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Clinical Anatomy of the Maxillary Sinus: Application to Sinus Floor Augmentation

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Abstract:
Background*: Endosseous implant insertion in the atrophic maxilla often proves complicated due to unavailability or lack of adequate bone support. Elevation of the maxillary sinus floor with bone substitutes has been proven to be a reliable treatment modality. This article aims toexplore the maxillary sinus anatomy and review the present literature so as to help clinicians to diagnose in a more elaborate form and enabling them to perform safer surgeries for maxillary sinus elevation.*
Key Word*:Maxillary Sinus, Posterior Maxilla, Sinus floor augmentation*

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I. Introduction

Dental caries and periodontal diseases are the main causes of tooth loss, resulting in resorption of the alveolar process and consequently reduction in the amount of bone available for rehabilitation. [1] The width of the posterior maxilla decreases at a more rapid rate than any other regions of jaws.[2] Implant restoration is often complicated by 1. Decreased bone density (types III and IV bone) (Jaffin and Berman, 1991) 2. Increased occlusal forces (Zimmer and Small, 1999) 3.Inadequate bone height (Smiler and colleagues, 1992) a. Pneumatization of the sinus b. Bone resorption toward the palate 4.Decreased interarch space (Tatum, 1986, 1989) 5. Tooth loss (Watzel and colleagues, 1998) 6. Prosthetic cantilevering of the buccal cusps (Rangert and colleagues, 1997, 1998).[3]The above-mentioned differences, in conjunction with the unique and varied anatomy of the maxilla with the maxillary sinus, poses a challenge to the surgeon in fabricating adequate bone height and sufficient width for implant placement.[4]

II. Anatomy of Maxillary Sinus

Leonardo Da Vinci in 1489, illustrated and described the maxillary sinus for the first time which was later documented by Nathaniel Highmore (an English anatomist) in 1651 hence also called Antrum of Highmore. The maxilla is situated within the body of the maxillary bone and is largest in dimension and first to develop paranasal sinuses. The average adult sinus is 2.5 to 3.5 cm wide, 3.6 to 4.5 cm tall, as well as 3.8 to 4.5 cm deep in dimension. Its volume is estimated to be approximately 12 to 15 cm^3. The bony cavity of the maxillary sinus is lined by a membrane, also known as the Schneiderian membrane.[2] This membrane consists of Pseudostratified Columnar Ciliated Epithelium which resembles the ciliated epithelium of the respiratory tract. It is in continuation and connects to, the nasal epithelium in the middle meatus through the ostium. The thickness of the membrane is approximately 0.8 mm. The possible theorized function of the sinus includes weight reduction of the skull, phonetic resonance,warming and humidification of inspired air, and olfaction-Ritter & lee 1978; Balton& Biggs 1969. [4,5]

III. Diagnostic Imaging

Diagnostic imaging is a crucial component in oral rehabilitation treatment planning by utilizing osseointegrated implants. The maxillary sinus borders appear as a thin, delicate, tenuous radiopaque line on the periapical radiograph. In adults the sinus is usually seen to extend from the distal aspect of the canine to the posterior wall of the maxilla above the tuberosity.[5] At present, the most common and initial dental radiographic examinations are periapical and panoramic radiography in implant dentistry. In 2011, the (European Academy

of Osseointegration) held a consensus workshop on radiological guidelines in implant dentistry. Previous EAO guidelines from 2002 were updated and expanded to include cone-beam computed tomography (CBCT). CBCT can offer cross-sectional imaging and 3D reconstructions at potentially lower radiation doses compared to medical multi-slice CT. While utilizing panoramic radiographic views of the posterior maxilla there lies a risk of underestimating bone availability for implant placement. CBCT aids in providing measurements of the available bone volume more accurately. CBCT can also assist the dental professionals by providing information on arterial channels present in the lateral sinus wall, the presence of septa, and pathology of the maxillary sinus.[6,7]

IV. Treatment Approach for Maxillary Sinus Elevation

In 1987, Misch created a classification for the treatment of edentulous posterior maxilla based on the amount of bone available below the antrum and ridge width. [2] Treatment categories ranged from sub-antral augmentation category 1 (SA1 to SA 4) based on bone height A (>5 mm) and B (2.5-5 mm) based on ridge width[2].

SA-1 (Sub-antral Option 1: Conventional Implant Placement)

It has sufficient vertical bone availability for implants, that is, 12 mm. No manipulation of the sinus is required. Endosseous implants are placed using a conventional protocol. In Division B:i.e Narrow bone Volume, In the first placeOsteoplasty can be done and if bone width is less than 2.5 mm then increase the bone width by onlayautogenous grafts then re-evaluate for a proper treatment plan.

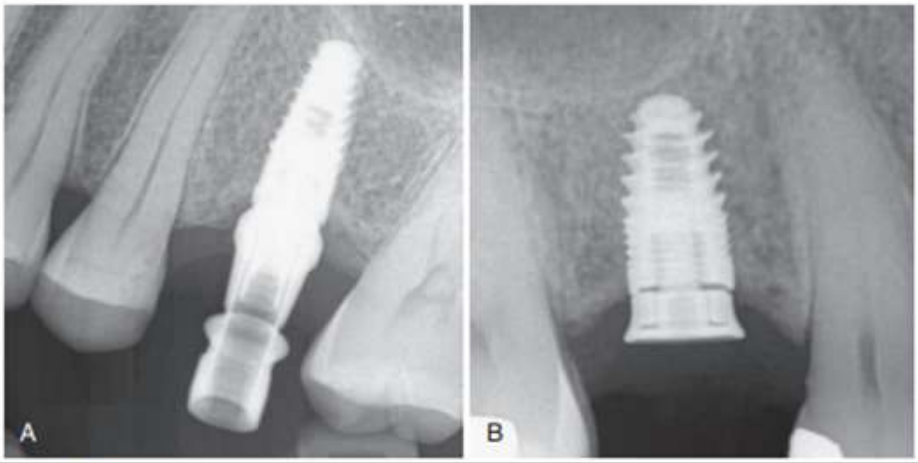

Figure 1: SA-1 (A and B) Treatment plan includes implant placement below the maxillary sinus

SA-2 (Sub-antral Option 2: Sinus Lift and Simultaneous Implant Placement):

It has10-12 mm less than the ideal height of bone and may require surgical correction. Sinus iselevated 1-2 mm by osteotomy technique.
The steps are as follows:

- Endosteal Implant osteotomy is prepared.
- Depth of osteotomy is prepared 1-2mm short of the floor of the antrum.
- Osteotome –Used for bone spreading and is now inserted until final position up to 2mm is prepared beyond osteotomy.
- Greenstick fracture is formed in sinus floor
- Sinus membrane is elevated with the simultaneous placement of the bone graft.

Figure 2: SA-2. (A) Radiograph depicting an SA-2 (maxillary second premolar) and SA-1 (maxillary first molar). (B) SA-2 implant that includes implant insertion with penetration into the maxillary sinus proper 1 to 2 mm without bone grafting.

SA-3 (Sub-antral Option 3): Sinus Graft with Immediate Endosteal Implant Placement:

It has only 5-10 mm of bone below the sinus. Criteria for immediate and delayed implant placement are:

IMMEDIATE IMPLANT PLACEMENT	DELAYED IMPLANT PLACEMENT
Greater than 5mm of bone Height	Less than 6 mm of bone width
Greater than 6 mm of bone width	D4 bone quality
D3 Bone quality or better	Treated sinus pathological condition within last few months
No sinus pathology	Medium to large sinus membrane perforation.
No relative contraindication	
No or small sinus membrane perforation during the surgery.	

Figure 3: SA-3: Implant insertion with bone grafting via the lateral-wall approach gaining more than 4 mm of height (i.e., amount of height is determined by size of lateral wall)

(SA-4) Sub-antral Option 4: Sinus Graft Healing and Extended Delay of Implant Insertion

Indicated when there is less than 5mm bone present between the residual crest of bone and floor of the sinus.
At first sinus elevation is done with the lateral window preparation followed by bone augmentation.Then evaluate the bone after 4 to 6 months and the treatment approach is planned accordingly.

Figure 4: SA-4: Treatment plan that includes bone grafting via the lateral-wall approach with no implant placement. Implant placement is delayed according to the healing of the sinus graft sites.

V. Biomaterials in sinus augmentation procedures

Bone augmentation in maxillary sinus elevation procedures has been intensely studied by a number of researchers (Boyne and colleagues, 1980; Smiler and colleagues, 1994; Lundgren and colleagues, 1996; Chanavaz, 1996). A review of their work reveals that the walls of the sinus act similarly to that of an extraction socket or infrabony defect. That is, the extraction socket not only houses the implant but also provides the primordial endosteal, endothelial, and mesenchymal cells necessary for bony regeneration (Vlassis and colleagues, 1993). This is provided that adequate space has been created between the sinus floor and the Schneiderian membrane: "when little or no grafting material is used bone still forms as long as space is maintained beneath an intact sinus lining to form a closed wound environment" (Nevins and colleagues, 1996).[2,3]

The biomaterials available for sinus augmentation are (autografts, allografts, xenografts, alloplast, and synthetic bone grafts) out of which that autogenous bone grafts are considered to be the gold standard.[2]Autograft comprises of transplantation of functioning organs, tissues, or maybe particular proteins from one part of the body to a different within the same person. In sinus augmentation procedures sites for harvesting autogenous grafts can be ramus, chin, or iliac crest. Allograft (or homograft) is also called an allogeneic transplant which is defined as the transplantation of cells, tissues, or organs to a recipient from a genetically non-identical donor of the same species. Isografts are grafts of tissue between two individuals who are genetically identical (i.e., monozygotic twins). Demineralized freeze-dried bone and acellular dermis are examples utilized in implant dentistry. Xenograft (or heterograft) may be a tissue graft or transplant from a donor of a different species from the recipient. Examples of DFDB are bovine or porcine sourced materials (cancellous bone or collagen membranes). Whereas,Alloplast is an inorganic material used as a bone substitute or an implant. Hydroxyapatite (HA) and tricalcium phosphate (TCP) are examples of alloplast.[8]

There are three properties of the bone graftsi.eOsteoconduction is defined as the process when bone graft material serves as a scaffold for new bone formation. In this process, the Osteoblasts from the margin of defect that's being grafted, utilize the bone graft material as a framework upon formation of new bone occurs. Osteoinduction is a process that involves stimulation of osteoprogenitor cells to differentiate into osteoblasts and then initiating the formation of new bone eg. Bone Morphogenic Proteins. A bone graft material that has osteoconductive and osteoinductive properties serves as a scaffold for existing osteoblasts and also initiates the formation of new osteoblasts, promoting faster integration of the bone graft. Osteopromotion is the intensification of osteoinduction without possession of osteoinductiveproperties whereasOsteogenesis occurs when vital osteoblasts originating from bone graft material contribute to the growth of bone formation.

Factors to be considered in Bone Grafting are local factors that affect the prognosis of the surgical procedure. It includes the absence of infection, space maintenance, graft immobilization, host bone vascularization, defect size, and topography.[2,9]

Sinus Grafting Layered Approach:

Autogenous bone graft for years has been considered the gold standard of grafting material but it is interesting to note that sinus grafts in the literature that have used 100% autogenous bone have lower success rates than sinus grafts with synthetic substitutes (Del Fabbro and colleagues,2004)[10]In the top layer (superior) a collagen membrane with a Local antibiotic (Ancef) is placed whereas in the middle or intermediate layer a 70% mineralized freeze-dried bone allograft with 30% demineralized freeze-dried bone allograft is placed followed by Platelet-rich fibrin .Lastly, The bottom layer (inferior) an Autogenous bone graft is positioned[2]Ideally, the use of cortico-cancellous bonegraftis recommended becauseit allows the advantages of both cancellous and cortical bone utilization in grafting process. The ideal particle size of the allograft material is very important for predictable bone regeneration to should be approximately 250 to 1000 μm(MS block 2002)[2,11]

VI. Conclusion

The pneumatization of the maxillary sinus after the extraction of posterior teeth compromises the available bone due to resorption in apical-coronal and Bucco-palatal directions. Hence posterior maxilla due array of anatomical and physiological constraints has limitations in ideal implant placement. The evolution of sinus augmentation procedures has aided in diminishing problems related to proper placement of the implant in the posterior maxilla. The availability and diversity ofbone grafting materials (autogenous, allografts, xenografts, alloplasts, and synthetics) have also increased the predictability if the treatment outcome.However, an organized approach needs to be followed in relation to patient selection, pathology evaluation, surgical and prosthetic protocol with proper selection of the bone grafting material to increase success and decrease potential morbidity of the procedures.

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