A novel approach to the antral sinus bone graft technique: Precise outlining of the lateral wall using SimPlant Module CMF for prototype cutting guides. A case report.

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Abstract
The antral sinus bone graft has become one of the most predictable and utilized surgical procedures. It is used to augment bone in the posterior maxilla in order to accommodate implant placement. The location of the lateral wall during this technique has traditionally been an intuitive process, whereby the surgeon relies on mental navigation to achieve proper identification. The purpose of this paper is to introduce a prototype cutting guide that is developed through the use of CT imaging, computer software and the stereolithographic process to precisely position the lateral wall and facilitate Schneiderian membrane elevation. This prototype cutting guide marks the beginning of future applications for “guided bone grafting” and associated techniques that focus on enhanced precision and accuracy in bone regeneration surgery.

Introduction
The antral approach to sinus bone grafting has become one of the most popular techniques to vertically augment bone in the posterior maxilla for dental implant placement. The goal of this procedure is to supplement bone inferior to the maxillary sinus to enable clinicians to subsequently place dental implants. Research over the past 20 years has clearly demonstrated that the antral sinus lift technique is one of the most predictable regenerative surgical procedures performed today and that implant survival is highly successful. While sophisticated imaging techniques (such as CT scans) have become more common to aid the surgeon for pre-surgical diagnostic purposes, there is currently no modality to transfer clinically relevant information and pre-surgical planning to the patient at the time of bone graft surgery.

The purpose of this article is to introduce a prototype cutting guide that facilitates precise osteotomy cuts which accurately defines the lateral boundaries of the maxillary sinus. This technique uses three dimensional CT imaging and SimPlant Module CMF software to pre-surgically outline the lateral boundaries of the maxillary sinus for antral sinus bone grafting surgery. Medical models and bone supported cutting guides are then created guided and precise positioning of the lateral window.

Case Report
The patient is a 53 year old female who presented for a fixed tooth replacement strategy in the maxillary right
posterior sextant. Teeth’s had been missing for several years. Sinus pneumatization and disuse atrophy of the alveolar bone were observed in the maxillary right (Figures 1a-b). As apart of the pre-surgical work up, a first generation scanning appliance was fabricated over the provisional prosthesis #2-5 and the patient was referred for CT scan imaging of the maxilla which was formatted to a computer software program (SimPlant® Planner; Materialise Dental, Glen Burnie, MD, USA) for diagnostic and treatment planning purposes. Figures 2a-c highlight the cross sectional and 3D images (using SimPlant) demonstrating inadequate bone height at the #3 position. The SimPlant plan was then loaded in a different module of Materialise’s SimPlant software, SimPlant CMF (CraniomaxilloFacial; Materialise Dental, Glen Burnie, MD, USA). In this case, the maxillary right sinus was outlined in 3D (Figure 3a) to define its boundaries. The polyplane cutting path was then utilized to trace the desired lateral window and osteotomy cuts in 3D (Figures 3b & 3c). The cutting paths were verified in all planes of space to ensure that the planned osteotomy cuts would maximize the operator’s ability to begin schneiderian membrane reflection directly on the remaining antral bony walls. Next, this 3D SimPlant CMF plan was emailed to Materialise Dental where a medical model and two prototype bone supported cutting guides were created through the process of stereolithography (Figures 4a-b). These guides defined the desired (1) superior cutting path outlined via the SimPlant CMF software as well as the (2) inferior, mesial and distal boundaries of the previously outlined lateral window based on the pre-surgical plan. Following full thickness flap reflection and exposure of the lateral aspect of the maxilla, the bone supported cutting guides were fitted to the underlying bone and verified for stability. (Figure 5a) The guides were then used to outline the desired, pre-surgically planned, configuration of the lateral wall. The distal portion of the cutting guide that defined the posterior boundary was modified to accommodate its placement and stability during surgery. Infracture, uneventful schneiderian membrane elevation and sinus bone grafting were accomplished. The anterior and inferior boundaries were, in particular, well defined by the cutting guides as planned and outlined by the SimPlant CMF software (Figures 5a-c). This allowed for more predictable schneiderian membrane reflection as reflection was carried out precisely on bone after the boundaries of the lateral window had been accurately identified. Simultaneous implant placement ensued without complications. (Figure 5d)
Fig. 3a. 3D reconstruction of maxilla in CMF® software with transparency toggle engaged. A visual outline of the maxillary sinus is visualized (red arrows).

Fig. 3b. 3D reconstruction of the maxilla in Simplant® CMF software and polyplane cutting path outlining desired lateral window (red arrows).

Fig. 3c. Superior view of 3D reconstruction of the maxilla in SimPlant® CMF software and the same polyplane cutting path visualized in the right sextant.

Fig. 4a. Medical model with polyplane cutting path outlined in red (yellow arrows). Bone supported cutting guide defining the desired anterior, inferior and posterior lateral wall boundaries.

Fig. 4b. Bone supported cutting guide defining the superior osteotomy boundary.

Fig. 5a. Bone supported cutting guide defining the desired anterior, and inferior lateral wall boundaries in place. Guide was modified at the distal aspect to better accommodate guide placement and stability during surgery.
Discussion

The anatomical orientation of the maxillary sinus is often complex and can be misleading to the surgeon which can result in inaccurate identification of the lateral wall. Arguably, the most common complication of the sinus bone graft is membrane perforation. Perforation can often result from uncontrolled reflection of the membrane rather than from remaining in contact with the antral walls. Sinus membrane perforation can lead to a greater incidence of sinus bone graft complications and may lead to poorer bone healing even without overt clinical signs of post surgical bacterial infection. In general, schneiderian membrane tears of any magnitude have the potential to increase the risk for post surgical infection and a reduction in overall graft success. To some degree, tears can be traced back to operator inaccuracy in lateral window positioning as precise determination of its boundaries are, for the most part, entirely intuitive. The SimPlant CMF module offered by Materialise Dental was used to develop this prototype surgical guide to direct osteotomy cuts that would precisely position the lateral window based on 3D imaging and pre-surgical planning.

To date, guided CT technology does not allow for the surgeon to identify and transfer the patient’s often complex anatomical configurations into precise osteotomy cuts at the time of surgical intervention for more predictable lateral wall positioning. Trans-illumination is a common modality used to define the sinus boundaries but is not effective at guiding the surgeon to create a precise outline, particularly when important and often misleading anatomic configurations are present in the maxillary skeleton. The cutting guides created through Materialise Dental SimPlant module CMF software and the stereolithographic process fit extremely well to the anatomical environment and accurately identified the boundaries that were pre-surgically planned. Membrane reflection was predictably initiated directly off of the remaining inferior and anterior antral walls without sequelae. There were no “surprises” or undue tension applied to the membrane as a result of spatial reflection rather than that directly applied off bone.

The presented cutting guide is a prototype guide that will require future research, development, and clinical trials to scientifically validate its accuracy and precision before its use in mainstream antral sinus lift surgery can be supported. This prototype guide does, however, define the beginning to future applications and techniques of “guided bone grafting”. Such applications will broaden the concept of collaborative accountability to include bone reconstructive surgery as apart of total implant rehabilitative therapy. These applications will also minimize the extent to which “mental navigation” (i.e. intuitively driven surgery) determines outcome success. Future applications involving CT scan imaging, computer software and stereolithography to facilitate guided bone grafting may include guided bone graft harvesting and guided recipient bed preparation in an attempt to make reconstructive techniques more accurate, precise and predictable for enhanced patient outcome in dental implant therapy.

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