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Use of Digital Design in the Reconstruction of Vascularized Fibula Grafts

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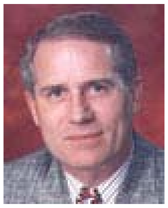


Microvascularized fibula transplants have become an established treatment option in the reconstruction of the mandible. The diameter of the fibula is limited when compared to the height of the mandible, and frequently the vertical distance between the reconstructed segment and the occlusal plane presents a complex restorative problem. Advances in digital imaging and computer manufacturing make it possible to easily visualize the restorative space and to make surgical guides and dental restorations.

Figure 1. Clinical view of patient with mandibular right vascularized fibula graft.

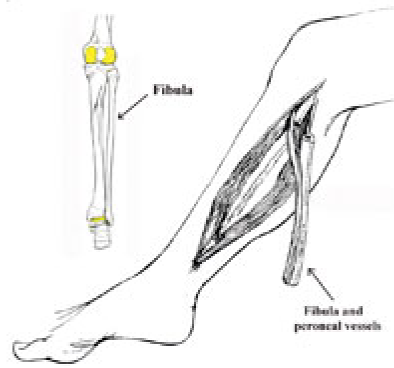


Figure 2. Diagram of fibula and view of fibula osteo-cutaneous flap.

The introduction of vascularized fibula grafts and osseointegrated dental implants presents the cancer patient with treatment options that were only dreamed of in the past (Figure 1). The fibula provides an ideal source of tissue for grafting. An island of soft tissue and skin can accompany the vacularized fibula graft, which can withstand high doses of radiation therapy.[1] The fibula also provides a long and straight portion of cortical bone with a good blood supply from the peroneal vessels (Figure 2). Taylor, et al[2] reported the first use of the free vascularized fibula graft. One problem with this graft is the difference in vertical height of the grafted site when compared to the preoperative height of the alveolar ridge. The low vertical height of the reconstructed segment leaves a large distance between the bone and the occlusal plane. Planning for the restorative phase of treatment is difficult because the position of bone plates and screws must be determined, and frequently a large amount of soft tissue is present between the bone and the occlusal plane.[3] If endosseous dental implants are placed only in the fibular graft, then a high crown-to-fixture ratio will be created with an increased possibility of failure for the prosthesis or the implants themselves.

DIGITAL IMAGING

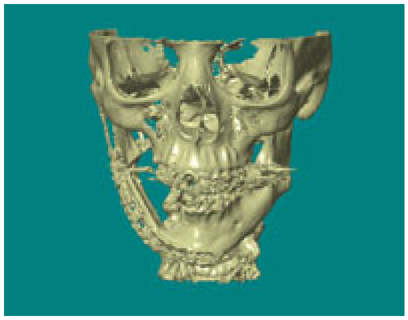


Figure 3. A 3-D rendering of CT data with distortion of teeth in the occlusal plane due to scatter.

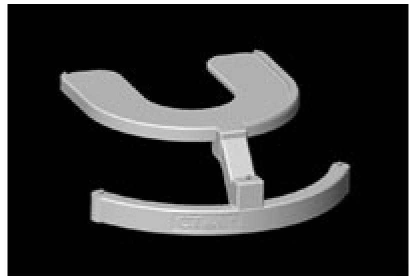


Figure 4. CT Byte device.

Many advances have occurred in the past decade that allow for the noninvasive imaging of patients using computed tomography (CT), and more recently the use of cone beam CT.[4-6] Unfortunately, using CT alone results in image data that is distorted due to radiographic scatter. This distortion is most evident in the occlusal plane (Figure 3), and if the patient has a large number of crowns, fillings, or root canal treatments, it may be impossible to determine the position of the occlusal aspects of teeth in the data. A new technique using a device called a CT Byte (Voxelogix) can now be used (Figure 4), thus eliminating this problem by joining image data from the CT scan with image data of dental casts to produce a composite 3-D image of the patient. It also allows for the design and manufacture of drill guides, transitional appliances, and the actual definitive fixed prosthesis. Most importantly, it makes it possible to communicate and plan treatment virtually before implant placement.

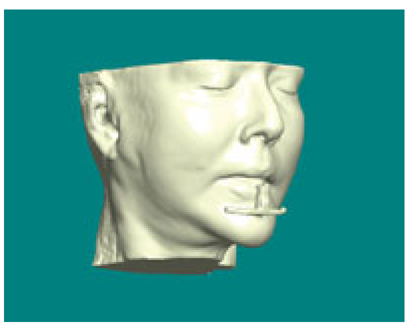


Figure 5. Rendering of CT data to produce patient's face with CT Byte extending out of the mouth.

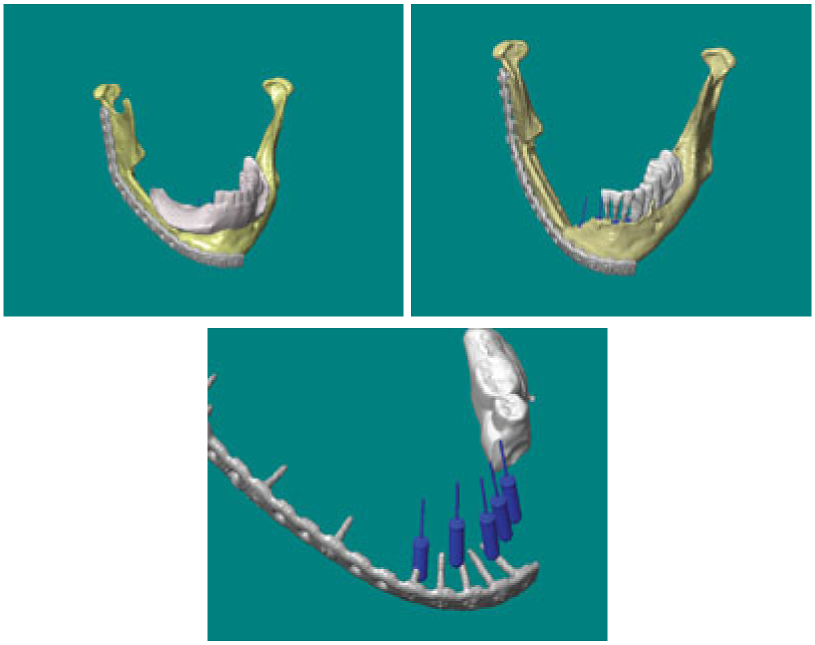
Figure 6. CT Byte with impression material attached to dental casts.

Figure 7. Dental cast (left) and virtual model (right).

The CT Byte device is designed so that the patient bites into regular-bodied impression material attached to the biting aspect of the device just before the CT scan. Three small radiopaque markers are attached to the plastic portion of the device that projects out of the mouth and below the plane of the teeth. This makes it possible to precisely locate the position of these markers in the CT data (Figure. 5). After the CT scan has been made, the CT Byte, DICOM data, and impressions are sent to Dental Implant Technologies to have the CT data translated and the dental casts made and scanned. This information is then joined in computer space to create a virtual representation of the patient and the planned position of dental implants, artificial tooth positions, bone reduction, and location of any diagnostically useful objects.

The intent of this system is to provide the restorative dentist and implant surgeon with important data about their patients via the Internet without the need for costly software or an understanding of the imaging or rendering process. Most surgeons and restorative dentists simply want drill guides and prosthetic devices that are accurately made and solve the surgical and restorative problems of their patient. Figure 6 shows the CT Byte attached to the dental model of the patient. The dental casts can be accurately scanned with light, laser, or contact digitizing, to create a virtual model with an accuracy of 15 to 25 µm (Figure 7). The actual position of the mounted casts can be recorded digitally to within 12 µm, and the position of the casts attached to the CT Byte can also be precisely recorded. The virtual dental casts are then positioned in the same computer space as the patient data when the CT scan was made.

CONCURRENT TREATMENT PLANNING

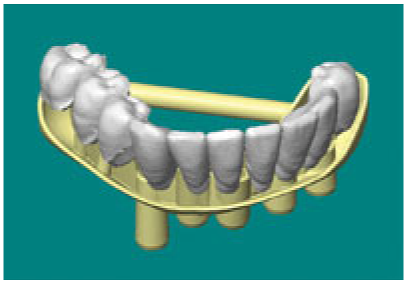


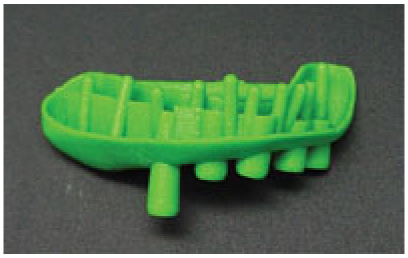
Figures 8a to 8c. Virtual model of dental cast and CT data (a). Teeth and roots from CT data with dental implant positions (b). Position of implants in relation to titanium screws (c).

Figure 9. Virtual model of planned prosthesis, dental implants, and alveolar reduction.

Three-dimensional images of the dental casts, artificial teeth, implants, bone, fixation devices, and/or any other diagnostically important object can be joined in computer space and viewed via the Internet. Individual objects can be made translucent or “turned on” or “off” to be viewed in the same virtual space. Lighting and coloring effects are simple to make, and the images can be printed as a 2-D hard copy. Figure 8a shows the dental cast and CT data joined together in the same spatial position. Figure 8b illustrates the position of dental implants and teeth along with the proper amount of alveolar bone reduction required for adequate restorative space. Figure 8c illustrates the fact that the most distal implant on the patient's right side is in the same location as a fixation screw. The patient was informed of the need to remove the screw at the time of surgery prior to implant placement to create an even distribution of implants. Finally, the complete prosthesis with artificial teeth can be designed and viewed prior to treatment (Figure 9). This concurrent treatment planning via the Internet helps eliminate confusion and improves patient understanding of treatment objectives and problems.

DIGITALLY MANUFACTURED PROSTHESIS





Figures 10a and 10b. Virtual model of planned prosthesis (a). Pattern for gold casting made using rapid prototyping (b).

Figure 11. Completed prosthesis.

Figure 12. Clinical view of the completed prosthesis.

Three-dimensional images of all aspects of the treatment can be viewed from files sent via the Internet. These files are around 1 to 2 megabytes and allow each member of the treatment team to see planned treatment objectives and make changes as needed. The data can also be used to manufacture the drill guide and immediate load prosthesis placed at the time of surgery. The image data can also create the definitive prosthesis using any number of modern manufacturing techniques. The most common techniques are 5-axis milling of titanium or ceramic, electron beam melting titanium, laser beam melting titanium, or dental castings from patterns made with rapid prototyping.[7-8] The patient illustrated in this article had her definitive prosthesis cast from gold using a rapid prototyping or layered manufacturing process that builds the investment pattern a layer at a time by jetting a thermoplastic material (Figures 10a and 10b). Processing denture teeth to the cast gold framework completed the prosthesis (Figure 11). The clinical view of the prosthesis is illustrated in Figure 12.

CONCLUSION

Advances in digital imaging make it possible to shape bone, plan for implants, position artificial teeth, and actually manufacture the transitional immediate load and definitive prosthesis. The key to this process is integration of digital data sets of the patient's dental casts with data from computed tomography. A simple intraoral device has been developed that eliminates the need for complex radiographic templates and can be used for imaging any implant patient.

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