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Bone Grafting Assessment: Focus on the Anterior and Posterior Maxilla Utilizing Advanced 3-D Imaging Technologies

By Scott D. Ganz, DMD

As dental implant reconstruction has evolved into a mainstream alternative to replace missing teeth, bone grafting techniques have also evolved as an ancillary procedure for site development, sinus augmentation, and guided bone regeneration. Concurrently, imaging technologies have been developed which allow unsurpassed inspection of the dental-alveolar complex, providing clinicians with innovative tools to plan for dental implant reconstruction. The ability to diagnose and treat dental implants have been forever changed by the ability to assess patient anatomy using Computed Tomography (CT), Cone Beam (CBCT), and interactive treatment planning software within the universal standard "language" of data called DICOM (Digital Imaging and Communications in Medicine). This increased ability has been expanded to include appraisal of bone grafting receptor and donor sites through innovations in the interpretation of three dimensional data.

In the completely edentulous mandible or maxilla, the use of CBCT technology is an essential tool for assessing anatomy in preparation for implants or grafting. The ability to visualize the extent of a defect from various angles, views, and 3-D reconstructions has helped to define a new set of diagnostic paradigms. A two-dimensional panoramic reconstruction of the maxilla can provide a good scout film of the anatomy; however, as a two-dimensional modality, it has inherent limitations and distortion. The right and left maxillary alveolar bone height can be approximated, and the relative size of the bilateral maxillary sinuses or extent of pnuematization can be assessed in relation to the underlying bone and nasal cavity. However, it is not until all possible two-dimensional and 3-D views have been examined that the actual bone anatomy can be appreciated and assessed in relation to the planned reconstruction.

Using CBCT, several different

views can provide invaluable information as to the patient's anatomical presentation. They include the axial, cross-sectional, panoramic, and 3-D views. The axial view helps to reveal the true magnitude of atrophy exhibited in the anterior maxilla of a patient wearing a complete denture (*see Figure 1*). Scrolling through the cross-sectional images, allows for an examination of the extremely thin strip of cortical bone representing the residual alveolar ridge supporting a complete denture (*see Figure 2*). Moving posteriorly, the lack of remaining vertical bone height beneath the maxillary sinus is evident (*see Figure 3a*). The sinus can be examined for pathology, thickening of the membrane, width and, in some instances, the osteomeatal complex can be clearly visualized. Additionally, the extent of sinus pneumatization can be visualized and substantiated through undistorted measurements available within the diagnostic tools of the software. Sometimes overlooked, but certainly important, are the significant arteries that supply vascularization to the maxillary sinus. These include the posterior/superior alveolar artery, the anterior superior alveolar artery, and the infraorbital artery. In a significant percentage of CT/CBCT scans, these vessels can be detected and differentiated in terms of vertical position on the external wall of the sinus, as well as a superficial, intraosseous, or intrasinus location (*see Figure 3b*). The location and diameter of these vessels should be an important consideration when performing a sinus augmentation because of the potential risk of bleeding during the procedure. When possible, depending upon the software utilized, a 3-D reconstruction of the maxilla is the final step to confirm the actual maxillary anatomy (*see Figure 4a*). Looking down upon the maxillary arch, the volume and asymmetry of the right and left maxillary sinus can be fully appreciated, as they are delineated from the nasal cavity (*see Figure 4b*). The treatment alternatives for this type of clinical presentation are narrowed considerably once these images are assimilated, yet these options will be based upon accurate knowledge of the anatomy, and can be decided well in advance of the surgical intervention.

Sinus Grafting Assessment

Advanced imaging technologies greatly enhance planning and execution of sinus augmentation procedures. In the cross-sectional view, the amount of bone volume necessary can be accurately determined by measuring from the lateral to the medial wall, and the height necessary to support an implant (*see Figure 5a*). Additionally, the surgical access "window" can be planned in advance of the procedure. Using the "sinus graft" software tool, a simulated implant can be placed within the sinus and a simulated graft can be software-generated to fill the cavity (*see Figure 5b*) (SimPlant; Materialise Dental, Glen Burnie, Md). Using advanced "clipping" features, the 3-D reconstructed maxilla can be sliced to view the single realistic simulated implant sitting in the sinus (green) with a yellow abutment projection aiding the position to emerge through the planned restoration (*see Figure 6a*). Information on graft volume can then be calculated by filling the sinus cavity with simulated bone to help predict the type and quantity of bone required for proper augmentation (*see Figure 6b*).

Using low-dose CBCT, post augmentation scans can be taken to verify the quality of the bone augmentation, to determine medial fill, density, height and width of the graft, and if perforations or graft leakage occurred. These unparalleled views can be of great value for all clinicians who are interested in achieving a higher degree of accuracy with surgical augmentation procedures and, when post-operative CBCT scans are made available, understanding actual treatment outcomes in three dimensions. The post-augmentation

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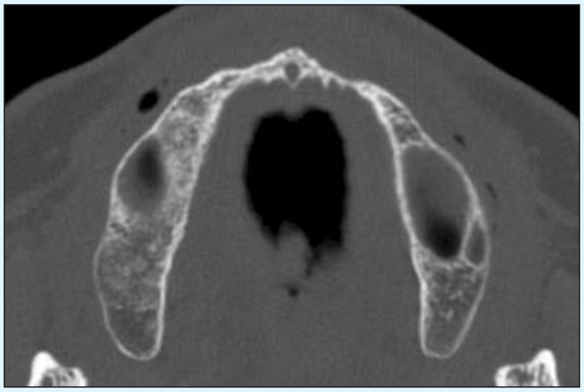

Figure 1: Axial view of severely atrophic anterior maxilla.

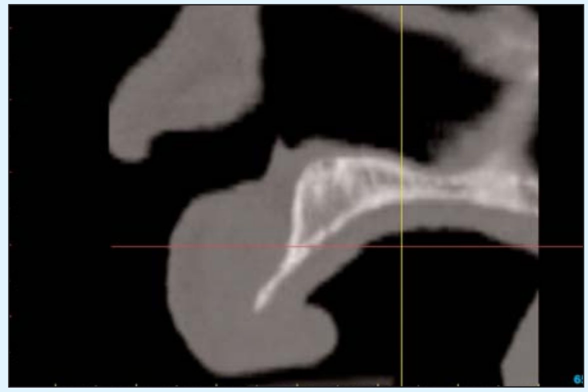

Figure 2: Cross-sectional view of thin alveolar crestal bone.

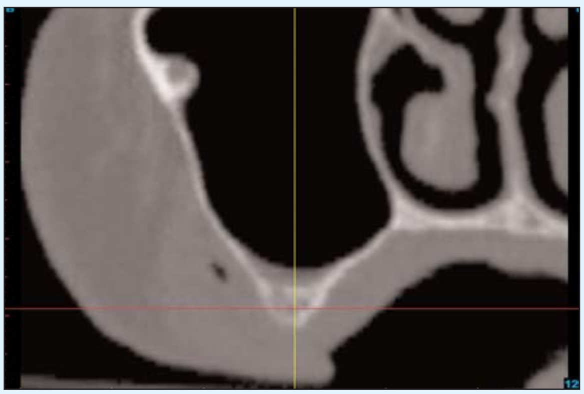

Figure 3a: Maxillary sinus volume as seen in cross-section.

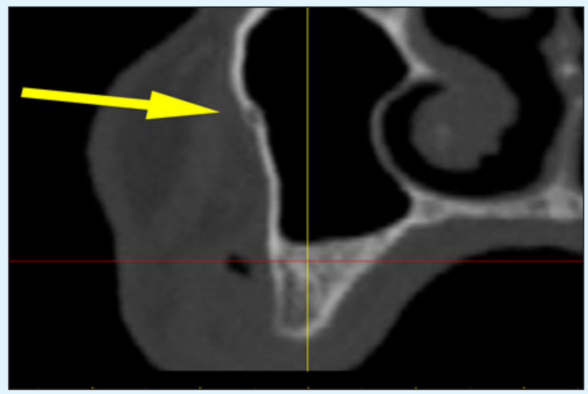

Figure 3b: Location of intraosseous vessel on wall of sinus.

scan can be utilized to properly assess the newly created graft volume and surrounding structures for subsequent implant placement (*see Figure 7a*). Undistorted measurements help provide valuable information which could not be determined without these advanced interactive tools. Once verified, the precise length and diameter of the most appropriate implant can be simulated to take advantage of the most available bone (*see Figure 7b*). The ability to slice through the 3-D reconstruction provides yet another valuable interactive view verifying implant placement within the zone of the "Triangle of Bone" (TOB) described in various articles since 1995 (*see Figure 7c*).

Block Bone Graft Assessment: Receptor and Donor Sites

The use of CT and CBCT has been demonstrated to be invaluable in small bone defects, and also large bone defects, when planning for either particulate or block grafting procedures. Proper assessment of large bony defects can be essential to long-term restorative success. It is not only important to visualize the defect itself but it is critical to understand the restorative requirements of the region so that the graft can be properly configured. A 3-D reconstructed view reveals loss of four maxillary incisors with concurrent loss of substantial alveolar ridge volume (*see Figure 8*). Depending upon philosophy and training, three or four implants would ideally be required to support the missing four anterior teeth. However, without a diagnostic wax-up, it could be difficult to place the implants within the desired restorative envelope while avoiding embrasures and, with resultant, proper emergence profiles for soft tissue maintenance and esthetic appearance. This would be especially significant if the patient has a high lip and smile line. To achieve true restoratively driven implant dentistry, the position of the teeth must be appreciated prior to placing a graft or an implant.

Through the use of diagnostic wax-ups and barium sulfate scanning appliances, the tooth position can be visualized on the scan. Often, patients are scanned without a template, which does not relate the desired tooth position to the underlying residual defect. The evolution

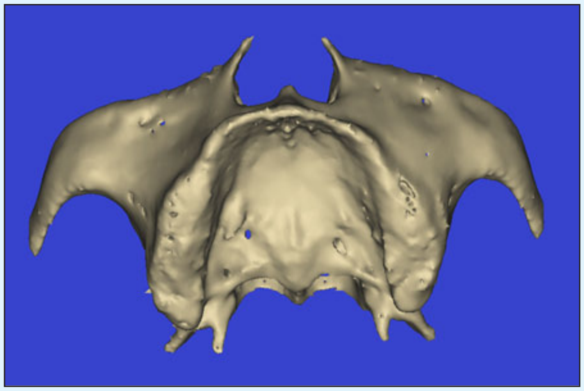

Figure 4a: Three dimensional reconstruction of maxilla.

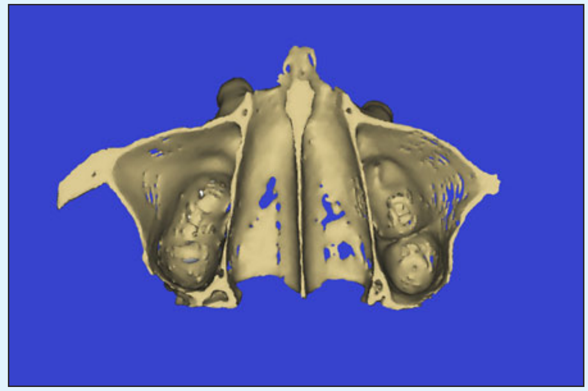

Figure 4b: Bi-lateral sinus volume, and nasal cavity in 3-D view.

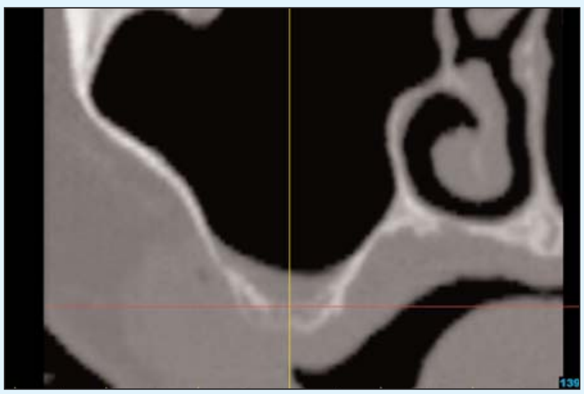

Figure 5a: The width and height of the sinus can be measured in the cross-sectional view.

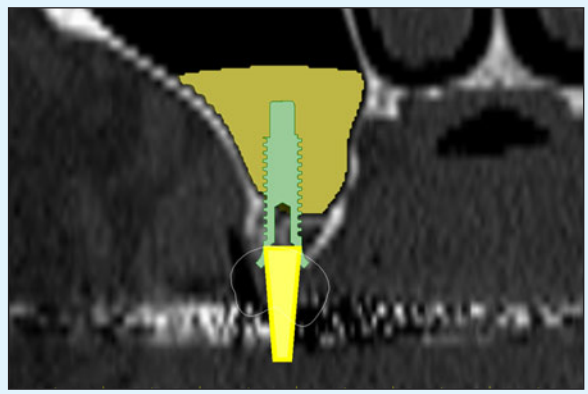

Figure 5b: A simulated bone graft can be generated to surround an implant placed within the sinus.

of the virtual tooth, or virtual occlusion, has added a new and important tool set for interactive treatment planning. When several teeth are missing, more control of the process is required and, thus, these virtual tools must continue to evolve into strategic diagnostic modalities. Due to the volumetric loss of buccal bone and to support the ideal, occlusion implants need to be placed facial to the residual bone, necessitating a substantial amount of graft thickness. The position of the four missing "virtual" incisor teeth should be created in the ideal position, so that the simulated implants can be positioned to best support the anticipated restoration (*see Figure 9*). However, there is insufficient bone to cover the exposure of threads on the facial aspect of the implants or to allow the implants to be fixated. The next step would, therefore, be to simulate the bone graft volume necessary to surround and fixate the implants after graft maturation. Using a simulated "j-graft" block graft shape, measurements can be made from the ideal implant position to determine the thickness of graft required to support the implant and the surrounding soft tissue. Once a virtual implant, virtual abutment, and virtual tooth have been placed, additional measurements can be made from the outer aspect of the implant to the outer aspect of the graft (*see Figure 10a*). With such a large volumetric defect crossing the midline of the anterior maxilla, it might be desirable to place more than one block bone graft, or use a reinforced membrane, to contain particulate grafting material. For this example, bilateral simulated bone grafts placed to support four implants, abutments, and the desired position of the restorations can be seen in *Figure 10b*. Of note, are the fixation screws that have also been strategically placed to help stabilize the grafts. The precision of this planning can not be underestimated.

Utilization of 3-D scans can also help locate graft donor sites in the posterior ramus or the symphysis. The thickness of the facial cortical plate and the location of the inferior alveolar nerve help to identify a safe

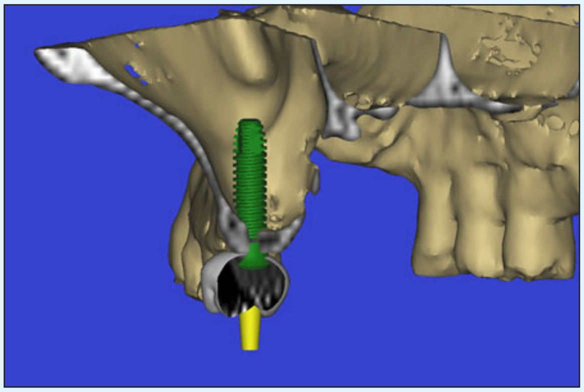

Figure 6a: A realistic implant (green) and abutment projection (yellow) positioned within the sinus.

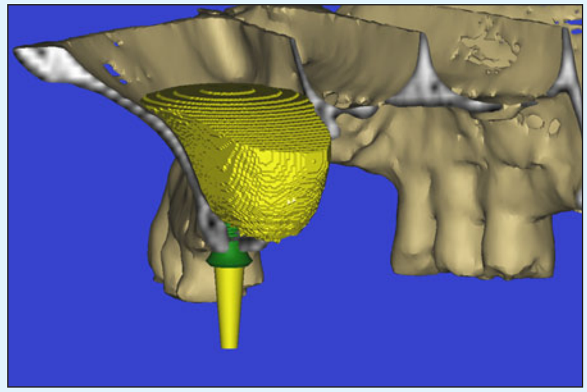

Figure 6b: To determine the volume of bone necessary the software generated bone graft fills the sinus.

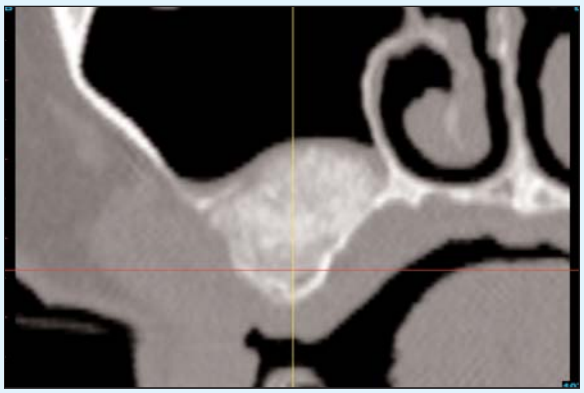

Figure 7a: Post augmentation scan allows for assessment of the graft placement.

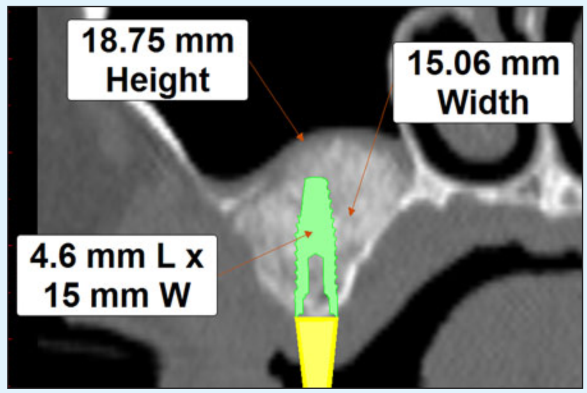

Figure 7b: Undistorted measurements help provide valuable information regarding the placement of an implant within the new graft.

and adequate donor site in the ramus (*see Figure 11a*). The proximity to the path of the nerve, the thickness of the cortical plate, and the density of the medullary bone can be fully appreciated. The shape and size of the graft can then be pre-determined and assessed for fit in the receptor site (*see Figure 11b*). Using the same process, donor sites can be evaluated in the anterior symphysis of the mandible. Once the graft has been harvested from either the ramus, the symphysis, or a bone bank, the receptor site is prepared to receive the graft. To continue the planning process, virtual positioning of the fixations screws helps to ensure intimate fit and stability of the graft. The cross-sectional "clipping" of the 3-D reconstruction shows how two fixation screws have been planned, the relationship between the simulated implant to be placed (after the graft has matured), and the underlying pre-existing alveolus (*see Figure 12a*). The 3-D reconstructions further emphasize the planning capabilities inherent in state-of-the-art treatment planning software by revealing the entire tooth-abutment-implant complex within the simulated grafted receptor site (*see Figure 12b*). To ensure accuracy of placement and to determine proper embrasures, the envelope of the teeth should be completely visualized in the occlusal view of the 3-D reconstruction with the four virtual maxillary incisors (*see Figure 13*). An actual bilateral graft procedure demonstrates the planning concepts presented in this paper (*see Figure 14*).

Conclusion

Imaging technology has advanced significantly in the past two decades. Both CT and Cone Beam CT scanning have gained acceptance as necessary pre-surgical planning tools for placement of dental implants and for an understanding of the patient's three dimensional bony anatomy for grafting procedures. When using software associated with the CBCT scan machine, details of the patient's anatomy can allow for inspection of the area of interest by utilizing several different

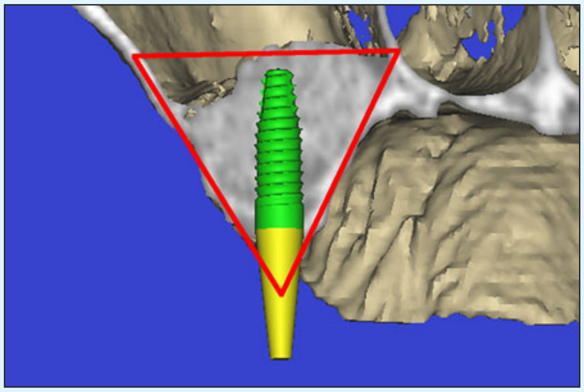

Figure 7c: The implant should be placed within the "Triangle of Bone" - the zone of available bone.

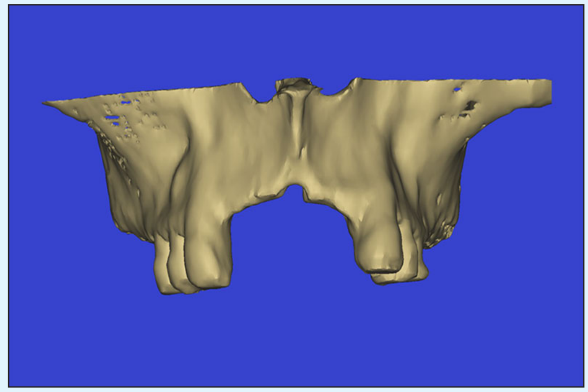

Figure 8: A 3-D reconstructed view of a maxilla with a significant anterior defect.

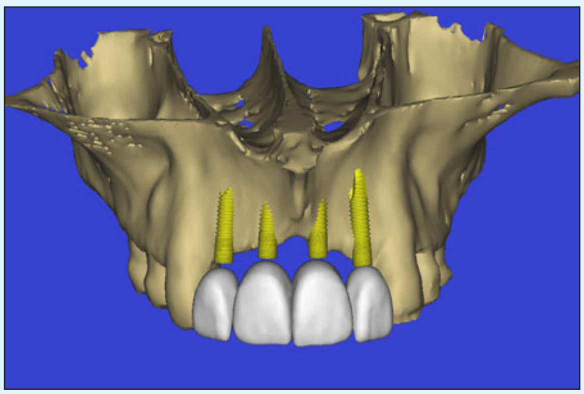

Figure 9: Simulated implants are ideally placed to support a virtual tooth set-up.

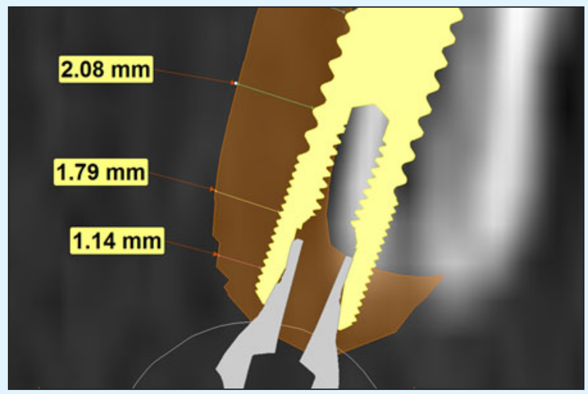

Figure 10a: Measurements can be made to help identify adequate graft thickness.

views, including the axial, cross-sectional, panoramic, and 3-D reconstructed views. Taking the technology to the next level of sophistication requires importing and converting the CT/CBCT scan DICOM data into interactive treatment planning software applications which can then be used to gain additional accuracy in the diagnosis and treatment planning for implants, particulate and block bone grafting, sinus augmentation, and improved assessment of both donor and receptor sites. Advances in 3-D imaging technologies offers clinicians new and powerful tools which are rapidly expanding our knowledge base, helping to define new diagnostic paradigms for a variety of clinical applications included within, and for exploration beyond the scope of this article. ■

Suggested Reading

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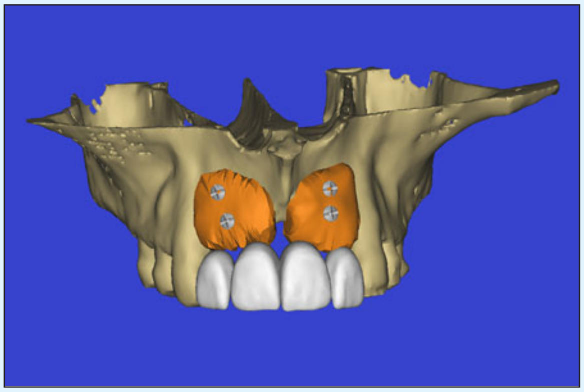

Figure 10b: Bilateral simulated bone grafts placed to reconstruct the anterior maxilla in anticipation of supporting four teeth.

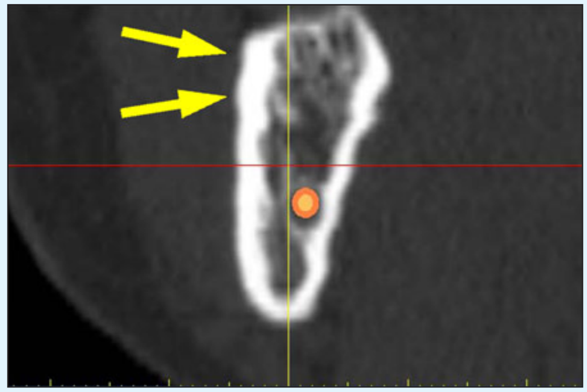

Figure 11a: Donor sites can be identified in the posterior ramus through cross-sectional assessment of the path of the nerve and the cortical bone thickness.

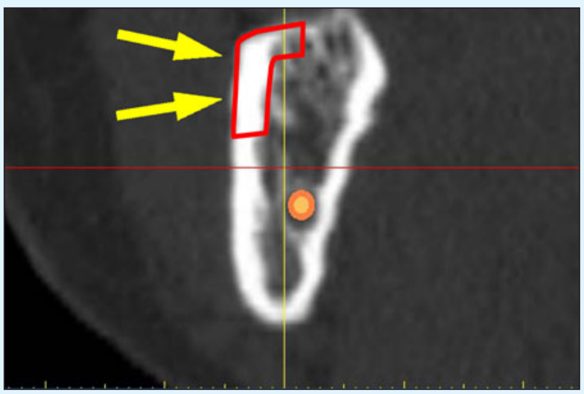

Figure 11b: The shape and size of the donor graft can be pre-determined.

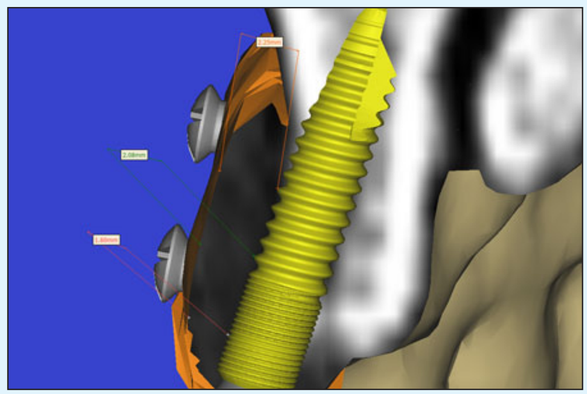

Figure 12a: Cross-sectional "clipping" shows how two fixation screws are planned to secure the simulated bone graft.

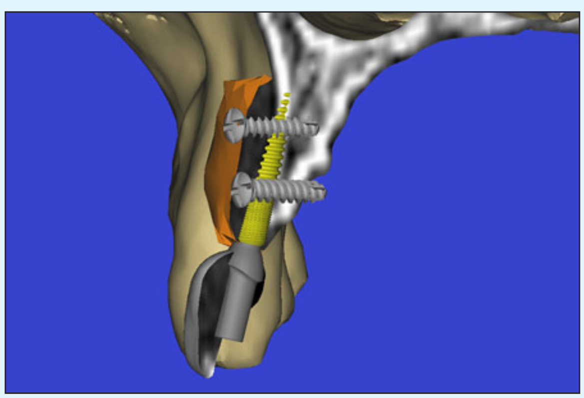

Figure 12b: The implant-abutment-crown complex and the fixated bone graft in a slice of the 3-D reconstruction.

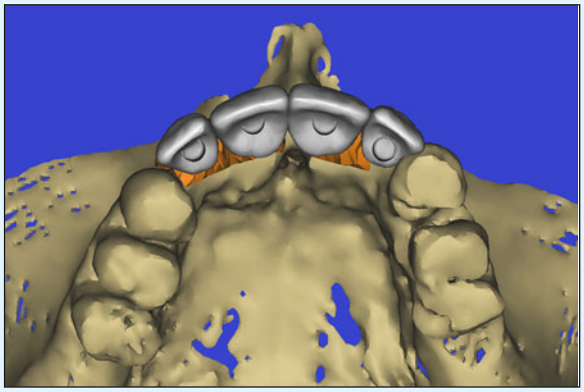

Figure 13: The envelope of the virtual occlusion aids in determining embrasures, and insures implant positioning within the body of each tooth.

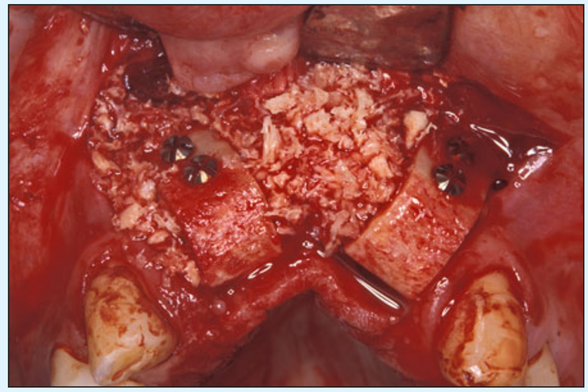

Figure 14: An actual bilateral bone graft in the anterior maxilla demonstrates the outcome of proper planning.

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