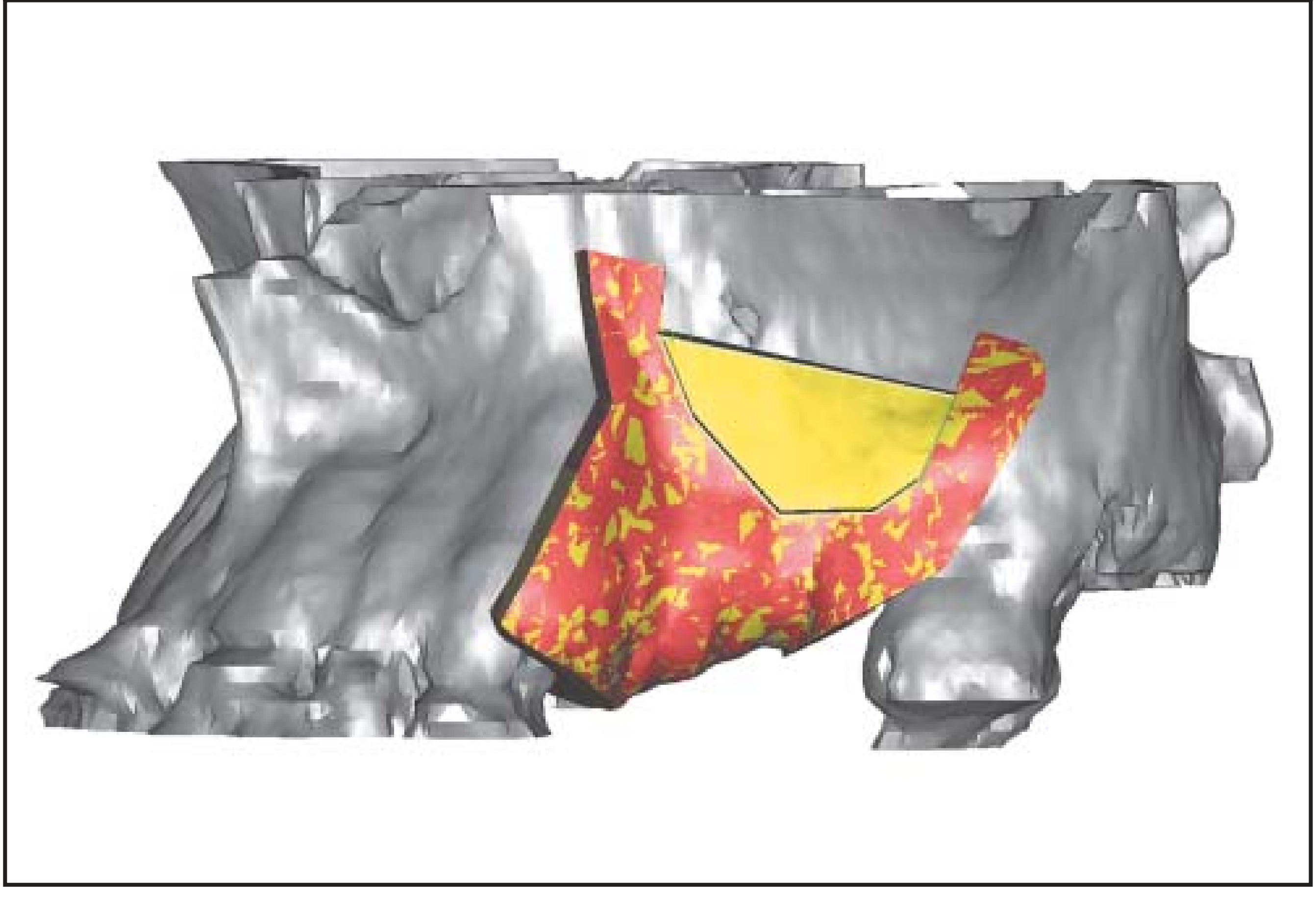

A Novel Approach to the Antral Sinus Bone Graft Technique: The Use of a Prototype Cutting Guide for Precise Outlining of the Lateral Wall. A Case Report

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The antral sinus bone graft has become one of the most predictable and commonly used surgical procedures to augment bone in the posterior maxilla and thereby accommodate implant placement. Positioning 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 article is to introduce a prototype cutting guide that is developed through the use of computerized tomographic 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 applications for "guided bone grafting" and associated techniques that focus on enhanced precision and accuracy in bone regeneration surgery. (Int J Periodontics Restorative Dent 2008;28:569–575.)

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The antral or so-called Caldwell-Luc 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 or when used simultaneously with implant placement. This technique was described in 1977 by Tatum[1] and in 1980 by Boyne and James.[2] The goal of this procedure is to supplement bone inferior to the maxillary sinus to enable clinicians to subsequently place dental implants. Since the mid-1990s, sinus research has been primarily focused on the material used for grafting and on the success of these materials as judged by implant survival.[3–5] It is clear that the antral sinus lift technique is one of the most predictable regenerative surgical procedures performed today and that implant placement can be successful with a multitude of grafting materials.[6–11]

While sophisticated imaging techniques (such as computerized tomographic [CT] scans) have become more common in presurgical diagnosis, there is currently no modality to transfer clinically relevant information and presurgical planning to the patient at

Fig 1 *Preoperative view of patient showing the missing maxillary left premolars and first molar.*

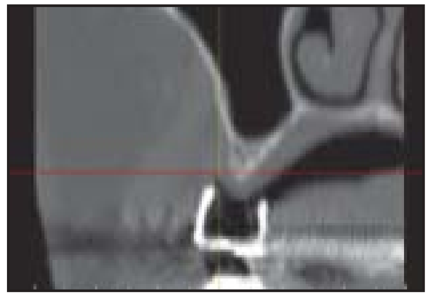

Fig 2a *Cross-sectional CT view of the first molar position using SimPlant software. This first-generation scanning appliance demonstrates the optimal final tooth position in space. Disuse atrophy and residual ridge resorption are apparent along with sinus pneumatization.*

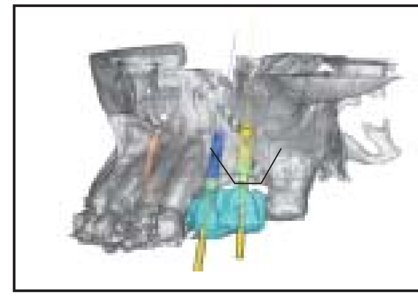

Fig 2b *SimPlant image in 3D of the maxillary arch with first-generation scanning appliance in place* (blue). *The transparency tool is engaged and optimal implant positioning has been planned at the positions of the second premolar and first molar. The black line outlines the anterior and inferior sinus boundaries.*

the time of bone graft surgery. In the case of the antral sinus lift procedure, inaccurate osteotomy cuts to define the lateral window can potentiate sinus membrane perforation, particularly when the membrane is thin and the anatomic environment is challenging. Some perforations may be small, repairable, and rather inconsequential, but others can prompt the need to discontinue the surgery.[12] Despite the abundance of research performed on the success of sinus bone grafting and long-term survival rates of osseointegrated implants in grafted sinuses, there has been no progress on the development of a method to facilitate the antral sinus lift technique. Such a method would ultimately make the technique more precise and time efficient and would enable more predictable clinical outcomes.

The purpose of this article is to introduce a prototype cutting guide that facilitates precise osteotomy cuts that accurately define the lateral boundaries of the maxillary sinus. This technique uses three-dimensional (3D) CT imaging and computer software to presurgically outline the lateral boundaries of the maxillary sinus for antral sinus bone grafting surgery. Medical models and bone-supported cutting guides are then created through the process of stereolithography for guided, precise positioning of the lateral window.

Case report

The patient (a 51-year-old man) presented for a fixed tooth-replacement strategy in the maxillary left posterior sextant. The maxillary left premolars and first molar had been missing for several years. Sinus pneumatization and disuse atrophy of the alveolar

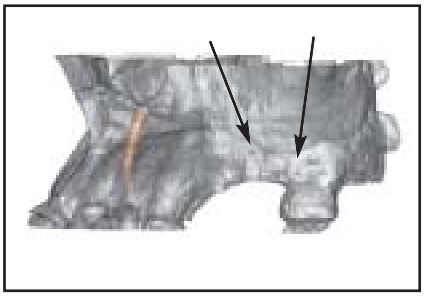

Fig 3a *3D reconstruction of maxilla in OMS software with transparency toggle engaged. An outline of the maxillary sinus is visualized* (arrows).

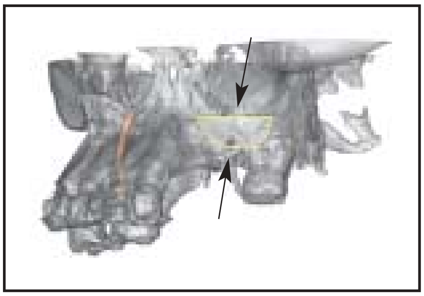

Fig 3b *3D reconstruction of the maxilla in Simplant OMS software and polyplane cutting path outlining the desired lateral window* (arrows).

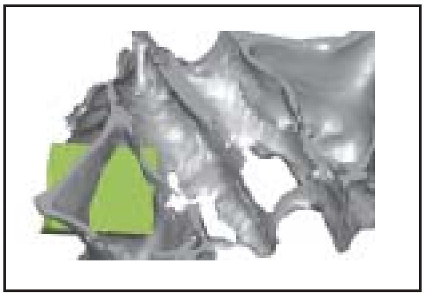

Fig 3c *Superior view of 3D reconstruction of the maxilla in SimPlant OMS software and the same polyplane cutting path visualized.*

bone were observed (Fig 1). As part of the interdisciplinary presurgical workup, maxillomandibular casts were mounted and a diagnostic waxup was performed to define the prosthetically directed, optimal final tooth position for the missing teeth. Because there was an arch size discrepancy in this patient, the treatment would use just two teeth to replace the missing dentition. A first-generation scanning appliance was fabricated, and the patient was referred for CT scan imaging of the maxilla, which was transferred into a computer software program (SimPlant Planner; Materialise Dental) for diagnostic and treatment planning purposes. Figure 2 highlights the presence of inadequate bone to accommodate implant placement.

The SimPlant plan was then loaded in a different module of Materialise's SimPlant software (SimPlant OMS [Oral and MaxilloFacial Surgery]). SimPlant OMS allows for virtual osteotomy cuts to be simulated in 3D for presurgical planning of craniomaxillofacial operations such as distraction surgery, Le Fort osteotomies, or sagittal split osteotomy techniques. In this case, the maxillary left sinus was outlined in 3D using the transparency tool, which demarcated the lateral sinus boundaries (Fig 3a). The polyplane cutting path in SimPlant OMS was then used to trace the desired lateral window and osteotomy cuts in 3D (Figs 3b and 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, the 3D SimPlant OMS plan was e-mailed to Materialise Dental, where a medical model and two prototype bone-supported cutting guides were created

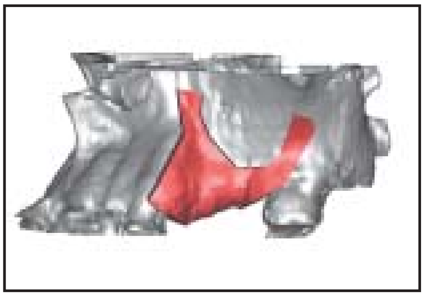

Fig 4a *3D reconstruction of maxilla and prototype cutting guide created to assist in anterior, inferior, and posterior lateral window osteotomies.*

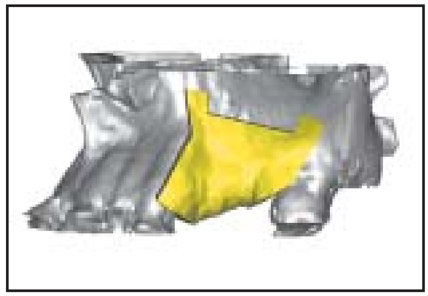

Fig 4b *3D reconstruction of maxilla and prototype cutting guide created to assist in superior lateral window osteotomy.*

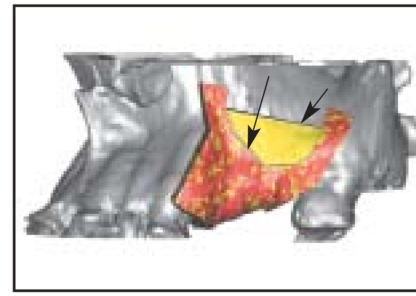

Fig 4c *3D reconstruction of maxilla and prototype cutting guides layered in place with the polyplane cutting path outlined* (arrows).

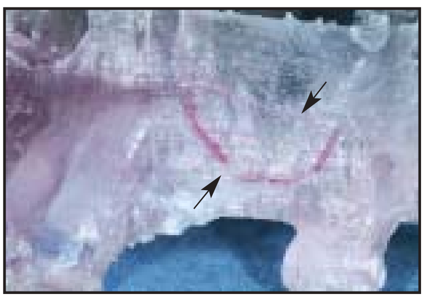

Fig 4d *Medical model with polyplane cutting path outlined in red* (arrows).

Fig 4e *Bone-supported cutting guide defining the desired anterior, inferior, and posterior lateral wall boundaries.*

Fig 4f *Bone-supported cutting guide defining the superior lateral wall boundary.*

Fig 5a *Bone-supported cutting guide in place defining the desired superior boundary.*

Fig 5b *Bone-supported cutting guide in place following infracture and membrane reflection demonstrating desired anterior, inferior, and posterior lateral wall boundaries observed.*

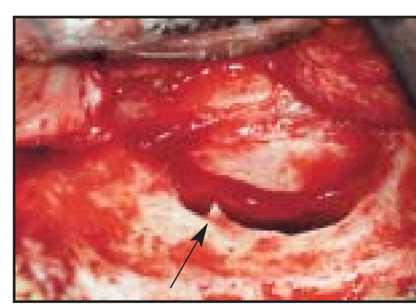

Fig 5c *The bone-supported cutting guide is removed and the desired superior boundary is observed, along with uneventful Schneiderian membrane elevation. Recipient bed preparation has been made for lateral ridge augmentation via block bone graft at the first premolar. Note septa* (arrow) *presence as observed via presurgical diagnostics.*

through the process of stereolithography (Fig 4). These guides defined the desired superior cutting path outlined via SimPlant OMS as well as the inferior, mesial, and distal boundaries of the previously outlined lateral window based on the presurgical plan.

The surgical procedure was performed following the technique described by Garg.[13] 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. The guides were then used to outline the planned configuration of the lateral wall. The cutting guides remained on the bone surface during outlining of the lateral window. Outlining may be performed by round burs or piezosurgery inserts. Infracture, uneventful Schneiderian membrane elevation, and sinus bone grafting then ensued. The anterior and inferior boundaries were particularly well defined by the cutting guides as planned and outlined by the SimPlant OMS software (Fig 5). This allowed for more predictable Schneiderian membrane reflection, as reflection was carried out precisely on the bone after the boundaries of the lateral window had been accurately identified.

Discussion

The anatomic 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. Common complications with the sinus bone graft technique include bleeding, membrane perforation, septa, osteomeatal complex obstruction, alveolar ridge fracture, and damage to adjacent teeth.[14] The most common of these is, arguably, membrane perforation.[15] 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 postsurgical bacterial infection.[16] In general, Schneiderian membrane tears of any magnitude have the potential to increase the risk of postsurgical infection and reduce overall graft success. To some degree, tears can be traced back to operator inaccuracy in lateral window positioning, because precise determination of the window's boundaries is, for the most part, entirely intuitive.

Earlier publications focused on the use of computer software to ensure prosthetically advantageous, precise implant placement and predictable prosthetic outcomes.[17–19] This approach uses computer-generated surgical drilling guides, which are generated through stereolithography and computer software (SimPlant Planner) that interfaces with a patient's CT scan. A different SimPlant module offered by Materialise Dental (SimPlant OMS) was used to develop the present surgical guide prototype to direct osteotomy cuts that would precisely position the lateral window based on 3D imaging and presurgical planning.

To date, guided CT technology does not allow the surgeon to identify and transfer the patient's often complex anatomic configurations viewed on a preoperative CT scan into precise osteotomy cuts at the time of surgical intervention for more predictable lateral wall positioning. Transillumination is a common modality that is used to define the sinus boundaries, but it is not effective at helping the surgeon to create a precise outline, particularly when important and often misleading anatomic configurations are present in the maxillary skeleton.

The questions posed with the present patient were: Can guided CT technology be employed for sinus bone grafting procedures using an antral approach? If so, will this enhance the precision of lateral window positioning and minimize the risk of Schneiderian membrane perforations by creating a more predictable environment to perform membrane reflection? In other words, can cutting guides be created to precisely direct bone graft surgery through the use of CT scan imaging, computer software, and stereolithography? If so, perhaps certain aspects of future guided bone regeneration surgery can be made even more precise, with more predictable clinical outcomes and fewer complications.

The cutting guides created through the SimPlant OMS software and the stereolithographic process fit extremely well in the anatomic environment and accurately identified the boundaries that were presurgically planned. Membrane reflection was predictably initiated directly off of the remaining inferior and anterior antral walls, without sequelae. There were no "surprises"; nor was 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 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 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 a part of total implant rehabilitative therapy.[17] These applications will also minimize the extent to which "mental navigation" (ie, intuitively driven surgery) determines outcomes. Future applications involving CT imaging, computer software, and stereolithography to facilitate 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 outcomes in dental implant therapy.

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