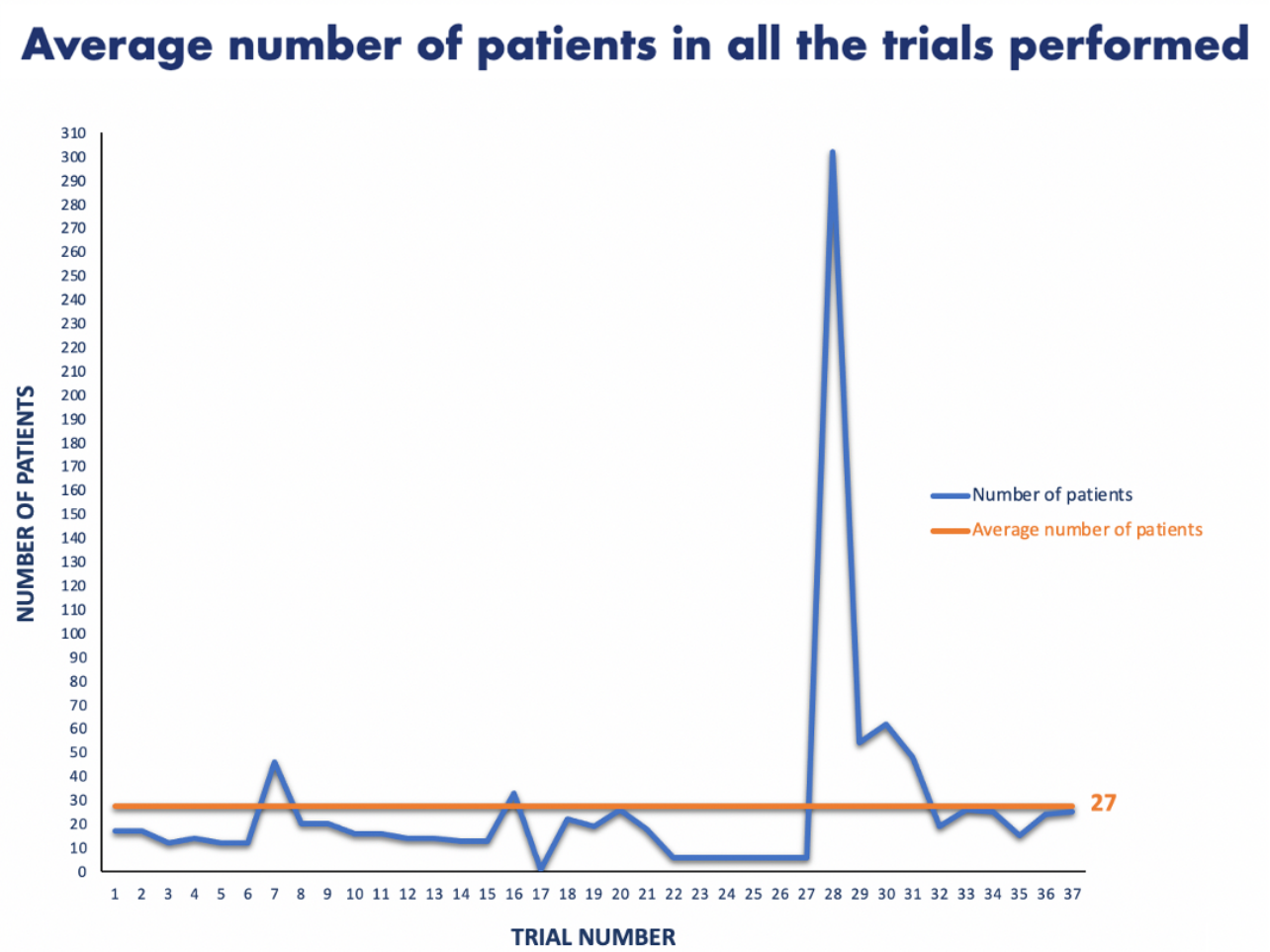


Figure 15. Graphical representation of the average number of patients in the clinical trials performed

4. Technique of sinus augmentation:

The main sinus augmentation techniques used in the studies were either using the lateral window approach or the Transcrestal approach. Each one of the techniques were applied to a number of patients as shown:

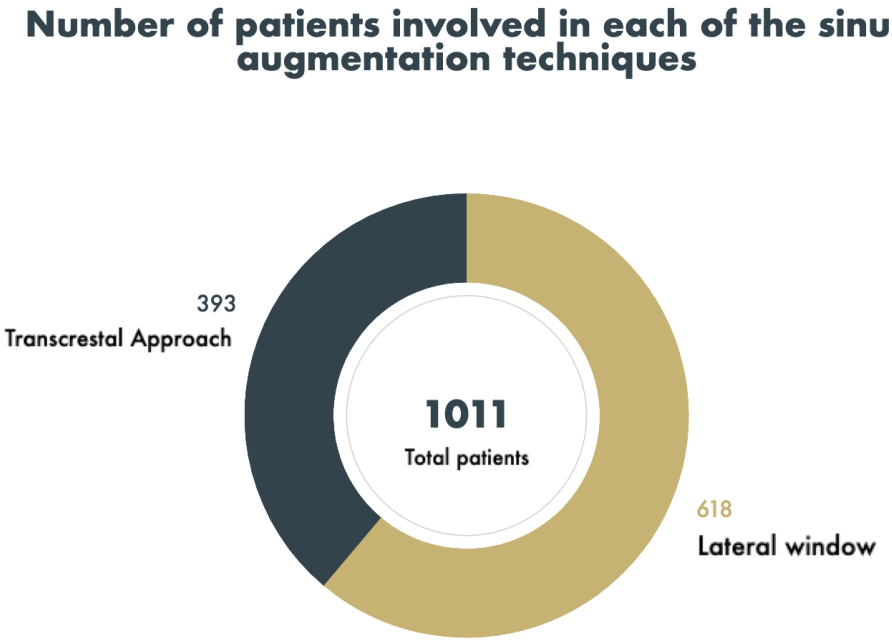


Figure 16. Representation of the number of patients involved in either the transcrestal approach or the lateral window technique of sinus augmentation

5. Residual bone height:

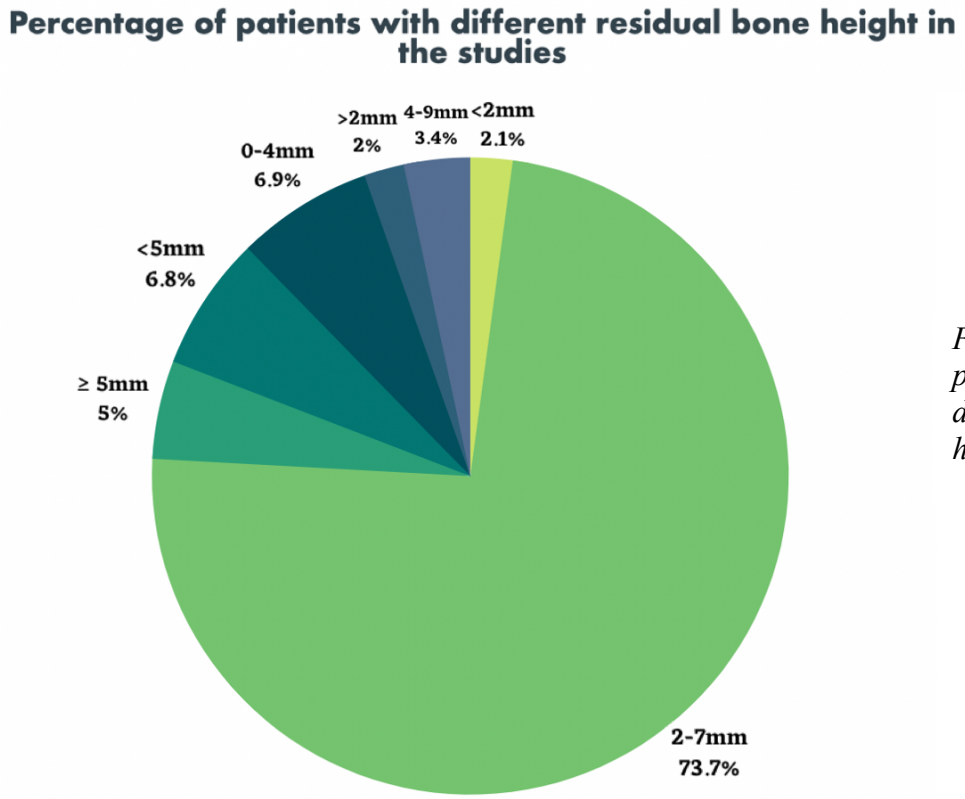


Figure 17. Representation of the percentage of patients presenting different ranges of residual bone height

6. Number of placed implants in relation to the timing of placement:

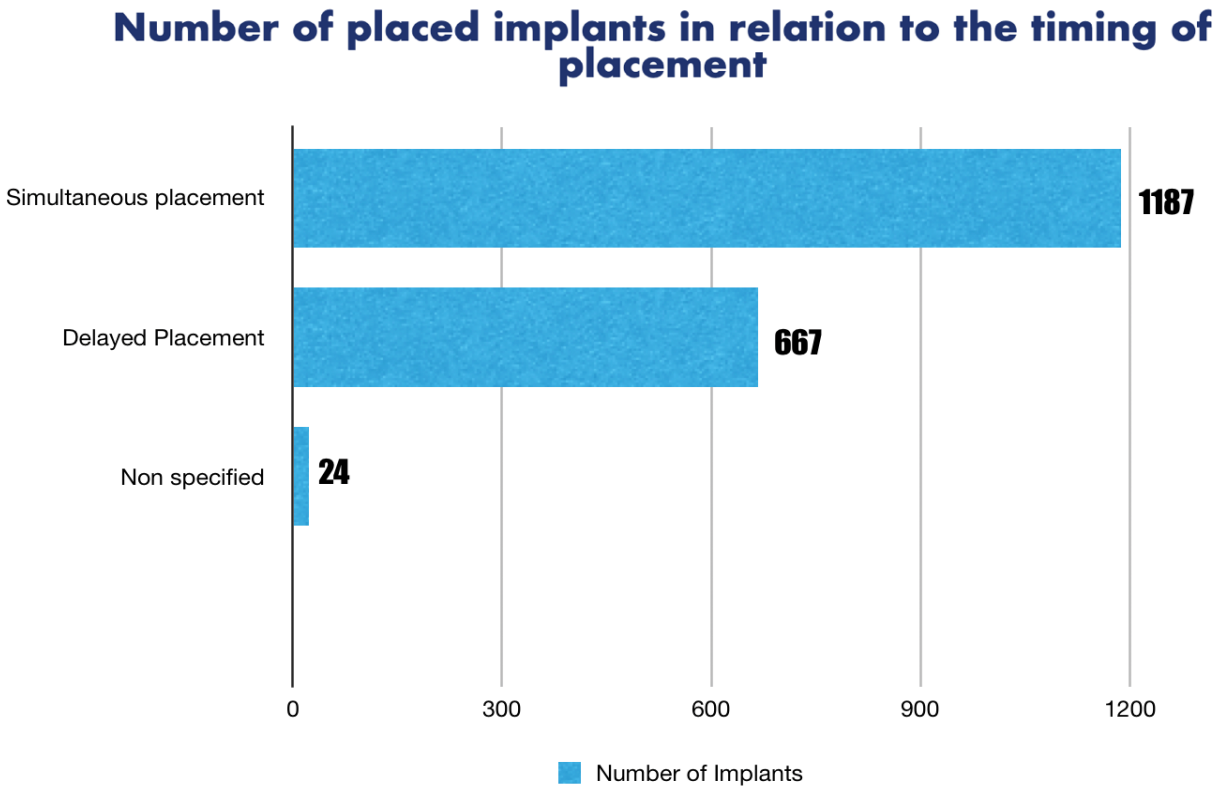


Figure 18. Graphical Representation of the number of placed implants in relation to the timing of placement

7. Complications:

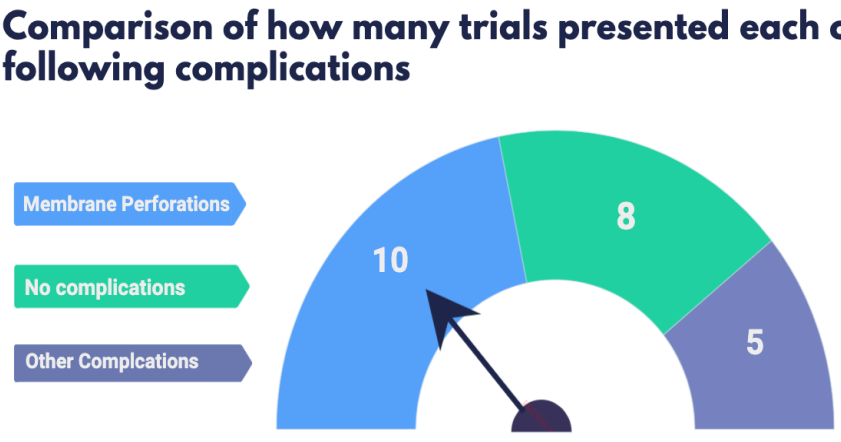


Figure 19. Comparison between the number of trials that presented membrane perforations, no complications or other complications

8. Grafting materials used in relation to the average gain in residual bone height in all of the trials:

Material Used for grafting	Number of placed implants	Average gain in residual bone height in the trials
Deprotinized bovine bone	34	8.59 mm
Graftless	172	4.092 mm
Autogenous hip bone	2	0.5-1 mm
Bovine bone substitute with platelet rich fibrin	40	10.86 mm
Putty form demineralized bone matrix	36	0.56 mm
Powder form demineralized bone matrix	36	0.40 mm
Platelet rich fibrin	111	9.8mm
Anorganic bovine bone	367	29.8% bone gain
50% inorganic bovine bone + 50% autologous bone	22	Loss of 1.18mm
Frozen dried bone allograft	13	29.8% bone gain
Biphasic calcium phosphate	13	22.15% bone gain
Intraoral autologous bone from ramus	177	5.3 mm
Autogenous bone block with or without particular bone	Non specified	12.55 mm
Particulated autogenous bone	Non specified	10.63 mm
Allogenic granulate	26	3.38 mm
Mineralized solvent dehydr ated bone (MCBA)	13	20.1% bone gain
Equine derived bone	13	22.8% bone gain
Bioapetite collagen	13	21.4 % bone gain
β Tricalcium phosphate	219	2.14 mm

Table 3. Illustration of the different types of bone grafting materials used in all the trials taking into account to the average gain in residual bone height and number of placed implants.

5. Discussion

Recently, maxillary sinus augmentation procedures are considered to be becoming increasingly prevalent before implant placement in the cases of bone atrophy of the posterior maxilla mainly due to maxillary sinus pneumatization (45). In 1970, *Hilt Tatum* first introduced the use of bone grafting materials in sinus augmentation procedures with the aim of increasing the bone level and most importantly the bone-implant contact area hence achieving an increased stability and long term prognosis of the implant (45). Maxillary sinus lift procedures have evolved over time, with the creation of new advanced and less invasive techniques with the use of different bone grafting materials to recondition the posterior maxilla.

This study had a major aim of comparing the main different techniques of sinus augmentation and how they could influence the long-term prognosis of implant placement. It also focuses on obtaining a complete analysis of the use of different bone grafting materials after sinus augmentation or even the use of graftless techniques. This will allow an assessment on whether sinus augmentation procedures should always require bone grafting or not and what grafting material achieved the best long-term prognosis and increased residual bone height. In order to achieve this goal, 23 studies (with a total of 37 trials) from the past 5 years were thoroughly evaluated. In order to achieve a correct review of the articles, specific variables were chosen and were compared in each of the studies presented.

According to the studies, sinus augmentation was performed on either humans or animals and therefore this was included as a first variable. Out of a total of 37 trials that were performed, 36 trials were achieved on humans having a value of 97.3% of the total trials as seen on *figure 13.* Only 1 trial was performed on animals in the form of sheep having a value of only 2.7% of the

total trials. Therefore, the majority of the sinus lift procedures were predominantly focused on humans in this study.

In addition, another variable that was taken into account was the age range of the individuals in the study. In order to achieve an accurate comparison between the success of each of the sinus lift procedure, it was essential to take into account the age of the individuals due to the fact that the age could have a direct effect on the results, in such that a change in bone density could occur with increased age. This variable was considered to present a limitation when splitting the trials into different age groups due to the fact that some studies did not mention the age of the patients and some articles did not mention an age range but mentioned an average age. The studies that mentioned the average age were placed in a range as mentioned in *figure 14.* The trials that presented only an age range, were classified corresponding to the age range seen in *figure 14.* Out of a total of 37 trials, 15 mentioned an average age, 5 trials did not specify the age and the rest mentioned an age range. As seen on *figure 14*, the age was split into 3 major groups. The first group demonstrated trials that have been performed on patients with an age range of below or equal to 25 years of age. Only 1 trial was performed according to the study by *Hanchi wang* on an individual aged 25 (33). On the other hand, the majority of trials were performed on individuals aged between 26 and 73 years of age with a value of 27 trials. One study performed by *Silvio Miloni* in the year 2017, involved 2 trials that were done on individuals with an age of greater than 18 years old. This study did not mention an average age or an age limit but stated a minimum age and hence had its own category in *figure 14* (28). In addition to that study, another study by *Adrián Millán* in 2020 performed 2 trials on individuals with an age of greater than 18, therefore a total of 4 trials were performed on individuals with an age of greater than 18 as seen

on *figure 14* (44). A total of 5 trials did not mention the age of the patients involved in sinus augmentation.

Furthermore, another variable was considered which was the number of patients in each of the trials. It was seen that maxillary sinus augmentation was performed on a various number of patients varying from only 1 patient to a peak of 302 patients in the studies. Therefore, in order to avoid mathematical errors, the average number of patients was calculated by adding the total number of patients involved in all the trials (1011 patients) and dividing that by the total number of trials (37 trials). As perceived in *figure 15* the average number of patients presented a value of 27 patients. When analyzing all 23 studies, one can notice that the study performed by *Kornel Krasney* was executed on a total number of 26 patients (35). Moreover, in the study performed by *Manuel Cara Fuentes,* sinus augmentation was achieved without bone grafting and with the use of the lateral window approach on a total of 26 patients as well (42). Both of these studies presented trials on a total number of patients that were seen to be the closest to our average number of patients in all the studies. On the other hand, the study performed by *Huda Ismael* in 2018 involved a total number of 302 patients which was seen to be the furthest away from our average (38).

Taking into account the technique of sinus augmentation, it was found that in all 23 studies the focus was on 2 main techniques which was either the Transcrestal approach or the Lateral window approach. As stated before, each of the two surgical techniques rely on one fundamental factor which is the distance in bone level from the floor of the maxillary sinus to the crestal bone level, also known as the residual bone height (10). Therefore, in our study the residual bone

height varied from one patient to another and hence the technique. It was decided to classify how many patients were involved in each of the sinus lift technique as seen in *figure 16.* After analyzing the total number of patients which were involved in each of the techniques, it was seen that most studies implemented the use of the lateral window approach when compared to the transcrestal approach. Out of a total of 1011 patients, 618 patients had sinus augmentation using the lateral window approach and 393 patients using the transcrestal approach. These values indicate that almost a double number of patients were involved in the lateral window approach when compared with the transcrestal approach.

When electing which treatment option should be implemented, the residual bone height counts as a fundamental aspect that we must take into account hence this was considered as a variable in the studies performed. According to all the studies, the range of residual bone height varied slightly and was not constant therefore it was decided to split the range of residual bone height into different groups and place the number of patients with the corresponding residual bone height into each of the groups. A limitation that was encountered during this classification was that not all studies mentioned the exact range of residual bone height, as well as some mentioning only a minimum value of residual bone height or not mentioning it at all. Therefore, it was found to be appropriate to split them into these following groups as seen on *figure 17* :

- <2 mm
- >2 mm
- 4-9 mm
- 0-4mm

- 2-7mm
- <5mm
- ≥ 5mm

The studies performed by *Rakshith Hegde* and *Dong Kang* did not mention the residual bone height that was present in their patients and therefore were excluded from the classification (30,43). It was observed that 73.7% of the population in our study presented a residual bone height that falls in the range between 2 and 7mm as seen on *figure 17.* Out of a total of 982 patients, only 21 patients had a residual bone height of less than 2mm hence with a percentage value of 2.1% of the whole population. One study by *Túlio Pignaton* presented a trial on 20 patients with residual bone height of >2mm, hence not specifying the range of residual bone height and therefore it had its own classification as seen in the chart in *figure 17.* In addition, the study by *Adrián Millán* presented the same issue by only mentioning a minimum residual bone height of more than or equal to 5 and hence was placed in its own classification, presenting a value of 5% of the total population. Only 1 study by *Marcello Maddalone* in 2017 presented 33 patients with a residual bone height between 4-9 mm, accounting for 3.4% of the total population. Finally, 6.9% of the total patients presented residual bone height of 0-4mm and 6.8 % presented bone height of <5mm.

As stated before, the chosen technique of sinus augmentation depends on one main factor which is the residual bone height. The article by *Khehra et al* in the year 2020 indicated that the use of the lateral window approach is implemented when the residual bone height is less than or equal to

4mm and the transcrestal approach is acheived when it is greater than 5mm. In our study, all of the articles comply with these requirements except one article by *Hanchi Wang*(10,33). In the year 2019, *Hanchi Wang* performed a clinical trial on a 25 year old patient that presented a residual bone height of less than 1mm using the transcrestal approach instead of the lateral window approach and consequently this study was considered to be an anomaly due to the fact that it does not fulfil the residual bone height requirements for sinus lift procedures and implant placement (33). Surprisingly, *Hanchi Wang* demonstrated remarkable results when implementing this surgical procedure, presenting a very high implant stability 10 months postoperatively and no complications during or after the procedure (33). He therefore concluded that a transcrestal approach in residual bone height levels of less than 1mm could possibly achieve an effective and reliable outcomes(33). Taking into account SA3 and SA4 by *Misch's* classification, *Misch* recommended the use of the lateral window approach with delayed implant placement and subsequent bone grafting (8). 6 out of our 23 articles complied with these requirements for example the study by *Silvio meloni* in 2017 performed sinus augmentation on 32 patients which were split into 2 groups of 16 (28). One group presented a residual bone height of 0-4mm and the use of 100% inorganic bovine bone as a bone graft with delayed implant placement was indicated, while the other group presented also a residual bone height of 0-4mm and the use of 50% bovine bone and 50% autologous bone with delayed implant placement was achieved (28).

When analyzing all the studies in this review, it was perceived that the timing of implant placement was of great importance during the surgical procedures that were performed. Implant placement was either simultaneously after sinus augmentation or delayed after a period of at least 6 months. Out of a total of 23 articles, only one article by *Rakshith Hegde* did not mention

whether implant placement was either simultaneous or delayed (30). A thorough comparison between the number of placed implants and the timing of placement can be observed in *figure 18*. It was seen that the preponderance of implant placement was done simultaneously during the surgical technique, with a value of 1187 implants. While on the other hand, only 667 implants were placed after a delay period of at least 6 months.

In order to conduct an in-depth comparison between the studies, the complications that each of the studies presented were taken into consideration. The most prevalent type of complication during the surgical procedure was the membrane perforation and hence it was mainly focused on in our study. Out of a total of 37 trials, membrane perforations have occurred in 10 trials as seen on *figure 19* showing the majority. On the other hand, 8 trials did not present any complications and only 5 trials presented other complications other than membrane perforations such as ecchymosis, hematoma, periimplantitis and numbness. 14 trials did not mention any information regarding any complications that occurred and hence were not taken into account in the evaluation. According to the study by *Radek Mounajjed* in 2020, membrane perforations were the highest in his study when compared with other studies, showing a total of 14 membrane perforations (39). It has been highlighted in the study by *B.Beck et al* in the year 2018 that early detection of sinus membrane perforations as well as their correction with immediate surgical dressing have led to no negative effect on the long-term prognosis and the implant survival rate of dental implants (15). Although many complications could occur when sinus lift is performed, the skills of the professional must be taken into account as it could have a direct influence on their appearance.

Many studies nowadays have been debatable on whether or not sinus augmentation should be performed with the use of bone grafting materials to achieve a better prognosis and a higher success rate of the procedure. The use of bone grafting materials has an ultimate goal of increasing the bone height and quantity hence allowing an increased implant stability. A myriad of biomaterials is present nowadays, however which biomaterial should be chosen for bone grafting is considered to be a well-pondered and controversial topic and is still currently under investigation.

When analyzing each of the articles in the study, many articles mentioned different types of biomaterials used for bone grafting as well as some studies performed graftless techniques, while others did not mention what was used. It was decided to calculate the total number of implants placed with each bone grafting material as seen in *Table 3*. In our study, it was seen that the highest number of placed implants were done using inorganic bovine bone as a biomaterial for bone grafting with a total of 367 placed implants. The least number of placed implants was using autogenous hip bone, where only 2 implants were placed. The study by *Luca Pisoni* in 2016, presented a comparison on the success of using autogenous bone block with or without particular bone or the use of particulated autogenous bone (34). The limitation of this study is that it did not mention how many implants were placed for each technique and hence was not taken into consideration when comparing the number of implants (34). A total of 5 trials performed sinus augmentation without the use of a bone graft and a total number of 172 implants were placed.

With the aim of obtaining an in-depth comparison of the effectiveness of each biomaterial when used as a bone graft, an average gain in residual bone height was calculated in all of the trials. It was aimed that the change in the value of residual bone height was calculated in units of millimeters, however some articles only presented the increase in bone height as a percentage and hence the heterogeneity of the data could have caused errors. As stated before, the gold standard for sinus augmentation procedures are considered to be Autografts which are obtained from intra or extraoral sources which present a very high osteogenic ability (3,21). In our studies, autografts have been obtained from various areas such as the ramus of the mandible or even the hip bone.

According to the average bone gain in all of the trials, autogenous bone with or without particulated bone presented the highest gain in residual bone height with a value of 12.55mm as seen on *table 3.* In the year 2016, *Luca Pisoni* concluded that the use of an autogenous bone block presented a significantly higher bone gain and decreased resorption when compared with particulated autogenous bone after a 3 year follow up(34). Autografts have seen to be the most effective in our study, for example as stated by the study by Marcello Maddalone, the use of an autograft from the mandibular ramus achieved remarkable results in terms of long term implant stability (32). One recent and interesting study by *Radek Mounajjed* in 2020 achieved bone grafting with autogenous bone from the ramus of the mandible and mixed it with an alloplast in the form of Beta tricalcium phosphate (39). This study concluded a total of 11.91 mm of bone gain with an implant success rate of 94.95% (39). The implementation of mixing biomaterials such as in this case should be considered when trying to achieve a significant bone gain as well as a better long-term prognosis.

The use of platelet rich fibrin has seen to have a positive effect on the residual bone gain with an average of 9.8mm, therefore using platelet rich fibrin as an autologous graft could be considered beneficial in sinus augmentation. In addition, some studies applied the use of xenografts in the form of bovine bone obtained from animals to evaluate their efficiency. One study by *Waleed Fouad,* achieved a randomized trial on a series of patients with the goal of comparing the use of a Xenografts, in the form of bovine bone, with graftless techniques after sinus floor elevation (22). The lateral approach was used in this study and the use of the xenograft provided a higher residual bone heigh gain of 8.59mm when compared with the graftless procedure, which presented only 4.85mm gain in residual bone height (22). He later concluded that both are considered to be reliable but the implementation of xenografts achieved better results (22). The comparison between xenografts and graftless techniques were also mentioned in a study by *Manuel Cara Fuentes* where he implemented the use hydroxyapatite of bone origin as a xenograft (42). In that study, he concluded that there was a 97% rate of implant survival when graftless techniques were used while 93% in the case of xenografts (42).

In 2018 *Gerrardo La monaca* achieved a comparative study of 6 biomaterials used in sinus augmentation with a 6 month follow up period (37). He compared the use of different allografts such as mineralized solvent dehydrated bone (MCBA), freeze dried mineralized bone graft (FDBA) and equine derived bone with alloplastic materials in the form of bicalcium phosphate and bioapatite collagen and finally a xenograft in the form of bovine bone (37). According to his study, he concluded that all biomaterials achieved notable biocompatibility, however FDBA achieved the highest percentage bone gain of 32.1% with the best histomorphological properties (37).

Although the wide range of biomaterials have achieved a great prognosis, especially with the increase in residual bone height, graftless procedures in the studies have also showed significant results for example in the study by *M.Falah* a 6.14mm of residual bone height gain with a 94% implant survival was achieved. The application of new materials are available nowadays due to updated technology for example the use of stem cells in sinus augmentation is seen to have presented notable results in regards with bone regeneration and hence new studies and trials are being implemented to find out which material is considered to be the ideal material in sinus floor elevation techniques (46).

It must be emphasized that some limitations in the study could have influenced the results this is due several factors. One factor is that not all the studies presented the same follow up period and hence diverseness between results could occur. Some articles did not mention the age of the patients, the exact residual bone height or how many implants were placed with each technique. The residual bone height change was sometimes mentioned in the form of a percentage instead of millimeters which could have led to errors. Consequently, further studies should be performed with the same variables and the same units with an exact follow up period to avoid anomalies and fluctuated results.

6. Conclusion

After a thorough evaluation of all the studies used in this review, it was able achieve an approximate conclusion:

- It was observed that in the studies, the 2 main sinus augmentation procedures used were the lateral window approach and the transcrestal approach. All studies except 1 correspond with the requirements that the lateral window approach should be implemented when the residual bone height is less than or equal to 4mm and the transcrestal approach is achieved when it is greater than 5mm.

- An abundance of biomaterials are present with the goal of achieving a successful increase in residual bone height and improved implant stability. It was identified that autografts achieved the highest residual bone height gain, although graftless techniques and other biomaterials have achieved comparable results.

- Several studies have mentioned complications that have occurred postoperatively or during the procedure, with sinus membrane perforations being the most prevalent.

- The long-term prognosis of implants is directly influenced according to the degree of membrane perforations. Early detection of membrane perforations with correct dressing has had a positive effect on implant survival.

7. Responsibility

Maxillary sinus augmentation is considered to be a profound and a well-discussed topic in the field of oral implantology. A significant number of scientific articles are being published day by day in order to achieve a thorough comparison of the different techniques as well as the different materials used in this surgical procedure. Several authors have introduced new techniques for elevation of the maxillary sinus in addition to the 2 standard techniques that were discussed in this review. These techniques vary from using minimally invasive procedures, with the aim of avoiding postoperative complications, to the use of fewer instruments and materials as well as a reduction in the number of steps thus allowing a vast reduction in the cost as well as the time needed to perform sinus elevation.

When approaching this surgical procedure from an economic point of view, a vast majority of patients have considered it to be an expensive procedure. Therefore, scientific trials and reviews are constantly being performed with the aim of reducing the cost of the procedure while keeping the quality of the treatment at the desired level and with an ultimate goal of achieving a more conclusive and definitive protocol for everyday use.

On the other hand, it has been evident that edentulism could possibly lead to negative emotional effects on patients and could potentially lead to depression. Therefore, the use of dental implants to restore posterior edentulous areas could eventually lead to a beneficial effect on the patient's self-esteem and social life.

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10. Annexes

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Anatomy, Head and Neck, Nose Paranasal Sinuses

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Introduction

The nasal cavity is a roughly cylindrical, midline, airway passage that extends from the nasal ala anteriorly to the choana posteriorly. It is divided in the midline by the nasal septum. On each side, it is flanked by the maxillary sinuses, and roofed by the frontal, ethmoid, and sphenoid sinuses, in an anterior to posterior fashion. While seemingly simple, sinonasal anatomy is composed of intricate and subdivided air passages and drainage pathways that connect the sinuses.

Structure and Function

There are 4 paired sinuses in humans. They are all in line with pseudostratified columnar epithelium.

- The maxillary sinuses: Largest of the paranasal sinuses, located under the eyes in the maxillary bones.
- The frontal sinuses: Located superior to the eyes within the frontal bone
- The ethmoid sinuses: Formed from several discrete air cells within the ethmoid bone between the nose and eyed
- The sphenoid sinuses: Located within the sphenoid bone

The function of the paranasal sinuses is debated. However, they are implicated in several roles:

- Decreasing the relative weight of the skull
- Increasing the resonance of the voice

Maxillary Sinus Augmentation

Naveen Mohan, DDS[a,*], Joshua Wolf, DDS[a], Harry Dym, DDS[a,b]

KEYWORDS

• Sinus elevation • Lateral window • Lateral antrostomy • Transalveolar

KEY POINTS

- Atrophy of the posterior maxillary alveolar bone is commonly encountered after tooth loss.
- There are 2 main approaches to sinus augmentation in preparation for implant placement: transalveolar and lateral antrostomy.
- Knowledge of the complications associated with this procedure is essential for successful treatment.

HISTORY

The presence of the maxillary sinuses mystified scientists for several hundreds of years. Galen is credited as one of the first people to recognize the existence of the paranasal sinuses. He noted porosities in the bone that he thought made the head less heavy.[1]

Little scientific progress was made during the middle ages. During the Renaissance, Leonardo da Vinci and Andreas Vesalius both described the paranasal sinuses, including the maxillary sinus, in great detail. Fallopius recognized the enlargement of the sinuses with age. In the seventeenth century, Nathaniel Highmore recorded a case of odontogenic, purulent sinusitis.[2]

The American George Caldwell and the Frenchman Henry Luc separately described a procedure to access the maxillary sinus using a lateral window in 1893.[3] The procedure was used to treat disorders of the antrum.

In the 1970s, Tatum and colleagues[4] used the sinus cavity to increase available bone using graft material, which allowed greater implant-to-bone contact area once the bone graft matured.

PNEUMATIZATION OF THE SINUS

There has been a downward trend in rates of tooth loss in the United States. However, because of the growing elderly population, the absolute number of lost teeth is

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Review

A comprehensive clinical review of maxillary sinus floor elevation: anatomy, techniques, biomaterials and complications

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Abstract

Several systematic reviews have shown that maxillary sinus augmentation is a predictable and effective procedure for augmentation of an atrophic posterior maxilla. However, we know of no reviews that have covered all the clinical aspects. We searched the PubMed, EMBASE, Cinhal, and Cochrane databases up to January 2015 to select relevant studies that cover the different objectives of this review, including the anatomy of the maxillary sinus, surgical techniques, biomaterials used in the sinus augmentation, and potential complications.

Keywords: Sinus augmentation; Bone grafting; Sinus lift; Membrane perforation; Septa; Piezosurgery

Anatomy

The maxillary sinus is the largest of the paranasal sinuses and in adults contains roughly 12-15 ml of air.[1] It is a pyramidal structure with its base close to the nasal cavity, the superior portion forming the floor of the orbit, and the apex towards the zygomatic bone.[2] The ostium is an oval or slit-shaped drainage port that acts as an overflow drain located in the superior aspect of the medial wall.[2,3] The distance between the nasal floor and the semilunar hiatus varies between 18 and 35 mm (mean 25.6 mm).[4] The fact that the ostium is high in the medial wall reduces the likelihood of a blockage during augmentation.[5]

The floor of the sinus extends anteriorly to the premolar or canine region and posteriorly to the maxillary tuberosity with in many cases its lowest part close to the area of the first molar.[6] The floor of the maxillary sinus is the thickest wall in dentate adults, and is about the same level of the nasal floor. In an edentulous patient it is 1 cm below the nasal floor. Septa are made of cortical bone and are located on both horizontal and vertical planes in the sinus floor.[7,8] Several authors have noticed the presence of septa in 25% to 31.7% of maxillary sinuses,[9,10] which can vary between 2.5 and 12.7 mm in length and can be found in any area of the maxillary sinus.[10], There were considerably more septa in edentulous or atrophic ridges than in partially edentulous or non-atrophic arches.[7,9]

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Review Article

Lateral trap-door window approach with maxillary sinus membrane lifting for dental implant placement in atrophied edentulous alveolar ridge

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Abstract

One of the most challenging and technically sensitive surgical procedures in conjunction with dental implant rehabilitation is sinus membrane lifting to increase the bone height or volume from the maxillary sinus floor. This important preprosthetic surgical technique has been available for >15 years, making possible the creation of bone volume in the edentulous posterior maxilla for the placement of dental implants in surgically compromised cases. Substantial literature exists regarding the most efficacious way to increase the predictability of this surgical procedure, and reduce its associated complications. In this article, we describe the regional anatomy of the maxillary sinus, the evolution of the sinus membrane lifting procedure, the current surgical technique, its survival rate and associated complications, the need for bone graft or bone substitutes, and current advances in the lateral approach through a trap-door window for sinus membrane lifting for dental implants.

Keywords: bone graft; dental implant; lateral approach; sinus lift

1. Introduction

The most challenging oral rehabilitation where dental implants are used is frequently found in severely surgically compromised atrophied edentulous alveolar ridges that are thin, sharp, and shallow. To meet the basic requirements for implant surgery in such conditions, the atrophic ridge could be rebuilt utilizing many well-known techniques.[1–5] The loss of maxillary molar teeth tends to have a rapid resorption in the alveolar bone below the maxillary sinus floor. Conventionally, placement and integration of endosseous implants in patients with such atrophic ridges requires elevation of the maxillary sinus floor. The process of sinus floor elevation, also called sinus lift procedure, is an internal augmentation of the maxillary sinus membrane, with or without grafts, in order to increase the vertical bony dimension of the sinus chamber in the lateral maxilla. This created space customarily allows the possibility of a dental implant to be inserted from the alveolar ridge to this chamber, to thereafter wait for osseointegration from the regenerating grafted bone.[6,7]

2. Anatomy of the maxillary sinus

The maxillary sinus has a multitude of conceivable functions. Some of these functions include adding resonance to the voice, participating in the olfactory process, warming and humidifying the inspired air, and reducing the weight of the skull. Typically, in the adult facial area of the skull, the maxillary sinus is a pyramidal-shaped bony cavity with its base at the lateral nasal wall and its apex extending into the zygomatic process of the maxilla. The whole sinus bony

Conflicts of interest: The authors declare that there are no conflicts of interest related to the subject matter or materials discussed in this article.

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Tridimensional Analysis of Maxillary Sinus Anatomy Related to Sinus Lift Procedure

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and Mario Groisman, DDS, MSc§

Purpose: *To evaluate the angulation of the maxillary sinus walls at the apical sinus region.*

Materials and Methods: *Using preoperative computerized tomographies of 15 patients selected for sinus lift procedures, the angulation of the maxillary sinus floor was measured drawing straight lines tangential to the mesial and lateral walls. The measurements were taken from sagittal images at specific areas (*i.e., *second bicuspid, first molar, and second molar).*

Results: *The results showed that the second bicuspid sites have a sharper angulation than the second molar sites, and these second molar sites have a sharper angle than the first molar sites.*

Conclusion: *The sharper angle observed in the second bicuspid area can influence the feasibility of schneiderian membrane evaluation when compared to the molar areas. (Implant Dent 2006;15:192–196)*

Key Words: *maxillary sinus, computerized tomography, sinus lift*

In the early stages of oral implantology, based on the treatment protocol for totally edentulous patients postulated by Adell *et al*,[1] the posterior areas, both in the maxilla and mandibula, were not used for oral rehabilitation with osseointegrated implants. This fact conferred to the prostheses installed over these implants biomechanical aspects that were unfavorable because of the absence of posterior fixtures. The alveolar ridge absorption process after dental extraction results in an initial lessening of the thickness of this ridge on the buccal aspects as well as a lessening of the height of the ridge. Consequently, these result in having inadequate bone height for the installation of osseointegrated implants. This is because the posterior regions of the arches present critical anatomical structures that make it impossible to use implants of adequate length.

New techniques have been created for bypassing and solving such limitations, like sinus lift surgery that can transform these posterior areas into potential sites for oral rehabilitation with osseointegrated implants. The maxillary sinus consists of an area of unique characteristics because after dental extraction, there may be pneumatization of the cavity, which consists of an increase in its volume so as to reduce, even more, the available bone height. Furthermore, in this area, we find bone density that is less favorable for the placement of osseointegrated implants.[2] These unfavorable aspects result in lower success rates of implants placed in this region when compared to others regions in the oral cavity.[3]

The maxillary sinus lift technique consists of surgical access through a lateral opening in the external maxilla wall to reach the schneiderian membrane for its apical displacement and installation of the graft material in the floor of the cavity. This process should result in sufficient bone height for insertion of implants. Usually this technique generates foreseeable and satisfactory results, even when using variations in the basic surgical protocol, such as the placement of implants and elevation of the maxillary sinus floor simultaneously, or the use of different types of grafts.[4] However, when the schneiderian membrane is perforated during the surgical procedure, the outlook for treatment is compromised. This membrane perforation can entail such consequences as bleeding,[5] the loss of the graft material, loss of the implants, sinus infections, sinusitis, and extraoral complications, like meningitis and brain abscesses.[6]

The complexity of the procedure for dissection and elevation of this membrane, which covers the maxillary sinus floor, is directly related to the angles formed by the walls, especially those that form the maxillary sinus floor. The sharper these angles, the more difficult the procedure becomes, and the higher the probability of perforating the membrane during its dissection and apical displacement.[7] This is a fact that can alter the surgical procedure or even lead to having to abort the surgery after it has begun. Thus, the objective of this study was

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Clinical anatomy of the maxillary sinus: application to sinus floor augmentation

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Abstract: The anatomy of the maxillary sinus, especially its vascular anatomy, and its relationships with the teeth and alveolar processes have been well documented. The development of cone-beam computed tomography has resulted in dentists being more familiar with maxillary sinus floor augmentation procedures. This paper aims to revisit the classic anatomy of the maxillary sinus and review the newly published literature in order to help dentists diagnose in more detail and perform safer surgery of the maxillary sinus.

Key words: Anatomy, Cadaver, Maxillary sinus, Sinus floor augmentation, Maxillary artery, Dental implants

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Introduction

The maxillary sinus (MS), one of the paranasal sinuses first identified by ancient Egyptians, has been well studied, especially its structure, vascular anatomy, and relationship with the teeth [1]. Since the introduction of cone-beam computed tomography (CBCT) into clinical practice, sinus floor augmentation (SFA) has become more popular. This approach requires the knowledge of the surrounding structures that might be seen in the CBCT images. However, most of these structures which have been shown in computed tomography (CT) images are hard to understand due to its complicated morphology. Therefore, the aim of the current paper is to review the clinical anatomy of the MS for a better understanding of SFA procedures with several cadaveric images which could help understand the structures three dimensionally.

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Anatomy

Embryology

The MS begins to form during the 10th week of development. The mucosa located at the deeper anterior end of the ethmoid infundibulum presents invaginations toward the surrounding mesenchyme [2]. These invaginations fuse during the 11th week of development, giving rise to a single cavity representing the primordium of the MS [2]. The primordial shape of the sinus is characterized as an oval cavity with smooth walls [2]. Rapid growth of the MS has been observed during two periods of development: from the 17th to the 20th week and from the 25th to the 28th week.

Ossification of the sinus begins during the 16th week of development, beginning in the lateral wall of the sinus and spreading to the anterior wall by the 20th week, and to the posterior wall by the 21st week. The medial wall shows signs of ossification by the 37th week of development [2].

The floor of the sinus is related to the roots of the first premolar teeth at age 4 years and the second molar teeth at age

Maxillary sinus augmentation

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ABSTRACT

Placing dental implants in the maxillary posterior region can be both challenging and un-nerving for a regular implant dentist who is not well versed with advanced surgical procedures. It is vital for a general dentist to understand the fundamentals of bone grafting the maxillary sinus if he/she is really committed to providing the best health care for their patients. The dental practice is seeing an increasing group of patients who are living longer, and this group of older baby boomers often has an edentulous posterior maxilla either unilateral or bilateral. When edentulous, the posterior maxilla more likely has diminished bone height, which does not allow for the placement of dental implants without creating additional bone. Through grafting the maxillary sinus, bone of ideal quality can be created (allowing for placement of dental implants), which offer many advantages over other tooth replacement modalities. The sinus graft offers the dental patient a predictable procedure of regenerating lost osseous structure in the posterior maxilla. This offers the patient many advantages for long-term success. If dentists understand these concepts, they can better educate their patients and guide them to have the procedure performed. This article outlines bone grafting of the maxillary sinus for the purpose of placing dental implants. This review will help the readers to understand the intricacies of sinus augmentation. They can relate their patient's condition with the available literature and chalk out the best treatment plan for the patient, especially by using indirect sinus augmentation procedures which are less invasive and highly successful if done using prescribed technique.

Key words: Dental implants, sinus augmentation, indirect sinus augmentation

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INTRODUCTION

The use of implants has significantly increased prosthetic options for the edentulous patient. However, implant placement in the posterior maxillary region is often hampered significantly by anatomic limitations such as inadequate vertical dimension, poor bone quality,[1-5] thinning or missing cortex,[6] and undercuts.[7] For implant placement in the posterior maxillary region, the maxillary sinus is one of the most important anatomic structures. Following tooth extraction, the periosteum of the maxillary sinus can exhibit an increase in osteoclastic activity.[8] The resulting reduced bone height due to pneumatization of the maxillary sinus influences the length and location of implants. Previously, many fixed restorations terminated at the second premolar due to insufficient alveolar ridge height.[9] Many reports have also concluded that when shorter implants (<10 mm) are placed, they are less successful than longer implants.[4,10-13] Thus, procedures such as sinus floor elevation (SFE), which facilitate the placement of longer implants in the posterior maxilla, have received a lot of attention in recent years.

The purpose of this review is to enumerate all the techniques used for sinus augmentation with their advantages and disadvantages and their indications. Thus, proper understanding of the anatomy and physiology of the maxillary sinus is a prerequisite for deciding the treatment plan for implant placement.

The largest of the paranasal air cavities, the maxillary sinus includes a medial wall that separates the maxillary

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Sinus Bone Graft - Where and Where Not to be? - A Review

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Abstract

The maxillary sinus augmentation procedure has gaining popularity in recent years. The aim of this review article is to provide an update about various indication, contraindication and treatment aspect of the maxillary sinus and their clinical relevance to the sinus augmentation procedure and subsequent implant placement in the atrophic maxilla.

Keywords: Maxillary sinus; Indication; Contraindications; Sinus graft

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Introduction

Implant therapy has become an excellent treatment modality since its inception into the modern era of dentistry. The ability to permanently replace missing teeth with a function and appearance close to that of the natural dentition has been possible due to advancement of implant dentistry. Implants are a conservative and esthetic alternative for treatment of partial edentulism and provide a stable foundation for treatment of complete edentulism. However, dental implants can be a viable treatment option only when there is sufficient quantity and quality of bone at the site of implant placement.

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 [1-3]. 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. Furthermore, bone density in the posterior maxilla is often poor, which may also lead to a diminished implant success rate.

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. 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.

Sinus floor elevation in the atrophic maxillary posterior region to make implantation possible has been increasingly popular in recent years. Two approaches have been described in literature for sinus floor augmentation: the direct approach/lateral approach/external sinus augmentation or the indirect approach/crestal approach/internal sinus augmentation, using either a one-stage or -two-stage protocol [4,5].

Although maxillary sinus augmentation and implant procedures are compatible, with most patients recovering uneventfully, various intra-operative and postoperative complications have been reported in the literature. These complications are fairly common with both lateral and crestal approach. Therefore, clinician should know detail knowledge regarding the indication and contraindication of maxillary sinus augmentation procedures and also where to go and where not to go for sinus augmentation.

Sinus grafting indications

Local conditions of the edentulous alveolar ridge, such as loss of alveolar bone height as a result of periodontal disease prior to tooth loss, can make implant placement unfavorable. Distal furcation of the maxillary molar frequently leads to bone loss

ABC Sinus Augmentation Classification

*Hom-Lay Wang, DDS, MSD, PhD**
*Amar Katranji, DDS***

Edentulism in the posterior maxilla can present with compounding variables that make it a difficult region to restore with implants. Pneumatization of the sinus floor is typically accounted for during surgical treatment planning, but other factors such as horizontal ridge deficiency and vertical defects may be overlooked. This report reviews the different classifications used to treat the posterior maxilla and introduces a new system that incorporates all factors critical for implant success. Class A represents abundant bone with ≥ 10 mm bone height below the sinus floor and ≥ 5 mm bone width, allowing proper implant placement. Class B indicates barely sufficient bone with 6 to 9 mm bone height below the sinus floor, and this can be further subclassified into division h (horizontal defect; < 5 mm bone width), division v (vertical defect; > 3 mm away from cementoenamel junction), and division c (combined horizontal and vertical defect). Class C indicates compromised bone with ≤ 5 mm bone height below the sinus floor, and this can also be subclassified similar to Class B. The ABC classification is a simple system to guide clinicians in proper implant treatment of the posterior maxilla. (Int J Periodontics Restorative Dent 2008;28:383–389.)

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The use of osseointegrated implants for rehabilitation of an edentulous space is quickly becoming the treatment of choice in dentistry. Numerous techniques and treatment protocols have been championed regarding the timing and placement of implants. However, factors such as the quantity and quality of the residual host bone play important roles in successful treatment planning and may shift timing sequences associated with the placement of implants. Specifically, the edentulous posterior maxilla poses a number of challenges that can complicate implant treatment planning. Cawood and Howell,[1] in their classification of edentulous jaws, reported that the posterior maxilla loses its shape upon tooth loss. This bone loss in combination with sinus pneumatization often resulted in deficient vertical height, creating a major challenge for future implant-supported restorations. Misch[2] developed a classification for treatment of the edentulous posterior maxilla based on the amount of bone below the antrum and the ridge width. Treatment categories ranged from SA-1 to SA-4 based on bone height and division A (> 5 mm) or B (2.5

Maxillary sinus augmentation procedures: a narrative clinical review

Anahat Khehra/Liran Levin, DMD, FRCD(C)

An edentulous posterior maxilla can present a challenge for placement of dental implants due to the proximity of the maxillary sinus. Sinus augmentation is a surgical bone grafting procedure aimed to increase the bone height for implant support. A number of sinus augmentation techniques have been presented and the outcomes show good implant success rates. In order to achieve the desirable outcomes, it is important to gain knowledge of the maxillary sinus anatomy and complete a thorough preoperative evaluation. Being aware of the location of vasculature, nerves, and the presence of septa will help reduce the risk of intraoperative and postoperative complications. This review provides a narrative clinical overview related to the anatomy, preoperative evaluation, contraindications, techniques, postoperative care, outcome measures, and complications of sinus augmentation procedures. *(Quintessence Int 2020;51:578–584; doi: 10.3290/j.qi.a44632)*

Key words: bone graft, dental implants, maxilla, sinus elevation, success, survival

The aim of maxillary sinus augmentation surgery is to increase the vertical height of the residual alveolar bone in order to achieve proper dimensions for dental implant placement.[1,2] Bone loss in the posterior maxilla might occur due to tooth extraction, aging, or pneumatization of air-filled cavities.[3] Sinus augmentation surgery can increase bone height by elevating the maxillary sinus floor to create a space between the sinus membrane and the osseous floor; a space that could then be filled with bone graft materials.[1] Ultimately, the end goal is to increase bone height enough to achieve dental implant stability and bone support in the long term.

Anatomy

Maxillary sinus

The maxillary sinuses are the largest of the paranasal sinuses.[4] They are filled with air and lie within the maxillae.[5] The paired sinuses are lateral to the nasal cavity, superior to the dentition, inferior to the floor of the orbit, and anterior to the infratemporal fossa. The apex of each maxillary sinus is neighboring the zygomatic bone.[4] The lateral wall of the sinus is made of thin bone and is the location of access when utilizing the lateral approach of the sinus augmentation procedure.[6] The medial wall contains the sinus ostium, which is located superiorly allowing for graft material to be inserted without jeopardizing the sinus drainage. The ostium opens into the ethmoid infundibulum within the middle meatus of the lateral nasal wall.[6] The function of the maxillary sinus is not completely understood but it is assumed to take part in warming aspirated air and reducing the weight of the craniofacial structures.[7] The sinus floor in relation to the dentition extends from the premolar or canine area to the back adjacent to the maxillary tuberosity.[8]

Sinus membrane

The maxillary sinuses are lined with a bilaminar mucoperiosteal membrane.[5] The sinus membrane has three layers: periosteum, connective tissue, and ciliated pseudostratified columnar epithelium (respiratory epithelium).[5,6] The presence of sinus membrane pathology prior to the surgery can increase the risk for complications and implant failure later.[1]

Maxillary Sinus Bone Augmentation Techniques

Vincent Carrao, DDS, MD*, Isabelle DeMatteis, DDS

KEYWORDS

• Maxillary • Sinus • Bone • Augmentation • Implant • Grafting

KEY POINTS

- When faced with implant reconstruction of a maxillary edentulous area with increased pneumatization of the maxillary sinus, treatment planning is of the utmost importance to achieve the desired result.
- The maxillary sinus can be grafted with multiple types of materials; depending on the case, the material of choice should be the one expected to produce the best functional and most stable result.
- Various surgical approaches can be used to achieve optimal results for a graft with enough volume for future implant stability.
- Occasionally the surgeon encounters complications during the surgery or the postoperative phase; the ability to manage these complications is crucial to ensure the best outcome for the patient.

HISTORY OF SINUS LIFTS

- Tatum,[1] 1975: first maxillary sinus augmentation in preparation for dental implant placement
- Boyne and James,[2] 1980: first case report on autogenous grafts for sinus augmentation followed by blade implant placement 6 months after grafting

Anatomy and Physiology of the Maxillary Sinus

The maxillary sinus, also known as the antrum of Highmore, is virtually nonexistent in the neonate. The maxillary sinus pneumatizes over time, thus causing the sinus volume to increase with age. The pneumatization process continues throughout life, resulting in the ever expanding sinus cavity. The bone that is lost secondary to this cavity expansion is the maxillary alveolar bone, which supports the teeth. The maxillary sinus is the largest of the paranasal sinuses. Its function is not well defined; however, it is thought to lighten the skull, humidify inspired air, and contribute to voice resonance.[3]

The sinus is lined with a pseudostratified ciliated columnar/cuboidal epithelium, which is called the schneiderian membrane. This thin membrane produces mucus via goblet cells and contains a basement membrane with occasional osteoblasts. The ciliated membrane functions to transport mucus and debris to the ostium semilunaris, allowing it to exit the sinus cavity. The ostium is situated superior to the depth of the sinus floor therefore requiring the ciliated cells to move the mucus in a cephalad direction. The ostium lies in the semilunar hiatus of the middle meatus of the nasal cavity and is a small opening that can easily be obstructed by mucosal swelling consequently preventing adequate drainage of the maxillary sinus.[4]

Blood supply to the maxillary sinus is robust and derived from the following[3]:

- Infraorbital artery
- Greater palatine artery
- Lesser palatine artery
- Sphenopalatine artery
- Posterior superior alveolar artery

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Maxillary Sinus Floor Augmentation: a Review of Selected Treatment Modalities

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ABSTRACT

Objectives: The objective of the present study is to present the current best evidence for enhancement of the vertical alveolar bone height and oral rehabilitation of the atrophic posterior maxilla with dental implants and propose some evidence-based treatment guidelines.
Material and Methods: A comprehensive review of the English literature including MEDLINE (PubMed), Embase and Cochrane Library search was conducted assessing the final implant treatment outcome after oral rehabilitation of the atrophic posterior maxilla with dental implants. No year of publication restriction was applied. The clinical, radiological and histomorphometric outcome as well as complications are presented after maxillary sinus floor augmentation applying the lateral window technique with a graft material, maxillary sinus membrane elevation without a graft material and osteotome-mediated sinus floor elevation with or without the use of a graft material.
Results: High implant survival rate and new bone formation was reported with the three treatment modalities. Perforation of the Schneiderian membrane was the most common complication, but the final implant treatment outcome was not influenced by a Schneiderian membrane perforation.
Conclusions: The different surgical techniques for enhancement of the vertical alveolar bone height in the posterior part of the maxilla revealed high implant survival with a low incidence of complications. However, the indication for the various surgical techniques is not strictly equivalent and the treatment choice should be based on a careful evaluation of the individual case. Moreover, further high evidence-based and well reported long-term studies are needed before one treatment modality might be considered superior to another.

Keywords: alveolar ridge augmentation; dental implants; oral surgical procedures; review; sinus floor augmentation.

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Sinus floor elevation utilizing the transalveolar approach

Bjarni E. Pjetursson & Niklaus P. Lang

As implant dentistry developed, it became more evident that the posterior maxillary region was often limited for standard implant placement because the residual vertical bone height was often substantially reduced as a result of the presence and pneumatization of the maxillary sinus. 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. However, for the placement of even short implants, there is still a need for at least 6 mm of residual bone height. Another way of avoiding grafting the maxillary sinus would be to place tilted implants mesially or distally to the sinus cavity if these areas have adequate bone. Furthermore, extra-long zygomatic implants may be placed in the lateral part of the zygomatic bone. However, elevation of the maxillary sinus floor is considered as the treatment for solving this problem.

Elevation of the maxillary sinus floor was first reported by Boyne in the 1960s. In 1980, Boyne & James (3) described elevation of the maxillary sinus floor in patients with large, pneumatized sinus cavities as a preparation for the placement of blade implants. The authors described a two-stage procedure: in the first stage, the maxillary sinus was grafted using autogenous particulate iliac bone; and, in the second stage (approximately 3 months later), blade implants were placed and later used to support fixed or removable reconstructions (3). Such a one- or a two-stage sinus floor elevation with a lateral window approach is, however, a relatively invasive treatment option.

In patients with appropriate residual bone height, augmentation of the sinus floor can also be accomplished via transalveolar approach using the osteotome technique (11, 26, 30). The problem of inadequate bone height can be overcome by elevating the maxillary sinus floor using the closed technique to provide sufficient quantity of bone for the placement of dental implants.

A transalveolar approach for sinus floor elevation, with subsequent placement of implants, was first suggested by Tatum, in 1986 (32). A ‘socket former’ for the selected implant size was used to prepare the implant site. A greenstick fracture of the sinus floor was accomplished by hand tapping the ‘socket former’ in a vertical direction. After preparation of the implant site, a root-formed implant was placed and allowed to heal in a submerged manner.

Summers (30) later described a different transalveolar approach using a set of tapered osteotomes with increasing diameters (Fig. 1). This concept was intended to increase the density of soft (type III and type IV) maxillary bone, resulting in better primary stability of inserted dental implants. Bone was conserved by this osteotome technique because there was no drilling. Adjacent bone was compressed by pushing and tapping as the sinus membrane was elevated. Then, autogenous, allogenic or xenogenic grafts were added to increase the volume below the elevated sinus membrane.

Currently, two main techniques of sinus floor elevation for dental implant placement are in use. The first is a two-stage technique with a lateral window approach, followed by implant placement after a healing period, and a one-stage technique using either a lateral or a transalveolar approach. The second is the transalveolar approach, also referred to as ‘osteotome sinus floor elevation’, the ‘Summers technique’ or the ‘Crestal approach’, which may be considered as more conservative and less invasive than the conventional lateral approach. In this technique a small osteotomy is performed through the alveolar crest of the edentulous ridge at the inferior border of the maxillary sinus. This intrusion osteotomy elevates the sinus membrane, thus creating a ‘tent’ and

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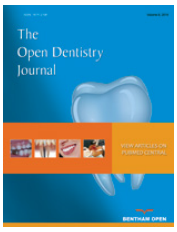

RESEARCH ARTICLE

Complications During Maxillary Sinus Augmentation Associated with Interfering Septa: A New Classification of Septa

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Abstract:

Purpose:

A new classification of maxillary sinus interfering septa based on its orientation is presented along with its relationship to the prevalence and severity of sinus membrane perforations. Additionally, the impact of membrane perforation on post-operative complications and marginal bone loss during the first year of loading is evaluated.

Materials & Methods:

Retrospective chart review of 79 consecutive sinus lift procedures with lateral window technique and 107 implants. Preoperative Cone Beam Computed Tomography (CBCT) images were evaluated for the incidence and the direction of maxillary septa. Chart notes were examined for the incidence of membrane perforation and postoperative complications. Measurements of mesial and distal marginal bone levels and average bone resorption adjacent to each implant were calculated in intraoral radiographs taken at implant placement and during follow up appointments.

Results:

Interfering septa were identified in 48.1 percent of sinuses. 71.1 percent of them had the septum oriented in a buccal-lingual direction (Class I). The overall incidence of membrane perforation was 22.8 percent, and the presence of an interfering septum on CBCT scan was found to be significantly associated with the occurrence of a sinus membrane perforation (P<0.001). The mean implant marginal bone loss for sinuses, which did not experience a membrane perforation, was 0.6±0.8mm, compared with 0.9 ± 0.9 mm for the sinuses that did experience a perforation (P = 0.325).

Conclusion:

Septa should be identified, classified and managed with a meticulous attention to technical details. A classification based on the septal orientation is proposed since the orientation of the septa can complicate the surgical procedure and requires modification of the surgical technique.

Keywords: Direct sinus lift, Maxillary septum classification, Schneiderian membrane perforation, Dental implant, Marginal bone loss, Post operative complication, Bone graft.

INTRODUCTION

The posterior maxilla represents a unique challenge when planning implant prosthetic rehabilitation of edentulous sites. Common problems facing the clinician are the lack of bone volume due to resorption of the alveolar process

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RESEARCH Open Access

Impact of surgical management in cases of intraoperative membrane perforation during a sinus lift procedure: a follow-up on bone graft stability and implant success

Benedicta E. Beck-Broichsitter[1*], Dorothea Westhoff[2], Eleonore Behrens[2], Jörg Wiltfang[2] and Stephan T. Becker[2]

Abstract

Background: Until now, sinus floor elevation represents the gold standard procedure in the atrophic maxilla in order to facilitate dental implant insertion. Although the procedure remains highly predictive, the perforation of the Schneiderian membrane might compromise the stability of the augmented bone and implant success due to chronic sinus infection. The aim of this retrospective cohort study was to show that a membrane tear, if detected and surgically properly addressed, has no influence on the survival of dental implants and bone resorption in the augmented area.

Methods: Thirty-one patients with 39 perforations could be included in this evaluation, and a control group of 32 patients with 40 sinus lift procedures without complications were compared regarding the radiographically determined development of bone level, peri-implant infection, and implant loss.

Results: Implant survival was 98.9% in the perforation group over an observation period of 2.7 (± 2.03) years compared to 100% in the control group after 1.8 (± 1.57) years. The residual bone level was significantly lower in the perforation group ($p = 0.05$) but showed no difference direct postoperatively ($p = 0.7851$) or in the follow-up assessment ($p = 0.2338$). Bone resorption remained not different between both groups ($p = 0.945$). A two-stage procedure was more frequent in the perforation group ($p = 0.0003$) as well as peri-implantitis ($p = 0.0004$).

Conclusions: Within the limits of our study, the perforation of the Schneiderian membrane did not have a negative impact on long-term graft stability or the overall implant survival.

Keywords: Sinus floor elevation, Intraoperative complication, Perforation, Schneiderian membrane, Implant survival

Background

Sinus floor elevation procedures have become a predictable and successful treatment, performed when the maxillary alveolar ridge is atrophied and the bone height is not sufficient for primary implantation. If the postoperative course remains uneventful, the outcome is highly predictable [1–3]. However, complications may have a negative impact on the overall treatment success. As a common complication, perforation of the Schneiderian membrane occurs in 12 to 44% of cases depending on the literature [2, 4–6], with an average of 20 to 25% [7–9] in all cases due to septa morphological aspects of the membrane or other pathologic conditions; the perforation itself represents the major intraoperative complication despite common complications, such as postoperative infection [5, 10].

Still, it is not completely clear to what extent these complications influence implant survival or might impact the augmented material in the sinus. To evaluate the impact of early-onset complications during implant insertion on the implant success, Becker et al. published a follow-up study evaluating the first year after a sinus lift procedure [11], which did not reveal a negative impact on implant survival after an observation period of

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CORRESPONDENCE

Schneiderian membrane repair with platelet-rich fibrin during maxillary sinus augmentation with simultaneous implant placement

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Maxillary sinus augmentation is used to gain adequate bone volume for the placement of dental implants in edentulous posterior maxilla. Schneiderian membrane perforation is one of the most common complications associated with maxillary sinus augmentation procedures. Choukroun's platelet-rich fibrin (PRF) protocol is a simple and free technique that allows one to obtain fibrin clots and membranes enriched with platelets and growth factors, after starting from an anticoagulant-free blood harvest.[1] The clinical applications of PRF have already been described in periodontal regeneration surgery,[2] sinus augmentation,[3] and bisphosphonate-related osteonecrosis of the jaw.[4] This report is the first to provide a quick and simplified option for the repair of Schneiderian membrane perforation with PRF during maxillary sinus augmentation with simultaneous implant placement.

A 62-year-old man, who has had diabetes mellitus for 10 years, had atrophy of the left maxillary posterior edentulous area that required a sinus lift before implantation. A preoperative panoramic radiograph exhibited bilateral maxillary bone atrophy with a residual crest height of <4 mm (Figure 1A). PRF clots and membranes were prepared as described previously.[1] During surgery, whole blood samples were taken from this patient and placed into glass-coated plastic tubes and immediately centrifuged at 400 *g* for 12 minutes. Sinus augmentation followed the lateral wall protocol with local anesthesia. In brief, after a buccal mucoperiosteal flap was raised, an osteotomy was prepared in the lateral wall of the sinus. Schneiderian membrane perforation was noted during hand manual instrumentation of the membrane (Figure 1B), then PRF clots and membranes were placed directly onto the membrane (Figure 1C). After repair of the sinus membrane perforation, sinus augmentation was continued with simultaneous placement of Dynamix implants (Cortex, Shlomi, Israel) and synthetic bone graft, then the lateral access window was covered with PRF membrane as a barrier (Figures 1D and 1E). The healing processes under regular clinical examination were uneventful. After a healing period of 12 months, the implant was exposed for crown fabrication. The patient was regularly followed up, and intraoral pictures revealed healthy gingival architecture and no gingival recession observed after 2.5 years. Form cone beam computer tomography (panoramic view) evaluation, compared with

Conflicts of interest: The authors have no conflicts of interest relevant to this article.

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SPECIAL ISSUE

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A review of complications of maxillary sinus augmentation and available treatment methods

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Maxillary sinus grafting is a dependable procedure that has been in use for a long time. However, clinical complications often arise. To prevent complications of maxillary sinus grafting, it is necessary to know the contra-indications, both for general implantation and for maxillary bone grafting. In addition, presence of various complications requires careful consideration of treatment method; therefore, dentists should be familiar with the treatment protocols. Complications can be divided into postoperative, immediate postoperative, and delayed postoperative complications. Particularly for the outpatient, it is necessary to quickly distinguish between treatable cases and cases for which transfer is required. The purpose of this review is to discuss the contra-indications, complications, and treatment options for complications of maxillary sinus graft.

Key words: Maxillary sinus, Contraindication, Complication

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I. Introduction

Dr. Hilt Tatum proposed a modified Caldwell–Luc operation as a maxillary sinus graft in the 1970s, and it has been recognized as a procedure with high predictability to date[1]. However, as in all surgical procedures, various complications may arise after maxillary sinus graft[2]. In this review, we aimed to investigate the types of complications associated with maxillary sinus graft, methods for prevention of said complications, and existing treatment options available in dental clinics.

A complication is a problem or difficulty that makes a situation harder to deal with, and multiple complications tend to occur at the same time in medicine[3]. In order to prevent complications in the present study, it was first necessary to correctly identify and differentiate the indications and contraindications for maxillary sinus surgery.

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II. Contraindications

The contraindications of maxillary sinus augmentation can be divided into general implant contraindications, absolute contraindications, and relative contraindications. Needless to say, maxillary sinus graft is not an appropriate treatment option for patients with general implant contraindications. Absolute contraindications include severe or uncontrollable general disease, large-dose radiation therapy on the maxilla, mental disorders, sepsis, heavy smoking, and severe alcoholism or drug abuse. On the other hand, the factors constituting relative contraindications are local hard or soft tissue lesions such as sinus infection, acute infection (dental origin), pathologic condition of the sinus (polyp, cyst, and tumor), and sinusitis including allergic rhinitis; history of sinus surgery; low-dose radiation therapy on the maxilla, habitual use of drugs, alcohol, and tobacco; mouth opening limitations; malocclusion; and severe bruxism[4].

In all dental procedures including implant placement, careful case selection is likely to lead to a successful outcome. For example, if sinusitis, a maxillary cyst, a maxillary tumor, or a root resting in the sinus is detected in the maxillary sinus,

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Research Article

Prevention and Treatment of Postoperative Infections after Sinus Elevation Surgery: Clinical Consensus and Recommendations

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Introduction. Maxillary sinus surgery is a reliable and predictable treatment option for the prosthetic rehabilitation of the atrophic maxilla. Nevertheless, these interventions are not riskless of postoperative complications with respect to implant positioning in pristine bone. *Aim*. The aim of this paper is to report the results of a clinical consensus of experts (periodontists, implantologists, maxillofacial surgeons, ENT, and microbiology specialists) on several clinical questions and to give clinical recommendations on how to prevent, diagnose, and treat postoperative infections. *Materials and Methods*. A panel of experts in different fields of dentistry and medicine, after having reviewed the available literature on the topic and taking into account their long-standing clinical experience, gave their response to a series of clinical questions and reached a consensus. *Results and Conclusion*. The incidence of postop infections is relatively low (2%–5.6%). A multidisciplinary approach is advisable. A list of clinical recommendation are given.

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Maxillary sinus augmentation - diagnostic and surgical technique

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ABSTRACT

Placing dental implants in edentulous patients is a difficult task, as the anatomy of patients has a high variability. The expansion of the pneumatized maxillary sinus after tooth extraction is the biggest impediment of all. Because of the undersized ridge width patients need bone grafting in order to compensate the loss of their own. This procedure is performed by the oro-maxillo-facial surgeon who evaluates, advises and offers the patient the best medical guidance. A series of surgical techniques and surgical implants have been performed in the field of bone grafting, but only a few of them are now being used.

Key words: dental implant, sinus lift, maxillary sinus, surgery

INTRODUCTION

The maxillary sinus is a cavity, an aerated space that occupies the maxillary bone and its elongations through inconstant recesses. (1) The shape and form of the maxillary sinus resemble an overturned pyramid: the base is the inter-sinusonasal wall and the apex is towards the zygomatic bone. The air volume inside the sinus depends of the pneumatization of the sinus, having approximately 15 ml air space. (2-4) It is the only sinus that has a non-physiologic, antigravity drainage. The floor of the maxillary sinus is formed by the alveolar recess; in adults the sinus floor is situated below the nasal level. (*figure 1*)

The anterior wall presents the canine fossa, the thinnest maxillary bone region, the place to access towards the sinus cavity. Mainly, the maxillary is a finely trabecular bone, with a lower density than the mandible. This consideration is important as the medullary bone must establish a stress-bearing surface for the implant in order to create a functional system; the implant must remain fixed and, in the same time, be able to transmit the mastication forces to the supporting bone. (5,6) Placing dental implants, after sinus lift interventions, is the best procedure to recreate a physiological dentition for patients with atrophic posterior maxilla. (7) (*figure 2*)

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ORIGINAL ARTICLE

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Osteoinduction, osteoconduction and osseointegration

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Abstract Osteoinduction is the process by which osteogenesis is induced. It is a phenomenon regularly seen in any type of bone healing process. Osteoinduction implies the recruitment of immature cells and the stimulation of these cells to develop into preosteoblasts. In a bone healing situation such as a fracture, the majority of bone healing is dependent on osteoinduction. Osteoconduction means that bone grows on a surface. This phenomenon is regularly seen in the case of bone implants. Implant materials of low biocompatibility such as copper, silver and bone cement shows little or no osteoconduction. Osseointegration is the stable anchorage of an implant achieved by direct bone-to-implant contact. In craniofacial implantology, this mode of anchorage is the only one for which high success rates have been reported. Osseointegration is possible in other parts of the body, but its importance for the anchorage of major arthroplasties is under debate. Ingrowth of bone in a porous-coated prosthesis may or may not represent osseointegration.

Keywords Osteoinduction · Osteoconduction · Osseointegration

Introduction

The terms osteoinduction, osteoconduction and osseointegration are frequently, but not always correctly, used terms in many orthopaedic papers. To give but one example of incorrect terminology, arthroplasties are commonly claimed to be osseointegrated based only on radiographic evidence, despite the fact that the resolution of radiography alone is too poor to determine whether an implant is osseointegrated or not. The aim of this paper is to first briefly explain and define these terms and then to look at them in some detail. Osteoinduction, osteoconduction and osseointegration are now the subject of much discussion, e.g. in connection with bone morphogenic proteins (BMP), bone growth factors and direct bone anchorage, respectively. Suggested definitions of the terms osteoinduction, osteoconduction and osseointegration read as follows:

Osteoinduction. This term means that primitive, undifferentiated and pluripotent cells are somehow stimulated to develop into the bone-forming cell lineage. One proposed definition is the process by which osteogenesis is induced [43].

Osteoconduction. This term means that bone grows on a surface. An osteoconductive surface is one that permits bone growth on its surface or down into pores, channels or pipes. Wilson-Hench [43] has suggested that osteoconduction is the process by which bone is directed so as to conform to a material's surface. However, Glantz [18] has pointed out that this way of looking at bone conduction is somewhat restricted, since the original definition bears little or no relation to biomaterials.

Osseointegration. This was first described by Brånemark and co-workers [12]. The term was first defined in a paper by Albrektsson et al. [4] as direct contact (at the light mi-

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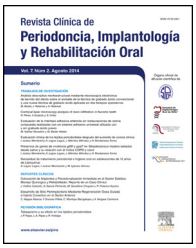

REVIEW ARTICLE

Current considerations on bone substitutes in maxillary sinus lifting

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KEYWORDS
Maxillary sinus;
Bone substitutes;
Biomaterials

Abstract The procedure of maxillary sinus lifting using autogenous bone was considered the reference standard choice for oral rehabilitation in cases of severe atrophic maxilla. However, it is not always a viable option, due to the limitations or morbidity caused by grafting techniques. This has led to the development of bone substitutes, which have been elaborated and improved. Choosing the best biomaterial becomes difficult due to the wide variety of bone substitutes. The aim of this article is to present some of these materials that are reported in the current scientific literature for maxillary sinus lifting.

PALABRAS CLAVE
Seno maxilar;
Sustitutos de huesos;
Materiales biocompatibles

Consideraciones actuales sobre sustitutos óseos en elevación del seno maxilar

Resumen El procedimiento de elevación del seno maxilar utilizando hueso autógeno se consideraba la opción estándar de oro para la rehabilitación oral en casos de maxilar atrófico grave. Sin embargo, no siempre es una opción viable, debido a las limitaciones o a la morbilidad causada por técnicas de injerto, lo que justifica la existencia de sustitutos óseos que han sido elaborados y mejorados. En cuanto a la amplia variedad de sustitutos óseos, se hace difícil la mejor elección de biomaterial. El objetivo de este informe es presentar una variedad de

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ORIGINAL ARTICLE

WILEY

Guided maxillary sinus floor elevation using deproteinized bovine bone versus graftless Schneiderian membrane elevation with simultaneous implant placement: Randomized clinical trial

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Abstract

Objective: The aim of this study is to evaluate the analytical difference between the use of xenograft (control group) and graftless tenting (test group) technique after sinus lift procedure with simultaneous implant placement.

Materials and methods: Seventeen patients and 20 sinuses where operated for sinus lift procedures using lateral window approach with simultaneous implant placement. Deproteinized bovine bone (Xenograft) was used as a filling material in control group while nongrafted sinus lifting was performed in the test group. Multislice CT was obtained preoperatively and CBCT were obtained immediately postoperative and 6 months after operation. Osstell readings were taken at the time of implant placement and implant exposure (6 months)

Results: Mean bone height gain in the xenograft group was 8.59 ± 0.74 while that of the tenting group was 4.85 ± 0.5 and it was statistically significant ($P < .05$). Mean bone density values in the xenograft group was 375.59 ± 49.38 while that of the tenting group was 269.08 ± 16.27 and it was statistically significant ($P < .05$). Mean ISQ values for the xenograft group was 78.3 ± 5.08 while that of the tenting group was 74 ± 3.19 and it was statistically significant ($P < .05$).

Conclusions: Within the limitation of this study, sinus lift procedures with simultaneous implant placement using xenograft as a filling material or graftless technique are considered reliable procedures, however, the use of xenograft provide better results in all aspects regarding (bone height gain, bone density, and implant stability).

KEYWORDS
atrophic maxilla, bone augmentation, bone substitutes, maxillary sinus floor elevation, sinus lift procedure

1 | INTRODUCTION

Bone resorption and atrophy of the posterior maxilla together with pnuematization of the maxillary sinus in addition to the poor bone quality are factors that hinder implant placement in the posterior maxilla.[1] Several techniques have been proposed to overcome these problems including the use of short implants and vertical augmentation using sinus floor elevation.[2]

Sinus floor augmentation has been considered a predictable procedure to provide vertical dimension to allow for implant placement in the posterior maxilla with high survival rate.[3]

Tatum et al.[4] proposed the lateral window approach to augment the maxillary sinus, which was later published by Boyne and James in 1980.[5] A bony window is created along the lateral wall of the sinus to visualize the sinus membrane, the sinus membrane is carefully elevated and the created underlying space is augmented using autogenous bone grafting material.

Although autogenous bone has been regarded as the gold standard for bone augmentation owing to its osteogenic, osteoinductive, and osteoconductive properties, along with the lack of immunogenic response.[6] However, it suffers from several drawbacks including increased morbidity, the need for second surgical harvesting procedure,

A description of the sequence of long-term behavior of autogenous boneblock in maxillary sinus augmentation in sheep: Additional morphologic and histomorphometric evidence

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Objective. To document the behavior of autogenous bone block in sinus lift and surgical consequences.
Study Design. Twelve sinus lifts with autogenous hip bone blocks and simultaneous insertion of two implants in 6 adult female sheep. Polychrome sequential labelling and histologic and histomorphometric evaluation after 6, 16, and 26 weeks.
Results. Augmentation material in the apical third was almost fully resorbed after 26 weeks ($P = .00388$). Percentage of bone tissue increased 0.5-1.0 mm from the implant in crestal region (15.3 ± 7.5% to 16.2 ± 10.1%), whereas it vanished in the apical region from 16 to 26 weeks (4.2 ± 10.4% to 0%) ($P = .363$).
Conclusions. Autogenous bone block leaves an apical thin but functionally crucial layer covering implants in a form follows function way. Denial of animal-originated biomaterials and prion diseases remain a rarely discussed issue. The use of an implant length–adapted autogenous transplant with osseoinductive advantages should be taken into consideration. (Oral Surg Oral Med Oral Pathol Oral Radiol 2018;125:6–13)

Postextraction alveolar bone resorption and pneumatization of the maxillary sinus often compromise the quantity and quality of available bone in the posterior upper jaw.[1] Formation of vital bone to allow osseointegration of delayed or simultaneously placed implants is initiated by apical displacement of the Schneiderian membrane (maxillary sinus mucosa) with or without the addition of bone (substitute) material.[2]

Generally the use of autogenous bone grafts continue to represent the "gold standard" in reconstructive surgery of the oral and maxillofacial region because of their osteoinductive, osteoconductive, and nonimmunogenic properties.[3] Harvesting methods are well documented and provide minimal risk of complications.[4] No statistical differences have been reported between implant survival in anorganic bovine bone (ABB) and in autologous bone plus ABB, particularly in the maxillary sinus.[5]

Augmentation with autologous bone is most commonly done using particulate bone material. The drawback of this material is the significantly reduced cell count after the comminution process as well as the rapid decrease of mineralized hard tissue substance.[6] Bone remodeling accounts for resorptions ranging between 7% and 38% during the first year.[7]

With the use of an autologous bone block,[8] both an increase in mineralized tissue and a significantly increased level of newly formed bone could be identified.[9,10] Moreover, the block-shaped bone can be optimally adjusted and fitted into the area lacking bone tissue.

However, even with the use of bone blocks a major loss of bone volume during the remodeling phase can occur. Remodeling processes are subject to successful revascularization, which is influenced and affected by the type of bone (cancellous/cortical),[11] by the trauma experienced during graft collection, and by the fixation of the augmentation material.[12] Moreover, it has also been discussed whether the resorption behavior of the autogenous bone was dependent on its developmental origin.[13] Autogenous bone transplants of membranous origin (calvaria, mandible) seem to retain their volume for considerably longer periods and may be subject to resorption to a lesser extent than is bone of endochondral origin (iliac crest),[14,15] and they seem to preserve more mineralized tissue after subantral augmentation.[16]

Statement of Clinical Relevance

The long-term behavior of autologous bone block in a sinus lift with simultaneous implantation is documented in a way that was never published before. The clinical consequence could bring some focus back to autologous transplants with a new design.

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Clinical Study

Maxillary Sinus Floor Augmentation to Enable One-Stage Implant Placement by Using Bovine Bone Substitute and Platelet-Rich Fibrin

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Nowadays it is possible to perform an optimal implant placement and to achieve a good long-term prognosis for an implant-borne prosthesis in the grafted posterior maxilla. This study evaluates the efficiency of one-stage piezosurgery by using as graft material a combination of particulate bovine bone substitutes with platelet-rich fibrin to achieve sinus lift. We included in this study 14 cases of one-stage sinus lift surgeries during which we placed 30 standard implants. The mean vertical bone height gain was 10.12 mm six months after surgery, and the mean postoperative follow-up time was 43.79 months. There were no major complications during or after surgery, and all implants are in use. Therefore, it can be concluded that one-stage sinus piezosurgery using particulate bovine bone substitutes and platelet-rich fibrin can be applied as a predictable and effective technique in the treatment of the posterior edentulous maxilla ensuring 4-5 mm vertical bone height.

1. Introduction

Maxillary sinus floor augmentation (also known as sinus lift, sinus graft, sinus augmentation, or sinus procedure) is a surgical procedure, which increases the amount of bone in the posterior maxilla by the elevation of the sinus (Schneiderian) membrane from the underlying sinus wall and by placing a bone graft under it. The aim of sinus augmentation is to obtain bone to support a dental implant. Implants can be applied at the same time as sinus surgery (simultaneous placement) or after a healing period (delayed placement).

Since 1974 when the first surgery of sinus lift was performed, the science of biomaterials has improved by enhancing the possibilities of graft augmentation and allowing clinicians to perform implant-borne dental restorations in complex situations. As a result, it is possible to perform an optimal implant placement and to achieve a good long-term prognosis for an implant-borne prosthesis in the posterior grafted maxilla. Currently, maxillary sinus augmentation is a well-documented surgery with long-term clinical success/survival of the implants similar to those placed in the pristine bone [1–3].

However, there is a debate about the best biomaterial or combination of biomaterials regarding sinus surgery. Studies reported that implants placed in the sinuses augmented with particulate grafts presented a higher survival rate than those augmented with block grafts [4]. Bovine bone mineral acts as a slowly resorbing space maintainer [5] and can diminish sinus pneumatisation after augmentation. Platelet-rich fibrin (PRF) [6] is a fibrin concentrate obtained from the patient's blood, with integrated growing factors and cytokines, which provides a favourable environment for cell migration and rapid vascularization [7]. Studies showed that PRF promotes bone healing and could increase the success rate of bone grafting [8, 9].

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Evaluation of implant stability simultaneously placed with sinus lift augmented with putty versus powder form of demineralized bone matrix in atrophied posterior maxilla

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ABSTRACT

Background: Rehabilitation of edentulous posterior maxilla with dental implants is a challenging problem in oral and maxillofacial surgery due to alveolar resorption and excessive pneumatisation of maxillary sinus. This study was designed to compare the efficacy of Putty Versus Powder Form of Demineralized Bone Matrix (DBM) augmented in lifted maxillary sinus in atrophied posterior maxilla with evaluating the implant stability simultaneously placed with both of them.

Patients and Methods: sixty four implants were placed in twelve patients in the period between 2013 and 2016. Lateral approach, open window method for sinus lift with peizosurgical unit and placement of Putty or Powder Form of DBM were carried out simultaneously with implant placement. The implant success was defined when the prosthesis had been delivered and followed for 18 months without infection, pain, marginal bone loss and the implant stability quotient (ISQ) of each implant was measured using resonance frequency analysis.

Results: Radiographic bone formation was evident in all 12 patients, and all implants were stable after 18 months of placement. No statistically significant differences were observed in marginal bone loss around the implants between the powder and the putty groups at 6 months ($p = 0.60$), 12 months ($p = 0.85$) and 18 months (0.49). The difference between ISQ values in both groups was only significant at the baseline ($p = 0.023$).

Conclusion: Sinus lifting with simultaneous implant placement could be used to treat atrophic maxilla with initial stability obtained by using taper designed implants and with minimal intraoperative complication susing peizosurgery. No statistically significant differences in the stability were observed between implants placed with both putty and powder forms of DBM.

1. Introduction

Recently, clinicians have recommended augmenting the maxillary sinus to facilitate placement of endosseous implants in the severely atrophic posterior maxilla [1]. There are various techniques for sinus lift such as lateral window, crestal approach, summers osteotomy, bone aided augmentation. The most popular technique for sinus lift is found to be lateral window with autogenous corticocancellous grafts. The most effective standardized grafting material is autogenous bone grafts due to osteoinductive and osteoconductive potential [2–4]. Various alternative materials have also been used however compromising the osteoinductive potential, such as allografts, xenografts and alloplastic grafts that used for bone substitution to make implantation more predictable and successful clinically [4–7].

Over the years demineralized bone matrix (DBM) has been frequently used for bone grafting. DBM contains active proteins such as bone morphogenetic protein (BMP), transforming growth factor-beta (TGF-β), osteogenin, insulin-like growth factor, and

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Platelet-Rich Fibrin in Maxillary Sinus Augmentation: A Systematic Review

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The aim of this study was to systemically assess the efficacy of platelet-rich fibrin (PRF) on maxillary sinus augmentation using the lateral approach. A PubMed search and a hand search of relevant journals and the bibliographies of selected articles were performed. Clinical studies using PRF with open maxillary sinus augmentation were included. The search provided 290 titles; only 8 studies fulfilled the inclusion criteria. Identified studies showed heterogeneity regarding surgical technique, grafting material, implant placement time, protocol, outcome measures, healing time for biopsy, and implant placement, as well as follow-up period. From the 8 identified studies, 3 studies used PRF as a sole filling material, whereas the other 5 studies used PRF with bone substitutes. PRF showed promising results as a sole filling material for sinus lift with simultaneous implant placement, and PRF seemed to accelerate maturation of a demineralized freeze dried bone allograft. Conversely, it had no effect on deproteinized bovine maturation. PRF fibrin membranes represent an easy and successful method to cover the sinus membrane or osteotomy window.

Key Words: dental implants, maxillary sinus lift, platelet-rich fibrin, systematic review

Introduction

The posterior maxilla represents a unique and challenging site for successful dental implant installation because of its relatively poor bone quality and deficient bone volume caused by ridge resorption and sinus pneumatization.[1–3] Reconstruction of posterior maxillary bone volume has been achieved by different procedures, such as onlay grafts, Le Fort I osteotomies with interpositional bone grafting, and sinus lifts.[4–9] Maxillary sinus augmentation is considered one of the most predictable procedures that can be performed using different grafting materials, such as autogenous, allograft, xenograft, alloplastic bone, and, recently, platelet concentrates.[10–16]

Platelet concentrates were originally used for the treatment and prevention of hemorrhage due to severe thrombopenia. The standard platelet concentrate for transfusion has been named platelet-rich plasma (PRP) and classically contains 0.5×10^{11} platelets per unit.[17–19]

Platelet concentrates have been used to improve healing and enhance bone generation by releasing growth factors. Platelets contain high quantities of key growth factors, such as platelet-derived growth factor, transforming growth factor β_1 and β_2, and vascular endothelial growth factor, which are able to stimulate cell proliferation and enhance angiogenesis.[20] A variety of autologous platelet concentrate techniques have been developed. Blood is collected with anticoagulant and processed by centrifugation, and finally the obtained platelet concentrate is applied with activator to trigger platelet activation and fibrin polymerization. However, all these techniques are expensive and time consuming, and their development in private practice remains quite limited.[21]

In 2001, a new protocol was introduced to concentrate platelets and fibrin in a simpler way without blood modification. Blood is collected and immediately centrifuged without the use of anticoagulant or activator, forming a platelet-rich fibrin (PRF) clot.[22,23] Unlike other platelet concentrates, PRF does not dissolve quickly after application: platelets and leucocytes are collected with high efficiency and platelets are activated during the process, leading to substantial embedding of platelet and leukocyte growth factors into the fibrin matrix. Another advantage of this method is its low cost and the great ease of the procedure.[24,25]

Recently, several clinical studies have been performed to evaluate the use of PRF in maxillary sinus augmentation. The aim of this systematic review was to determine the effect of PRF on the graft quality, quantity, and clinical outcome (based on implant survival).

Materials and Methods

Search strategy

A search was performed on PubMed electronic database, using the following search terms ("sinus augmentation" OR "sinus lift" OR "sinus floor elevation" OR "sinus graft") AND ("platelet" OR "growth factors").

In addition, a further hand search was performed on the major international journals in the field of implant dentistry, as well as oral and maxillofacial surgery, from 2000 to 2014 (*British*

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ORIGINAL RESEARCH

WILEY CLINICAL ORAL IMPLANTS RESEARCH

Influence of residual bone height and sinus width on the outcome of maxillary sinus bone augmentation using anorganic bovine bone

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Abstract

Objective: To evaluate the influence of the posterior residual bone height and sinus width on the outcome of maxillary sinus bone augmentation using anorganic bovine bone.

Material and methods: Bilateral sinus bone augmentation was performed using anorganic bovine bone in 20 patients with residual bone height <2 mm in at least one site on each side. Trephine samples were removed at the implant insertion site 8 months after the grafting procedure, and histological and histomorphometric analyses were performed to examine the relative amount (%) of new bone, anorganic bovine bone, and soft tissue in the grafted area. Based on cone beam computed tomography evaluation, the sites of implant insertion were classified according to sinus width into narrow, average, and wide, and according to residual bone height into ≤2 and >2 mm.

Results: A total of 146 implants were installed and 103 biopsies were evaluated. New bone formation in sites classified as narrow (69 sites), average (19 sites), and wide (15 sites) was 28.5% ± 9.24, 28.9% ± 8.61, and 30.3% ± 7.80, respectively. The mean posterior maxillary residual bone height was 4.0 ± 2.43 mm, and 26 and 77 sites were classified as ≤2 and >2 mm, respectively. New bone formation was 26.2% ± 9.10 and 29.8% ± 8.67 for residual bone height ≤2 and >2 mm, respectively. The differences were non-significant.

Conclusions: Within the limitations of the present study, posterior residual bone height and sinus width were not factors with influence on new bone formation in sinuses grafted exclusively with anorganic bovine bone after 8 months of healing.

KEYWORDS

bone formation, bone substitutes, clinical trial, sinus floor augmentation

Silvio Mario Meloni, Sascha Alekshander Jovanovic, Milena Pisano, Erta Xhanari, Giacomo De Riu, Antonio Tullio, Marco Tallarico

Sinus lift grafting with anorganic bovine bone vs 50% autologous bone mixed with 50% anorganic bovine bone: 2 years after loading results from a randomised controlled trial

Key words *anorganic bovine bone, atrophic maxilla, autologous bone, dental implants, sinus lift*

Purpose: To compare the outcome of implants inserted in maxillary sinuses augmented with anorganic bovine bone (ABB) grafts vs mixed 50% ABB and 50% autologous bone graft, using a lateral window approach.

Materials and methods: This study was designed as a randomised controlled trial of parallel groups. Patients in need of an implant-supported prosthesis in a maxillary posterior area with a residual alveolar bone height no greater than 4 mm (range 0–4 mm) were recruited for lateral sinus grafting. Patients were randomly allocated to receive 50% ABB and 50% autogenous bone (group A) or 100% ABB (group B). After 7 months, tapered implants were inserted with an insertion torque between 20 and 45 Ncm. After 3 months, implants were loaded with screw-retained temporary crowns. Definitive crowns were delivered 3 months later. Outcome measures were implant survival, complications, radiographic marginal bone-level changes, probing pocket depths (PPD) and bleeding on probing (BOP). Clinical data were collected at definitive prosthesis delivery, 1 and 2 years after loading.

Results: Thirty-two consecutive patients were treated with 32 sinus lift procedures (16 group A, 16 group B). A total of 46 implants were installed. No patient dropped out. No crown/implant failed by the end of the study. Three complications (one sinus membrane perforation and two chipping of the ceramic) were observed in three patients in group A, vs none in group B (RR 0.81; 95% CI 0.64 – 1.03 mm; $P = 0.225$). At the 2-year after final loading follow-up, the mean marginal bone loss was 1.18 ± 0.50 mm (95% CI 0.95 – 1.45 mm) in group A and 1.28 ± 0.48 mm (95% CI 0.97 – 1.43 mm) in group B, with no statistically significant differences between the two groups (difference 0.11 ± 0.22 mm; 95% CI -0.06 – 0.16 mm; $P = 0.586$). At the same follow-up, the mean PPD value was 2.70 ± 0.39 for group A and 2.54 ± 0.66 for group B, with no statistically significant difference between groups (difference 0.17 ± 0.39 mm; 95% CI 0.06 – 0.32 mm; $P = 0.456$), while the mean BOP value was 1.21 ± 0.79 for group A and 1.28 ± 0.68 for group B, (difference: 0.06 ± 0.49 mm; 95% CI -0.23 – 0.25 mm; $P = 0.297$).

Conclusions: Within the limitations of this study, the present data seem to confirm the hypothesis that the clinical outcome of implants inserted in sinuses grafted with ABB vs implants inserted in sinuses grafted with mixed 50% ABB and 50% autologous bone are comparable.

Conflict-of-interest statement: *This study was not supported by any company. All the authors declare no conflict of interest.*

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Original Article - Comparative Study

Direct Maxillary Sinus Floor Augmentation for Simultaneous Dental Implant Placement

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Abstract

Aim: The present study was done to evaluate the efficacy of platelet-rich fibrin (PRF) with bovine bone graft (Bio-Oss™) in direct sinus augmentation for simultaneously dental implant placement. **Materials and Methods:** The study included 14 patients who fulfill the inclusion criteria, among them 10 were male and 4 were female with PRF with Bio-Oss™. For each patient, bone level was assessed preoperatively and postoperatively after 1, 6, and 12 months with a panoramic X-ray and radiovisiography to evaluate the vertical bone height from the shoulder of the implant to the most apical end. **Results:** The outcome of the sinus lift and the implants placed was evaluated periodically at 1, 6, and 12 months postoperatively. All the patients underwent two-stage procedures. At the end of 20th week, implants were exposed; radiological parameters were assessed again for implant integration, and prosthetic rehabilitation was started after 2 weeks and it was completed by the end of 24 weeks (6 months postoperatively). Twelve months postoperatively, the endosinus bone gain noted was 7 mm, which indicated the use of PRF with bovine bone graft as a reliable filling material during simultaneous sinus lift and implantation. **Conclusion:** PRF with bone graft (Bio-Oss) is used as an augmentation material after direct maxillary sinus lift, and the resulting bone formation was adequate for placement of dental implant.

Keywords: Bone graft (Bio-Oss™), dental implant, direct sinus augmentation, platelet-rich fibrin

Introduction

Nowadays, the use of dental implants for oral rehabilitation has become a clinical routine. Several studies have reported successful and predictable results in patients with normal bone volume and density, which provide adequate stabilization for implants of standard diameter and length.[1] The loss of teeth in the posterior upper jaw is the main cause for patients requiring dental implant. There are two main reasons which make the rehabilitation of posterior maxilla difficult. First, after loss of teeth in the posterior maxilla, the alveolar ridge decreases by bone atrophy and resorbs vertically and horizontally.[2,3] Second, pneumatization of maxillary sinus causes insufficient vertical bone volume on posterior maxilla.[4] Hence, the restoration of edentulous posterior maxilla with dental implants is challenging due to a deficient posterior alveolar ridge. Grafting the floor of the maxillary sinus is a method of attaining sufficient bone height for posterior maxilla implant placement and has proven to be a highly successful and predictable technique to overcome this problem. The "sinus lift" procedure with bone grafting was reported by Tatum in 1975 and published for the first time by Boyne and James in 1980.[4] Among the variety of sinus floor elevation techniques described in the literature, two approaches, the crestal approach and the lateral window approach, have been mostly used.[5] Various types of grafting material have been successfully utilized for sinus augmentation. Autogenous bone, xenogenic bone, or a mixture of material may be used for sinus augmentation. However, these grafting materials have a high success rate, but they have their associated disadvantage of second site surgery or the cost factor.[6] To overcome these problems, platelet-derived preparations which are rich in growth factors may contribute to an accelerated tissue regeneration

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Review Article

Maxillary sinus augmentation using sinus membrane elevation without grafts - A Systematic Review

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Abstract

Implants have a predictable outcome and are the foremost treatment modality for prosthetic rehabilitation of edentulous patients. Due to loss of bone after extraction and pneumatization of maxillary sinus, there is insufficient bone volume for implant placement. The direct maxillary sinus lift procedure has been performed with different grafting materials (autogenous bone grafts, alloplasts, allografts, and xenografts) and without grafting material, having new bone formation around the implant. There is no evidence to prove the need for grafting material in all direct sinus lift procedures, hence the need for this review. Previous meta-analysis showed that survival rates of implants placed in grafted maxillary sinuses had similar survival rates whether autogenous, allogenous, or alloplastic grafts were used. This paper aims to review scientific data on the direct sinus elevation technique without use of any grafting material, volume of new bone formed, and also mechanism behind this technique. Articles were searched from 1997 to October 2014 in PubMed, Google Scholar, and Cochrane CENTRAL. The study eligibility criteria were (1) direct sinus lift procedure without any graft material during implant placement and (2) human or animal studies with a minimum follow-up of 6 months or more. Two authors independently scrutinized the literature and if any controversy was raised, third author's opinion was sought to arrive at a mutual consensus for including the study in the review. Due to the heterogeneity across all studies in all study designs, the data were not pooled and a meta-analysis was not performed. Taking into consideration all factors reviewed in this regard along with the outcomes, the direct sinus lift technique without grafting can be suggested as a viable treatment option keeping in mind the limitations involved. The average bone gain was seen across all studies ranging from 2.37 to 10 mm and with an implant survival rate ranging from 79.9% to 100% across studies.

Key Words: Dentistry, implants, maxillary sinus lift, systematic review

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INTRODUCTION

Osseointegrated implant prosthesis has evolved over the years. Continuous residual ridge resorption is seen after tooth loss. In the maxillary posterior region, the residual ridge resorption is accompanied by pneumatization of the maxillary sinus. This leads to lack of adequate bone height, and implant placement

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ORIGINAL ARTICLE

WILEY

Comparison between mineralized cancellous bone allograft and an alloplast material for sinus augmentation: A split mouth histomorphometric study

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Abstract

Background: Several grafting materials have been used in sinus augmentation procedures including autogenous bone, demineralized freeze-dried bone, hydroxyapatite, β-tricalcium phosphate, anorganic deproteinized bovine bone, and combination of these and others. Yet, the issue of the optimal graft material for sinus floor augmentation is controversial.

Purpose: This prospective, randomized split-mouth study was undertaken to histomorphometrically compare a biphasic calcium phosphate (BCP) alloplastic bone substitute and a human bone mineral allograft (freeze-dried bone allograft, FDBA) in patients undergoing bilateral maxillary lateral sinus floor augmentation.

Material and methods: Apico-coronal core biopsies were harvested at 9 months from 26 bilateral sites in 13 treated patients. Specimens were processed for histological and histomorphometrical analyses.

Results: Newly formed bone (NB) was evident in all specimens with values of 27.5% and 24.0% at the FDBA and BCP sites, respectively ($P = .331$). The residual graft particle values were 12.5% and 25.4% ($P = .001$), and the connective tissue values were 60.0% and 50.6%, respectively. The osteoconductive value was 52.6% for the FDBA and 26.7% for the alloplast ($P = .001$). The values for the measured residual graft particles, connective tissue, and osteoconductivity, but not for NB, showed highly significant differences between the two groups. All sections in the alloplast material showed evidence of a light chronic inflammatory infiltrate, mainly comprising lymphocytes and multinucleated giant cells.

Conclusions: Both graft materials are suitable for sinus floor augmentation, with the allograft material being more osteoconductive.

KEYWORDS
biomaterials, bone substitute, sinus floor elevation

1 | INTRODUCTION

Alveolar bone resorption in the posterior maxilla is a common sequela of tooth loss and periodontal disease.[1] A lack of sufficient alveolar bone height in this area, especially below the maxillary sinus, often makes it impossible to place standard implants. The most common intervention currently used to increase bone height in this region is to augment the maxillary sinus floor with autogenous bone grafts,[2,3] a procedure referred to as "sinus floor elevation/augmentation." Tatum first described this procedure,[4] and Boyne and James coined the term "sinus lift procedure" shortly thereafter and described the surgical intervention of raising the maxillary sinus floor by elevating the sinus mucosa and interposing bone grafts between the mucosa and bony sinus floor, resulting in adequate bone formation to anchor dental

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WILEY

ORIGINAL ARTICLE

Long-term stability of autologous bone graft of intraoral origin after lateral sinus floor elevation with simultaneous implant placement

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Abstract

Background: Lateral approach to maxillary sinus floor elevation (LSFE) with autologous bone grafts and simultaneous implant insertion is a widespread technique for prosthetic rehabilitation of the atrophic maxilla.

Purpose: To analyze implant survival and autologous bone graft resorption after LSFE, in patients with at least 5 years follow-up.

Materials and Methods: Thirty-three patients (mean age 56 years, range 46-68 years) who had undergone LSFE with intraoral autologous bone graft from mandibular ramus and simultaneous implant insertion were included. A minimum of 5 years of follow-up was required. The total peri-implant bone height was measured at mesial and distal aspects of the implants immediately after surgery (T0) and after a period ranging from 5 to 11.5 years after surgery (mean 7.65 ± 1.80 years) (T1) on digital panoramic and periapical radiographs. Wilcoxon matched-pairs signed rank test was used to compare bone graft height at T0 and T1. The influence of patient-, surgery-, and implant-related factors on the outcomes was investigated.

Results: Of the 58 implants placed, no one was lost. All prostheses were in function, and no biological or mechanical complications occurred. The residual ridge height at the involved sites averaged 6.48 ± 1.72 mm. The mean bone height at grafted regions was 12.05 ± 2.47 mm at T0 and 12.13 ± 2.39 mm at T1 (not statistically significant). Marginal bone level change at T1 averaged −1.22 ± 1.60 mm. None of the evaluated factors significantly affected the results.

Conclusion: Autologous bone grafts from intraoral donor sites display excellent volume stability over time that may contribute to optimal outcomes of the procedure.

KEYWORDS

autogenous bone graft, autologous bone, bone resorption, implant survival, maxillary sinus floor elevation, radiographs, sinus augmentation, sinus lift procedure, survival rate

1 | INTRODUCTION

Rehabilitation of the atrophic posterior maxilla has been widely examined in the literature. Different types of studies, including systematic reviews of the literature and meta-analyses, have shown that implant survival rate tends to decrease when residual bone height decreases, and particularly if the latter is less than 5 mm.[1–5] This correlation requires further consideration when planning implant rehabilitation of the posterior maxilla. Residual bone height and width and even bone density may influence implant positioning in the posterior maxilla. In this anatomical region, in fact, inadequate bone quantity and quality often results in low primary implant stability and increased failure rates.[6–8] Advanced periodontal disease and long-term tooth loss further increase bone resorption in the posterior maxilla. In association

Clinical Case Report

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The endoscopically assisted transcrestal sinus floor elevation with platelet-rich fibrin at an immediate implantation of periapical lesion site

A case report

Hanchi Wang, MS, Jia Wang, DDS, Tianqi Guo, DDS, Xinxin Ding, MS, Wanqi Yu, MS, Jinghui Zhao, DDS, PhD*, Yanmin Zhou, DDS, PhD*

Abstract

Rationale: The traditional maxillary sinus floor elevation has serious postoperative complications and long healing periods, for patients with insufficient residual bone height (RBH). The endoscopic technique improves the blind nature of the sinus floor elevation procedure. Platelet-rich fibrin (PRF) can promote tissue healing and prevent perforation.

Patient concern: A 25-year-old female with residual roots in the maxillary right second molar visited our hospital for dental implants.

Diagnose: CBCT results showed a low-density shadow at the root tip, and the height of the periapical distance from the maxillary sinus floor was less than 1 mm.

Intervention: Patient was immediately subjected to implant after root extraction. Two-step sinus floor elevation was performed under endoscopy. A 12 mm-long implant was installed.

Outcomes: At 10 months after surgery, the hard and soft tissues were stable, and a full-ceramic crown was placed.

Lessons: Immediate implant and endoscope-guided sinus floor elevation through a transcrestal approach by using PRF as the only grafting material is viable in periapical infected sites with a RBH of less than 1 mm.

Abbreviations: CBCT = cone-beam computer tomography, PESS = platelet-rich fibrin endoscope sinus floor elevation and simultaneous implant placement, PRF = platelet-rich fibrin, ISQ = implant stability quotient, RBH = residual bone height.

Keywords: endoscope, immediate implant placement, periapical infection, platelet-rich fibrin, sinus floor elevation

1. Introduction

Dental implants are an excellent choice for many patients with dentition defects. Traditionally, the implantation of apical inflammatory areas should be postponed several months after tooth extraction to prevent infection in the implant surfaces. However, a systematic review suggested that the implant can be placed into sites with endodontic infection if appropriate clinical procedures are performed before implantation.[1] Hence, the treatment time can be shortened effectively, and bone loss can be reduced.[2]

Bone deficiency caused by maxillary sinus gasification and alveolar bone absorption will affect the successful implantation of dental implants and their long-term effects.[3] Maxillary sinus floor elevation is a common surgical method for the reconstruction of maxillary defects. Tatum first described "the lateral approach to the maxillary sinus floor" during a lecture in 1977.[4] Summers[5] introduced a less invasive procedure in 1994. The sinus membrane was elevated by osteotomes through the transcrestal approach. However, this method was subject to visual limitations, which can increase postoperative complications.[6] In 1997, endoscopically controlled sinus floor elevation was introduced, which allowed the operation to be carried out under direct vision.[7] Platelet-rich fibrin (PRF) has a 3D fibrin scaffold structure that is rich in platelets and various cytokines, which can effectively promote the regeneration of soft and hard tissues and control the inflammatory reaction.[8,9] The use of PRF as the only filling material can effectively promote bone regeneration in the case of sinus floor elevation.[10,11]

A modified precise minimally invasive technique termed platelet-rich fibrin endoscope sinus floor elevation and simultaneous implant placement (PESS) was established by our research team. In PESS, P stands for platelet-rich fibrin, E is for endoscope, S is for sinus floor elevation and S represents simultaneous

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ORIGINAL ARTICLE

Sinus lift: 3 years follow up comparing autogenous bone block versus autogenous particulated grafts

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KEYWORDS
autogenous bone graft;
bone block;
maxilla;
particulated bone;
sinus floor elevation

Abstract *Background/purpose:* The aim of this prospective randomized controlled clinical trial was to compare vertical bone gain and bone resorption after sinus graft procedures performed either with particulate or with autogenous bone block.
Material and methods: Forty-one patients underwent sinus graft procedures with autogenous bone. They were randomly assigned to one group. The first group of 22 patients was treated with autogenous bone block with or without particulated bone, while in the second group of 19 patients sinus floor elevation was performed only with particulated autogenous bone. Linear measurements were recorded before surgery with a computed tomography scan at surgery and at 36 months after sinus lift grafting with a second computed tomography scan. To detect statistical differences Student *t* test was applied. Differences were considered significant if P values were < 0.05.
Results: There was a statistically significant difference in bone gain for the group treated with bone block grafts.
Conclusion: As a general clinical guideline the clinician should prefer, wherever feasible, en-block bone grafts for sinus floor augmentation procedures.

Introduction

Rehabilitation of the posterior maxilla with the placement of dental implants is often a challenging procedure due to the reduced bone volume. The loss of bone volume is a consequence of alveolar bone resorption which occurs immediately after extraction of teeth. The pneumatization of the maxillary sinus steadily continues throughout life and

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ORIGINAL PAPER

Two-stage closed sinus lift: a new surgical technique for maxillary sinus floor augmentation

Kornel Krasny · Marta Krasny · Artur Kamiński

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Abstract Bone tissue atrophy may constitute a relative contraindication for implantation. The methods used in reconstruction of the alveolar ridge within the lateral section of the maxilla have been well known but not perfect. Presentation of the two-stage, closed sinus lift technique as well as efficacy evaluation of reconstruction of the alveolar ridge in the maxilla within its vertical dimension with the use of this technique. The total procedure was performed in 26 out of 28 patients qualified for the study. The height of the alveolar ridge at the site of the planned implantation was no <3 mm, the width of the ridge was no <5 mm. During the treatment stage 1 the sinus lift was performed for the first time. The created hollow was filled with allogeneic granulate. After 3–6 months stage 2 was performed consisting in another sinus lift with simultaneous implantation. The treatment was completed with prosthetic restoration after 6 months of osteointegration. In 24 out of 26 cases stage 1 was completed with the average ridge height of 7.2 mm. In stage 2, simultaneously with the second sinus lift, 26 implants were placed and no cases of sinusitis were found. In the follow-up period none of the implants were lost. The presented method is efficient and combines the benefits of the open technique—allowing treatment in cases of larger reduction of the vertical dimension and the closed technique—as it does not require opening of the maxillary sinus.

Keywords Maxillary sinus floor augmentation · Allograft · Alveolar ridge augmentation · Dental implants

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Introduction

The height of the alveolar ridge in the maxilla is the resultant of masticatory forces transferred by the periodontal ligament system to the bone and pneumatisation of maxillary sinuses beginning with eruption of the third molars (Misch 1999). Bone atrophy in the maxilla is a physiological process, which accelerates in case of tooth extractions (Sorní et al. 2005). In females higher post-extraction bone resorption is observed compared to males (Sağlam 2002), which may be related to density of the bone

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Clinical Paper
Dental Implants

Graftless sinus augmentation with simultaneous dental implant placement: clinical results and biological perspectives

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M. Falah, D.-S. Sohn, S. Srouji: Graftless sinus augmentation with simultaneous dental implant placement: clinical results and biological perspectives. Int. J. Oral Maxillofac. Surg. 2016; xxx: xxx–xxx.

Abstract. After a sinus lifting procedure, the compartment around the implants under the sinus mucosal lining in the sinus floor is filled with a blood clot from surrounding bleeding. The aim of this study was to evaluate the feasibility of bone formation following graftless sinus lifting with the simultaneous placement of dental implants. Thirty graftless sinus lifting procedures were performed and 72 dental implants placed in 18 consecutive patients, using the lateral window approach. Clinical and radiological follow-up was conducted throughout the 6-month healing period. Biopsies of 30 cases were collected at 6 months post-treatment: 15 biopsies were taken from the newly formed bone near the basal floor and 15 from the newly formed bone near the elevated membrane. New bone consolidation in the maxillary sinus was apparent radiologically and histologically at 6 months after sinus augmentation, providing an average 6.14 ± 1.34 mm of bone-gain. Based on histological analysis and histomorphometric data, the consolidated bone in the augmented sinus comprised 56.7 ± 11.9% to 59.9 ± 13.4% vital bone tissue. Out of the 72 implants placed, only four failed, indicating a 94% overall implant survival rate. Based on this case series, blood clot can be considered autologous osteogenic graft material, to which osteoprogenitors can migrate, differentiate, and regenerate bone.

Key words: sinus lifting; maxillary sinus; Schneiderian membrane; fibrin clot.

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Sinus lifting procedures are performed routinely to provide the required height of proper and stable bone tissue around inserted dental implants.[1,2] The surgical technique of maxillary sinus Schneiderian membrane (MSSM) lifting with immediate/simultaneous installation of dental implants, generally results in significant bone formation.[1,3–8] The recently reported graftless MSSM elevation procedure and the subsequent augmentation of bone have greatly changed our perspective of bone

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Clinical Study

Comparative Histological and Histomorphometric Results of Six Biomaterials Used in Two-Stage Maxillary Sinus Augmentation Model after 6-Month Healing

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Objectives. To evaluate the performances of six different bone substitute materials used as graft in maxillary sinus augmentation by means of histological and histomorphometric analysis of bone biopsies retrieved from human subjects after a 6-month healing period. *Materials and Methods*. Six consecutive patients (3 males, 3 females, aged 50-72 years), healthy, nonsmokers, and with good oral hygiene, presenting edentulous posterior maxilla with a residual bone crest measuring ≤ 4 mm in vertical height and 3 to 5 mm in horizontal thickness at radiographic examination, were selected to receive sinus augmentation and delayed implant placement. Under randomized conditions, sinus augmentation procedures were carried out using mineralized solvent-dehydrated bone allograft (MCBA), freeze-dried mineralized bone allograft (FDBA), anorganic bovine bone (ABB), equine-derived bone (EB), synthetic micro-macroporous biphasic calcium-phosphate block consisting of 70% beta-tricalcium phosphate and 30% hydroxyapatite (HA-β-TCP 30/70), or bioapatite-collagen (BC). After 6 months, bone core biopsies were retrieved and 13 implants were placed. Bone samples were processed for histological and histomorphometric analysis. CT scans were taken before and after surgery. After 4 months of healing, patients were restored with a provisional fixed acrylic resin prosthesis, as well as after further 2-4 months with a definitive cemented zirconia or porcelain-fused-to-metal crowns. *Results*. There were no postoperative complications or implant failures. The histological examination showed that all biomaterials were in close contact with newly formed bone, surrounding the graft granules with a bridge-like network. No signs of acute inflammation were observed. The histomorphometry revealed 20.1% newly formed bone for MCBA, 32.1% for FDBA, 16.1% for ABB, 22.8% for EB, 20.3% for HA-β-TCP 30/70, and 21.4% for BC. *Conclusions*. Within the limitations of the present investigation, all the six tested biomaterials showed good biocompatibility and osteoconductive properties when used in sinus augmentation procedures, although the FDBA seemed to have a better histomorphometric result in terms of newly formed bone and residual graft material. This trial is registered with ClinicalTrials.gov Identifier (Registration Number): NCT03496688.

1. Introduction

The lack of adequate bone height and thickness negatively affects implant-supported rehabilitation in the edentulous posterior maxilla. Therefore, bone-grafting procedures are needed to increase the available bone volume and to provide structural and mechanical support for the placement of dental implants.

Among graft materials, autologous bone is considered the gold standard due to its osteogenic, osteoinductive, and osteoconductive properties [1–3]. However, the use of autogenous bone has significant drawbacks such as a limited

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International Journal of Implant Dentistry

REVIEW Open Access

Is antral membrane balloon elevation truly minimally invasive technique in sinus floor elevation surgery? A systematic review

Huda Moutaz Asmael

Abstract

Background: Minimally invasive antral membrane balloon elevation was introduced as a less traumatic technique in sinus floor elevation surgery. This is the first systematic review to assess the results of previous studies utilizing this technique.

Aims of the study: The objectives of this study were to assess the bone gain, sinus augmentation success rate, implant survival rate, and complications with minimally invasive antral membrane balloon elevation technique in comparison with the sinus floor elevation by traditional transalveolar technique (Summers' technique).

Materials and methods: An electronic search including MEDLINE (PubMed) and Cochrane database sites was conducted and supported by manual searching for articles on minimally invasive antral membrane balloon elevation from 1945 to 16 January 2017. Sometimes the researchers were contacted to fill the missing information which was not mentioned in their articles.

Results: The extracted articles which involved utilization of balloon technique in maxillary sinus floor elevation surgery were 27 articles, among which only 10 articles met the inclusion criteria. The average of schneiderian membrane perforation with minimally invasive antral membrane balloon elevation (MIAMBE) technique was 6.76%. The sinus augmentation success rate ranged from 100 to 71.4% with average of 91.6%. Bone gain with this technique could reach for more than 10 mm with an average of 6.96 mm.

Conclusions: Minimally invasive antral membrane balloon elevation combined the beneficial points of both lateral window approach and transalveolar approach in which it produced ≥ 10 mm of gained bone in minimally invasive manner. Anyhow, long follow-up period is needed to accurately identify the long-term success rate of dental implants placed with this technique.

Keywords: MIAMBE technique, Sinus augmentation, Sinus floor elevation surgery

Review

Several sinus floor elevation techniques had been introduced as a minimally invasive surgical procedure. Among which, minimally invasive antral membrane balloon elevation technique was developed to achieve better results with minimal trauma to the patient also to reduce complications and intra-operative time. Conventionally, sinus augmentation procedure is performed either via lateral approach (modified Caldwell-Luc approach) [1] or through more conservative transcrestal approach (Summers' technique) [2].

The antral membrane balloon elevation (AMBE) technique was introduced via lateral approach (direct sinus lift surgery) [3, 4].

After that, the minimally invasive antral membrane balloon elevation (MIAMBE) technique was described via transcrestal approach (indirect sinus lift) which involved utilization of balloon device through conservative 3-mm osteotomy site [5]. Since then, several articles were published utilizing this technique. This is the first systematic review for evaluation of the (MIAMBE) technique in sinus lift surgery.

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Research Article

Open Access

Two-stage Lateral Maxillary Sinus Lift using Autogenous Bone and β-Tricalcium Phosphate: Clinical and Histomorphometric Evaluation

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Abstract

Background: To assess the clinical and histomorphometric data of the new bone tissue from a mixture of autologous bone and *β*-tricalcium phosphate.

Materials and methods: A total of 72 two-stage sinus lift were performed in 54 patients during 2007 to 2010. The autologous bone was harvested from the mandibular ramus and mixed with the *β*-tricalcium phosphate Poresorb® TCP sized 1-2 mm. The materials were used in a proportion ranged between 1:1 and 1:3. After the healing period a total of 119 implants were placed and 10 samples of the regenerated bone were collected for the histomorphometric analysis. CBCT or panoramic X-rays were performed pre-surgically, before the implant placement, six months after implant placement and then yearly to evaluate the bone formation and marginal bone loss. The implant success rate was determined using the Albrektsson et al. Criteria.

Results: The mean of the residual bone was 4.07 mm ± 1.87 mm. The bone gain in the sinus was 11.91 mm ± 2.80 mm. The implant success rate was 94.95%. The histomorphometric measurements on the biopsies showed a bone area mean of 39.7 ± 9.71%. The residual allograft area was 16.21 ± 8.78%. The connective tissue was 44.16 ± 5.85%.

Conclusion: Within the limit of this study, the osteoconductive *β*-tricalcium phosphate associated with autologous bone is a viable grafting material for sinus lift procedures. The use of composite grafts can help to reduce the morbidity and aggressivity of the bone harvesting.

Keywords: Sinus lift; Bone regeneration; Dental implants; *β*-tricalcium phosphate; Bone graft; Bone atrophy.

Introduction

The lack of adequate bone volume complicates the rehabilitation of the posterior edentulous maxilla with dental implants. The sinus floor elevation is an accepted treatment procedure to increase the bone in the atrophic upper jaw [1-3]. The implants can be placed simultaneously (one-stage) or delayed (two stages). The one stage procedure is recommended if the residual bone allows to stabilize the implants, and can be performed using either a lateral or transalveolar approach. In cases of severe atrophy, the sinus lift and the implant installation are preferably performed in two stages with a lateral window approach. The autogenous bone graft is the more widely used augmentation material. Because of its osteogenic, osteoconductive and osteoinductive properties is considered the gold standard for maxillary sinus floor augmentation [4-7].

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Simultaneous and delayed direct sinus lift versus conventional implants: Retrospective study with 5-years minimum follow-up

Javier Romero-Millán [1], Federico Hernández-Alfaro [2], Miguel Peñarrocha-Diago [3], David Soto-Peñaloza [1], David Peñarrocha-Oltra [4], María Peñarrocha-Diago [5]

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Abstract

Background: To compare the radiological parameters and success of posterior maxillary direct sinus lift with simultaneous or delayed implant placement, or implant placement in native bone, after a minimum follow-up period of 5 years.

Material and methods: A retrospective cohort study was carried out in a university clinic, selecting patients subjected to implant treatment in the posterior maxilla between the years 2005 and 2011. The patients were divided into three groups: 1) implants placed in native bone; 2) direct sinus lift with simultaneous implant placement; and 3) direct sinus lift with delayed implant placement. Bone crest level, bone loss, vertical bone gain, and implant success and survival after a minimum follow-up period of 5 years after prosthetic loading were analyzed.

Results: A total of 163 patients and 329 implants were included in the study. The mean duration of follow-up was 7.0 ± 1.9 years. Bone loss and implant success and survival were very similar in all three groups, with no significant differences among them. Graft reabsorption was greatest during the first 12 months, though graft stabilization was confirmed after 5 years of follow-up.

Conclusions: Bone loss and percentage success and survival proved very similar for the implants placed in native bone and for sinus lift with simultaneous or delayed implant placement. The height of the graft material decreased mainly in the first 12 months, and continued until stabilization after 5 years, with no significant variations thereafter.

Key words: *Sinus lift, pristine bone, native bone, dental implants, marginal bone loss, radiological study, implant survival, implant success.*

CLINICAL ORAL IMPLANTS RESEARCH

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Implant survival following sinus membrane elevation without grafting and immediate implant installation with a one-stage technique: an up-to-40-month evaluation

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Key words: dental implants, implant survival, new bone formation, sinus elevation

Abstract

Purpose: Various augmentation procedures involving the maxillary sinus, using bone substitutes or bone, have been used to enhance bone support for dental implants. The aim of this study was to retrospectively evaluate the status of implants in patients who had undergone a maxillary sinus lift and immediate implant placement without the addition of graft material.

Materials and Methods: Nineteen patients who had required bone augmentation of their maxillary sinus floor were evaluated in this study. After a bone window in the lateral wall of the sinus has been prepared and the Schneiderian membrane had been carefully elevated, dental implants were inserted in the residual bone, creating a membrane elevation. Resorbable collagenous membrane was used to seal the lateral access window of the maxillary sinus after implant placement. Clinical and radiological follow-up was carried out up to 40 months after implant installation.

Results: A total of 28 implants in lengths of 10 and 12 mm were placed in a one-stage healing protocol, with an average residual bone height of 5.25 mm (SD = 1.48). All implants remained stable, with a survival rate of 100%. An increase in mean bone height of 4.75 mm (SD = 1.13) was gained. The marginal bone levels relative to the coronal aspect of the implant shoulder exhibited a mean change of 1.01 mm (SD = 0.49) from the baseline. Of the 19 patients, none showed a plaque index or gingival index greater than 2, and 14 patients showed no presence of plaque.

Conclusion: The findings of the study regarding the immediate placement of implants without the use of bone grafts or other bone substitute materials demonstrate a successful approach for new bone formation around implants in the posterior part of the maxilla, when the preoperative height of the subantral bone is moderate and enough to achieve primary stability.

Long-term edentulism may result in resorption of the alveolar process and, as a result, in difficulties in placing dental implants. For the posterior maxilla, augmentation of the atrophic alveolar crest has been successfully carried out using various sinus augmentation techniques, in combination with or without bone substitute and prior to or simultaneously with dental implant installation (Esposito et al. 2010; Riben & Thor 2012). Recent studies have described modified techniques with which no graft material was needed in placing dental implants when sinus membrane elevation was carried out simultaneously, and where a blood clot acted as a scaffold for bone formation (Lundgren et al. 2004; Palma et al. 2006; Thor et al. 2007; Sohn et al. 2008; Cricchio et al. 2011).

To further simplify the treatment concept for the patient, a non-submerged one-stage implant surgical protocol may be used when possible, without apparent negative effects on marginal bone levels after healing (Cecchinato et al. 2004).

The aim of this study was to retrospectively evaluate implant survival rates and to evaluate the average new bone formation around the implants in maxillary sinuses, in patients treated with sinus membrane elevation without bone grafts and simultaneous installation of dental implants in residual bone using a non-submerged one-stage implant surgical protocol.

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Long-term outcome of dental implants after maxillary augmentation with and without bone grafting

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Abstract

Background: This study aims to evaluate the technique of sinus bone reformation, which consists of elevating the sinus membrane and placement the implant without bone graft, compared with the widely-used technique involving raising the maxillary sinus and grafting, using animal hydroxyapatite as the filler, while simultaneously fixing the implants.

Material and Methods: This is a retrospective study on two groups of patients who underwent elevation of the sinus membrane and simultaneous placement of the implant. The grafting technique was applied to one group, while the other had no graft. An alveolar ridge height of 4 to 7 mm was necessary. Radiological control was undertaken at 6 months and one year post-prosthetic loading. In each group 38 implants were placed.

Results: No significant behavioural differences were observed in the implants according to the Albrektsson success criteria. Implant failure was observed in 2 implants from the bone grafting group (success rate 93%) and in 1 implant from the reformation group (success rate 97%). In this group, bone formation was observed on both sides of each implant, the bone gain was measured using image management software (2.7±0.9mm mesial and 2.6±0.9mm distal). There was no correlation between mesial and distal bone gain and implant´s length.

Conclusions: The results indicate that bone reformation is a valid technique in cases involving atrophy of the posterior maxilla. Primary stability, maintenance of space by the implant, and the formation of a blood clot are crucial in this technique in order to achieve bone formation around the implant. It is an alternative to the conventional technique of sinus lift with filling material, and has several advantages over this procedure, including a lower infection risk, as it does not involve a biomaterial, reduced cost, a simpler technique, and better acceptance by the patient.

Key words: *Bone formation, sinus membrane elevation, maxillary sinus, bone grafting.*

Maxillofacial Plastic and Reconstructive Surgery

REVIEW Open Access

Sinus bone graft and simultaneous vertical ridge augmentation: case series study

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Abstract

Background: This study aims to examine the outcome of simultaneous maxillary sinus lifting, bone grafting, and vertical ridge augmentation through retrospective studies.

Methods: From 2005 to 2010, patients with exhibited severe alveolar bone loss received simultaneous sinus lifting, bone grafting, and vertical ridge augmentations were selected. Fifteen patients who visited in Seoul National University Bundang Hospital were analyzed according to clinical records and radiography. Postoperative complications; success and survival rate of implants; complications of prosthesis; implant stability quotient (ISQ); vertical resorption of grafted bone after 1, 2, and 3 years after surgery; and final observation and marginal bone loss were evaluated.

Results: The average age of the patients was 54.2 years. Among the 33 implants, six failed to survive and succeed, resulting in an 81.8% survival rate and an 81.8% success rate. Postoperative complications were characterized by eight cases of ecchymosis, four cases of exposure of the titanium mesh or membrane, three cases of peri-implantitis, three cases of hematoma, two cases of sinusitis, two cases of fixture fracture, one case of bleeding, one case of numbness, one case of trismus, and one case of fixture loss. Prosthetic complications involved two instances of screw loosening, one case of abutment fracture, and one case of food impaction. Resorption of grafted bone material was 0.23 mm after 1 year, 0.47 mm after 2 years, 0.41 mm after 3 years, and 0.37 mm at the final observation. Loss of marginal bone was 0.12 mm after 1 year, and 0.20 mm at final observation.

Conclusions: When sinus lifting, bone grafting, and vertical ridge augmentation were performed simultaneously, postoperative complications increased, and survival rates were lower. For positive long-term prognosis, it is recommended that a sufficient recovery period be needed before implant placement to ensure good bone formation, and implant placement be delayed.

Keywords: Sinus bone graft, Vertical ridge augmentation, Dental implant

Background

After extracting a tooth in the maxilla, the alveolar bone undergoes resorption, and buccopalatal or vertical bone loss results in an edentulous area of the maxilla [1]. Normally in an edentulous area, atrophy of alveolar bone first affects the width of the alveolar ridge and then the vertical aspect of the alveolar ridge [2]. In patients with severe vertical defects in the alveolar bone due to various causes such as tooth loss, periodontal disease, trauma, and surgical resection of tumors, it is difficult to place implants of appropriate axis, depth, and width. In such cases, it is advantageous to reconstruct the alveolar bone through bone grafting and soft tissue surgery and to place the implants in a second surgery. If the amount of alveolar bone is insufficient, various surgeries such as bone grafting, guided bone regeneration (GBR), onlay bone grafting, ridge splitting, ridge expansion, distraction osteogenesis (DO), interpositional bone grafting, and sinus lifting with or without bone grafting have been performed [3, 4].

It is known that a titanium mesh or non-absorbable barrier membrane is effective for providing stability to

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Article

Assessment of the Simultaneous Use of Biomaterials in Transalveolar Sinus Floor Elevation: Prospective Randomized Clinical Trial in Humans

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Abstract: Implants inserted in the posterior maxilla frequently need additional surgery for successful bone augmentation. One of the most common procedures for this is transalveolar sinus floor elevation. There are different protocols for this procedure, and there is controversy over the simultaneous application of grafting material upon elevating. In this prospective randomized clinical study in humans, a total of 49 transalveolar sinus floor elevations were performed in 49 different patients, divided into a control group (without graft, 25 patients) and a test group (with graft, 24 patients). The analyzed variables were obtained through digital orthopantomography on day 0 (day of surgery) and 18 months after surgery. These measurements showed a tendency towards greater vertical bone gain in the test group, but this was not statistically significant. Therefore, considering that sinus elevation and implant placement without the application of grafts is a successful treatment with fewer complications, a critical assessment of the need for these biomaterials is necessary.

Keywords: osteotome; transalveolar sinus floor elevation; bone grafting

1. Introduction

Since the 1970s, classical longitudinal studies have shown that the first teeth to be lost due to periodontal disease are the maxillary molars, whose prolonged absence causes a reduced bone volume due to pneumatization of the maxillary sinus and alveolar bone resorption from the lack of mechanical stimulation [1–7]. The success of implant therapy is directly related to primary stability, and in turn, to the bone volume present at the implant site. As a result, the long-term prognosis can be poor due to the presence of insufficient bone volume [8–12].

The first author to propose a transalveolar approach to correct the pneumatization of the sinus cavity and place implants was Tatum in 1986 through a "socket former", which is the same size as the implant to be placed [13,14]. In 1994, Summers proposed the use of tapered osteotomes with increasing diameters to conserve more bone when drilling was not carried out. After elevating, autografts, allografts, xenografts, or synthetic materials were added [15–18].

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Maxillary sinus augmentation

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Abstract

Placing dental implants in the maxillary posterior region can be both challenging and un-nerving for a regular implant dentist who is not well versed with advanced surgical procedures. It is vital for a general dentist to understand the fundamentals of bone grafting the maxillary sinus if he/she is really committed to providing the best health care for their patients. The dental practice is seeing an increasing group of patients who are living longer, and this group of older baby boomers often has an edentulous posterior maxilla either unilateral or bilateral. When edentulous, the posterior maxilla more likely has diminished bone height, which does not allow for the placement of dental implants without creating additional bone. Through grafting the maxillary sinus, bone of ideal quality can be created (allowing for placement of dental implants), which offer many advantages over other tooth replacement modalities. The sinus graft offers the dental patient a predictable procedure of regenerating lost osseous structure in the posterior maxilla. This offers the patient many advantages for long-term success. If dentists understand these concepts, they can better educate their patients and guide them to have the procedure performed. This article outlines bone grafting of the maxillary sinus for the purpose of placing dental implants. This review will help the readers to understand the intricacies of sinus augmentation. They can relate their patient's condition with the available literature and chalk out the best treatment plan for the patient, especially by using indirect sinus augmentation procedures which are less invasive and highly successful if done using prescribed technique.

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Full Text

Introduction

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Mesenchymal stem cells in maxillary sinus augmentation: A systematic review with meta-analysis

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Data sharing statement: Technical appendix, statistical code, and dataset available from the corresponding author at Francesco Mangano (francescomangano1@mclink.net). Participants gave informed consent for data sharing even though are anonymized and the risk of identification is low.

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Abstract

AIM: To investigate the effectiveness of mesenchymal stem cells (MSCs) in maxillary sinus augmentation (MSA), with various scaffold materials.

METHODS: MEDLINE, EMBASE and SCOPUS were searched using keywords such as sinus graft, MSA, maxillary sinus lift, sinus floor elevation, MSC and cell-based, in different combinations. The searches included full text articles written in English, published over a 10-year period (2004-2014). Inclusion criteria were clinical/radiographic and histologic/ histomorphometric studies in humans and animals, on the use of MSCs in MSA. Meta-analysis was performed only for experimental studies (randomized controlled trials and controlled trials) involving MSA, with an outcome measurement of histologic evaluation with histomorphometric analysis reported. Mean and standard deviation values of newly formed bone from each study were used, and weighted mean values were assessed to account for the difference in the number of subjects among the different studies. To compare the results between the test and the control groups, the differences of regenerated bone in mean and 95% confidence intervals were calculated.

RESULTS: Thirty-nine studies (18 animal studies and 21 human studies) published over a 10-year period (between 2004 and 2014) were considered to be eligible for inclusion in the present literature review. These studies demonstrated considerable variation with respect to study type, study design, follow-up, and results. Meta-analysis was performed on 9 studies (7 animal studies and 2 human studies). The weighted mean difference estimate from a random-effect model was 9.5% (95%CI: 3.6%-15.4%), suggesting a positive effect of stem cells on bone regeneration. Heterogeneity was measured by the I^2 index. The formal test confirmed the presence of substantial heterogeneity (I^2 = 83%, P < 0.0001). In attempt to explain the substantial heterogeneity observed, we considered a meta-regression model with publication year, support type (animal *vs* humans) and