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MAXILLARY SINUS AUGMENTATION
For Implant Rehabilitation

MASTERS THESIS

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III-ABBREVIATIONS

BMP: Bone Morphogenic Protein

e-PTFE: Expanded Polytetrafluoroethylene

PRP: Platelets Rich Plasma

1-ABSTRACT

The maxillary sinus grafting has become one of the most popular and successful bone grafting procedures undertaken in the maxillofacial region. Traditionally, the maxillary sinus has been an area that has been avoided by most dentists and augmentation surgery has been performed only when absolutely necessary.

Philip Boyne (16) was the first to propose the use of bone grafting in the maxillary sinus for prosthetic purposes. When he started in the 1960s, grafting of the maxillary sinus was used to increase the bulk of bone for subsequent maxillary ridge reduction for optimal prosthodontic inter-arch distance. With the introduction of root-form titanium implants practitioners started utilizing sinus grafting for those sinuses that were deficient in bone height to hold this type of implants.

Indications for maxillary sinus augmentation include loss of alveolar bone height, poor bone density, and strong occlusal forces. Contraindications include narrowing of the osteomeatal complex, malignancy, severe deformities of the maxillary sinus, scarring of the sinus mucosa from trauma, radiotherapy of the head and neck, sinusitis, inadequate oral hygiene, untreated periodontal disease, severe para-functional habits, fulminant mucosal disease, and severe xerostomia.

Advances in grafting techniques have allowed simultaneous implant placement with maxillary sinus augmentation. Nevertheless, delayed implant placement after sinus grafting still gives better results than placing the implant simultaneously with sinus grafting (101).

Complications of maxillary sinus augmentation include bleeding, buccal flap tear, infraorbital nerve injury, membrane perforation, incision line opening, barrier membrane exposure, graft loss or failure, implant failure, oroantral fistula, and implant migration (80).

Alternatives to maxillary sinus augmentation are indicated when the operation is contraindicated. These alternatives include placing tilted implants to avoid the sinus, placing short implants, and zygomatic implants (2, 56, 69). However, all of these alternatives offer inferior results to the sinus augmentation option and must be used only if it is absolutely contraindicated to perform sinus augmentation.

The sinus floor, and to a smaller extent the elevated sinus membrane, offers an ideal environment for bone formation. Though it would seem intuitively counterproductive to bone graft healing, this area is remarkably forgiving of complication, infection, resorption, or rejection (34).

The best grafting material to use is natural autogeneous bone, but this golden standard has been loosing the battle against new grafting materials that are xenogenic which proved to provide faster healing and regeneration capabilities when mixed with Platelets Rich Plasma.

This thesis will underline the techniques used for maxillary sinus augmentation while reviewing the success rates of each technique. Indications and contraindications will be outlined together with the possible complications that might be encountered while attempting to graft the maxillary sinus. A comparison will be made between simultaneous and delayed implant placement protocols. Also various grafting material will be outlined.

The aim is to provide a reference and act as a guideline for clinicians, and interested students, summarizing a great deal of the science and literature available on maxillary sinus augmentation up to the date that this thesis was finished

2-INTRODUCTION

Loss of alveolar height and width following tooth removal is significant and often accounting for up to 50% of the alveolar mass in the area. Such resorption often precludes implant placement, or forces placement of narrower, shorter implants than desired, often in positions that are not ideal. The compromised final clinical result may have significant functional, hygienic, and esthetic consequences (67).

The maxillary sinus can vary in size and shape, making implant placement in some cases impossible without surgical modification (103). The purpose of elevation of the maxillary sinus is to achieve sufficient bone volume of at least 10 mm long for implant placement.

2.1 History of Sinus Floor Augmentation

Increasing osseous tissue in the maxillary sinus area for prosthetic purposes was first proposed by Boyne in the 1960s in a series of lectures to his postgraduate students at the United States Navy Dental School (16). At that time grafting of the maxillary sinus was used to increase the bulk of bone for subsequent maxillary ridge reduction for optimal prosthodontic inter-arch distance. Some patients presenting for a conventional complete denture had bulbous or enlarged tuberosities that impinged on the inter-arch space, making it impossible to construct complete mandibular and maxillary prosthesis. Because removal of bone from the mandible was not feasible, removal of bone from the maxillary tuberosity was the obvious option. However, some of these patients presented with large, pneumatized sinuses that would not permit bone removal to produce the necessary inter-arch accommodation. Therefore, construction of a functional prosthesis was difficult or impossible. In dealing with this situation, Boyne utilized a Caldwell-Luc opening in the maxillary antrum, the sinus membrane was elevated, and then an autogeneous particulate marrow cancellous bone graft was placed beneath the sinus floor. Approximately 3 months later, the bone of the tuberosity was ready to be reduced without the risk of opening into the antrum, which was now protected by additional osseous structure. This unique surgical treatment enabled many patients, who otherwise would have been denied adequate

reconstruction, to have conventional prosthesis. Thus, the first sinus elevation bone graft procedure was undertaken for placing a conventional denture.

During the late 1970s, grafting of the maxillary sinus as described for conventional prosthesis was undertaken for patients who had large, pneumatized antra in preparation for blade implant placement to enable construction of fixed, simplified, or removable prosthesis for the posterior maxilla. Autogeneous particulate iliac bone was usually used as the grafting material. After a postoperative period of approximately 3 months, the blade implants were placed and subsequently used as abutments for removable or fixed prosthesis (14).

With the introduction of root-form titanium implants, it became apparent that many potential posterior maxillary sites were too deficient in vertical bone height and width for placement of such implants. Several practitioners undertook various surgical techniques designed to enter the antrum, elevate the sinus membrane, and place a bone graft. Of these techniques, entrance to the antrum was made from one of three anatomic sites: The first utilized the classic superior position of the Caldwell-Luc opening, located just anterior to the zygomatic buttress (53). The second used a mid-maxillary position, between the level of the crest of the alveolar ridge and the level of the zygomatic buttress area (111). The third approach was at a low position along the anterior surface of the maxilla, very near the level of the existing alveolar ridge (111).

The third entrance site became quite popular because it provided quick access to the sinus floor and enabled the practitioner to make an antral window, infracture the buccal osseous plate into the antrum, place the bone graft material, and close the incision. However, several possible complications such as hematoma, pre-existing sinus disease, or an infection that would lead to drainage; would all lead to collection in the area of the osteotomy and tend to produce an oroantral fistula. Thus the mid-position antrostomy and the high classic Caldwell-Luc opening were the ones preferred by most oral and maxillofacial surgeons (53).

Another surgical technique was described by Bruschi and coworkers for augmentation of an atrophic alveolar bone under the maxillary sinus without utilization of bone grafts or membranes (18). This technique was called *Localized Management of the*

Sinus Floor. It comprises the dissection of a partial-thickness flap, buccal expansion of the residual alveolar bone, and the fracture and elevation of the sinus floor with simultaneous implant placement. This technique offered the advantage of placing implants in a single stage in the posterior maxilla with as little as 5 mm of residual bone. The authors reported a success rate of 97.5%.

Summers 1994 (92), described a conservative technique for sinus floor elevation which utilizes osteotomes instead of drilling. The objective of the technique was to maintain the existing maxillary bone by apical relocation. The technique was recommended for type 3 and type 4 bones. In type 4 bone, the osteotomes can be used alone, whereas in type 3 bone some drilling may be required. If bone graft material is added, the technique is called the *bone-added osteotome sinus floor elevation*. Summers suggested autogeneous bone graft mixed with demineralized freeze-dried bone and a small quantity of resorbable hydroxyapatite to provide radiographic visibility (92, 83, 95).

Recently the lateral window technique with its modifications is still the most commonly used technique. The modifications have been concentrated on newer grafting materials going deeper into the synthetic industry which has become a large area of research in today's competing corporative market. Moreover, new ideas are emerging and techniques are being modified for the minimal invasive surgery that branched out of the Summers osteotome technique, utilizing what is being discovered and innovated in the rapidly advancing biotechnological field.

2.2 Anatomy of the Maxillary Sinus

The maxillary sinus is a large pyramidal cavity, within the body of the maxilla. Its apex, which is directed lateralward, is formed by the zygomatic process. Its base is directed medialward, and is formed by the lateral wall of the nose (Figure 1). Its walls are everywhere exceedingly thin, and correspond to the nasal orbital, anterior, and infra-temporal surfaces of the body of the bone. Its nasal wall, or base, presents, in the disarticulated bone, a large, irregular aperture, communicating with the nasal cavity. In the articulated skull this aperture is much reduced in size by the following bones: the uncinate process of the ethmoid above, the ethmoidal process of the inferior nasal concha below, the

vertical part of the palatine behind, and a small part of the lacrimal bone above and in front the sinus communicates with the middle meatus of the nose, generally by two small apertures left between the above-mentioned bones.

Usually only one small opening exists, near the upper part of the cavity; the other is closed by mucous membrane on the posterior wall are the alveolar canals, transmitting the posterior superior alveolar vessels and nerves to the molar teeth. The floor is formed by the alveolar process of the maxilla.

Projecting into the floor of the antrum are several conical processes, corresponding to the roots of the first and second molar teeth; in some cases the floor is perforated by the roots of the teeth. The infraorbital canal usually projects into the cavity as a well-marked ridge extending from the roof to the anterior wall; additional ridges are sometimes seen in the posterior wall of the cavity, and are caused by the alveolar canals. The size of the cavity varies in different skulls, and even on the two sides of the same skull (89).

Branches of the internal maxillary artery supply this sinus. These include the infraorbital artery, lateral branches of the sphenopalatine, greater palatine, and the alveolar arteries (109). Venous drainage runs anteriorly into the facial vein and posteriorly into the maxillary vein and jugular system. The sinus is innervated by branches of the maxillary nerve. Specifically, the greater palatine nerve and the branches of the infraorbital nerve.

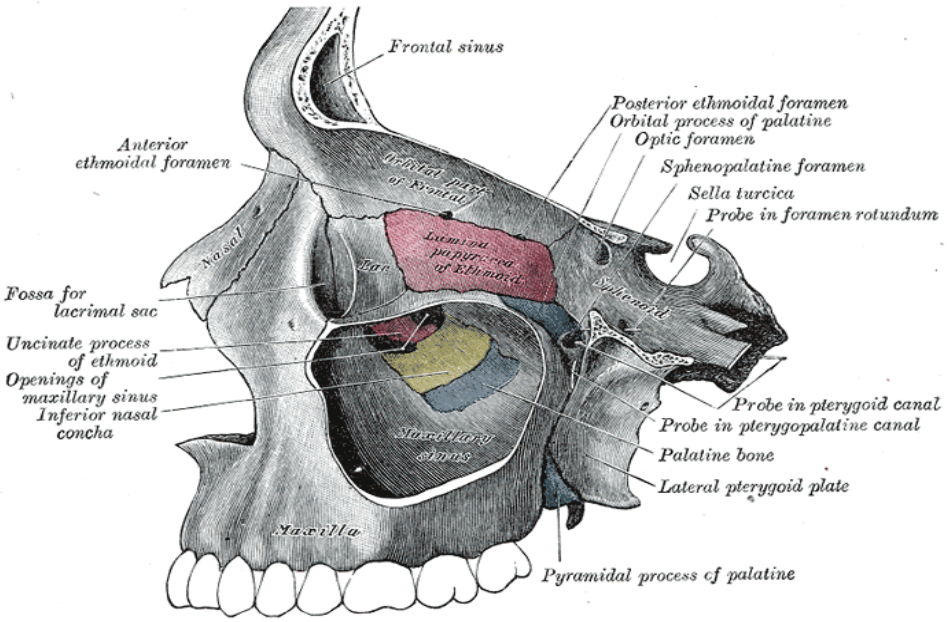

Figure 1: Left maxillary sinus opened from the exterior ‡

‡ Figure taken from (gray's anatomy online www.bartleby.com)

2.3 Physiology of the Maxillary Sinus:

The maxillary sinus provides resonance to the voice and lightens the weight of the craniofacial complex. The healthy maxillary sinus is self-maintained by postural drainage and actions of the ciliated epithelial lining, which propel microorganisms toward the ostium. The sinus also produces mucous containing lysosome and immunoglobulins (4).

2.4 Classification of the Posterior Maxilla Relating to the Sinus

2.4.1 Misch's Classification of the Posterior Maxilla

Misch 1999 (65), proposed a classification for the maxillary sinus which was a modification of his earlier classification in 1987. The modification in this new classification was to include the lateral dimension of the sinus cavity. He used this dimension to modify the healing period protocol. This classification was presented in the form of 4 treatment options as follows:

Option 1: Conventional Implant Placement

This requires the presence of sufficient bone height to permit the placement of endosteal implants following standard surgical protocol (Figure 2). Here the bone height bellow the floor of the maxillary sinus should be more than 12 mm and the crestal ridge greater than 5 mm. If the crestal ridge is less than 5 mm wide, this requires augmentation, ridge splitting, and/or ridge expansion prior to implant placement.

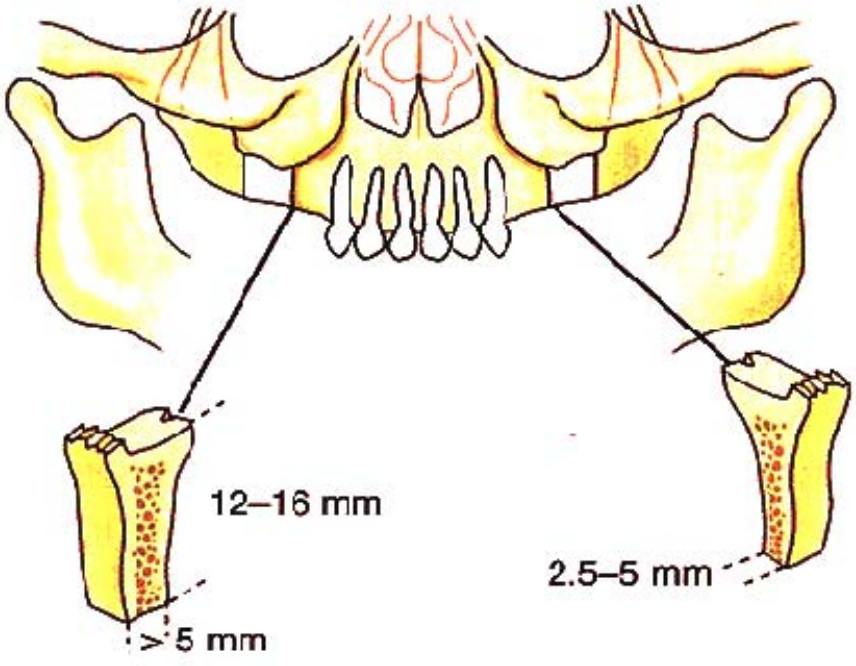

Figure 2: Option-1. More than 12 mm of bone below the floor of the maxillary sinus offers adequate height for an implant supported prosthesis. ‡

Option 2: Sinus Augmentation

Here the bone height below the sinus is 10 to 12 mm (Figure 3). Sufficient bone height is achieved using osteotomes through the alveolar crest. The osteotomy is performed approximately 1 to 2 mm below the floor of the sinus using a flat end osteotome firmly tapped 2 to 3 mm beyond the prepared implant osteotomy. A greenstick upfracture of the sinus floor elevates the bone and sinus membrane above the blunt end of the osteotome. A longer implant is then placed into the osteotomy, extending into the sinus cavity 2 to 3 mm beyond the available bone. It is not necessary to place any graft material since the elevation is minor.

‡ Figure taken from Misch C., Contemporary Implant Dentistry, 1999

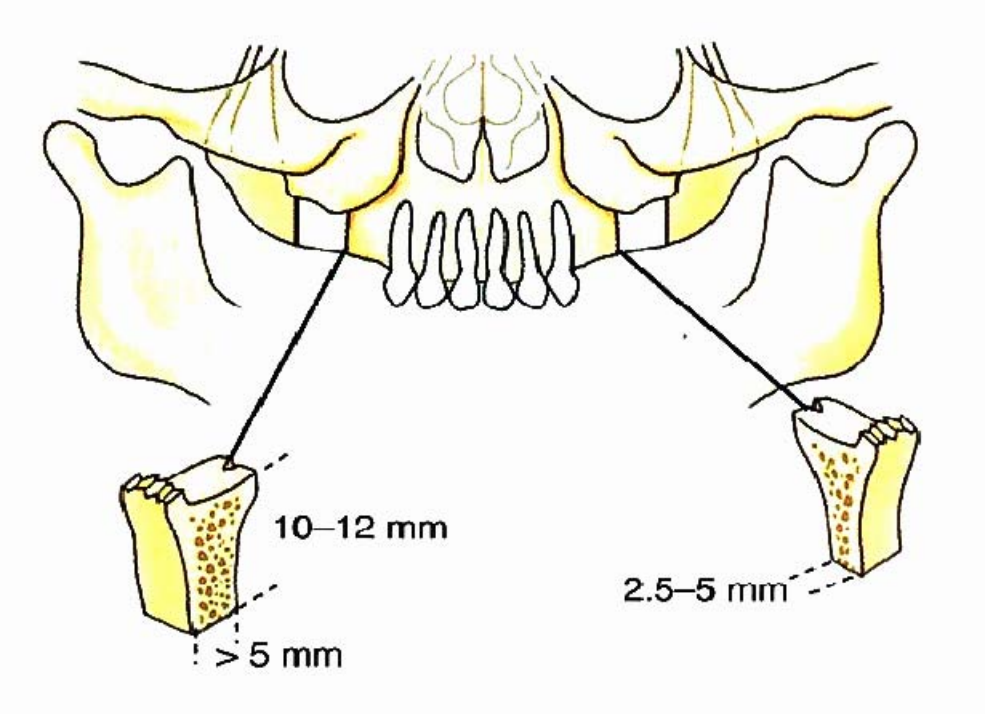

Figure 3: Option 2. When 10-12 mm of bone is present between the maxillary sinus and the crest of the ridge, sinus augmentation can be performed through the implant osteotomy accompanied by implant placement. ‡

Option 3: Sinus Grafting and Immediate Implant Placement

If the bone below the antral floor is at least 5 mm and the original ridge is narrow (Figure 4), then a lateral approach to sinus augmentation is combined with onlay grafting. If the ridge is adequate, the implant is placed at the same time as the sinus augmentation.

Option 4: Sinus Grafting and Delayed Implant Placement

When the alveolar ridge height is 4 mm or less (Figure 5), a delayed approach is advocated. A compromised osseous bed, extensive pneumatization, and insufficient bone structure for primary implant stabilization require more time for bone graft consolidation prior to implant placement.

‡ Figure taken from Misch C., Contemporary Implant Dentistry, 1999

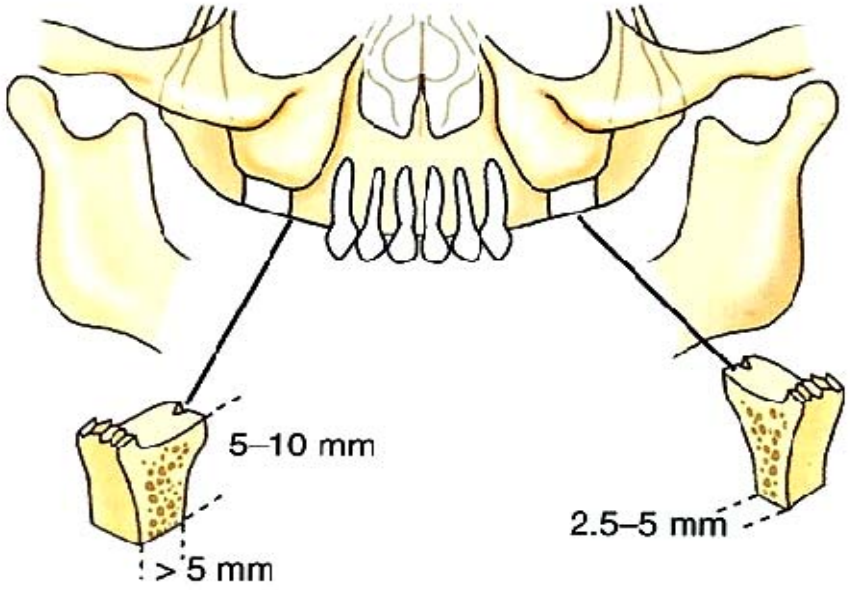

Figure 4: Option 3. When remaining vertical bone height is 5-10 mm, a sinus graft is needed to augment the residual bone. Implants can be placed either simultaneously or after a delay.‡

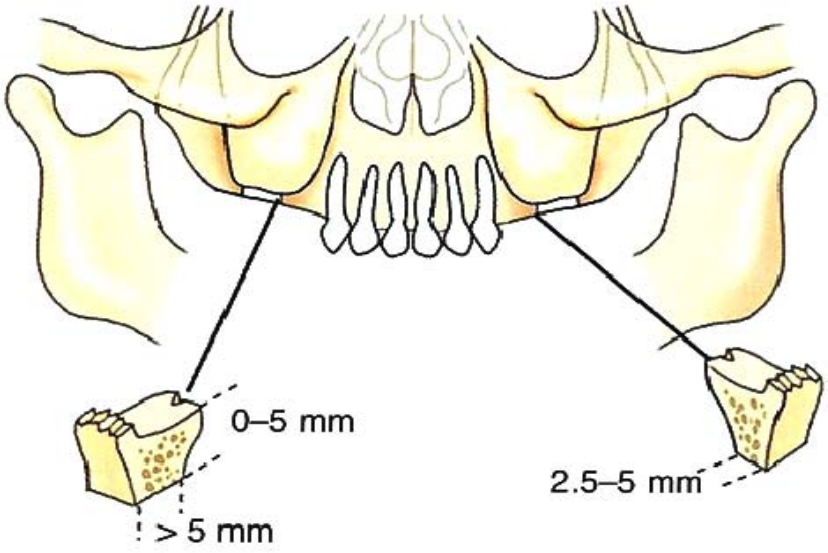

Figure 5: Option 4. Less than 5 mm of bone between the cortical floor and the crest of the ridge requires sinus grafting prior to implant placement.‡

‡ Figures taken from Misch C., Contemporary Implant Dentistry, 1999

2.4.2 Chiapasco's Classification of the Posterior Maxilla

This classification is based on three variables: width and height of the residual alveolar bone, and inter-ridge relation (21). These 3 variables are used to define nine types (classes A to I) of sinus morphologies according to their treatment needs. Classes A to D address height and width, and the remaining classes define crown height space.

Class A:

- Residual alveolar ridge height of 4 to 8 mm
- Residual alveolar ridge width of at least 5 mm
- Absence of vertical resorption of the alveolar ridge with maintenance of acceptable vertical *inter-maxillary* relation

Suggested surgical protocol:

A. Sinus elevation with osteotome technique
B. Sinus elevation via lateral approach

Class B:

- Residual alveolar ridge height of 4 to 8 mm
- Residual alveolar ridge width of less than 5 mm (ie; presence of horizontal resorption)
- Absence of vertical resorption of the alveolar ridge with maintenance of acceptable vertical inter-arch distance

Suggested surgical protocol:

A. Sinus elevation and lateral bone grafting
B. Sinus elevation and guided bone regeneration

Class C:

- Residual alveolar ridge height of less than 4 mm
- Residual alveolar ridge width of at least 5 mm (ie; absence of horizontal resorption)
- Absence of vertical resorption of the alveolar ridge with maintenance of acceptable vertical inter-arch distance

Suggested surgical protocol:

A. Sinus elevation via lateral approach

Class D:

- Residual alveolar ridge height of less than 4 mm
- Residual alveolar ridge width of less than 5 mm
- Absence of vertical resorption of the alveolar ridge with maintenance of acceptable vertical inter-arch distance

Suggested surgical protocol:

A. Sinus elevation via lateral approach with lateral bone grafting
B. Sinus elevation and guided bone regeneration

Class E:

- Same characteristics as class A except with increased crown height space (Figure 6)

Suggested surgical protocol:

A. Vertical onlay grafts with autogeneous bone block
B. Interpositional alveolar bone graft
C. Vertical guided bone regeneration
D. Vertical distraction osteogenesis

Class F:

- Same characteristics as class B except with increased vertical crown height space (Figure 6)

Suggested surgical protocol:

A. Simultaneous vertical and horizontal onlay grafts with autogeneous bone blocks
B. Interpositional bone graft without sinus grafting
C. Simultaneous vertical and horizontal guided bone regeneration

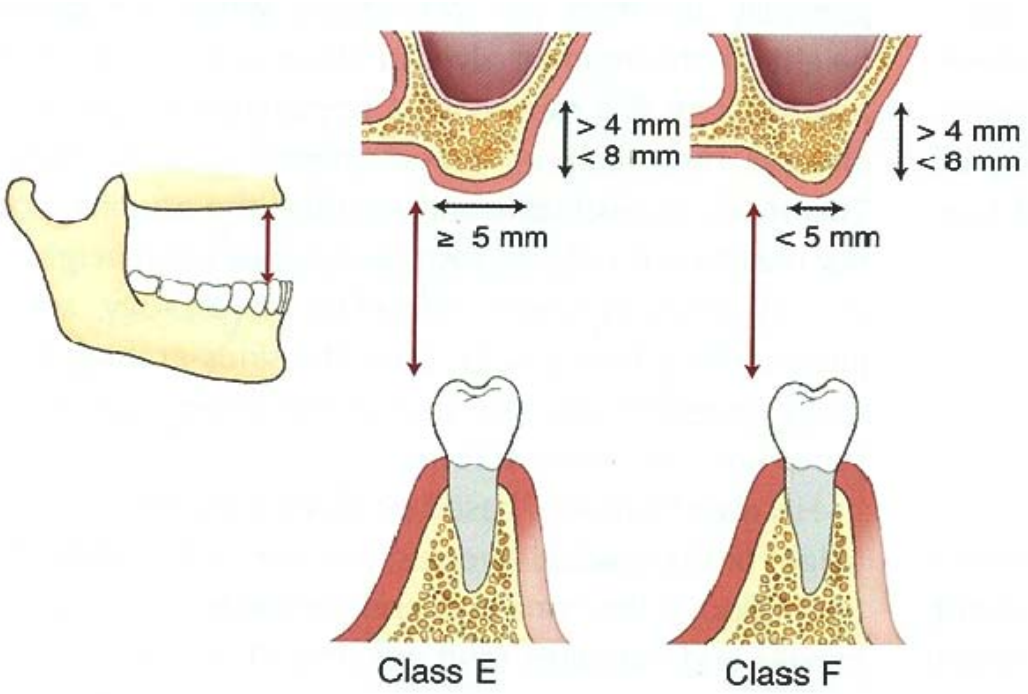

Figure 6: Class E; increased crown height space with 4 to 8 mm of bone below the antrum and 5 mm or more of crestal bone width. Class F; increased crown height space with 4 to 8 mm of bone below the antrum and less than 5 mm width of bone on the crest ‡

Class G:

- Same characteristics as class C except with increased vertical crown height space (Figure 7)

Suggested surgical protocol:

A. Sinus graft via a lateral approach combined with vertical autogenous block onlay graft
B. Sinus graft with vertical guided bone regeneration

Class H:

- Same characteristics as class D except with increased vertical crown height space (Figure 7)

Suggested surgical protocol:

A. Sinus graft via a lateral approach with simultaneous vertical and horizontal onlay block grafts
B. Sinus graft with simultaneous vertical and horizontal guided bone regeneration

‡ Figure taken from Chiapasco's prosthetic rehabilitation of complex cases 2003

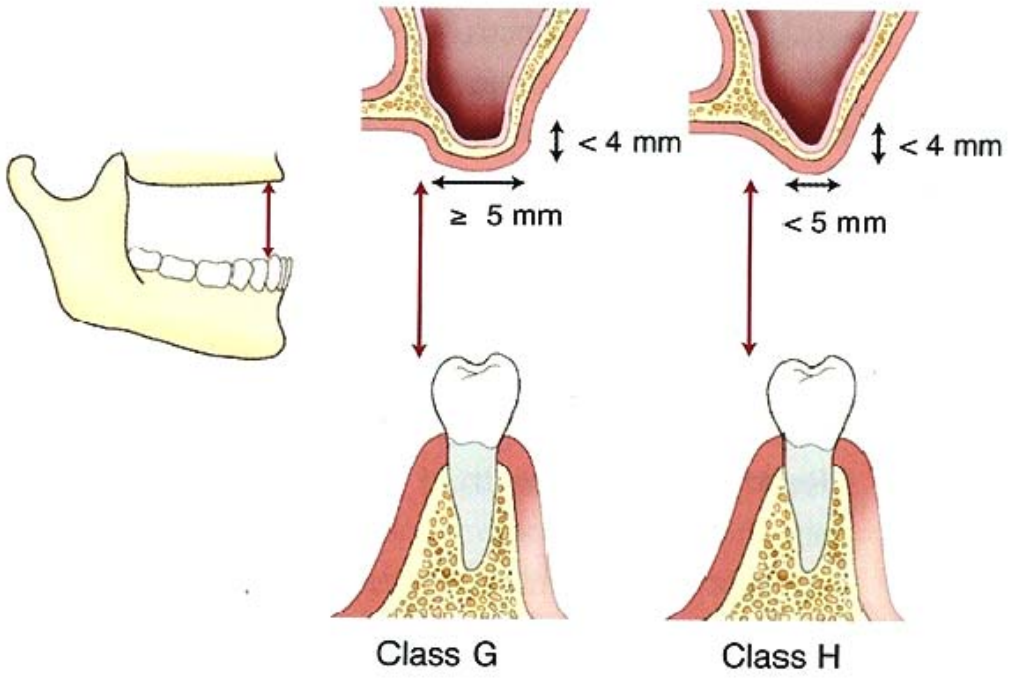

Figure 7: Class G; increased crown height space with less than 4 mm of bone below the antrum and 5 mm or more of bone on the crest. Class H; increased crown height space with less than 4 mm of bone below the antrum and less than 5 mm of bone width on the crest. ‡

Class I:

- Severe tridimensional atrophy of the edentulous maxilla to basal bone with increased vertical crown implant space, horizontal resorption, sagittal intermaxillary discrepancy with maxillary retrognathism, and flat maxillary morphology (Figure 8)

Suggested surgical protocol:

A. Le Fort 1 osteotomy with advancement and interpositional autogeneous bone graft (Figure 9)

B. Reconstruction with revascularized free flap

‡ Figure taken from Chiapasco's prosthetic rehabilitation of complex cases 2003

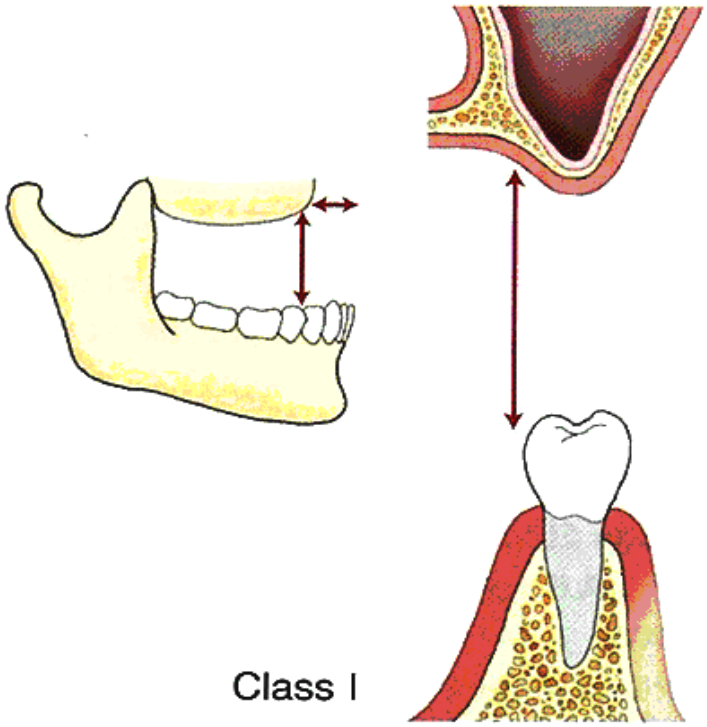

Figure 8: Class I; Three-Dimensional atrophy of the edentulous maxilla with increased crown height space. ‡

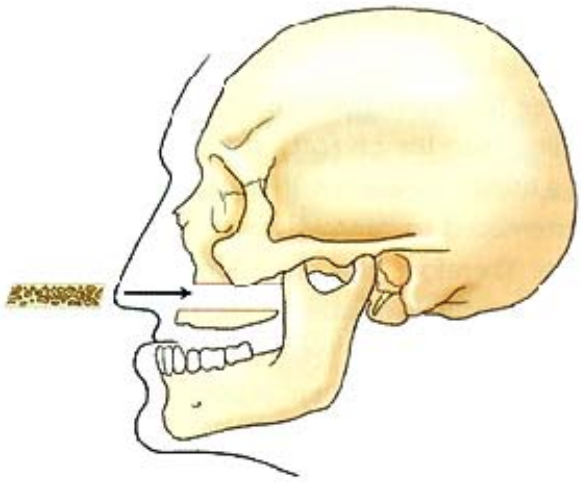

Figure 9: Le Forte I osteotomy with downward and forward repositioning of the maxilla and interpositional bone grafts. ‡

‡ Figures taken from Chiapasco's prosthetic rehabilitation of complex cases 2003

2.5 Evaluation and Examination Prior to Treatment Planning

Patient evaluation for posterior maxillary implant reconstruction must include conventional record taking as well as a thorough history and clinical evaluation of the maxillary sinus. Articulated study casts, plain film radiographs, and computerized tomography (CT) scanning to reveal ridge anatomy, inter-arch relationships, and conspicuous anatomic information in preparation for optimal implant selection and placement (65).

A physical examination of the maxillary sinus evaluates the infraorbital, latero-nasal, and superior labial areas of the face for tenderness to palpation, swelling, asymmetry, or ecchymosis. Nasal congestion, discharge, and/or the presence of epistaxis are also evaluated. Acute, allergic, and chronic sinusitis may be diagnosed on the basis of patient history and clinical evaluation; the symptomatology is generally nonspecific and includes allergic rhinitis. The patient usually presents with throbbing pain of the maxillary sinus area, headaches and swelling, and erythema overlying the infraorbital area. Although chronic sinusitis is an infection of long duration (greater than 3 months), symptoms are similar to those of acute sinusitis except in a milder form (25). Symptomatic chronic sinusitis as well as acute and allergic sinusitis must be treated prior to sinus graft surgery.

The blockage of normal mucous flow from the middle meatus into the posterior nasal pharynx can result in infection of the sinus graft. These patients must be treated with antibiotics, steroids, and in some cases surgery to establish a new sinus ostium prior to grafting (72).

Preoperative evaluation for pathology of the maxillary sinus should include plain film radiography and CT scans. Although generally not considered mandatory, CT scanning prior to sinus grafting may be advisable for evaluating disease of the nose and paranasal sinuses, and for detecting both benign and malignant neoplasms of the maxillary sinus (59). In addition, the scan reveals periapical, radicular, and odontogenic cysts that extend into the sinus, which may be missed with conventional radiography. Osteomeatal complex patency, especially in the presence of mucus cysts, also is important to assess pre-surgically via CT imaging.

2.6 Indications for Maxillary Sinus Augmentation

a) Reduced bone height: Implants of 10 mm length or less have a 16% lower survival rate than implants greater than 10 mm in height (30). Because of periodontal disease, tooth loss, and sinus expansion, there is often less than 10 mm of bone between the alveolar ridge crest and the maxillary sinus floor.

b) Poor bone density: The bone density of the maxilla is often 5-10 times lower than the anterior mandible (64). Bone mineral density is critically important for implant survival under load. Implants are at greater risk of failure under conditions of poor mineralization. When implants are placed in the poorest bone mineral density, survival is reduced by an average of 16% (30), with some reports as low as 40% (40).

c) Strong occlusal forces: Occlusal forces in the posterior region are greater than in the anterior region of the mouth by a factor of five (85). Following the natural tooth model, implant support should be greater in the posterior region than in any other area of the mouth (67). Therefore, decreased bone quantity and quality as well as increased bite forces should be considered in the treatment of this region of the mouth.

2.7 Contraindications for Maxillary Sinus Augmentation

In some patients, local conditions of the edentulous alveolar ridges may be unfavorable for implant placement. The posterior edentulous maxilla often presents a challenge as a result of alveolar ridge resorption and/or maxillary sinus pneumatization, which leads to bone loss. Moreover, low-quality residual bone can compromise final results.

Proper function of the maxillary sinus depends on a delicate balance between mucus production, transport by ciliated epithelium, sinus ventilation, and sustainable drainage through the ostium. In addition, there are communicating ethmoid and frontal sinuses that affect the maxillary sinus if they are unhealthy or chronically inflamed. These conditions can arise unilaterally or bilaterally. Any factor interfering with one of these functions will compromise maxillary sinus health (80). A grafting procedure generally does not interfere with sinus function when performed on a healthy sinus (99). However, when performed on an unhealthy sinus, the same procedure will contribute to fluid stagnation

and bacterial overgrowth, leading to an exacerbated sinusitis (73). Moreover, the presence of space occupying masses such as polyps, tumors, and hyperplastic mucosa represent obstacles to the elevation of the sinus mucosa. Pre-existing local pathologic conditions represent relative or absolute contraindications to the sinus graft procedure and therefore must be carefully scrutinized before surgery (84).

Sinus-grafting procedures are performed to enable implant placement and rehabilitation with implant-supported prostheses. Therefore, all intraoral contraindications for the placement of dental implants must be considered as well.

Contraindications can be classified into 4 subcategories: 1) Local Contraindications, 2) Intraoral Contraindications, 3) General Medical Contraindications, 4) General Surgical Contraindications

2.7.1 Local Contraindications

These can be subdivided into two main groups: *(a)* Potentially Reversible (Relative); and *(b)* Irreversible (Absolute). The first group includes pathologies that, if not treated, contraindicate sinus grafting. The second group includes pathologies that, even after surgical management, leave irreversible dysfunction of the osteomeatal complex.

a) Potentially Reversible, Relative Contraindications

Some anatomic and/or structural alterations of the nasomaxillary complex may interfere with normal ventilation and mucociliary clearance of the maxillary sinus. Compensation may occur over time, leaving such abnormal conditions clinically silent or with only mild to moderate, sometimes intermittent, symptoms (88).

Sinus-grafting procedures in this setting decompensate a compromised sinus, causing mucus stasis, suprainfection, and subacute sinusitis. The elevation of the sinus floor and/or modification of sinus anatomy may on occasions lead to better sinus drainage in the presence of mild sinus membrane dysfunction. But in general, alterations in function of the maxillary sinus membrane and the osteomeatal complex should be identified and treated before sinus grafting is performed. It is imperative that patients undergo thorough

radiographic evaluation to identify underlying sinus pathology and anatomic disturbance. CT scans, plain film radiographs, and patient history are part of the comprehensive workup of the patient.

Positive radiographic findings include:

1. Narrowing of the osteomeatal complex due to a deviated septum; abnormal morphology of the middle turbinate; enlargement of air cells within the middle turbinate, known as *concha bullosa*; enlargement of an air cell in the roof of the sinus (Haller cell); medial or lateral rotation of the uncinate process; enlargement of the bulla ethmoidale with narrowing of the uncinate process; or post-traumatic or postsurgical scarring (73).
2. Benign tumors of the nasomaxillary complex such as papillomas, schwannomas, osteomas, polyps, or mucus retention cysts
3. Viral, bacterial, and micotic rhinosinusitis; allergic sinusitis; sinusitis caused by intrasinusal foreign bodies; or odontogenic sinusitis originating from necrotic teeth of the lateral-posterior maxilla
4. Malignancy of the nasomaxillary region

b) *Irreversible, Absolute Contraindications*

Some anatomic and/or structural alterations or pathologies of the nasomaxillary complex may represent absolute contraindications to the sinus graft procedure. These include (67, 73, 103):

1. Severe (non-correctable) deformities of the maxillary sinus.
2. Scarred and hypofunctional sinus mucosa following trauma or previous operation.
3. Radiotherapy of the head and neck area.
4. Chronic recurrent sinusitis, with or without polyposis, which disrupts mucociliary clearance and is unresponsive to medical or surgical treatment.
5. Local expression of a systemic granulomatous disease such as Wegener granulomatosis or midline idiopathic granuloma.
6. Sarcoidosis.

7. Benign but locally aggressive tumor (eg. ameloblastoma, myxoma, desmoplastic fibroma, inverted papilloma).
8. Malignant tumor, both primary and metastatic, deriving from epithelial, connective, or odontogenic tissues (eg, squamous cell carcinoma, esthesioneuroblastoma, adenoid cystic carcinoma, adenocarcinoma, and sarcoma). These tumors may require extensive resection and may permanently disturb mucociliary function.

2.7.2 Intraoral Contraindications

Abnormal intraoral conditions may compromise the sinus grafting procedure and/or survival of dental implants placed into the grafted sinuses (80). These contraindications are similar to those reported in non-sinus-directed implant locations and include the following:

1. Grossly inadequate oral hygiene or inability to perform or maintain appropriate oral hygiene.
2. Untreated periodontal disease of adjacent dentition.
3. Gross malocclusion and insufficient freeway space for restoration.
4. Severe pathologic parafunctional habit (clenching or bruxism).
5. Fulminant mucosal disease (desquamative mucosal disease, erosive lichen planus).
6. Severe xerostomia.

2.7.3 General Medical Contraindications

Compromised general health may represent a relative or absolute contraindication to sinus grafting (5). Generally speaking, systemic pathoses, such as increased risk for myocardial infarction, hypertensive crisis, or sudden hypoglycemia, may prohibit surgical intervention. The sinus graft procedure should be avoided in patients with compromised healing, such as patients with uncontrolled diabetes, immunocompromised patients, or patients on antitumoral chemotherapy (88). Also, in general, osseointegration has been shown to be impaired by certain systemic diseases and medications, in which case the

surgeon is compelled to carefully review the patient's history and consider other options available if implant failure is to be expected (106). The following conditions, unless treated and under control with the patient's cooperation, generally contraindicate the sinus graft procedure:

1. Chronic renal disease
2. Chronic liver disease
3. Uncontrolled diabetes
4. Uncontrolled hypertension
5. Hemophilia or treatment with anticoagulant therapy
6. Metabolic bone disorders
7. Uncontrolled thyroid disorders
8. Uncontrolled adrenal disorders
9. Immunocompromise, including HIV
10. Steroid treatment at the time of the sinus graft procedure
11. Pregnancy

2.7.4 General Surgical Contraindications

1. Chemotherapy for the treatment of malignant tumors at the time of the graft procedure
2. Radiotherapy
3. Drug or alcohol abuse
4. Heavy smoking
5. Physical or psychiatric handicaps
6. Patient noncompliance (88)

2.8 Techniques for Maxillary Sinus Augmentation

2.8.1 Lateral Approach for Sinus Augmentation

This technique uses the Caldwell-Luc procedure that was initially proposed in 1893 to gain access to the sinus through the canine fossa (35).A full thickness mucoperiosteal flap is performed to gain access to the lateral bony wall of the sinus (Figure 10). An antrostomy, or window, is made in the lateral wall with a diamond bur using either a surgical or a high speed hand piece.

The bony window can then be rotated horizontally along with Schneiderian membrane elevation (Figure 11a) (or it can be completely removed). The membrane is reflected across the sinus floor and then superiorly up the medial sinus wall. The elevated membrane thus becomes the superior and distal walls of a compartment in the lower 1/3 of the sinus that will receive the bone graft (Figure 11b). Once the graft material is placed the lateral window should be covered with a biologic barrier membrane prior to suturing the flap back into position (Figure 20). The graft is allowed to mature prior to implant placement, with the formation of new bone around the graft particles. The implants are given sufficient time to integrate in the grafted sinus and then restored with traditional implant prosthetic components.

If bony septa are encountered (Figure 12a), they should not be removed; instead, the sinus can be grafted into two compartments and the septum can be used as an interior border (Figure 12b) (108). Special effort should be made to retain as much original bone as possible to take full advantage of its endosseous capacity for bone repair.

Whenever possible, at least 3 mm of bone should be left between the inferior border of the window and the crest of the ridge to preserve the shape of the original outer wall and to prevent flap collapse into the graft site.

If bone was initially satisfactory in height then the surgeon has the option to perform immediate implant placement utilizing the lateral window technique.

The lateral window technique might still be the only solution in cases that are severely atrophied and that present with an extremely thin and fragile Schneiderian

membrane which might display risks of perforation while trying to gain access through the more modern techniques (43).

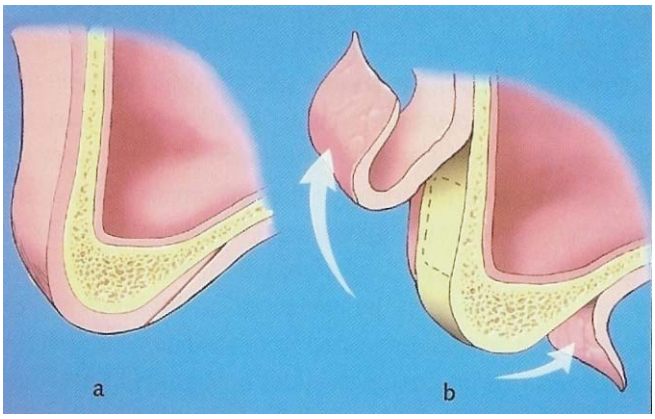

Figure 10: Elevation of split thickness buccal and palatal flaps expose the underlying bone. The osteotomy is made in the lateral wall of the sinus ‡

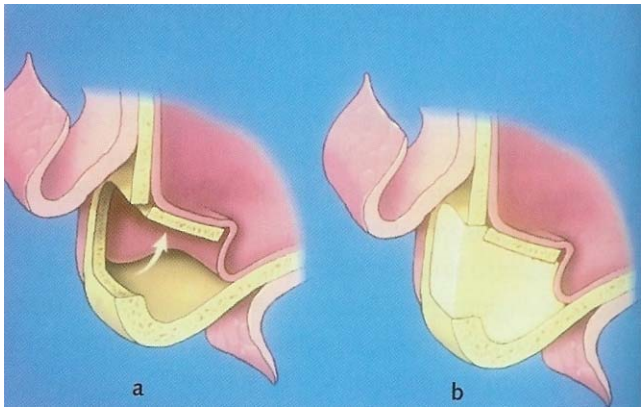

Figure 11: a) Infracturing the external wall of the sinus and elevation of the membrane, b) dense grafting of bone graft into the cavity created by the elevation.‡

‡ Figures taken from Marks SC. Nasal and Sinus Surgery 2000

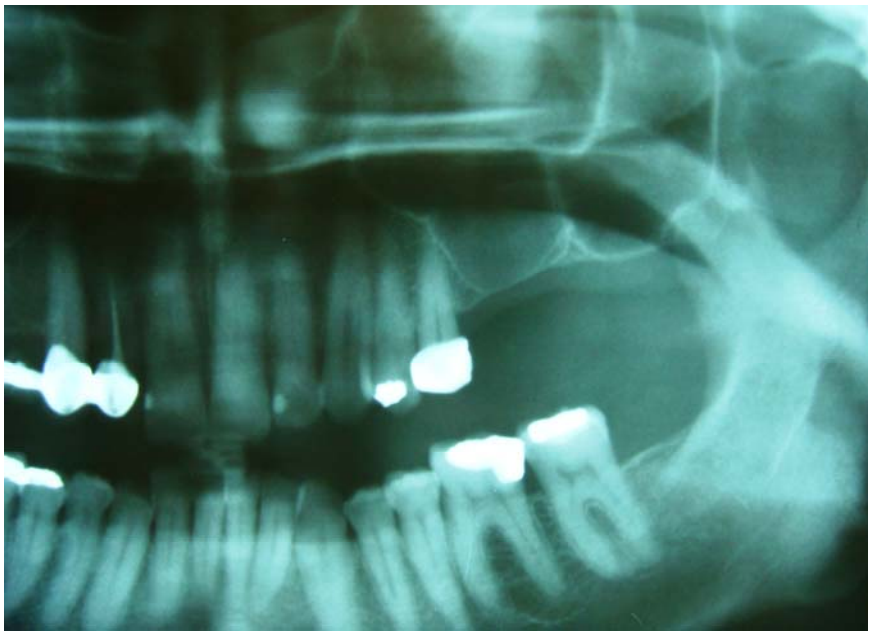

Figure 12a: A normal anatomic variation showing a septum separating the maxillary sinus into two chambers

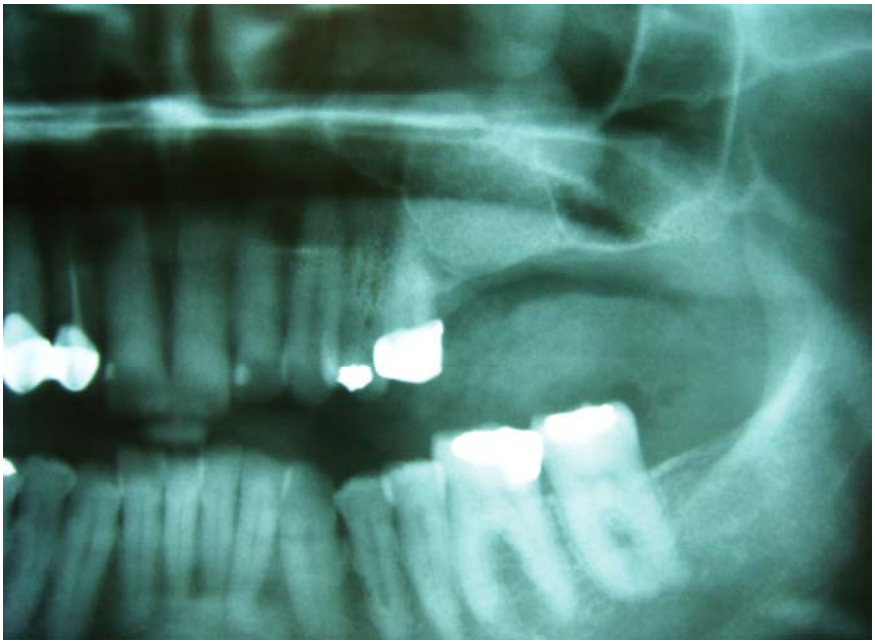

Figure 12b: The septum is not removed and the chambers can be augmented as separate units

2.8.2 Le Forte-I Osteotomy

Modification of the surgical approach for Le Fort I osteotomy with sinus membrane preservation proceeds as follows (6):

1. A circumvestibular incision is accomplished, and lateral antrostomy windows are made over the sinus bilaterally. The antrostomy windows are long and narrow to provide access posteriorly and yet make bone plating possible. Sinus membrane elevation of the entire sinus floor is accomplished. The sinus membrane is generally elevated about 10 mm.
2. A relatively low-level Le Fort I osteotomy, protecting both sinus and nasal membranes, is completed.
3. Osteotomes are used to free the lateral nasal walls after membrane elevation. A trans-sinal approach may be needed if the lateral nasal wall is strong and healthy.
4. The nasal septum and the pterygomaxillary sutures also are freed using osteotomes, and the maxilla is carefully downfractured and mobilized.
5. Rigid fixation is applied using resorbable bone plates and screws to establish a down and forward maxillary position (76). Average movement is 5 mm forward and 5 mm downward.
6. Following placement of internal fixation of the maxilla, particulate bone is used to augment the sinus floor, and struts of corticocancellous block bone and cancellous marrow are used to augment the maxilla laterally over the resorbable fixation. Unlike the internal fixation, this external grafting is fixated with titanium screws, so that they can be accessed for removal at a later stage.
7. Blocks of corticocancellous bone are interposed into the gap created by maxillary advancement between the pterygoid plate and posterior maxilla to help prevent maxillary relapse (7).
8. Because the maxilla is tilted interiorly by several millimeters, care should be taken to interpose particulate bone graft in the nasal fossa and block graft anteriorly. Sometimes block bone can be partially supported by a retained anterior nasal spine.
9. Barrier membranes should be used selectively since membrane exposure increases the risk of infection (34).

10. Implant placement should be deferred until after the graft has incorporated, usually about 6 months later, to improve stability and location. Simultaneous implant placement requires that at least a portion of the host basal bone is engaged and therefore should be reserved for less resorbed cases (10). If bone resorption is uneven, excess bone from one site can be used to supplement areas of excess resorption. Such secondary bone graft redistribution shapes and restores alveolar form.

11. Wound closure is accomplished using resorbable sutures in all three layers (periosteal, subcutaneous, and mucosal). Mucosal wound closure should be passive.

12. For implant placement, it is important to make the incision 3 to 4 mm crestal into the fixed palatal tissue. A palatally related guide stent should be used. In most cases, eight implants are placed. The best bone for implant placement is in the sinus grafted areas.

13. Six months after placement, implants are exposed through the original palatal-crestal incision, and releasing incisions are made posteriorly.

14. As wound closure progresses around the arch, the entire facial flap advances forward. The wound is closed from anterior to posterior.

15. Final restorative procedures begin 3 weeks after implant exposure, whether for a fixed hybrid or over-denture prosthesis.

2.8.3 Osteotome Technique

a) General Technique

The osteotome technique was developed to compress soft maxillary bone. Improved initial fixation obtained from bone compression of the osteotomy walls leads to better primary stabilization, which is a key to osseointegration, especially in types 3 and 4 bone (92).

The underlying biologic principle of bone compression osteoplasty is to increase the mineral density intra-alveolarly by osseous deformation and trabecular microfracture. The net effect of this process is to increase the stiffness of the bone.

To systematize surgical bone compression, a set of osteotome instruments with concave tips and tapered shape has been designed for this procedure. In type 4 bone, these

instruments create an osteotomy for implants from 3.3 to 5.0 mm in diameter. The intention is to conserve bone by displacing it laterally to form a dense wall (66). In contrast, drilling in areas of inferior bone quality does not improve the site and results in increased failure rates (40).

The osteotome technique requires a two-person team. The protocol is to insert a series of osteotomes of successively larger diameter until full depth is reached, if possible. The surgeon positions and guides the instrument with both hands. One hand creates a rest and maintains stability while the other hand gently rotates and applies pressure with the osteotome. Meanwhile, the second member of the team uses a gentle malleting technique. The surgeon turns the instrument after each push or stroke of the mallet to prevent the tip from binding in the bone. The osteotome must be maintained in a precise axial position as it is turned. The osteotomes are kept lubricated, but irrigation is not necessarily required.
To form a round osteotomy, side-to-side movement of the instrument must be eliminated. The surgeon should maintain constant visual contact with the osteotome and the operative site throughout the procedure. Body or head movement, including reaching for a mallet, decreases tactile sensation and causes inadvertent movement of the osteotome. The surgeon must focus on maintaining the position of the instrument while allowing the assistant to mallet or transfer the next successive osteotome to the surgeon's hand.

The assistant's role is critical. Each strike of the mallet is applied to the osteotome in exactly the same path that it is held, and only after a specific verbal instruction to do so is given by the surgeon. Off-angled malleting causes the osteotome to migrate and creates an elliptical osteotomy, which compromises initial fixation.

When the site is well lubricated and the osteotome is slightly loose, it will advance much more readily. Hard malleting is avoided, and embedding the osteotome too firmly can have a jarring effect on the patient. The surgeon places restraining pressure on the osteotome to prevent it from advancing more than 1 mm with each impact of the mallet. This is particularly important under the sinus, since an instrument that is not held back to some degree can perforate the sinus floor without warning (Figure 13).

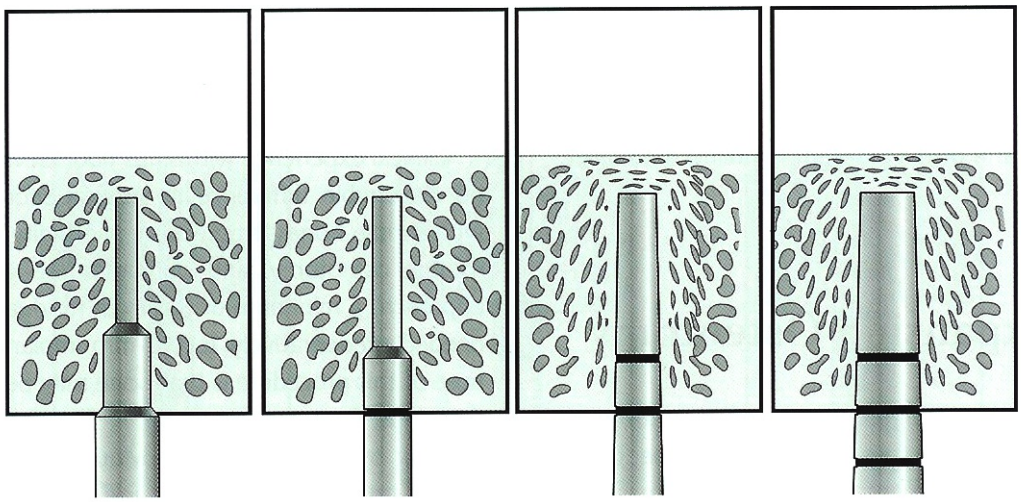

Figure 13: Once the osteotome reaches the bone to the desired mark, the tip of the next larger instrument can be introduced without a drill. If necessary, drilling can be used at any point to facilitate the procedure and ease entry of the subsequent instrument. ‡

If, after several light mallet strikes or pushes, the osteotome does not advance, the surgeon can go back to a smaller-sized instrument or use a drill. It is often surprising how easily a smaller osteotome penetrates an area after the larger instrument has been used. In this situation, restraint of the smaller instrument is of great importance.

The surgeon cannot rely on denser bone quality or a different malleting sound to identify when the sinus floor has been reached (3, 93). Taking accurate preoperative radiographs and maintaining precise control of the penetration are critical.

A drill can be used at any step to increase the diameter of the osteotomy or deepen the preparation (95). Drilling is always used with caution and at the lowest possible speed. Reproducing a consistent angle of penetration in the posterior maxilla with a drill is extremely challenging because of loss of tactile sensitivity in soft bone, limited access, and blocked sight lines. Compounding these problems are the irrigation stream and handpiece torquing. With osteotomes, vision of the surgical site is better, and no heat is produced as the instrument penetrates the bone (92).

During osteotome surgery, the surgeon will often find that the osteotomy is deeper than the original preoperative radiographic measurement of the area from the crest to the sinus floor (Figure 14). Probing demonstrates that the sinus floor is not perforated, though it is elevated as much as 2 mm (95).

‡ Figure taken from Summers RB, Part 3: less invasive methods of elevating the sinus floor, Compendium 1994

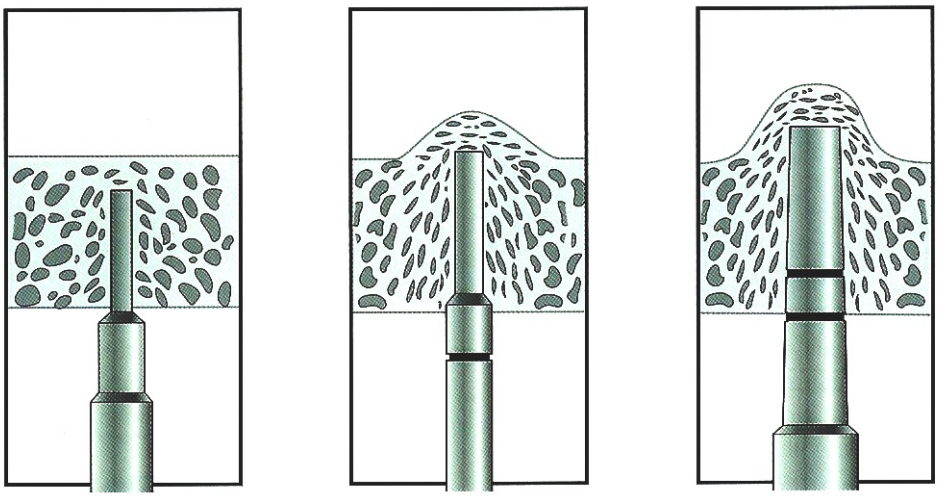

Figure 14: Osteotome sinus floor elevation requires precise measurement of the height and width of available bone. Insertion of the instruments is restrained so that the tip does not penetrate beyond the sinus floor. The osteotome does not directly contact the sinus membrane. ‡

b) Bone-Added Osteotome Sinus Floor Elevation

The protocol for using the sinus-directed osteotomes is not to enter the sinus cavity itself. In this procedure, repositioned bone particles and trapped fluid create a hydraulic effect, thus moving the sinus floor and the membrane upward. The advantage of this approach to bone grafting is that the osteotome creates a predictable quantity of particulate material, which then forms a hydraulic plug. Although type 4 bone requires no drilling, drilling and osteotomes can be used in combination without sacrificing the outcome of the procedure. This technique ensures accurate and consistent control over the ultimate height of the grafted space with reduced chance of membrane perforation (24).

In the bone-added osteotome procedure, pressure on trapped fluid and particulate graft creates a blunt force over an expanded area that is larger than the osteotome tip. The membrane is less likely to tear under this type of pressure, which has a fluid consistency, than it is under direct application of force from a hard surgical instrument (84).

Once osteotome bone grafting is mastered, the sinus floor can be elevated from 3 to 7 mm with simultaneous placement of the implant (49, 70). A variety of graft materials yield equally successful results (70), and there is no need to open a distant site.

‡ Figure taken from Summers RB, Part 3: less invasive methods of elevating the sinus floor, Compendium 1994

A minimum pretreatment bone height is needed to ensure adequate fixation of the implant in the residual bone, given that the grafted area provides no immediate support (Figure 15). After approximately 3 months, the implant gains stability from osseointegration in the ridge as well as formation of bone in the graft space. Initially, at least 5 mm of ridge height under the sinus was proposed for an implant 10 mm or longer (92, 94).

Variations of this technique have been described, but the fixation requirements remain the critical factor (29, 100). Simplicity of removal of the fixture mount is paramount when choosing an implant that is fixated in only 4 mm of native bone. It may be helpful to loosen and then partially retighten the mount prior to delivering the implant to the site. A variety of implant designs and surfaces can achieve excellent results as long as the basic surgical requirements of instrumentation and graft handling are followed.

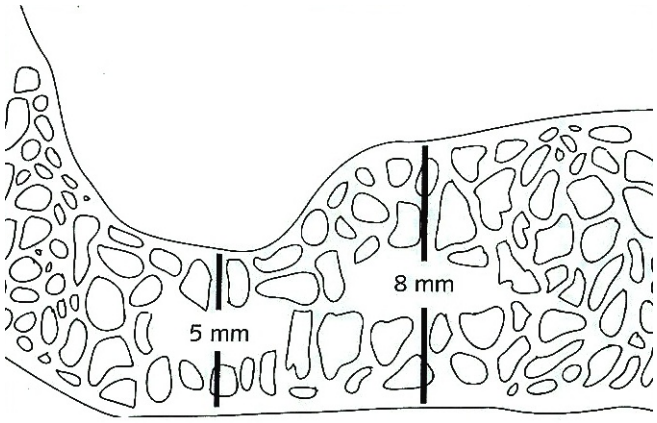

Figure 15: Typical dimensions for using the bone-added osteotome technique. A 5 mm site can be altered to support a 10 mm implant. An 8 mm site can be deepened for a 12 or 13 mm implant.‡

‡ Figure taken from Rosen PS., Summers R, The bone added osteotome sinus floor elevation, IJOMI 1999

Approaching the sinus floor is the key step in bone-added osteotome sinus floor elevation. If drilling is needed, a pilot drill stops 2 mm from the floor, and the no. 1 osteotome is reinserted (Figure 16). If the instrument does not penetrate with hand pressure or light malleting, the drill is advanced into the site an additional millimeter. This step requires only a few revolutions (Figure 17). A radiograph with a depth indicator in place provides valuable information. If the radiograph shows the drill at the depth of the sinus floor, additional drilling is contraindicated.

Figure 16: Summer's osteotome No.1 is inserted into the sinus floor. Hand pressure or light malleting is recommended. ‡

‡ Figure taken from Rosen PS., Summers R, The bone added osteotome sinus floor elevation, IJOMI 1999

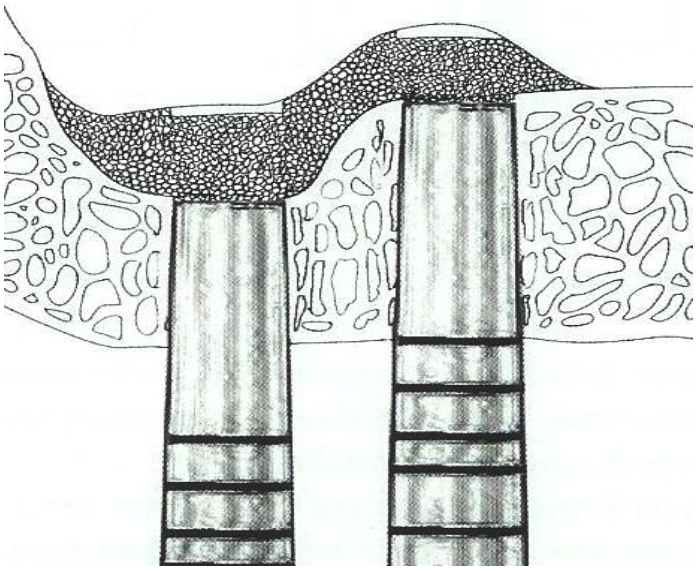

Figure 17: The osteotomy is widened, and successive osteotomes are seated to the sinus floor. After the floor is upfractured a prepared bone mix is added into the osteotomy. The No.3 or 4 osteotome is used to gently advance the material beneath the sinus membrane. ‡

Each load of bone graft adds about 1 mm to the elevation (Figure 18). The graft material is inserted directly into the osteotomy. The no. 3 osteotome creates a slightly undersized osteotomy for a 3.75-mm-diameter implant. The no. 4 osteotome is designed for a 4.0- *or* 4.1-mm-diameter implant, and the no. 5 is designed for a 4.8- to 5.0-mm-diameter implant (Figure 19).

‡ Figure taken from Rosen PS., Summers R, The bone added osteotome sinus floor elevation, IJOMI 1999

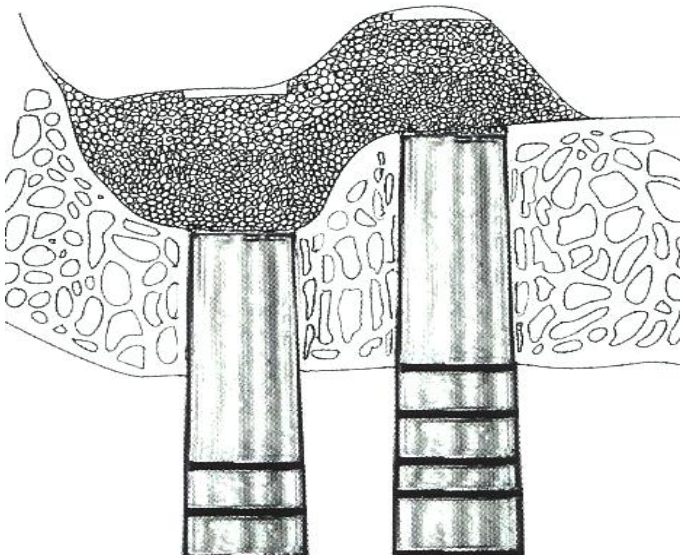

Figure 18: With the addition of each measured load of bone the largest-sized osteotome previously used is reinserted to the sinus floor. ‡

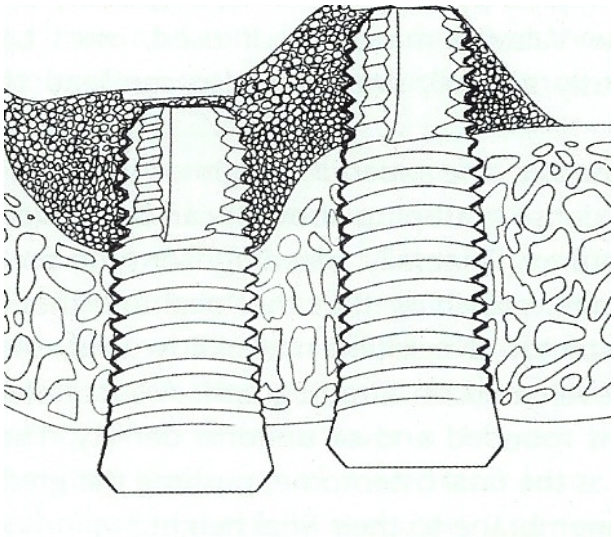

Figure 19: When the antral floor is displaced, the graft moves freely, thus elevating the intact membrane. The implant serves as the final osteotome to push up the membrane to its ultimate height. ‡

‡ Figures taken from Rosen PS., Summers R, The bone added osteotome sinus floor elevation, IJOMI 1999

2.9 Grafting Materials Used in Maxillary Sinus Augmentation

2.9.1 Autogeneous Bone Grafts

During the early development of the sinus grafting procedure in the 1970s, autogeneous bone alone was used to augment the posterior maxilla for dental implants (14). Advantages of autogeneous bone are:

- It contains viable cells that proliferate and contribute to the new bone growth (8)
- It contains bone Morphogenic proteins, which are capable of inducing osteocompetent cells in the surrounding tissues to produce bone (70)
- It contains many growth factors important for the process of graft healing and incorporation (55).

Healing of autogeneous bone grafts is faster compared with that of allografts, xenografts, and alloplasts. The healing period for sinuses grafted with autogeneous bone can be as short as 3 to 4 months versus the 8 to 10 months often encountered with bone substitutes; the addition of autogeneous bone particles to other graft materials also can shorten the healing time for such materials (33)

Common sites used for harvesting autogeneous bone intraorally are the maxillary tuberosity, maxillary buttress, mandibular symphysis, and the mandibular ramus. Extraorally it can be harvested from the tibia, the ilium, and the calvarium.

2.9.2 Allograft Materials

Allograft offers the means to repair and augment lost bone in many applications without the need to harvest autogeneous bone from a secondary site. It is usually harvested from donor corpses, but this type of graft material is mainly used in the United States. The bone is freeze-dried and treated with various agents before being finally sterilized and packaged for use (101). Allograft materials have experimentally and clinically produced similar success rates to those of the autogeneous bone grafts (104).

2.9.3 Alloplast Materials

Hydroxyapatite, beta-tricalcium phosphate, and bioactive glass are the most commonly used alloplastic materials.

Resorbable and non-resorbable alloplasts have similar capacity for space maintenance, osteoconduction, and facilitation of bone migration from the sinus floor (110). All of the above mentioned alloplasts are excellent at forming bone sufficient for osseointegration, but this might be mostly due to the favorable bone-growing capacity of the sinus floor.

2.9.4 Xenograft Materials

Bovine bone matrix alone and in combination with autogeneous bone is the graft material of choice for many practitioners. Xenografts are osteoconductive, not osteoinductive, and thus the bony walls of the sinus must provide the vascularity, the cells, and growth factors responsible for bone formation (70).

Because xenografts lack growth factors, they require a longer period of graft healing to achieve new vital bone (63).

2.9.5 Platelet-Rich Plasma and Bone Morphogenic Protein

Platelet-Rich-Plasma (PRP) is a concentration of human autologous platelets suspended in a small volume of plasma. PRP contains seven growth factors as well as 3 cell adhesion molecules (82).

Bone Morphogenic Protein (BMP) is a single growth factor; however, PRP and BMP have a fundamentally similar mechanism of action (15).

PRP can be mixed with any graft material but it has to be activated first before being inserted to the grafting site (48). The activation is done by inducing clotting which will trigger the release of the growth factors from the platelets. Calcium chloride mixed with bovine thrombin can be used to induce clotting for activation.

BMP can be expected to form a bone on its own without the addition of any grafting material. It is placed into the sinus cavity using a carrier absorbable collagen sponge instead of using graft materials (15).

2.10 Use of Barrier Membranes in Maxillary Sinus Augmentation

The concept of placing a barrier membrane over the lateral sinus window is a logical extension of barrier applications in orthopedics, periodontal guided tissue regeneration, and pre-prosthetic guided bone regeneration.

The success of guided bone regeneration depends on the maintenance of space, the stability of the membrane, the duration of barrier function, and the prevention of membrane exposure. Implants placed into regenerated bone demonstrate excellent success rates (19, 71, 22, 112). A recent evidence-based review by Fiorellini and Nevins (27) shows an implant survival rate of 97.3% for implants placed into grafted bone.

When used in sinus grafting, the surgical objective is to position an effective barrier membrane over the lateral window in such a manner as to exclude the connective tissue from the wound. Various materials have been used as barriers over the lateral window antrostomy, including non-resorbable Expanded Polytetrafluoroethylene (e-PTFE) membranes, long and short term bioabsorbable cross-linked collagen membranes, synthetic membranes, titanium mesh membranes, freeze-dried lamellar bone sheets, calcium sulfate barriers, and the repositioned original lateral bony window (107, 52).

The membrane should cover the window by a minimum of 3 to 5 mm (Figures 20, 21). Placing the membrane under the incision line should be avoided, as this may lead to the complication of exposure. Many membranes are packaged with templates that can be cut to the appropriate size after the window is made and the sinus membrane elevated. Using this template, the barrier membrane is then cut to size and hydrated prior to grafting the sinus. Once grafting is complete, the shaped membrane can be applied immediately (107).

Depending on their stiffness, bioabsorbable barrier membranes may have the ability to remain in place without mechanical stabilization. The more adaptable (thin) membranes

conform well to the surface of the lateral sinus wall (Figure 22). Most of the bioabsorbable membranes can be stabilized with tacks; however, unless the tacks are bioabsorbable, re-entry for tack removal will be required.

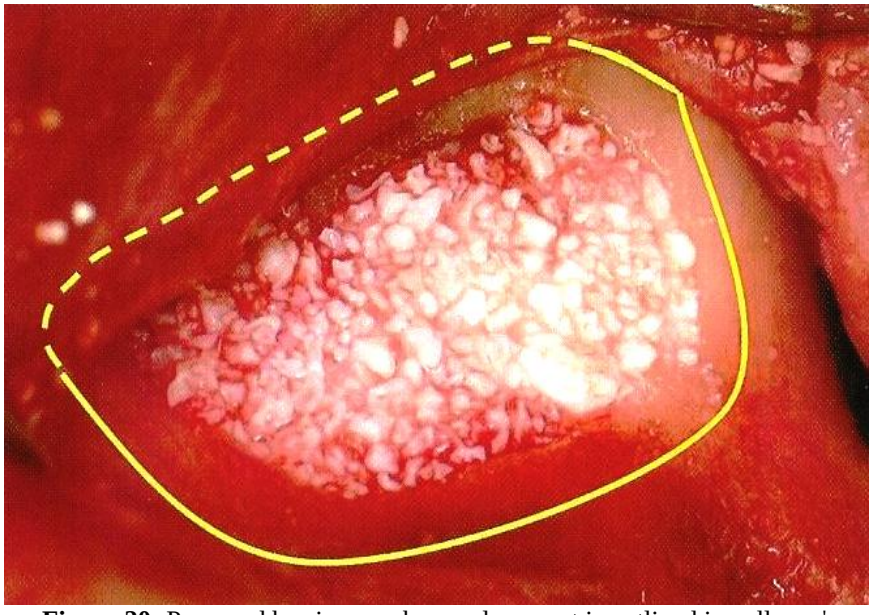

Figure 20: Proposed barrier membrane placement is outlined in yellow. ‡

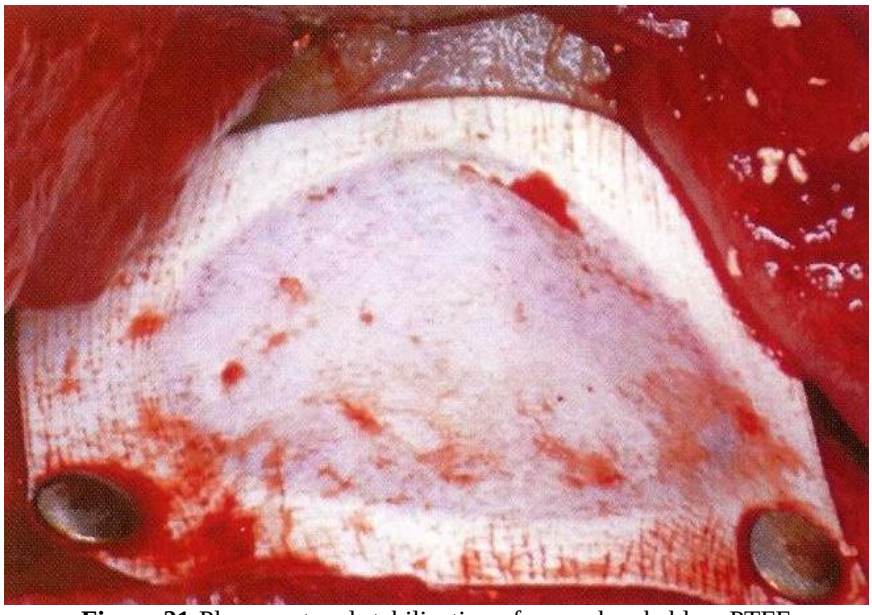

Figure 21: Placement and stabilization of a nonabsorbable e-PTFE barrier membrane so as to avoid incision line. ‡

‡ Pictures taken from Wallace SS, et al. sinus augmentation utilizing anorganic bovine bone (Bio-Oss) with absorbable and non-absorbable membranes placed over the lateral window, IJPRD 2005

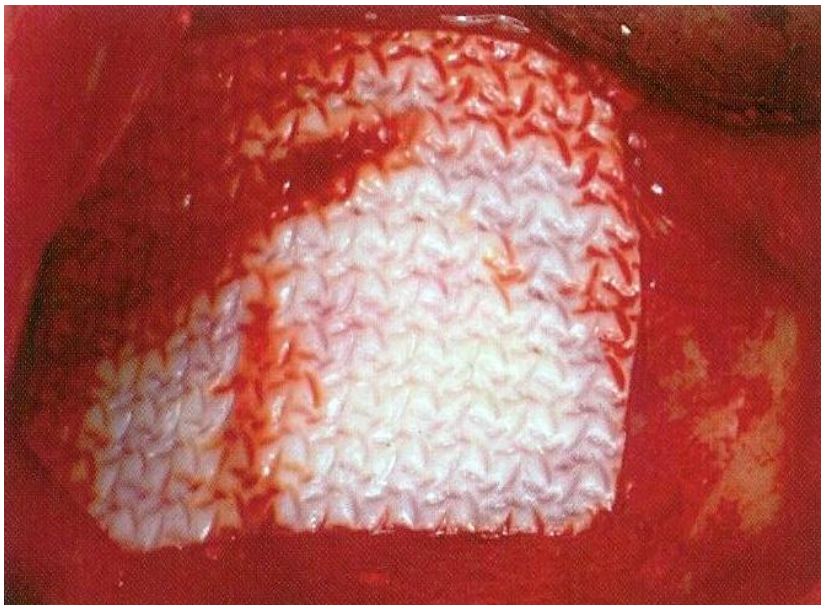

Figure 22: Placement of a bioabsorbable barrier membrane so as to avoid incision line. ‡

‡ Pictures taken from Wallace SS, et al. sinus augmentation utilizing anorganic bovine bone (Bio-Oss) with absorbable and non-absorbable membranes placed over the lateral window, IJPRD 2005

2.11 Simultaneous vs. Delayed Implant Placement in Sinus Grafted Sites

2.11.1 Sinus Augmentation with Simultaneous Implant Placement

Tatum (1998) (96), simultaneously placed implants with grafting procedures, via both lateral and crestal approaches. In the latter, a "socket former" was used to establish the implant position, and greenstick fracture of the sinus floor was accomplished by hand tapping in a vertical direction.

Summers (1994) (95), later described a similar technique using tapered osteotomes with increasing diameters. Adjacent bone is compressed by pushing and tapping as the sinus membrane is elevated. Bone is conserved by the osteotome technique because no drilling is done. Summers added autogeneous, allogeneic, or xenogenic bone and compacted the elevated sinus. Elevation of the sinus floor 4 to 5 mm was reported for this one-stage implant technique. Summers followed 143 press-fit submerged implants for 18 months of loading and reported a success rate of 96%.

Toffler (2004) (100), presented the results of osteotome-mediated sinus floor elevation using autogeneous and xenograft bone and a variety of screw-type implants. The mean residual bone height of 7.1 mm was relatively high, with a range of 3 to 10 mm. The overall survival rate for 276 implants placed simultaneously was 93.5% after an average period of 27.9 months. A residual bone height of 5 mm or greater had a 94.7% success rate. With a residual bone height of 4 mm or less, the survival rate dropped to 73.3%. The primary determinant of implant survival was the pretreatment height of the residual alveolus. Implant type and proportion of autogeneous graft to xenograft had a much weaker influence on implant survival.

Hatano et al. (2004) (36), reported long term maintenance of sinus graft height with simultaneous placement of implants in sinuses with 4 to 6 mm of alveolar bone height available for implant stabilization, the survival rate was 94.2% for those implants in the 3 years of evaluation.

Based on empirical observations, a one-stage procedure with simultaneous grafting and implant placement is not performed unless at least 4 mm of alveolar bone is available

to stabilize implants (54). Less than 4 mm is considered insufficient endosteum to mechanically maintain the implants, and a two-stage procedure is recommended. The key to determining if the procedure should be performed in one stage or two is the ability of the surgeon to place a fixed dental implant. The distance between the threads of most threaded dental implants ranges from 0.65 to 0.80 mm. Therefore, in order to engage three threads, one must have at least 2.5 mm of bone, and for five threads, about 4 mm of bone (54). Most clinicians would prefer to have more than a few threads engaged in bone for a simultaneous sinus graft procedure. The 4 to 5 mm level is often suggested as a minimum by experienced sinus graft surgeons. In the end, it is a judgment call and should be based on surgical experience.

CLINICAL CASES

Case 1:

A 67 years old female patient presented to the Oral & Maxillofacial Surgery Department at Yeditepe University-Faculty of Dentistry with a resorbed ridge on the edentulous left side of her maxilla. She was seeking rehabilitation with implants but the resorption in the ridge would impair the conventional placement of implants (Figure 23).

The patient was healthy in general with no systemic diseases and she was indicated for surgery.

Radiographic examination showed the remaining ridge beneath the schneiderian membrane to be approximately 6 mm high (Figure 24). The decision was made to perform grafting of the floor of the maxillary sinus and place 2 implants in the grafted site.

The procedure started with infraorbital anesthesia, and then a full thickness mucoperiosteal flap was raised to uncover the bony ridge and the lateral wall of the maxilla (Figure 25).

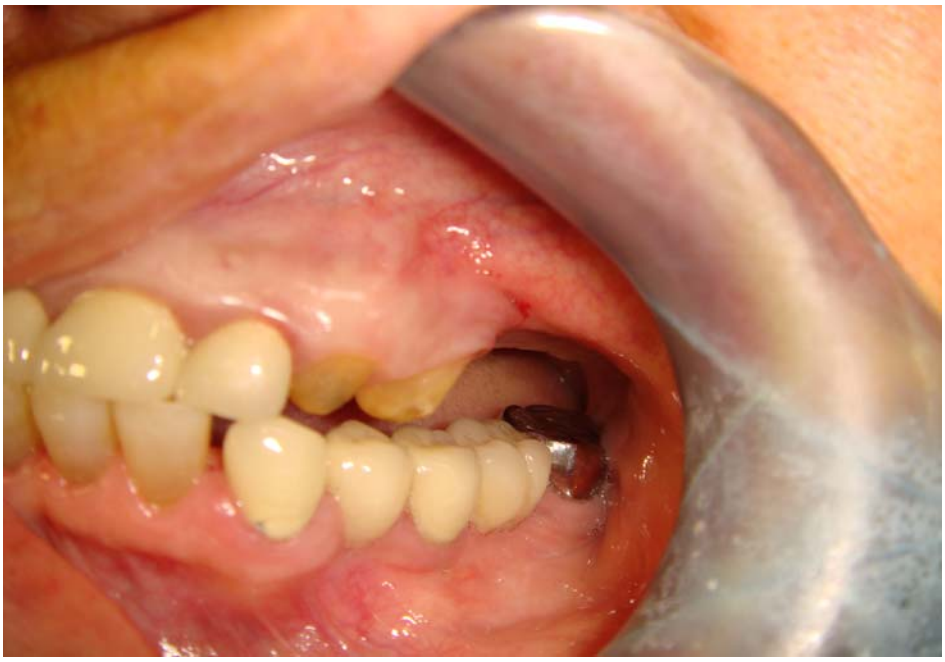

Figure 23: Location of the missing teeth with resorbed residual alveolar bone

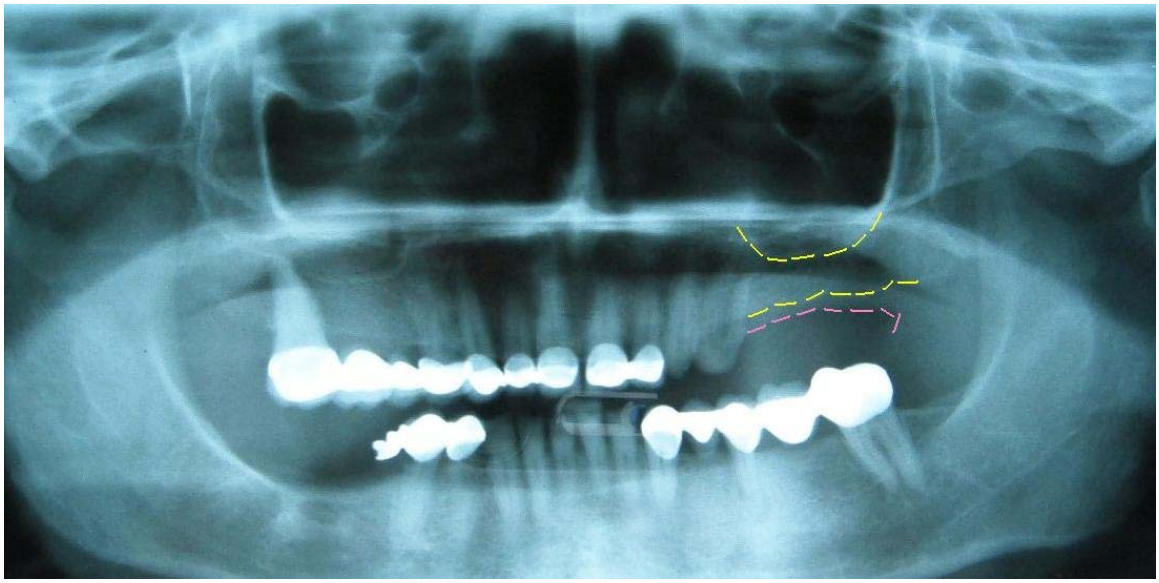

Figure 24: The posterior left side of the maxilla showing resorption

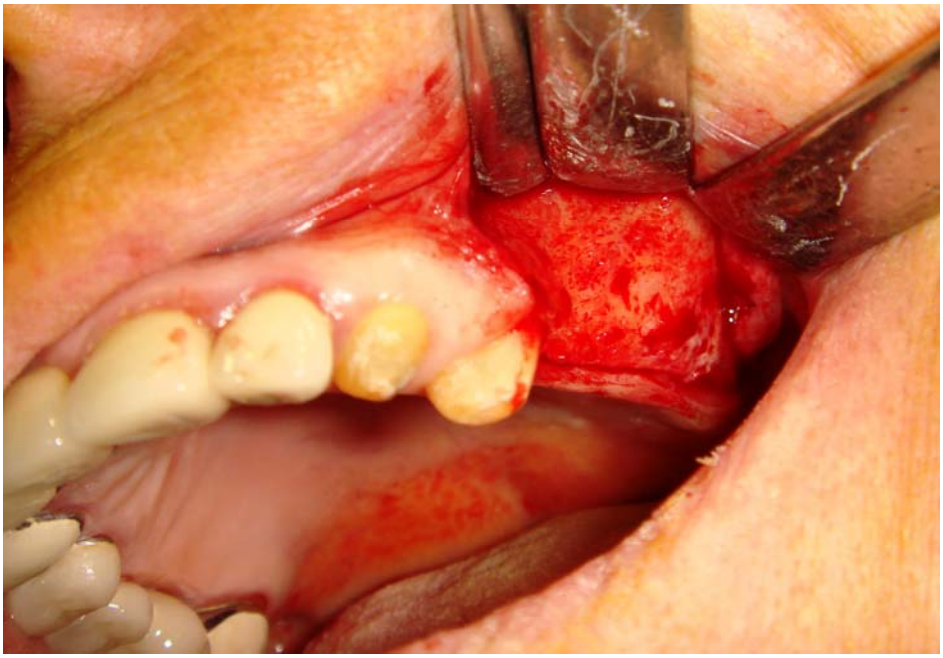

Figure 25: Raising a flap to uncover the lateral bony wall of the Maxillary Sinus

The location of the window was estimated clinically based on the radiographic appearance in relation to the nearby dentition.

Using A surgical round bur, a window was outlined on the lateral wall (Figure 26), and then with the aid of a chisel and a mallet this outlined window was broken of and separated from the rest of the lateral bone.

The schneiderian membrane was carefully separated from the inner surface of the sinus cavity using a delicate periosteal elevator (Figure 27). And then the membrane was lifted laterally and upwards creating an open cavity underneath it (Figure 28).

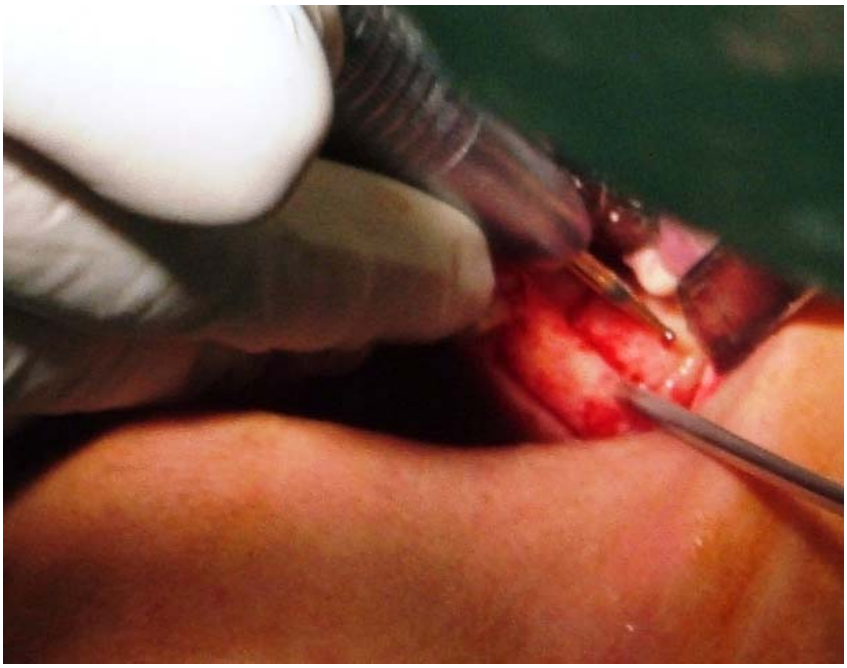

Figure 26: A window was outlined in the lateral wall of the sinus cavity using a surgical bur

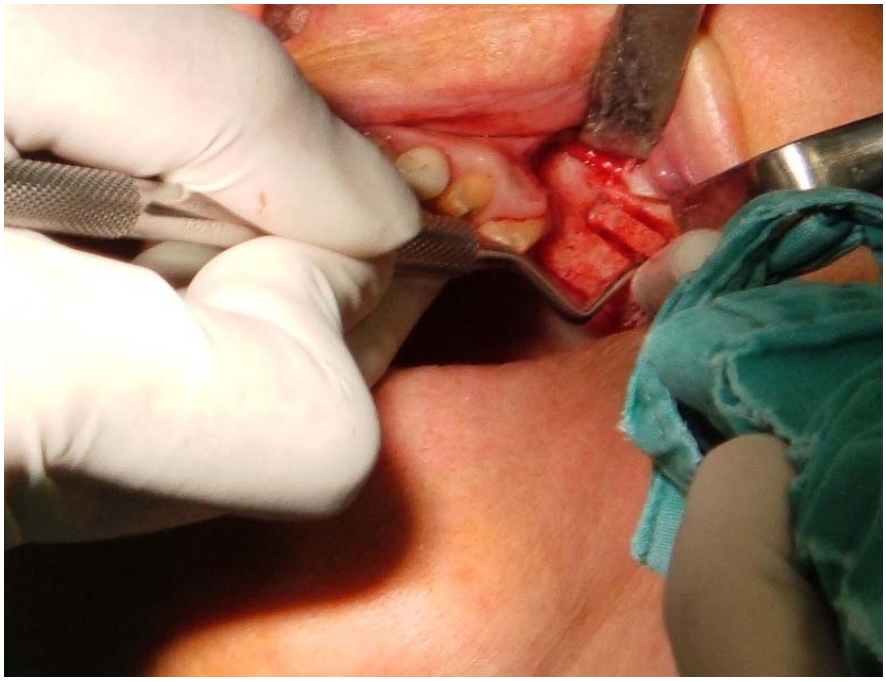

Figure 27: The schneiderian membrane being carefully separated from the internal walls of the sinus cavity

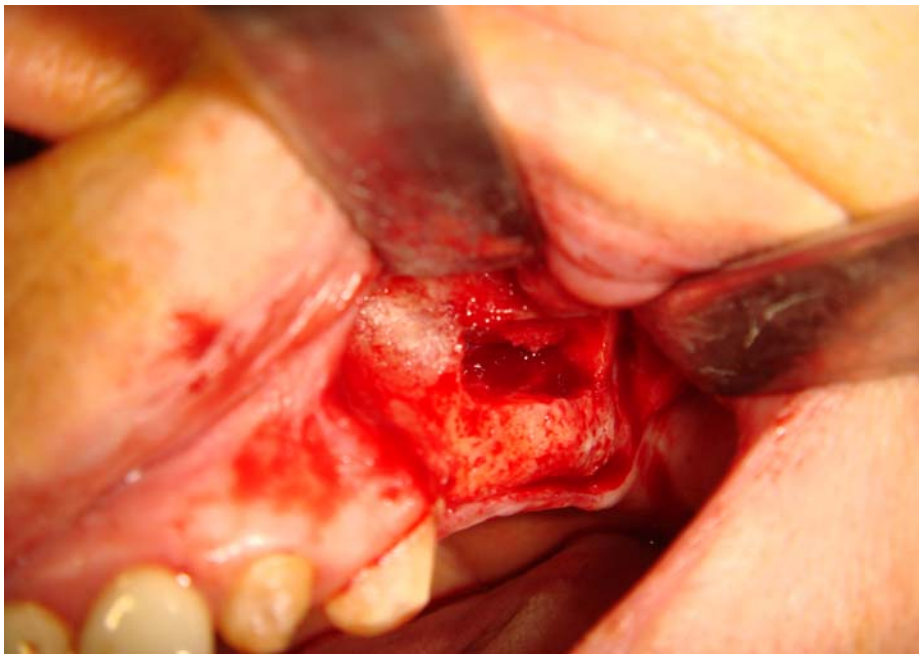

Figure 28: The membrane was lifted laterally and upwards creating a cavity space below it

Preparation for the implants' sites took place while protecting the base of the membrane that was lifted by placing a metallic barrier underneath it to avoid accidental exaggeration in force while drilling (Figure 29). Paralleling pins were used in between drillings to verify drilling paths (Figure 30)

The grafting material was wetted with saline and then inserted and packed inside the cavity, which was almost 1 gram of Unilab Surgibone® made from ground natural bovine bone mixed with hydroxyapatite (Figure 31).

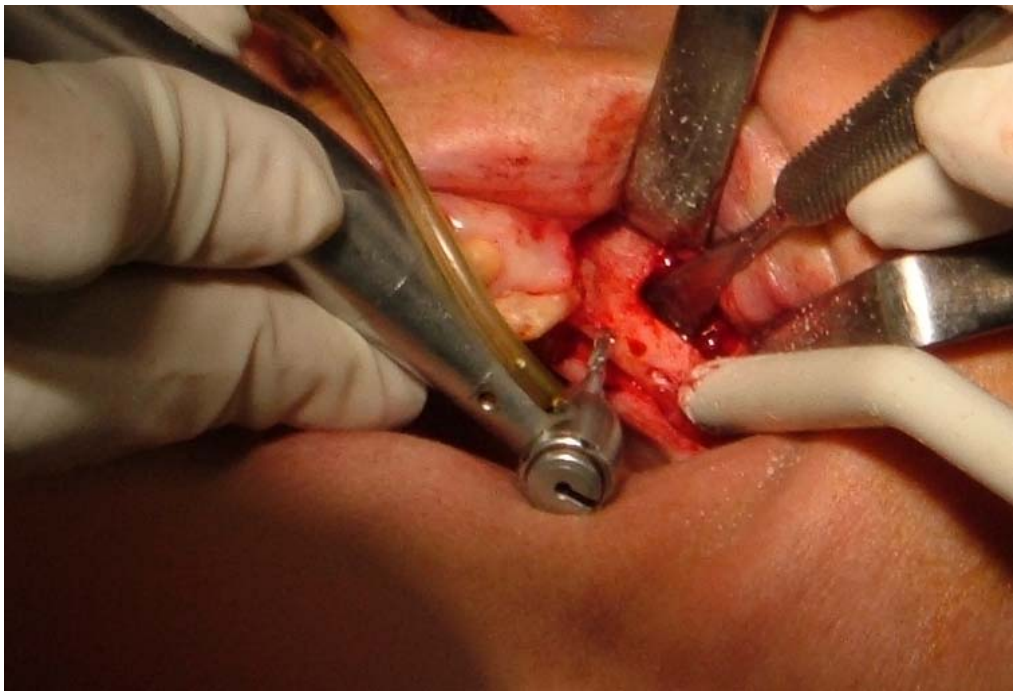

Figure 29: Drilling for the implants while protecting the schneiderian membrane

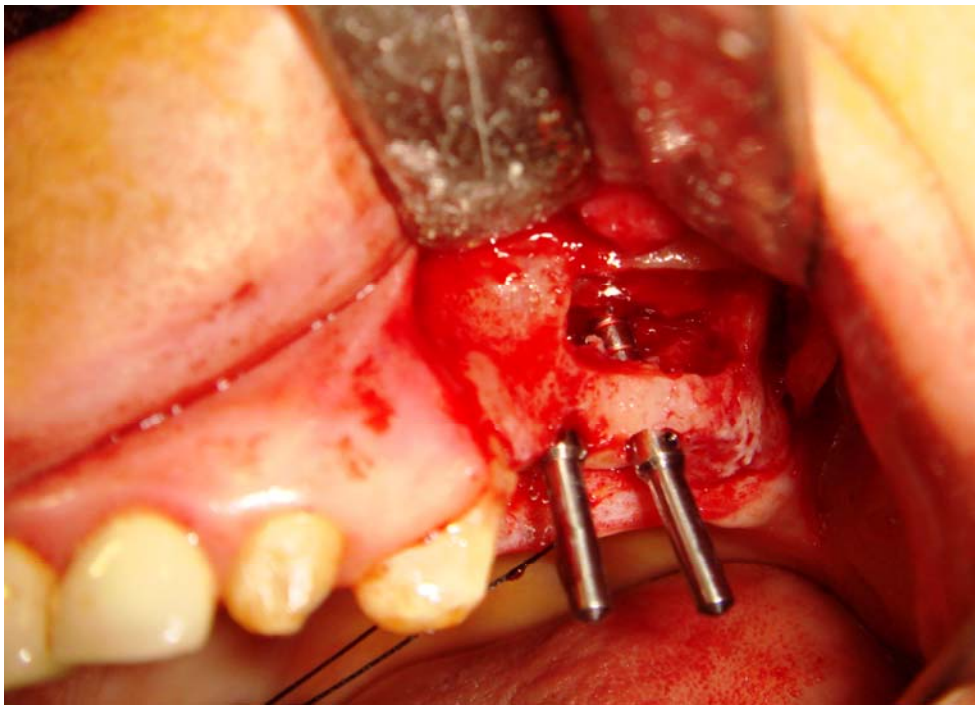

Figure 30: Paralleling pins used to verify drilling path and path of insertion of the implant

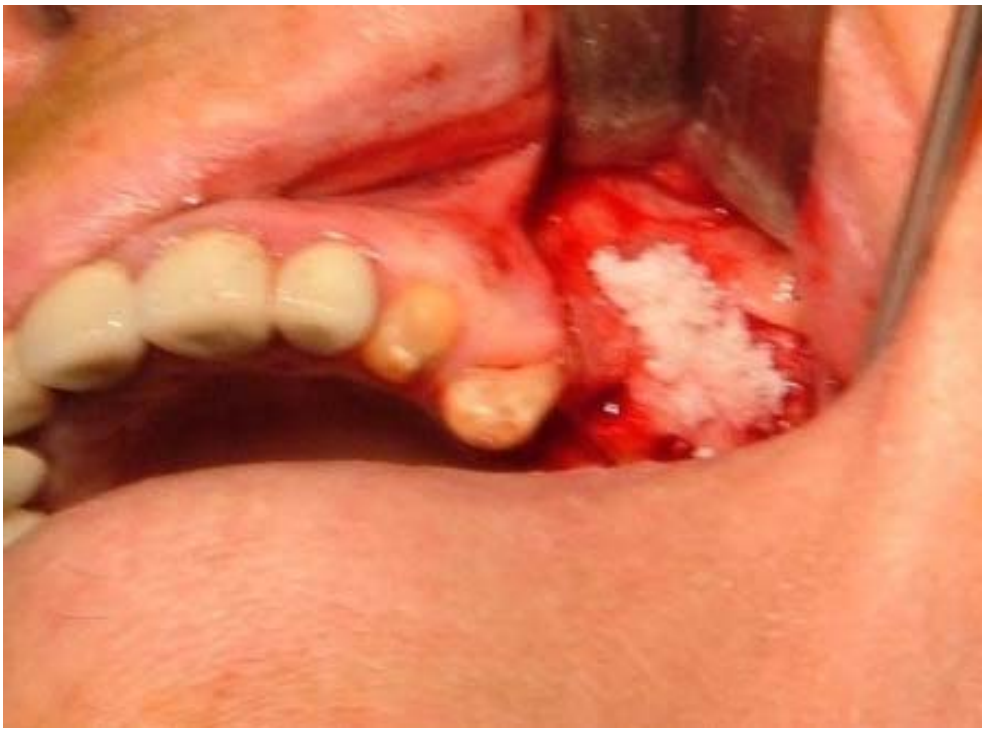

Figure 31: Packing of the surgibone graft material into the cavity

The 2 implants were inserted in the prepared sites following standard implant insertion protocol. The implants used were SwissPlus tapered implants from Zimmer®.

The anterior implant was 12 mm in length and 3.7 mm in width and the posterior implant was 10 mm in length and 4.1 mm in width (Figure 32).

A bioresorbable collagen membrane was adjusted and placed to cover the open cavity filled with the graft material (Figure 33). The membrane used was Sistema AT® bioresorbable collagen membrane.

Finally, the mucoperiosteal flap was returned back to position and sutures were made to close up the surgical site.

Figure 34 shows the one-week postoperative panoramic radiograph of the sinus grafting with implant placement.

Figure 35 shows the final prosthesis placed six months after surgery.

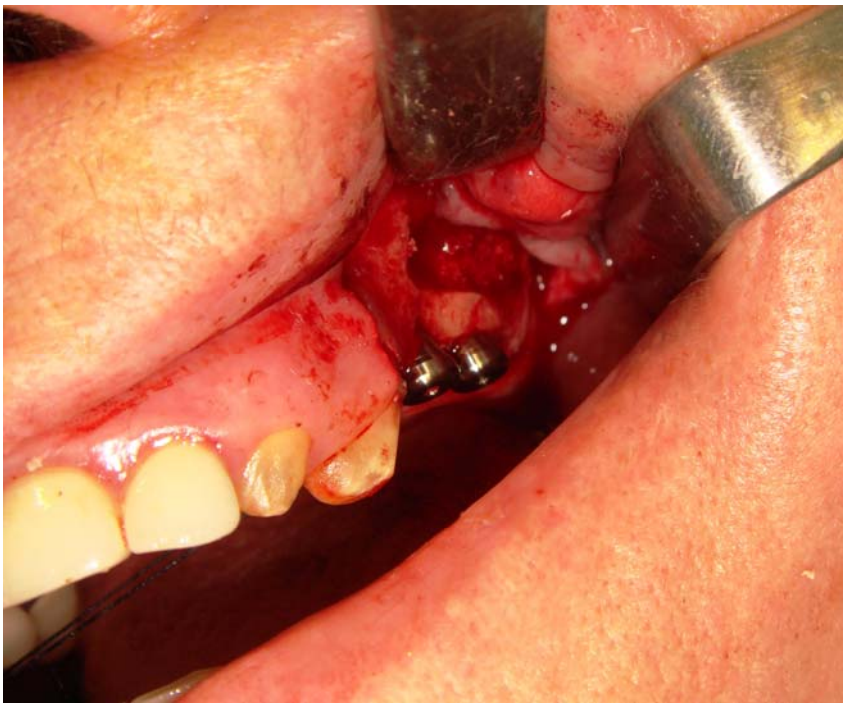

Figure 32: the 2 implants were inserted in the prepared sites

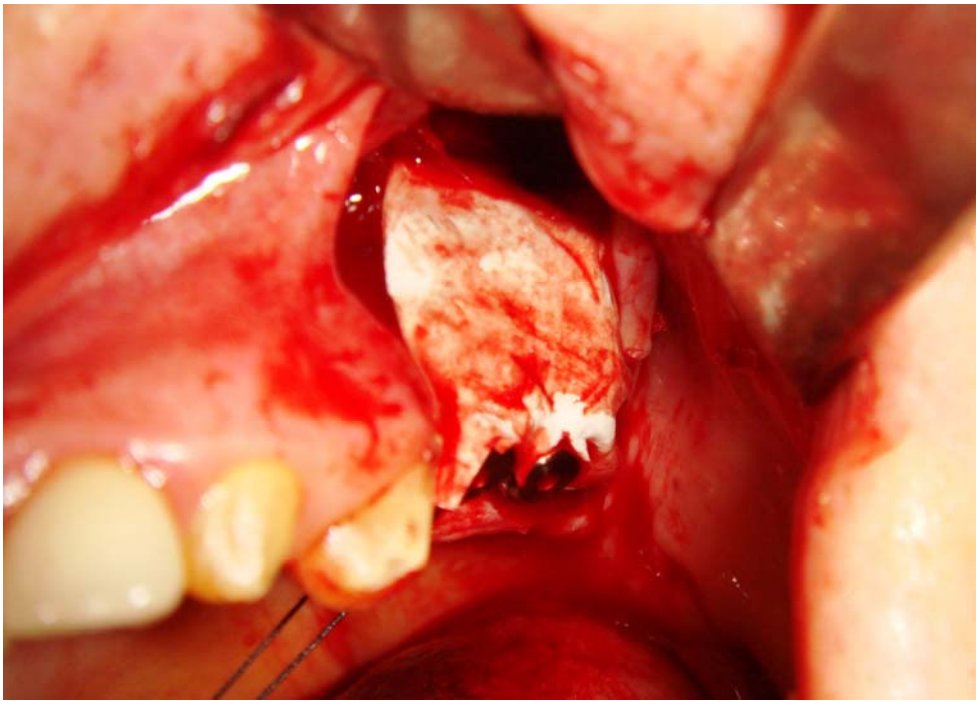

Figure 33: A bioresorbable membrane adjusted to cover the open lateral window after the procedure was finished

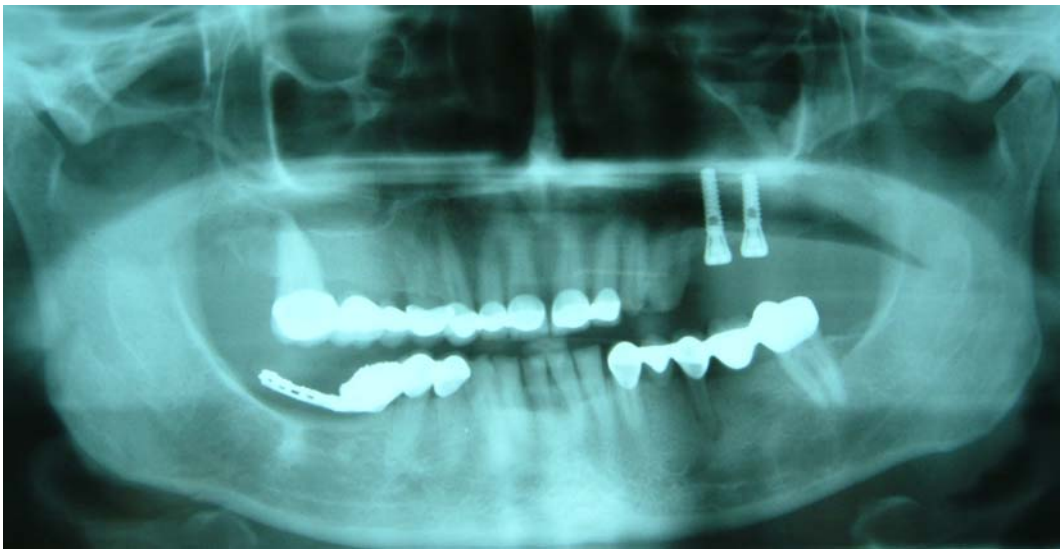

Figure 34: One week post-operative radiograph showing the results of the grafting procedure

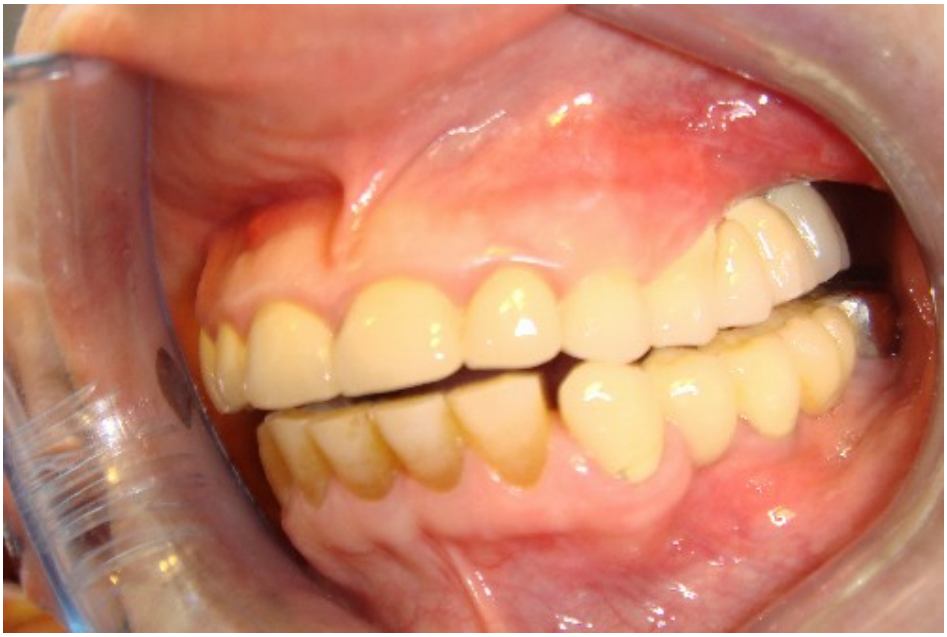

Figure 35: Final prosthesis

Case 2:

A 44 years old female patient presented to the department with missing teeth in her upper left quadrant. The initial plan was to augment the sinus and place 2 implants as shown in figure 36.

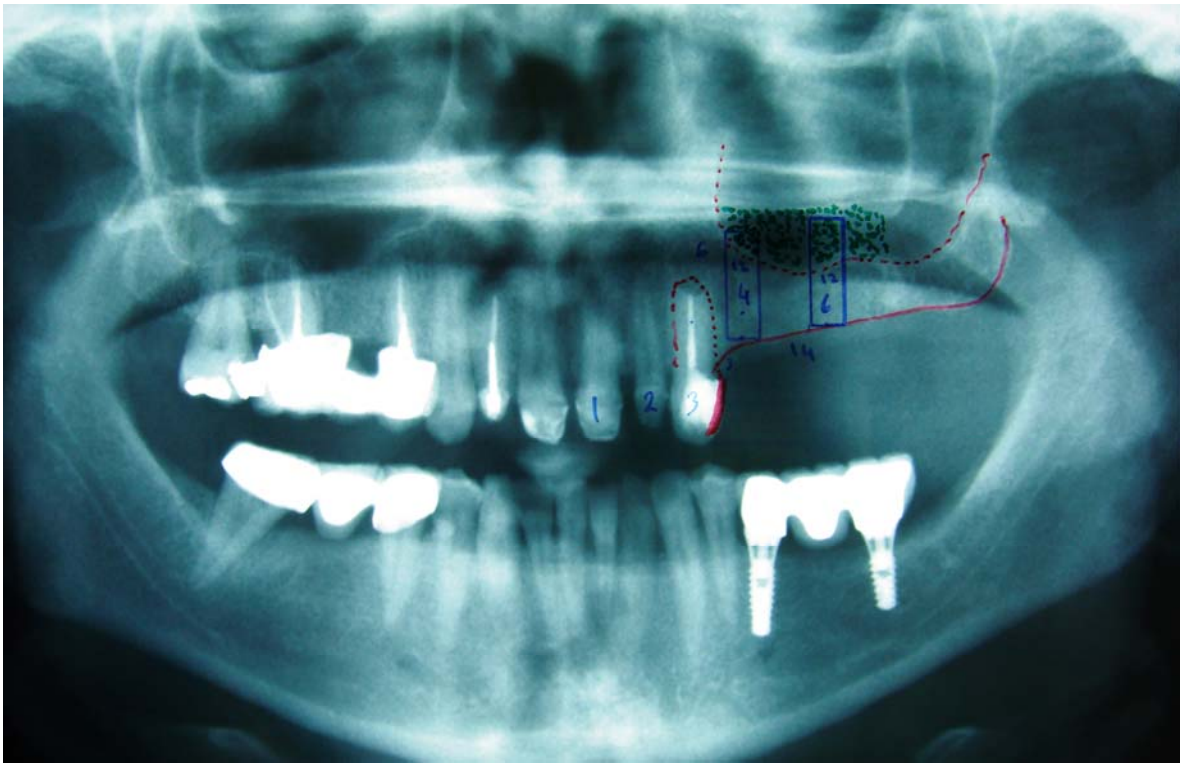

Figure 36: A radiograph showing the treatment plan for augmenting the left maxillary sinus

The sinus was augmented using Unilab Surgibone® made from ground natural bovine bone mixed with hydroxyapatite. Simultaneously two implants where placed. The implants used where Zimmer® swiss plus tapered implants having a 3.7 mm diameter and a 12 mm length (Figure 37). This case shows how the treatment plan could change during the surgery since after the flap was lifted we noticed that the width of the ridge was too narrow near the remaining natural tooth which forced placement of the implants further distal than was originally planned.

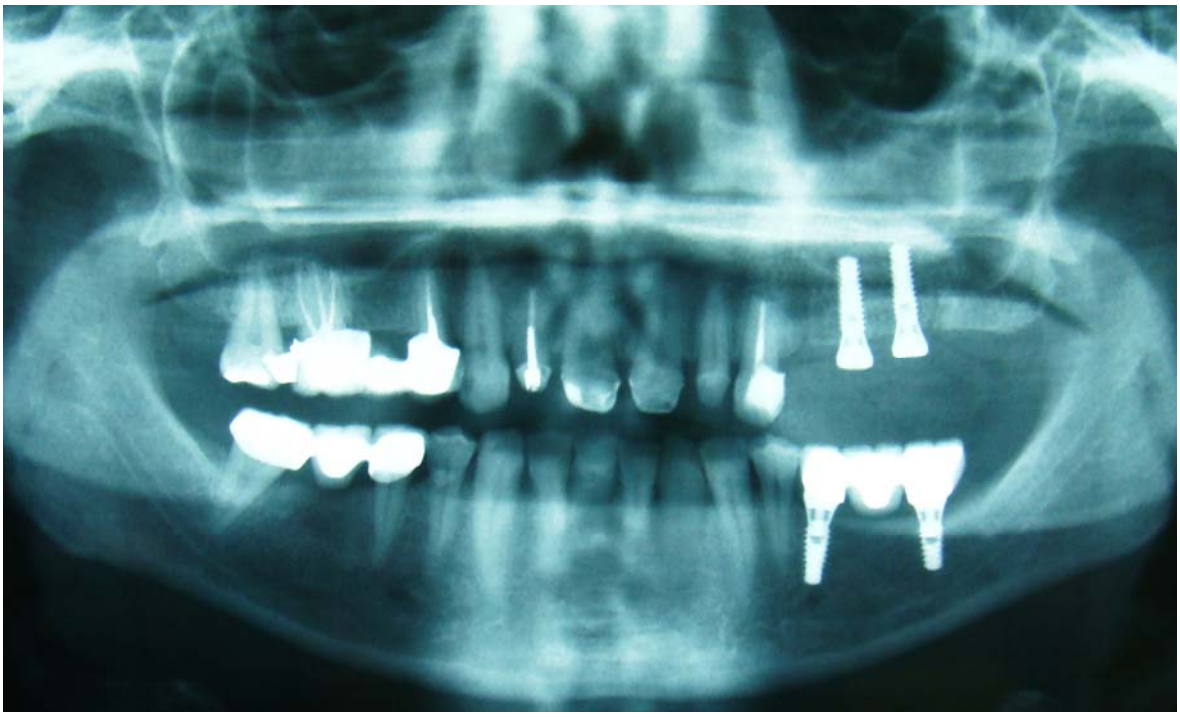

Figure 37: A postsurgical radiograph showing the location of the implants placed distal to the initial treatment plan

2.11.2 Sinus Augmentation with Delayed Implant Placement

Sinus augmentation with delayed implant placement has been performed for more than 20 years (102, 101).

Jensen et al. (1990) (41), rehabilitated severely atrophic maxillae using bilateral sinus bone grafting and delayed placement of implants 4 months later. Nine of the 36 implants placed in the grafted bone failed.

Hallman et al. (2002) (32), evaluated the survival rate of implants placed in delayed fashion into 30 maxillary sinuses augmented with a mixture of 80% bovine hydroxyapatite and 20% autogeneous bone mixed with fibrin glue. The mean alveolar bone height was 3.8 mm. After 6 months of primary healing, 108 implants were placed and followed for 1 year. Implant survival rate was 90.7%. Dimensional change of the bone grafts was also evaluated. A mean decrease of 1.4 mm (< 10%) in the height of the bone grafts was found after 1 year, which was statistically significant ($p < .001$).

Hallman and Nordin (2004) (31), retrospectively evaluated a mixture of bovine hydroxyapatite and fibrin glue as grafting material using a delayed placement with nonsubmerged implants after graft consolidation. A total of 71 maxillary sinuses were augmented and the grafts allowed to consolidate for 8 months. A total of 218 solid titanium screw-type implants were placed, and a mean of 10 weeks of healing was allowed before loading. In this study, there was a 94.5% implant survival rate after 20 months of occlusal function.

CLINICAL CASES

Case 3:

A 27 years old male patient presented to the department with missing teeth bilaterally. Radiographic examination showed the areas of interest to have undergone bone resorption and the distance between the ridge and the maxillary sinuses was not sufficient for implant placement (Figure 38).

Treatment comprised of lifting of the left maxillary sinus with simultaneous implant placement and right maxillary sinus lifting with deferred implant placement of six months (Figure 39).

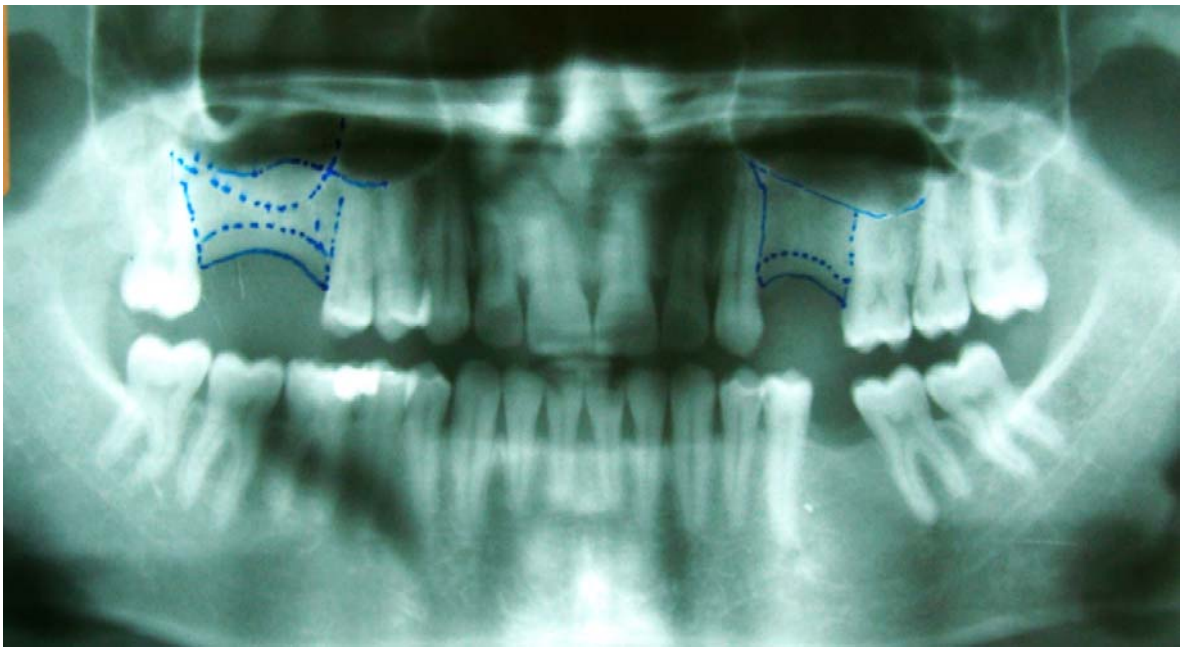

Figure 38: A panoramic radiograph showing the bilateral treatment plan for rehabilitation

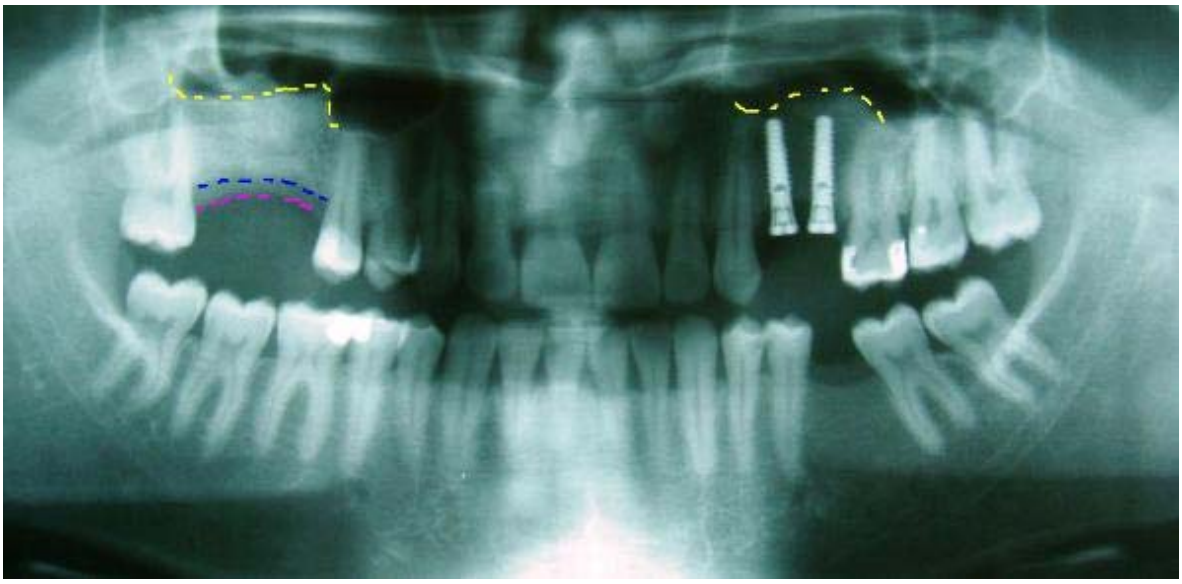

Figure 39: First stage postoperative radiograph showing the bilateral sinus augmentation

The graft used was Unilab Surgibone® made from ground natural bovine bone mixed with hydroxyapatite.

The patient was rehabilitated with Zimmer® swiss plus tapered implants: on the left side the two implants where 3.7 mm in diameter and 12 mm in length and on the right side the mesial implant was 4.2 mm in diameter and 12 mm in length and the distal implant was 4.8 mm in diameter and 10 mm in length (Figure 40)

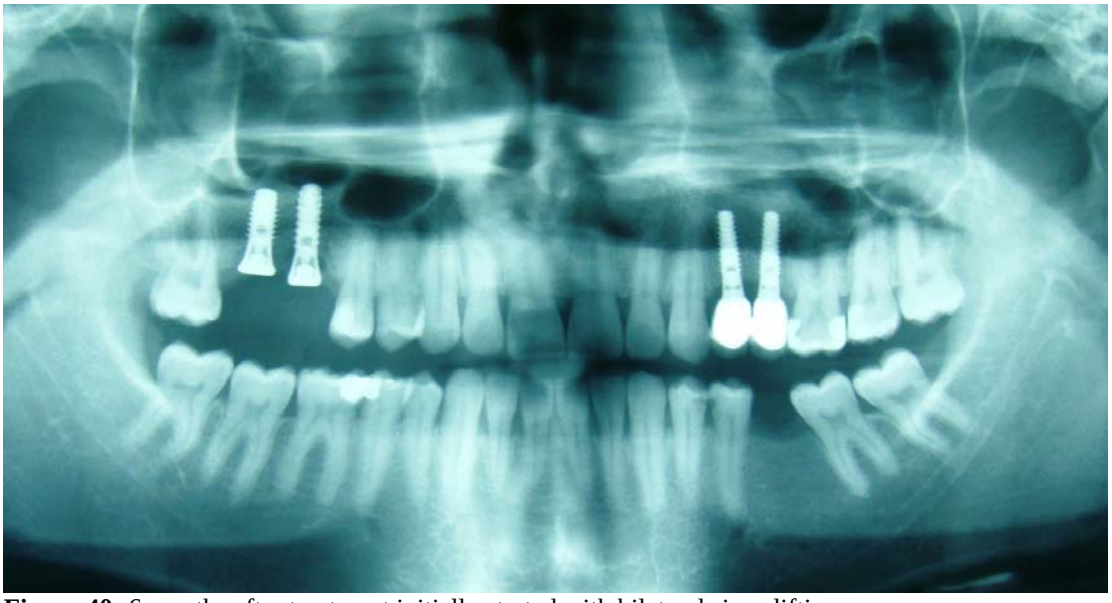

Figure 40: 6 months after treatment initially started with bilateral sinus lifting

Case 4:

A 56 year old male patient presented to the department with an almost edentulous mouth with 3 teeth remaining that are of questionable prognosis. The patient wanted to rehabilitate his mouth with implants but the maxillary ridge was severely resorbed (Figure 41). The decision was to augment the sinuses to allow for proper implant rehabilitation (Figure 42).

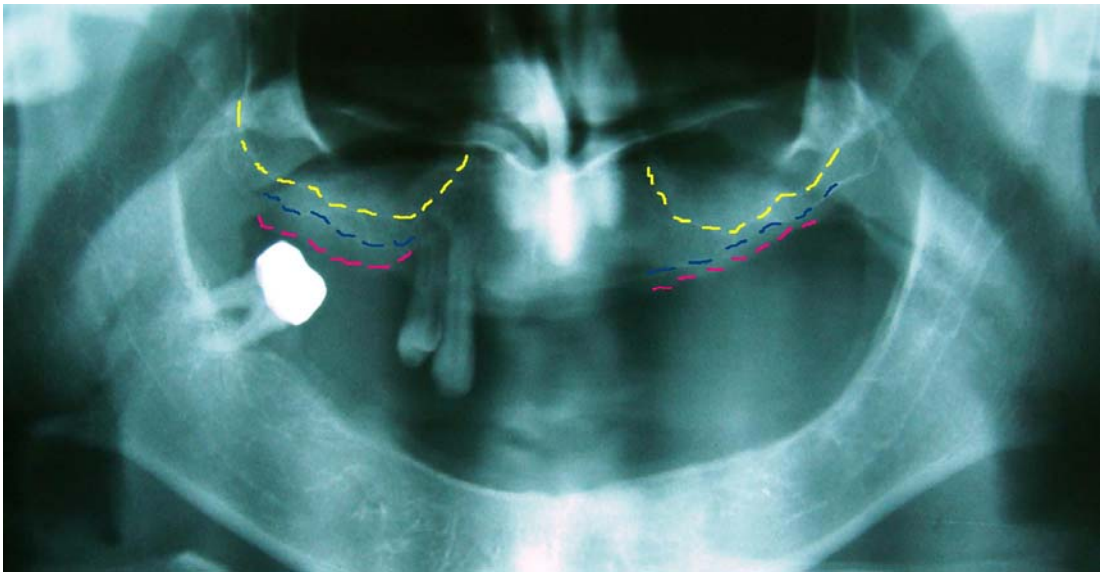

Figure 41: case2 showing the severely resorbed maxillary ridge

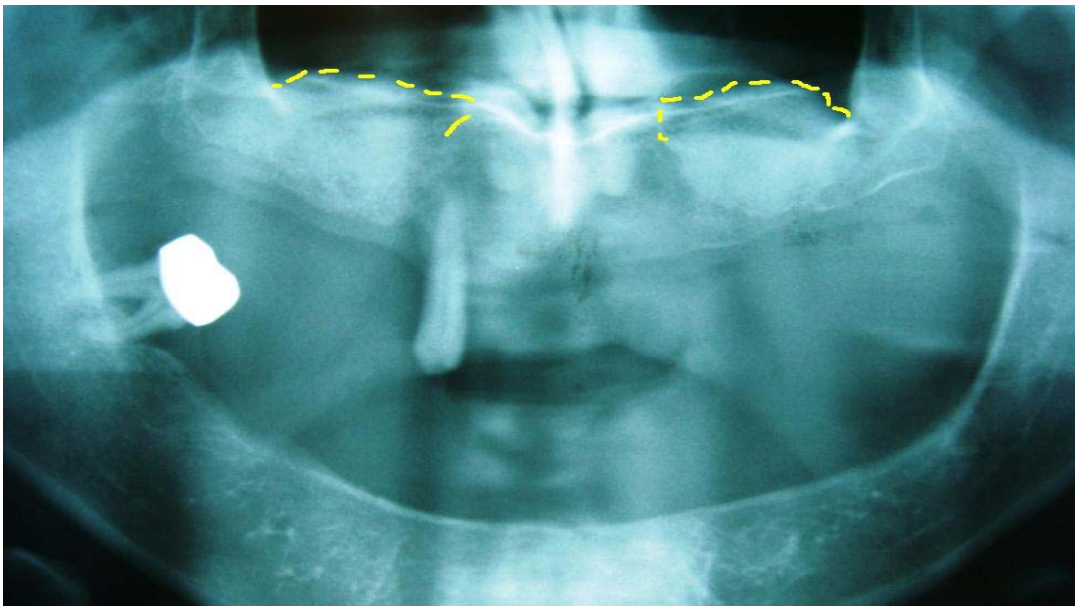

Figure 42: Bilateral sinus augmentation

The sinuses were augmented using Unilab Surgibone® made from ground natural bovine bone mixed with hydroxyapatite and one hopeless tooth was extracted. Then six months later the remaining tooth in the upper jaw was extracted and 8 implants of varying sizes were inserted depending on the location and final bone available (Figure 43). The implants used were Zimmer® swiss plus tapered implants. The sizes of the implants where (from right to left): 4.8/12, 4.1/12. 4.8/12, 4.1/10, 4.1/10, 4.1/10, 4.1/12, 4.8/12 (all measurements are in millimeters).

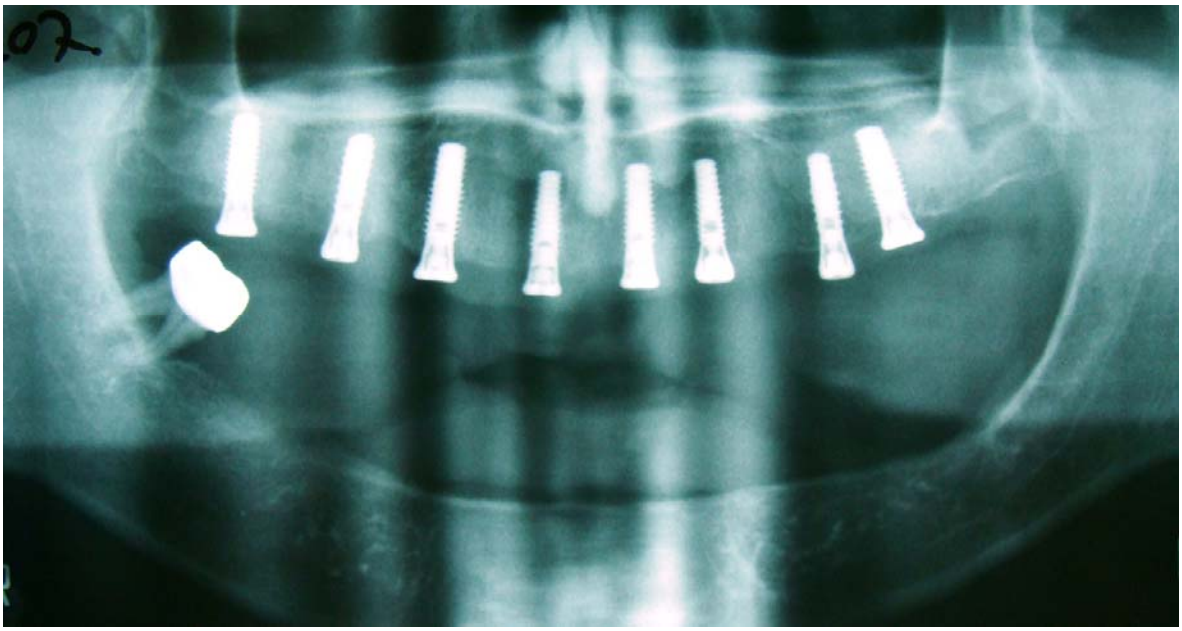

Figure 43: A radiograph showing post surgical result of placement of 8 implants

2.12 Complications of Maxillary Sinus Augmentation

2.12.1 Intraoperative Complications

A number of complications can occur during the sinus elevation surgery (Table 1). Bone bleeds from the bony window, as well as bleeding from the schneiderian membrane itself, can easily be handled using cautery. Care must be taken to avoid laceration to the buccal flap, which can result in oroantral fistulae. Careful handling of the buccal flap with good surgical technique will prevent this potential complication (80).

Injury to the infraorbital neurovascular bundle can result from dissection to free up the buccal flap for tension-free closure. It can also result from blunt trauma when a retractor is placed directly over the nerve bundle. This injury causes transient loss of sensation of the lateral nasal, infraorbital, and superior labial areas of the face. Prevention of these injuries requires careful surgical technique (84).

Membrane perforation is the most common intraoperative complication associated with maxillary sinus augmentation. During the sinus graft procedure, the sinus membrane must be elevated superiorly, away from the bony floor and walls, to allow for grafting of the area beneath it. The sinus membrane is composed of pseudo-stratified, ciliated, cuboidal, or columnar epithelium with goblet cells and ranges in thickness from 0.3 to 0.8 mm (68).

Because it has very few elastic fibers, its elevation from the bony walls often presents a significant challenge. Ideally, the membrane is not perforated and will confine the graft to the space created between it and the bony floor. In practice, however, membrane perforation occurs 10% to 40% of the time during elevation. When perforation occurs intraoperatively, it is best to continue membrane elevation in a direction opposite that of the tear to prevent creation of a larger opening. Elevation should expose the bony floor as well as the anterior, posterior, and medial walls. Small tears (less than 5 mm) can easily be resolved by placing a fast-resorbing collagen membrane over the opening. Large tears along with total membrane perforation require the use of a more rigid collagen membrane of longer duration. A large tear can result from the presence of a thin membrane or from over-instrumentation (77).

TABLE 1: Intraoperative, early-postoperative, and late-postoperative complications of maxillary sinus augmentation with identification of their most probable cause

Complication	Possible cause
Intraoperative	
Bleeding	Osteomeatal complex obstruction
Buccal flap tear	Thin periostium, improper flap design
Infraorbital nerve injury	Alveolar ridge fracture
Membrane perforation	Thin membrane/ improper instrumentation
Early Postoperative	
Incision line opening	Acute infection
Bleeding	Graft loss (partial or complete)
Barrier membrane exposure	Improper sutures
Infraorbital nerve paresthesia	Oroantral fistula
Intraoral swelling	Infection
Graft migration	Inflammation
Sinusitis	Infection
Late Postoperative	
Graft loss/failure	Soft tissue invasion over access window
Implant failure	Maxillary cyst, lack of osseointegration
Oroantral fistula	Chronic sinus disease
Implant migration	Chronic infection

Even with loss of a large portion of the sinus membrane, it is not necessary to abort the graft surgery. Instead, a resorbable (6 to 8 weeks), biocompatible, hemostatic membrane can be used to create a superior barrier to confine the grafts.

Because the incidence of infection increases with membrane perforation, it is best to avoid simultaneous sinus grafting and implant placement in the presence of a membrane tear. A waiting period of at least 4 months is recommended for healing of the graft complex

before placing implants. In general, membrane perforation can lead to short- and long-term complications as a result of bacterial contamination from the nasal sinus floor (65).

2.12.2 Early Postoperative Complications

Early complications are defined as those that occur within 7 to 10 days of surgery (Table 1). Though uncommon, incision line opening can result in graft extravasation, infection, and even total graft failure. Conventional surgical principles for proper incision design, as well as appropriate suture material selection and technique, will prevent this problem. In addition, care must be exercised when placing prosthesis. A complete maxillary denture can be placed immediately postsurgery if the buccal flange in the area of the graft is reduced and/or soft-lined. A partial denture, however, should be used only if it is acrylic-based to allow alteration for appropriate relief and to facilitate placement of a soft liner (30).

Bleeding of the original incision line is uncommon. Nasal bleeding also is unusual and can be treated with a cotton ball pressure pack as needed for hemostasis. Premature exposure of the membrane has been seen but is very unlikely unless there is total wound breakdown. When this occurs, the site is treated as indicated for graft failure (44).

Paresthesias of the lateral nasal, infraorbital, or superior labial areas of the face are caused by blunt retraction over the infraorbital neurovascular bundle. Typically this is transient (a few weeks) though occasionally relatively long lasting (several months). Care in positioning the buccal flap retractor anterior and posterior to the neurovascular bundle will prevent this complication (60).

Graft migration is one potential complication, evidenced by granules in the ostium and nasal pharynx. Mucosal inflammation secondary to sinus graft surgery can lead to obstruction of the osteomeatal complex, greatly increasing the potential for infection (44). The patient is also advised to avoid sneezing so as not to damage the graft. An anti-histamine medication is prescribed as a precautionary measure after the surgery.

Infection of the grafted sinus, although uncommon, is usually seen 3 to 7 days postsurgery. Despite presurgical antibiotic prophylaxis and good surgical technique, postoperative infection can occur, sometimes leading to total graft failure. Potential

sequelae secondary to infection may involve a pansinusitis as well as infection spreading to the orbit, dura, or even the brain (88).

Intraoral swelling over the grafted window area is the most common initial finding associated with infection. It is usually seen 1 week postsurgery, although it can occur as early as 3 days postsurgery. Antibiotic therapy, such as clindamycin is recommended as an empiric drug of choice. Metronidazole can also be added, especially for anaerobic coverage. Anti-inflammatory drugs such as Ibuprofen are also recommended to be used with antibiotic therapy. Sometimes an infection is restricted to a local area and will respond to antibiotic therapy alone (60).

In cases of persistent symptomatology, however, it is imperative to pursue aggressive treatment that includes incision and drainage. The graft should be re-entered via the original incision line. It may be tempting to make an incision in the area of the window, but this can result in an oroantral fistula. A full-thickness mucoperiosteal flap is reflected, allowing for direct visualization of the graft site. Aerobic and anaerobic culture and sensitivity, in addition to a gram stain, is recommended. If the infection is confined to a localized area, then local debridement is the appropriate therapy.

If infection has penetrated the entire graft, then removal of the entire graft and possibly of the sinus membrane is recommended. If implants were placed simultaneously with the graft, they also should be removed, and a long-acting collagen membrane should be placed over the window (80).

Oroantral fistulae can occur as a result of sinus graft infection. If small, they often respond to antibiotic therapy and oral chlorhexidine gluconate rinses. Larger ones, however, can persist and may require surgical intervention. It is nevertheless recommended to always give the patient antibiotics and chlorhexidine mouth rinses after the surgery.

Sinusitis is thought to be a common complication of sinus grafting (25). One factor that predisposes to sinusitis is perforation of the sinus membrane. With delayed placement of implants, acute sinusitis risk is reduced as it relates to potential implant loss (84). For this reason, many practitioners advocate a two-stage approach.

In an interesting analysis of sinus function following sinus elevation, 45 patients who received 85 sinus bone grafts underwent evaluation by endoscopy, Water's view

radiography, and questionnaire 12 to 60 months postsurgery. Of the 45 patients, only 5 were found to have sinusitis after sinus grafting. In the 5 patients, endoscopy revealed oversized turbinates and septal deviation (99). The results of this study clearly show that the incidence of sinusitis after bone grafting is low and is predominantly found in patients who are predisposed to sinusitis.

2.12.3 Late Postoperative Complications

Complications of maxillary sinus augmentation that occur more than 3 months postoperatively are very uncommon (Table 1). Most of these are seen at stage-one surgery when a two-stage approach is used. Graft infection can manifest as a dehiscence of the mucosa overlying the access window, resulting in partial graft loss. Treatment of this condition involves antibiotic therapy, followed by incision and drainage using the original mid-crestal incision with an anterior oblique release for full flap reflection. As with treatment of immediate postoperative infections, it is important to obtain an aerobic and anaerobic culture and sensitivity, including a gram stain. Debridement of the infected graft should follow. If no active infection is found, re-grafting can be performed at this time. Otherwise, a re-entry graft can be accomplished 3 to 4 months later (84).

Total graft failure can also occur, at this time, requiring complete removal of the graft. Re-grafting can be accomplished approximately 3 to 4 months later. If implants were placed in a one-stage approach, they also would be removed along with the graft. An oroantral fistula can occur secondary to a late-infected graft, which would require closure by one of a variety of surgical procedures prior to re-grafting (23).

Implant failure at stage-two surgery can result from lack of osseointegration. Implant migration, either early or late postoperative, can also be seen if there is inadequate bone volume and/or density for implant stabilization (60).

Another cause of stage-two implant failure is insufficient graft fill resulting from failure to elevate the membrane up to and including the medial wall. This can also occur if the recess adjoining the anterior wall is not grafted adequately. Treatment requires secondary grafting of the spaces (84).

Loss of implants cannot be the sole criterion for determining the success of a sinus graft. The failure rate of implants placed without sinus elevation surgery, regardless of the type of graft used, is lower than that with sinus elevation surgery. Prospective studies (11, 45) show success ranging from 61.2% to 89.5%. Retrospective clinical studies (9, 37, 43, 46, 51, 78) also report similar results. Implants that are lost before loading indicate a failure of osseointegration. Nevertheless, implant survival of 80% to 90% is considered acceptable.

Loss of implants placed as part of the sinus elevation procedure remains inadequately explained. A randomized clinical trial that compared one-stage and two-stage techniques with iliac bone grafts (108) reported that the results of the two-stage approach were twice as good. Nonetheless, the success rate for sinus elevation using iliac bone grafting material is lower than the success rate for other materials after 1 year.

Calvarial bone grafting combined with human recombinant tissue factor, platelet-rich plasma (PRP), and tetracycline in a prospective clinical trial of 18 patients with 25 grafted sinuses induced a high success rate (90% for the graft and 91.3% for implant integration) (74). However, 2 of the 25 sinuses were excluded due to focal infections, and for the other failures no explanation was offered for the loss of the implants.

Loss of implants due to failure of integration can lead to therapeutic problems as well as patient anxiety and discomfort. One author compared patients who had lost a significant number of implants (43%) with those who had lost only one or two (6%) but could find no significant hematological, osteometric, or anamnestic differences between the two groups (9).

Soft tissue invasion of the graft site can occur at stage-one surgery if a barrier membrane was not used to cover the access window. A long-lasting collagen membrane with tack fixation will prevent this complication. Treatment involves re-grafting the void after soft tissue debridement (60).

Development of an epithelial cyst of the maxillary sinus post-surgically has been associated with virtually every procedure that involves the sinus. This cyst is thought to derive from epithelial tissue tags that become entrapped during wound closure. This cyst has been referred to by a variety of names, including postoperative maxillary cyst

postoperative buccal cyst mucocele and postoperative paranasal cyst (47). Treatment consists of complete removal of the cyst with simultaneous bone grafting of the cyst cavity.

Chronic infection can occur secondary to an initial sinus graft infection, resulting in a persistent disease process refractory to conventional antibiotic treatment. This is especially true if a fungal infection is involved. These patients must be aggressively treated with intravenous drug therapy and surgical intervention. Finally, chronic pain can occur secondary to maxillary sinus augmentation, especially in the presence of implants (99). Although rare, this problem can be persistent and may require implant removal.

2.12.4 Other Complications

Many other complications have been reported, including (38, 80, 84, 87, 99):

- Dehiscence of oral mucosa
- Profuse bleeding during surgery
- Implant migration
- Hematoma
- Suture abscess
- Adjacent tooth sensitivity
- Loss of bone graft and late-term sequestration

For other authors, late-term complications included: (61, 72, 78)

- Chronic infection
- Oroantral fistula
- Graft exposure
- Separation of the graft from basal bone
- Expulsion of the implant through the nose
- Chronic pain
- Fungal infection
- Wound dehiscency
- Sinus cyst and scar tissue replacement of the graft

2.12.5 Complications at the Donor Site

Many authors rationalize the use of bone substitutes based on the potential morbidity of bone harvesting. However, very few donor site complications have been reported. Common forms of morbidity associated with the iliac crest are hematoma, seroma, pain, discomfort, gait disturbances, and paresthesia (38). Tibia bone harvesting rarely results in fracture of the tibial plateau; mandibular ramus bone harvesting has caused transient hypoesthesia of the labial gingiva and of inferior alveolar bone; and the harvesting of calvarial bone has occasionally caused intracranial penetration in the dura (88).

2.13 Alternatives to Maxillary Sinus Augmentation

2.13.1 Avoiding the Sinus with Tilted Implants

The effectiveness of placing implants into the tuberosity area of the pterygoid process is well documented, but the technique has been associated with the risk of causing injury to the descending maxillary vasculature (22). When placed into the retromaxilla, implants are generally tilted anteriorly; however, by tilting them posteriorly, the implants follow the anterior sinus wall and completely avoid the maxillary sinus (Figure 44).
Cross-arch multi-unit implant placement using this approach extends the prosthetic support posteriorly and anchors the implant in dense bone structures (2, 50, 58).

The prosthetic load is transferred to the bone via the implant head or platform. It is the position of the platform at the bone crest, rather than the tilting of the implant beneath the platform, that defines the support point (Figure 45). The tilting technique, therefore, provides for prosthetically favorable positioning of the implant heads as well as optimal anchorage in bone. Results of biomechanical analyses (50) and clinical follow-up studies (2, 20, 26) indicate high survival rates and that the use of tilted implants does not increase bone resorption.

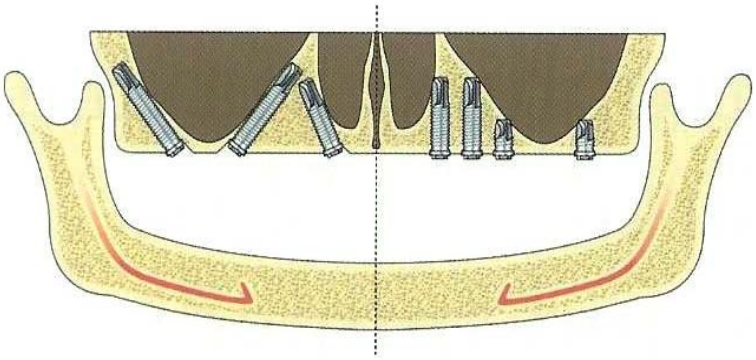

Figure 44: By following the anterior sinus wall, tilted implants may be placed in the bone pyramid anterior to the maxillary sinus, where no vital anatomic structures are present. ‡

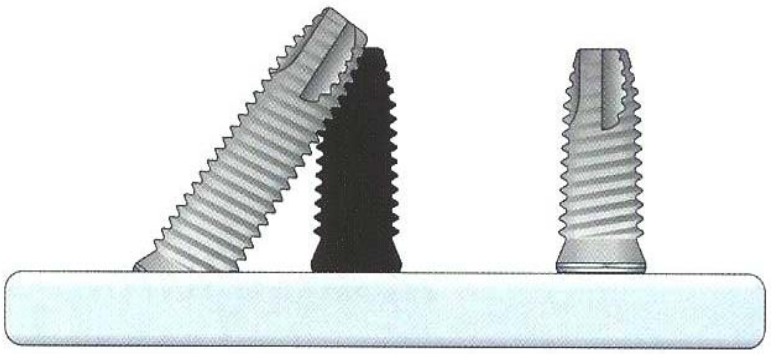

Figure 45: The prosthetic load is transferred to the bone via the implant platform (head). Tilting beneath the platform has no influence on the prosthetic support; the position of the platform at the bone crest defines the support point. ‡

‡ Figures taken from Aparicio C, et al. Tilted implants as an alternative to maxillary sinus grafting CIDRR 2001

a) All-on-4

The complete-arch rehabilitation concept known as “All-on-4” (58) uses two posterior tilted implants and two anterior vertical implants to support a complete-arch fixed prosthesis that is placed under immediate function. The concept may be applied in either jaw but provides the greatest benefit in the maxilla. Both in vivo implant load analysis and clinical studies demonstrate that four implants are as effective as six for complete-arch rehabilitation of the maxilla (17, 26). Each implant is placed without impinging on adjacent implants. Remarkably, minimal bone volume is needed to establish a 12-tooth fixed prosthesis (Figure 46).

Placement of the posterior implants is facilitated by the use of a surgical guide that is specially designed for precise implant positioning and obtaining the correct tilt of the posterior implant in relation to the occlusal plane (Figure 47). Tilting makes it possible to place the implant in a canine or first premolar site and yet to position the implant head in the second premolar or even first molar region. Such an arrangement results in a relatively large inter-implant distance and a shortened cantilever length while keeping the implant heads and prosthetic screws placed in prosthetically favorable positions. A high-density, all-acrylic prosthesis with titanium cylinders is delivered to the patient within hours of implant placement. A more definitive prosthesis may be placed at a later stage. It is estimated that 75% of patients who qualify for maxillary sinus bone grafting could benefit from this procedure.

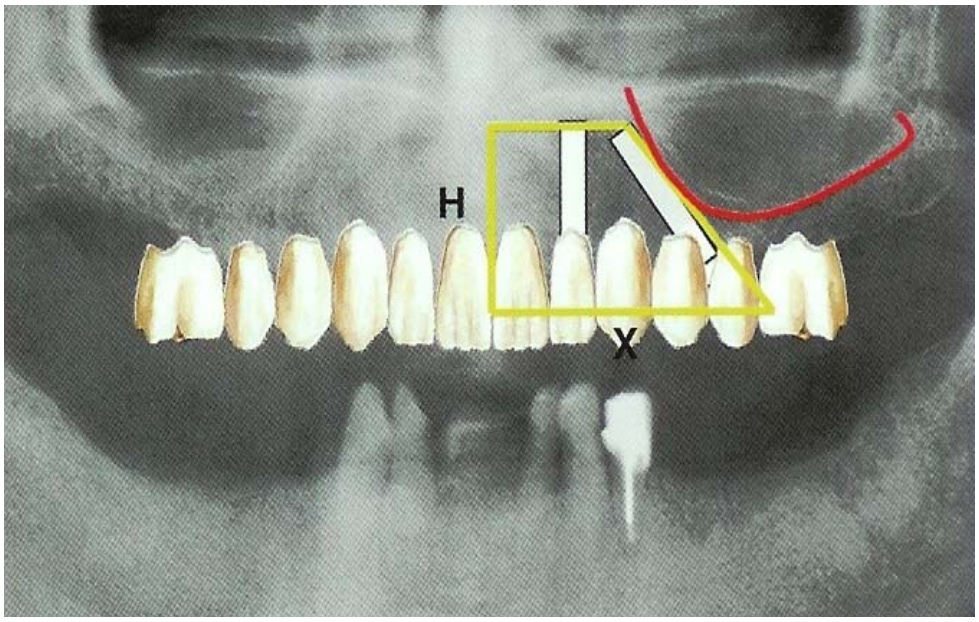

Figure 46: The All-on-4 concept can be used to treat varying maxillary atrophies; the determining factor is the position of the posterior implant. The posterior implant head will emerge from different positions at the bone crest, depending on the degree of resorption. ‡

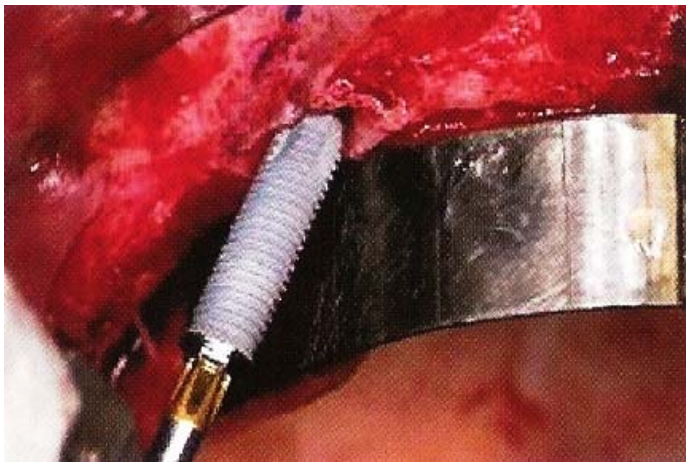

Figure 47: A special surgical guide facilitates precise positioning of the implant sites in relation to the opposing jaw and correct tilting of the posterior implant. Tilting the posterior implant makes it possible to position the implant head in the second premolar region rather than the canine region. ‡

‡ Pictures are taken from Malo P, et al. “All on 4” immediate function concept with Branamark system implants for completely edentulous maxilla, CIDRR 2005

b) Partially Edentulous Treatment

Restoration of the partially edentulous resorbed maxilla also can be accomplished with the use of tilted implants (2, 20). Partial restorations can be placed under immediate function without cross-arch stabilization, provided that adequate consideration is given to critical load factors (79). For immediate loading in this situation, the reduction of occlusal contacts, particularly the elimination of lateral forces and cantilevers, are means to control the load distribution.

2.13.2 Avoiding the Sinus with Short Implants

The use of short implants (Figure 34) has long been associated with low success rates (28, 40, 69, 86, 105). However, recent clinical studies indicate that short implants (ie, less than 8.5 mm) that are designed for and achieve high initial stability support most prosthetic restorations quite adequately (81, 91, 97, 98). These clinical findings are supported by theoretical analyses suggesting that long implants often are biomechanically unnecessary, since load transfer between implant and bone often is limited to a few millimeters at the implant's most coronal point. Bone stress intensity diminishes along the length of the implant body apically, and the effects of loading are often negligible beyond the length of 7 to 8 mm (1, 62, 75).

Most of the implants used in these studies featured modified surfaces for improved osseointegration and resulted in a survival rate of about 95%, which compares favorably with the global survival rate (90%) of treatment involving bone grafting in preparation for the placement of standard-length implants.

This change of philosophy regarding short implants is a result of improvements in surface morphologies and surgical technique as well as load factor considerations (79). The oxidized implant surface contributes to the effectiveness of osseointegration (39). Thread anchorage in available cortical bone as well as surgical underpreparation improves initial stability (81).The use of tapered implants may dramatically increase stability, even in low-density bone. There is also speculation that the increased bone flexion of short implants may be an advantage for partial prostheses and lead to reduced lateral forces on the implants (75).

2.13.3 Zygomatic Implants

The zygomatic implant differs from a traditional dental implant in its extended length of 35 to 50 mm and its unconventional anchorage site; the zygomatic arch (56). However, perhaps the most important difference is that it is not intended to be used as a stand-alone fixture and cannot accommodate a maxillary restoration, but must be accompanied with traditional dental implants in the anterior maxilla. As a general rule, each zygomatic implant must be accompanied by at least two traditional dental implants. This allows for the construction of a semi-circular rigid bar that readily sustains and resists functional loading.

Studies have demonstrated a remarkable success rate (97%) associated with the use of the zygomatic implant in the severely resorbed maxilla. Compared with conventional implant modalities, the zygomatic technique demonstrates the highest overall success rate (13). The zygomatic implant approach satisfies a long-unfulfilled need for a viable grafting alternative to maxillary reconstruction that should be discussed with patients (12, 57, 90).

a) Surgical Protocol

In the office setting, IV sedation and local anesthesia are quite adequate, but care must be taken to assure that appropriate and profound local anesthesia is obtained. Posterosuperior alveolar blocks with anterior infiltrations and supplemental palatal infiltrations are needed in conjunction with percutaneous zygomaticofacial nerve block (12).

A crestal incision is made in the anticipated placement site, extending slightly to the palatal and anteriorly to the midline, with a releasing incision made posterior and parallel to the zygomatic buttress. Mucopehosteal exposure for antrostomy and palatal reflection are accomplished; a short midline releasing incision can be made if additional exposure and retraction are necessary. Adequate reflection along the facial aspect of the zygomatic body facilitates visualization of the instruments as they perforate the lateral cortex on the facial aspect of the zygoma (Figure 48).

The antrostomy should be positioned parallel to the zygomatic buttress, rectangular in shape, and as far lateral as possible to ensure that the implant will be placed parallel to and against the buttress itself. Care should be taken in the reflection of the sinus membrane, and it should be preserved when possible. Removal of the bony window is optional (Figure 49).

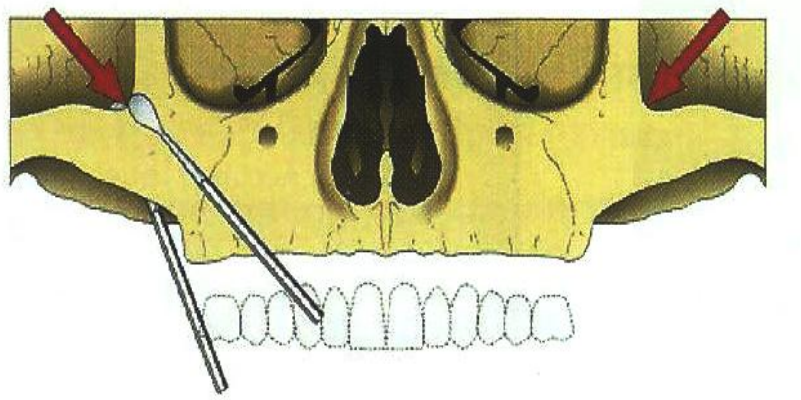

Figure 48: Reflection of the soft tissue should permit visualization of the zygomatic body and zygomaticofacial nerve. Retraction of these tissues is critical for appropriate visualization during site preparation. ‡

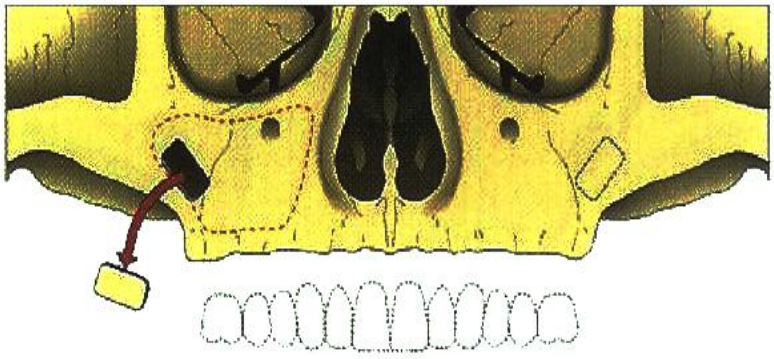

Figure 49: The entrance into the sinus should be made as far lateral as possible and parallel to the buttress. The bony window attached to the reflected sinus membrane may be retained or removed. ‡

‡ Figures taken from Malevez C, et al. Use of zygomatic implants to deal with resorbed posterior maxilla JP 2000

Reflection of the sinus membrane can be carried out along the entire area of insertion, that is, in the superior and lateral aspects of the sinus, to ensure that soft tissue is not introduced into the osteotomy site in the body of the zygoma (Figure 50).

A standard osteotomy protocol is followed, although a diameter greater than 3.5 mm is rarely needed since the residual alveolus is often thin and not very dense. The use of a small-diameter osteotomy (ie, less than 4.0 mm) at the alveolar aspect allows for improved stability. The use of drill guides is imperative to prevent laceration of the soft tissue of the lips (Figure 51).

Implant length must be properly gauged to prevent palpability of the tip of the implant through the skin (Figure 52).The implant may be placed using a dental implant handpiece or by hand according to the surgeon's preference (Figure 53).

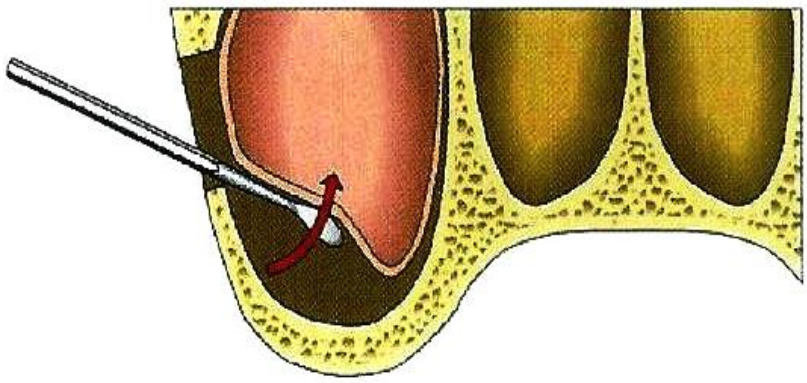

Figure 50: The sinus membrane must be thoroughly elevated along the lateral and superior aspects of the sinus to avoid tracking soft tissue into the osteotomy during placement of the implant. ‡

‡ Figures taken from Malevez C, et al. Use of zygomatic implants to deal with resorbed posterior maxilla JP 2000

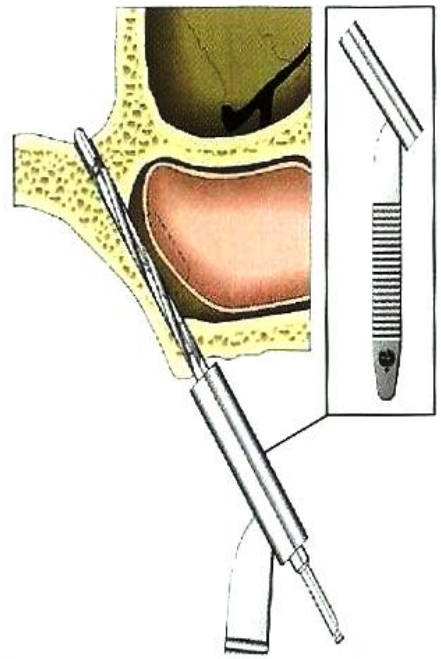

Figure 51: Use of drill guides is imperative to prevent inadvertent laceration of the lips. ‡

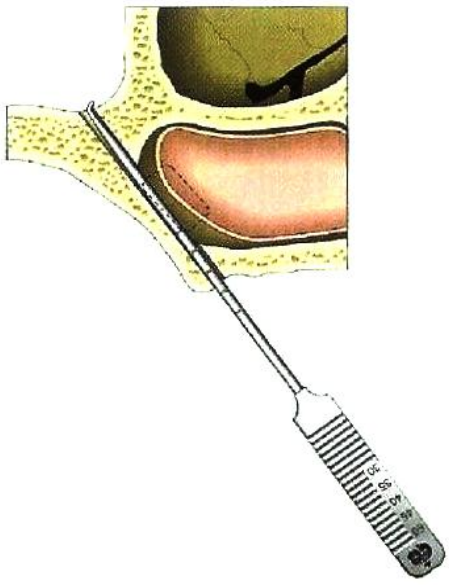

Figure 52: Accurate length measurement will minimize the possibility of placing the implant at a depth that is too shallow, which will make the tip palpable. ‡

‡ Figures taken from Malevez C, et al. Use of zygomatic implants to deal with resorbed posterior maxilla JP 2000

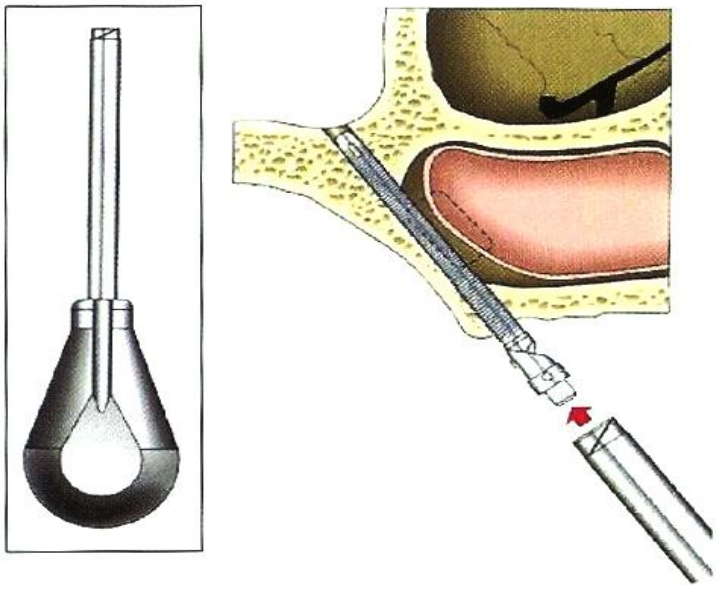

Figure 53: Placement can be easily accomplished using the hand driver. An implant drill may also be used. ‡

Because it is not visible, the osteotomy site may be difficult to locate in the zygoma. For this reason, it is helpful to use a curved titanium curette to help stabilize and guide the implant into the osteotomy site. If at all possible, the implant should be oriented so that the restorative platform is perpendicular to the alveolus and nearly centered on the residual ridge. This ensures that tongue space will be adequate following prosthetic rehabilitation.

Once the implant has been placed to the proper depth, a 4-mm healing abutment (rather than a healing screw) is placed to facilitate identification of the implant during the uncovering procedure. The healing cap and abutment screwdriver are used to orient the implant into parallel alignment with the cross-arch and anterior implants (Figure 54).

Anterior implants should be placed according to standard protocols. Wounds are closed with a resorbable suture in a continuous fashion. Integration typically takes 3 months but may require as many as 6 months if the anterior implants necessitate bone grafting (12, 13, 57, 90).

‡ Figure taken from Malevez C, et al. Use of zygomatic implants to deal with resorbed posterior maxilla JP 2000

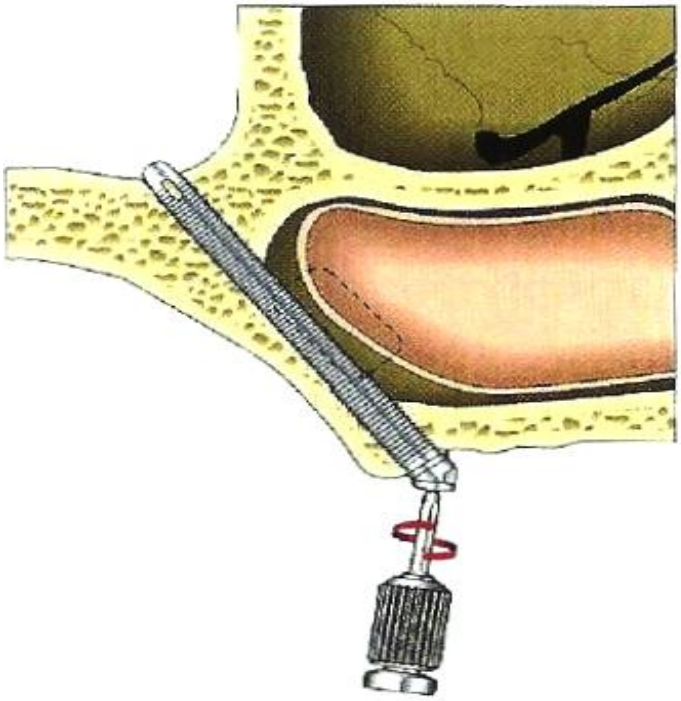

Figure 54: The cover screwdriver can also be used to visualize the orientation of the implant in relation to those more anterior and across the arch.

b) Potential Complications

A number of complications have been associated with the placement of zygomatic implants, but most can be avoided by following a careful surgical technique. Potential complications include pain, infection, excessive bleeding, palpability, zygomaticofacial paresthesia, ocular injury (if the orbit is entered), loss of implants, and sinusitis. Informed consent that includes the possibility of ocular injury is important. Extreme caution should be exercised during implant placement to prevent inadvertent entry into the orbit (57).

‡ Figure taken from Malevez C, et al. Use of zygomatic implants to deal with resorbed posterior maxilla JP 2000

3-METHODS

A systemic online and manual search of literature was performed through spring and summer of 2006. The online search included MEDLINE (National Library of Medicine) implementing PubMed and Web of Science. Multiple key words including maxillary sinus, sinus, sinus lift, elevation, augmentation, graft, antral, antral membrane, schneiderian, lateral window, osteotomes, Le Forte, barrier membrane. And different strategies and combinations of the above listed words were used. The manual search included the following journals from 1994 until 2006: Journal of Oral Implantology, Journal of Periodontology, Periodontology 2000, Journal of Oral and Maxillofacial Implants, Journal of Oral and Maxillofacial Surgery, Journal of Implant Dentistry, Dental Clinicians of North America, Journal of Rhinology, and the Compendium on Continuing Dental Education. Any article that included a reference relative to this thesis and published prior to these years was manually searched after being identified.

Articles were screened based on the following criteria: 1) Nothing was used that was only published in abstract form; 2) Only those articles that were published in respected journals were used; 3) No articles from private websites or personal publications.

Additionally the bibliographies of relevant publications were checked for further studies. The chosen articles were viewed using access to some of the relevant journal online and those that were difficult to get online access to, were photocopied from the libraries of Yeditepe University-Faculty of Dentistry, Marmara University-School of Dentistry, and the library of The Hebrew University of Jerusalem-School of Medicine and Dentistry.

The online search identified hundreds of results dealing with maxillary sinus augmentation. These results were screened out for the ones relevant to this thesis which included all clinical cases and experiments dealing with the chosen headlines of the thesis and techniques for the maxillary sinus augmentation, this yielded a total of 204 articles.

The examination of the bibliographies used in the relevant articles lead to further results that were not found in the online search for a total of 58 articles. The manual search

through the above mentioned journals added 20 articles that were not present in the online search.

Of all the articles found the ones listed in the references section of this thesis were the ones that were finally used in relevance to the objectives of this thesis.

4-DISCUSSION

A review of the literature shows that delayed implant placement is more likely used in cases that have minimal available bone as opposed to simultaneous placement which is mostly performed in cases that have a greater residual crestal bone height (41, 32, 31).

The most common technique to be used by clinicians was found to be the lateral window approach with delayed implant placement of 4 to 8 months. And recently the graft material of choice for maxillary sinus augmentation was bovine demineralized freeze dried bone.

Bioresorbable collagen membranes are seen to be preferred over non-resorbable membranes when covering the bony window after grafting the sinus. This makes more sense since there will be no need for an extra session of re-opening and reclosing the surgical site to remove the non-resorbable membrane.

Moreover, there has been a trend to place implants in the surgical site simultaneously with the grafting procedure if the bone height to start with was found to be higher than 5 mm. Summers technique for osteotome elevation is still not commonly performed although it has been proposed almost 13 years ago.

In the Sinus Consensus Conference in 1996 (44), the survival rate of implants placed simultaneously with a bone graft into the maxillary sinus was compared with the survival rate of those placed 6 to 9 months after sinus augmentation. Of the 785 implants in the simultaneous group, 133 had failed after 5 years for an overall success rate of 85.8%. However, this outcome was not statistically significant ($p > .001$). Nevertheless, when all simultaneous cases were compared with all delayed approaches, a better success rate was found with a delayed approach.

When comparing simultaneous grafting to implant placement with delayed approaches, the length of the delay also was found to be a factor. A delay of greater than 8 months demonstrated a much better success rate compared with a delay of 4 to 8 months, with a 3-year survival rate of 97%. The shorter 4 to 8 month delay yielded a 3-year survival rate of 84% (44).

The choice of graft material could be a key factor in the survival of implants

regardless of immediate or delayed placement protocols. Jensen, 1991 (42) has shown that bone resorption and implant loss is less when using mandibular autogeneous graft instead of the iliac crest graft. His study demonstrated a survival rate of 93.5% in the implants placed in the grafted maxillary sinus.

Zitzmann and Scharer (1998) (111), compared three of the described methods for sinus elevation: *(1)* a two-step lateral antrostomy procedure, *(2)* a one-step lateral antrostomy procedure, and *(3)* the osteotome technique with a crestal approach. A total of 79 implants were placed. When residual bone height was less than or equal to 4 mm, the two-step procedure was performed; residual bone heights of 4 to 6 mm were treated with a one-step lateral antrostomy; and residual bone heights greater than 6 mm were treated with the osteotome technique. The success rate for the osteotome technique was 95% over the 30 months study period; no failures occurred in any site treated by lateral antrostomy. The authors concluded that the osteotome technique is recommended when more than 6 mm of residual bone is present.

Zitzmann and Scharer (1998) (111), also investigated the resulting bone height after sinus augmentation. The gain in bone height was comparable for the one-step (median = 10 mm) and two-step (median = 12.7 mm) lateral approaches. These sites exhibited a significantly greater increase in bone height ($p < .001$) than the sites treated by osteotome (mean = 3.5 mm).

It is beneficial to use autogeneous bone for sinus grafting when placing simultaneous implants. But since our goal in simultaneous implant placement is to achieve fast healing and bone formation, other options are available that would produce the same if not even better results than autogeneous bone alone. The use of PRP and BMP has been shown to greatly increase the speed of bone formation and healing. Such options can reduce the stress the patient is subjected to, and the discomfort that can be encountered from harvesting autogeneous bone from secondary sites.

The future might still hold more surprises that will make sinus augmentation surgery less stressful and will probably reach higher success rates than the relatively high ones present today, especially with the hope of the stem cell research that is still in the process of being born in the near future.

5-REFERENCES

1. Akca K, Cehreli MC, Iplikcioglu H. A comparison of three-dimensional finite element stress analysis with in vitro strain gauge measurements on dental implants. International Journal of Prosthodontics (15)115-121;2002

2. Aparicio C, Perales P, Rangert B. Tilted implants as an alternative to maxillary sinus grafting: A clinical, radiologic, and Perio-test study. Clinical Implant Dentistry and Related Research (3) 39-49;2001

3. Artzi Z, Parson A, Nemcovsky CE. Wide-diameter implant placement and internal sinus membrane elevation in the immediate postextraction phase: Clinical and radiographic observations in 12 consecutive molar sites. International Journal of Oral Maxillofacial Implants (18) 242-249; 2003

4. Arun K. Garg. Augmentation Grafting of the Maxillary Sinus for Placement of Dental Implants: Anatomy, Physiology, and Procedures. Implant Dentistry (8) 36-46;1999

5. Balshi TJ, Wolfinger GJ. Management of the posterior maxilla in the compromised patient: Historical, current, and future perspectives. Periodontology 2000. (33) 67-81;2003

6. Bell WH. Le Fort I osteotomy for correction of maxillary deformities. Journal of Oral Surgery (33)412-426;1975

7. Bell WH. Ridge augmentation as an aid in jaw surgery. In: Bell WH, Proffit WR, White RP. Surgical Correction of Dento-facial Deformities. Philadelphia: Saunders, 1425-1433;1980

8. Block MS, Kent JN. Sinus augmentation for dental implants: the use of autogeneous bone. Journal of Oral and Maxillofacial Surgery (55) 1281-1286;1997

9. Blomqvist JE, Alberius P, Isaksson S. Retrospective analysis of one-stage maxillary sinus augmentation with endosseous implants. International Journal of Oral Maxillofacial Implants (11)512-521;1996

10. Blomqvist JE, Alberius P, Isaksson S. Sinus inlay bone augmentation: Comparison of implant positioning after one- or two-staged procedures. Journal of Oral and Maxillofacial Surgery (55)804-810;1997

11. Blomqvist JE, Alberius P, Isaksson S. Two-stage maxillary sinus reconstruction with endosseous implants: A prospective study. International Journal of Oral and Maxillofacial Implants (13)758-766;1998

12. Boyes-Varley JG, Howes DG, Lownie JF, Blackbeard GA. Surgical modifications to the Branemark zygomaticus protocol in the treatment of severely resorbed maxilla: A clinical report. International Journal of Oral and Maxillofacial Implants (18) 232-237;2003

13. Boyes-Varley JG, Lownie JF, Howes DG. The zygomaticus implant protocol in the treatment of the severely resorbed maxilla. Journal of the South African Dental Association 58(3):106-114; 2003

14. Boyne PJ, James R. Grafting of the maxillary sinus floor with autogenous marrow and bone. Journal of Oral Surgery (38)613-618;1980

15. Boyne P, Marx RE, Nevins M, et al. A feasability study evaluating rhBMP-2/absorbable collagen sponge for maxillary sinus augmentation. International Journal of Periodontics and Restorative Dentistry (17)11-25;1997

16. Boyne PJ. The history of maxillary sinus grafting. In: Jensen OT (ed). The Sinus Bone graft. Chicago:Quintessence, (1) 3-10 1999

17. Branemark P, Svensson B, van Steenberghe D. Ten-year survival rates of fixed prostheses on four or six implants ad modum Branemark in full edentulism. Clinical Oral Implants Research (6) 227-231;1995

18. Bruschi GB, Scipioni A, Calesini G, Bruschi E. Localized management of sinus floor with simultaneous implant placement: A clinical report. International Journal of Oral and Maxillofacial Implants (13) 219-226;1998

19. Buser D, Dula K, Lang NP, Nyman S. Long-term stability of osseointegrated implants in bone regenerated with the membrane technique. Five-year results of a prospective study with 12 implants. Clinical Oral Implants Research (7) 175-183;1996

20. Calandriello R, Tomatis M. Simplified treatment of the atrophic posterior maxilla via immediate/early function and tilted implants: A prospective 1-year clinical study. Clinical Implant Dentistry and Related Research (7) (supplement 1):S1-S12; 2005

21. Chiapasco M. Reconstructive techniques with and without an osteotomy. In Chiapasco M, Romeo E. (eds). Prosthetic Implant Rehabilitation of complex cases. UTET Torino 225-303;2003

22. Choi J, Park HS. The clinical anatomy of the maxillary artery in the pterygopalatine fossa. Journal of Oral Maxillofacial Surgery (61)72-78;2003

23. Corrente G, Abundo R, Cardaropoli D, Cardaropoli G, Martus-celli G. Long-term evaluation of osseointegrated implants in regenerated and nonregenerated bone. International Journal of Periodontics and Restorative Dentistry (20)391-397;2000

24. Davarpanah M, Martinez H, Tecucianu J, Hage G, Lazzara R. The modified osteotome technique. International Journal of Periodontics and Restorative Dentistry (21)599-607;2001

25. Doud Galli SK, Lebowitz RA, Giacchi RJ, Glickman R, Jacobs JB. Chronic sinusitis complicating sinus lift surgery. American Journal of Rhinology (15)181-186;2001

26. Duyck J, Van Oosterwyck H, Vander Sloten J, De Cooman M, Puers R, Naert I. Magnitude and distribution of occlusal forces on oral implants supporting fixed prostheses: An in vivo study. Clinical Oral Implants Research (11)465-475;2000

27. Fiorellini JP, Nevins ML. Localized ridge augmentation/preservation. A systematic review. Annual Periodontology (8) 321-327;2003

28. Friberg B, Jemt T, Lekholm U. Early failures in 4,641 consecutively placed Branemark dental implants: A study from stage 1 surgery to the connection of completed prostheses. International Journal of Oral and Maxillofacial Implants (6) 142-146;1991

29. Fugazzotto PA. Immediate implant placement following a modified trephine/osteotome approach: Success rates of 116 implants to 4 years in function. International Journal of Oral and Maxillofacial Implants (17)117-120;2002

30. Goodacre JC, Bernal G, Riringcharassaeng K, Kan JY. Clinical complications with implants and implant prosthesis. Journal of Prosthetic Dentistry (2) 121-132;2003

31. Hallman M, Nordin T. Sinus floor elevation with bovine hydroxyapatite mixed with fibrin glue and later placement of nonsubmerged implants: A retrospective study in 50 patients. International Journal of Oral and Maxillofacial Implants (19) 222-227;2004

32. Hallmann M, Hedin M, Sennerby L, Lundgren S. A prospective 1-year clinical and radiographic study of implants placed after maxillary sinus floor augmentation with bovine hydroxyapatite and autogenous bone. Journal of Oral and Maxillofacial Surgery (60)277-284;2002

33. Hallmann M, Sennerby L, Lundergen S. A clinical and histologic evaluation of implant integration in the posterior maxilla after sinus floor augmentation with autogeneous bone, bovine hydroxyapatite, or a 20:80 mixture. International Journal of Oral and Maxillofacial Implants (17) 635-643;2002

34. Hammerle CH. Jung RE. Bone augmentation by means of barrier membranes. Periodontology 2000 (33) 36-53;2003

35. Han JK, Smith TL, Loehrl TA, Fong KJ, Hwang PH. Surgical revision of the post-Caldwell-Luc maxillary sinus. American Journal Rhinology. 19(5):478-82;2005

36. Hatano N, Shimizu Y, Ooya K. A clinical long-term radiographic evaluation of graft height changes after maxillary sinus floor augmentation with a 2:1 autogenous bone/xenograft mixture and simultaneous placement of dental implants. Clinical Oral Implants Research (15) 339-345;2004

37. Isaksson S, Ekfeldt A, Alberius P, Blomqvist JE. Early results from reconstruction of severely atrophic (class VI) maxillas by immediate endosseous implants in conjunction with bone grafting and Le Fort I osteotomy. International Journal of Oral and Maxillofacial Surgery (22) 144-148;1993

38. Iturriaga MT, Ruiz CC Maxillary sinus reconstruction with calvarium bone grafts and endosseous implants. Journal of Oral and Maxillofacial Surgery (62) 344-347;2004

39. Ivanoff CJ, Widmark G, Johansson C, Wennerberg A. Histologic evaluation of bone response to oxidized and turned titanium micro-implants in human jawbone. International Journal of Oral and Maxillofacial Implants (18) 341-348;2003

40. Jaffin RA, Berman CL. The excessive loss of Branemark fixture in type IV bone: A 5-year analysis. Journal of Periodontology (62) 2-4;1991

41. Jensen J, Krantz-Simonsen E, Sindet-Pedersen S. Reconstruction of the severely resorbed maxilla with bone grafting and osseointegrated implants: A preliminary report. Journal of Oral and Maxillofacial Surgery (48) 27-32;1990

42. Jensen J, Sindet-Pedersen S. Autogenous mandibular bone grafts and osseointegrated implants for reconstruction of the severely atrophied maxilla: A preliminary report. Journal of Oral and Maxillofacial Surgery (49) 1277-1287;1991

43. Jensen J, Sindet-Pedersen S, Oliver AJ. Varying treatment strategies for reconstruction of maxillary atrophy with implants:Results in 98 patients. Journal of Oral and Maxillofacial Surgery (52) 210-216;1994

44. Jensen OT, Shulman LB, Block MS, lacono VJ. Report of the Sinus Consensus Conference of 1996. International Journal of Oral and Maxillofacial Implants (13) 11-45;1998

45. Kahnberg KE, Ekestubbe A, Grondahl K, et al. Sinus lifting procedure. I. One-stage surgery with bone transplant and implants. Clinical Oral Implants Research (12) 479-487;2001

46. Kan JY, Rungcharassaeng K, Kim J, Lozada JL, Goodacre CJ. Factors affecting the survival of implants placed in grafted maxillary sinuses: A clinical report. Journal of Prosthodontic Dentistry (87) 485-489;2002

47. Kaneshiro S, Nakajima T, Yoshikawa Y, Iwasaki H, Tokiwa N. The postoperative maxillary cyst: A report of 71 cases. Journal of Oral Surgery (39) 191-198;1981

48. Kassolis JD, Rosen PS, Reynolds MA. Alveolar ridge and sinus augmentation utilizing platelet-rich plasma in combination with freeze-dried bone allograft: Case series. Journal of Periodontology (84-A) 2123-2134;2000

49. Komarnyckyi OG, London RM. Osteotome single-stage dental implant placement with and without sinus elevation: A clinical report. International Journal of Oral and Maxillofacial Implants (13) 799-804;1998

50. Krekmanov L, Kahn M, Rangert B, Lindstrom H. Tilting of posterior mandibular and maxillary implants of improved prosthesis support. International Journal of Oral and Maxillofacial Implants (15) 405-414;2000

51. Krekmanov L. A modified method of simultaneous bone grafting and placement of endosseous implants in the severely atrophic maxilla. International Journal of Oral and Maxillofacial Implants (10) 682-688;1995

52. Laurell L, Falk H, Fornell J, Johard G, Gottlow J. Clinical use of a bioresorbable matrix barrier in guided tissue regeneration therapy. Case series. Journal of Periodontology (65) 967-975;1994

53. Lazzara RJ. The sinus elevation procedure in endosseous implant therapy. Current Opinions in Periodontology (3) 178-183;1996

54. Loannidou E, Dean J. Osteotome sinus floor elevation and simultaneous, non-submerged implant placement: Case report and literature review. Journal of Periodontology (71) 1613-1619;2000

55. Lorenzetti M, Mozzati M, Campanino PP, Valente G. Bone augmentation of the inferior floor of the maxillary sinus with autogeneous bone or composite bone grafts: A histologic-histomorphometric preliminary report. International Journal of Oral and Maxillofacial Implants (13) 69-76;1998

56. Malevez C, Abarca M, Durdu F, Daelemans P. Clinical outcome of 103 consecutive zygomatic implants: A 6-48 months follow-up study. Clinical Oral Implants Research (15) 18-22;2004

57. Malevez C, Daelemans P, Adriaenssens P, Durdu F. Use of zygomatic implants to deal with resorbed posterior maxillae. Journal of Periodontology, (33) 82-89;2000

58. Malo P, Rangert B, Nobre M. "All-on-4" immediate-function concept with Branemark System implants for completely edentulous maxillae: A 1-year retrospective clinical study. Clinical Implant Dentistry and Related Research (7) (supplement 1):S88-S94;2005

59. Marks SC. Nasal and Sinus Surgery. Philadelphia: Saunders 65-81;2000

60. Maskoud, Mohamed A. Complications after maxillary sinus augmentation. Journal of Implant Dentistry 10(3):168-71;2001

61. McCarthy PF, Patel RR, Wragg PF, Brook IM. Sinus augmentation bone grafts for the provision of dental implants: Report of clinical outcome. International Journal of Oral and Maxillofacial Implants (18) 377-382;2003

62. Meijer HJA, Kuipner JH, Starmans FJM, Bosman F. Stress distribution around dental implants: Influence of superstructure, length of implants and height of mandible. Journal of Prosthetic Dentistry (68) 96-102;1992

63. Merkx MAW, Maltha JC, Stoelinga PJw. Assessment of the value of anorganic bovine bone additives in sinus floor augmentation: A review of clinical reports. International Journal of Oral and Maxillofacial Surgery (32) 1-6;2003

64. Misch CE. Bone Character: Second vital implant criterion. Dentistry Today (7) 39-40;1998

65. Misch CE. Contemporary Implant Dentistry, ed 2. St Louis: Mosby, 469-495;1999

66. Misch CE. Maxillary sinus augmentation for endosteal implants. Organized alternative treatment plans. International Journal of Oral Implantology (4) 49-58;1987

67. Misch CE. Treatment planing for edentulous maxillary posterior region. Misch CE. Contemporary Implant Dentistry. St Louis: Mosby, 241-255;1993

68. Morgensen C, Tos M. Quantitative histology of the maxillary sinus. Journal of Rhinology (15) 129;1977

69. Moy PK, Bain CA. Relation between fixture length and implant failure. Journal of Dental Research (71) 637;1992

70. Moy PK, Lundgren S, Holmes RE. Maxillary sinus augmentation: Histomorphometric analysis of graft materials for sinus floor augmentation. Journal of Oral and Maxillofacial Surgery (51) 857-862;1993

71. Nevins M, Mellonig JT, Clem DS, Reiser GM, Buser DA. Implants in regenerated bone: Long-term survival. International Journal of Periodontics and Restorative Dentistry (18) 35-45;1998

72. Olson JW, Dent CD, Morris HF, Ochi S. Long-term assessment (5 to 71 months) of endosseous dental implants placed in the augmented maxillary sinus. Annual Periodontology (5) 152-156;2000

73. Peleg M, Chaushu G, Mazor Z, et al. Radiological findings of the post-sinusitis lift maxillary sinus: A computerized tomography follow-up. Journal of Periodontology (70) 1564-1573;1999

74. Philippart P, Brasseur M, Hoyaux D, Pochet R. Human recombinant tissue factor, platelet-rich plasma, and tetracycline induce a high-quality human bone graft: A 5-year survey. International Journal of Oral and Maxillofacial Implants (18) 411-416;2003

75. Pierrisnard L, Renouard F, Renault P, Barquins M. Influence of implant length and bicortical anchorage on implants stress distribution. Clinical Implant Dentistry and Related Research (5) 254-262;2003

76. Pietrzak WS, Verstynen ML, Sarver DR. Bioabsorbable fixation devices, status for the craniomaxillofacial surgeon. Journal of Craniofacial Surgery (8) 92-96;1997

77. Pikos MA. Maxillary sinus membrane repair: Report of a technique for large perforations. Implant Dentistry (8) 29-33;1999

78. Raghoebar GM, Timmenga NM, Reintsema H, Stegenga B, Vissink A. Maxillary bone grafting for insertion of endosseous implants: Results after 12-124 months. Clinical Oral Implants Research (12) 279-286;2001

79. Rangert B, Sullivan R, Jemt T Load factor control for implants in the posterior partially edentulous segment. International Journal of Oral and Maxillofacial Implants (12) 360-370;1997

80. Regev E, Smith RA, Perrot DH, Pogrel MA. Maxillary sinus complications related to endosseous implants. International Journal of Oral and Maxillofacial Implants (10) 451-461;1995

81. Renouard F, Nisand D. Short implants in the severely resorbed maxilla: A 2-year retrospective clinical study. Clinical Implant Dentistry and Related Research (7) (suppl 1):S104-S110;2005

82. Rodriguez A, Anastassov GE, Lee H, Buchbinder D, Wettan H. Maxillary sinus augmentation with deproteinated bovine bone and platelet rich plasma with simultaneous insertion of endosseous implants. Journal of Oral and Maxillofacial Surgery (61) 157-163;2003

83. Rosen PS, Summers R, Mellado JR, et al. The bone-added osteotome sinus floor elevation technique: Multi-center retrospective report of consecutively treated patients. International Journal of Oral and Maxillofacial Implants (14) 853-858;1999

84. Schwartz-Arad D, Herzberg R, Dolev E. The prevalence of surgical complications of the sinus graft procedure and their impact on implant survival. Journal of Periodontology (75) 511-516;2004

85. Scott I, Ash MM Jr. A six-channel intra-oral transmitter for measuring occlusal forces. Journal of Prosthetic Dentistry 1966;16:56. (Final report of 1967- available online)

86. Sennerby L, Roos J. Surgical determinants of clinical success of osseointegrated oral implants. A review of literature. International Journal of Prosthodontics (11) 408-420;1998

87. Small SA, Zinner ID, Panno FV, Shapiro HJ, Stein Jl. Augmenting the maxillary sinus for implants: Report of 127 patients. International Journal of Oral and Maxillofacial Implants (8) 523-528;1993

88. Smith RA, Berger R, Dodson TB. Risk factors associated with dental implants in healthy and medically compromised patients. International Journal of Oral and Maxillofacial Implants (7) 367-372;1992

89. Standring S, Gray's Anatomy, 39th edition. Mosby, 2005.

90. Stella JP, Warner MR. Sinus slot technique for simplification and improved orientation of zygomaticus dental implants: A technical note. International Journal of Oral and Maxillofacial Implants (15) 889-893;2000

91. Stellingsmaa C, Meijer HJA, Raghoebar GM. Use of short endosseous implants and an overdenture in the extremely resorbed mandible. A five-year retrospective study. Journal of Oral and Maxillofacial Surgery (58) 382-387;2000

92. Summers RB. A new concept in maxillary implant surgery: The osteotome technique. Compendium on Continuing Education in Dentistry (15) 152-160;1994

93. Summers RB. Conservative osteotomy technique with simultaneous implant insertion. Dental Implantology Update (7) 4-53;1996

94. Summers RB. The osteotome technique: Part 2. The ridge expansion osteotomy (REO) procedure. Compendium on Continuing Education in Dentistry (15) 422-436;1994

95. Summers RB. The osteotome technique: Part 3. Less invasive methods of elevating the sinus floor. Compendium on Continuing Education in Dentistry (15) 698-708;1994

96. Tatum H Jr. Maxillary and sinus implant reconstructions. Dental Clinics of North America (30) 207-229;1986

97. Tawil G, Younan R. Clinical evaluation of short, machined-surface implants followed for 12 to 92 months. International Journal of Oral and Maxillofacial Implants (18) 894-901;2003

98. Ten Bruggenkate CM, Asikainen P, Foitzik C, Krekeler G, Sutter F. Short (6-mm) nonsubmerged dental implants. Results of a multi-center clinical trial of 1 to 7 years. International Journal of Oral and Maxillofacial Implants (13) 791-798;1998

99. Timmenga NM, Raghoebar GM, Boering G, van Weissenbruch R. Maxillary sinus function after sinus lifts for the insertion of dental implants. Journal of Oral and Maxillofacial Surgery (55) 936-939;1997

100. Toffler M. Osteotome mediated sinus floor elevation: A clinical report. International Journal of Oral and Maxillofacial Implants (19) 266-273;2004

101. Tolman DE. Reconstructive procedures with endosseous implants in grafted bone: A review of the literature. International Journal of Oral and Maxillofacial Implants (10) 275-294;1995

102. Tong D, Rioux K, Drangsholt M, Beirne O. A review of survival rates for implants placed in grafted maxillary sinuses using meta-analysis. International Journal of Oral and Maxillofacial Implants (13) 175-182;1998

103. Van den Berg JP, Ten Bruggenkate CM, Disch FJ, Tuinzing DB. Anatomical aspects of sinus floor elevations. Clinical Oral Implants Research (11) 256-265;2000

104. Van den Berg JP, Ten Bruggenkate CM, Krekeler G, Tuinzing DD. Maxillary sinus floor elevation and grafting with human demineralized freeze dried bone. Clinical Oral Implants Research (11) 487-493;2000

105. Van Steenberghe D, Lekholm U, Bolender C, et al. Applicability of osseointegrated oral implants in the rehabilitation of partial edentulism. A prospective multicenter study on 558 fixtures. International Journal of Oral and Maxillofacial Implants (5) 272-281;1990

106. Van Steenberghe D, Quirynen M, Molly L, Jacobs R. Impact of systemic diseases and medication on osseointegration. Periodontal 2000. (33) 163-171;2003

107. Wallace SS, Forum SJ, Cho SC, et al. Sinus augmentation utilizing anorganic bovine bone (Bio-Oss) with absorbable and non-absorbable membranes placed over the lateral window: a histomorphometric and clinical analysis. International Journal of Periodontics and Restorative Dentistry (25) 551-559;2005

108. Wannfors K, Johansson B, Hallman M, Strandkvist T A prospective randomized study of 1-and 2-stage sinus inlay bone grafts: 1-year follow-up. International Journal of Oral and Maxillofacial Implants (15) 625-632;2000

109. Watzek G, Ulm CW, Haas R. Anatomic and physiologic fundemtals of sinus floor augmentation. In: Jensen OT (ed). The Sinus Bone graft. Chicago:Quintessence, 31-47;1999

110. Wheeler SL. Sinus augmentation for dental implants: The use of alloplastic materials. Journal of Oral and Maxillofacial Surgery (55) 1287-1293;1997

111. Zitzmann N, Scharer P. Sinus elevation procedures in the resorbed posterior maxilla: Comparison of the crestal and lateral approaches. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics (85) 8-17;1998

112. Zitzmann NU, Scharer P, Marinello CP Long-term results of implants treated with guided bone regeneration: A 5-year prospective study. International Journal of Oral and Maxillofacial Implants (16) 355-366;2001

6- CURRICULUM VITAE

I was born in Jerusalem-Palestine on the 22nd of June 1979. I graduated from De La Salle High school in Jerusalem in 1996. From the University of Western Ontario-Canada I graduated in 2000 with a BSc. in Biology. I aquired my Doctor of Dental Surgery degree from the Arab American University-Palestine in 2005. Currently I am a Masters student in the Department of Oral Implantology at Yeditepe University-Turkey.