

Radiologic Techniques Using CBCT and 3-D Treatment Planning for Implant Placement

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ABSTRACT Determining the placement of dental implants can be greatly improved through the use of medical CT or dental cone beam computed tomography. As the use of CBCT technology has become more accessible, 3-D treatment programs have evolved considerably. Two cases will be reviewed to illustrate how model-based CBCT treatment planning and 3-D multiplane treatment programs can assist with the pretreatment evaluation and decision-making process for the complex placement of implants.

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DISCLOSURE

Jerome N. Peck is owner and chief executive officer of both C-Dental X-Ray, Inc., and Rapident Surgical Guides, Inc. Rapident Surgical Guides is the exclusive California distributor for iDent software and manufacturer of iDent surgical guides.

In May 2001, CBCT imaging for dentistry was introduced to the United States by QR srl of Verona, Italy, the manufacturer of the New-Tom. Since then, several different hardware and software manufacturers have developed CBCT machines and 3-D software packages, which have significantly contributed to the advancement and adoption of both technologies.

Prior to the advent of CBCT, medical CT was not embraced in dentistry because of its high cost and the high radiation dose to the patient.^{1,2} The average cost for medical CT in 2000 was \$750 per arch. Additionally, the high cost of the medical CT examinations directly affected the adoption of virtual 3-D treatment planning programs. Today, with an average cost of \$400 for both arches and radiation levels that are comparable to

an orthopantomograph, CBCT is experiencing enormous success.¹ Furthermore, the acceptance of CBCT has assisted the growth of many 3-D treatment planning companies.

The potential treatment complications with the placement of implants are well documented and one of the most important steps is obtaining appropriate radiographs. The complex task of determining the proper placement of implants prior to surgery is an essential one. "Two dimensional images such as orthopantomographs and periapical films have inherent shape and size distortion along with changes in magnification."³

Utilization of CBCT clearly illustrates the true 3-D shape and size of all anatomical structures. By combining CBCT and 3-D treatment planning, implants are being placed with ideal prosthetic results.

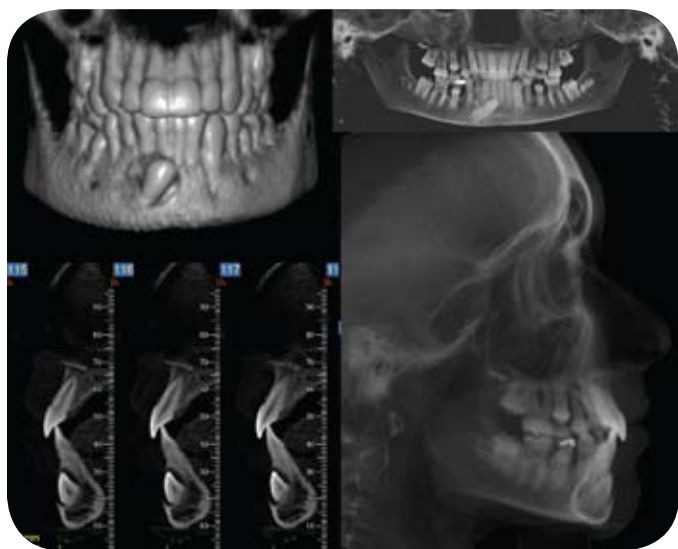


FIGURE 1. Three-dimensional view, panoramic, lateral cephalometric, and anterior cross sections illustrating capability of CBCT and voxel opacity necessary to render these different images. (Images created in Dolphin 3D and NewTom software, C-Dental X-Ray, Inc.)

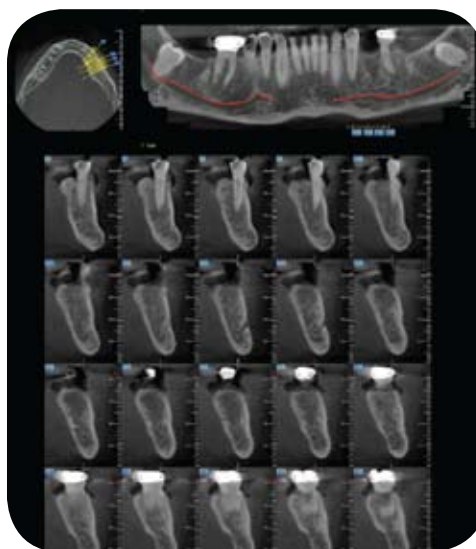


FIGURE 2. Axial, panoramic, and cross-sectional views of a CBCT scan. (Images created in NewTom software, C-Dental X-Ray, Inc.)

Determining the Accuracy of CBCT

The error factor in CBCT is determined by the size of the voxel.

Voxel, short for volume pixel, is the smallest distinguishable box-shaped part of a three-dimensional image. Voxelization is the process of adding depth to an image using a set of cross-sectional images known as a volumetric dataset. The dataset is processed when slices are stacked in computer memory based on interpixel and interslice distances to accurately reflect the real-world sampled volume. Now that the data set exists as a solid block of data, the pixels in each slice have taken on volume and are now voxels. For a true 3-D image, voxels must undergo opacity transformation. Opacity transformation gives voxels different opacity values. This is important when it is crucial to expose interior details of an image that otherwise would be hidden by darker more opaque outside-layer voxels.³

The lateral cephalometric in (FIGURE 1) is an ideal example of voxels that have changed their opacity, thus allowing the visualization of sella-turcia. The size of a voxel directly represents the detail of an image, the smaller the voxel, the better the resolution.

DICOM Standards

CT scanners used in medical CT as well as the dental CBCT scanners create their own proprietary file formats. Today's manufacturers of CBCT machines comply with the 3.0 DICOM (digital information communication for medicine) standards; they export their proprietary files into the DICOM standard.

DICOM is the industry standard for transfer of radiological images and other medical information between computers. Patterned after the Open System Interconnection of the International Standards Organization, DICOM enables digital communication between diagnostic and therapeutic equipment and systems from various manufacturers.⁴

CBCT programs allow the clinician to pinpoint, visualize, and define anatomical structures. Subsequently, the DICOM protocol allows the transfer of CBCT files into third-party 3-D treatment programs written specifically for dentistry. The ability to share DICOM files improves communication between dentists in every modality of dentistry. Images are stored electronically further reducing the necessity for additional patient exposure. It should also be noted: one

CBCT scan provides information that can be used by every modality in dentistry. Images in FIGURE 1 illustrate how one volume can be used by multiple 3-D programs, the lateral cephalometric and orthopantomograph were processed using Dolphin 3-D. The cross-sectional and 3-D model images were processed using the NewTom software.

CBCT Imaging for Implants

Implant placement through the use of CT and CBCT has dramatically helped to improve the placement of implants. In 2001, the American Association of Maxillofacial Radiologists recommended that a CBCT scan be obtained for the placement dental implants.⁵ But, CBCT alone does not tell the entire story. FIGURE 2 clearly illustrates all anatomical boundaries of the mandible. The software used to create this image utilizes tools that accurately mark the delineation of the nerve and provide 1:1 images, allowing for accurate measurements. But, many surgeons require additional information. They desire the ability to integrate the CBCT data into implant surgery. Using CBCT without any type of radiographic markers or a 3-D program that places implants into the study can be as analo-



3A.

FIGURE 3. Intraoral photographs, buccal and occlusal views of lower left molar.



3B.



FIGURE 4. The model is prepared from a vacuform of the diagnostic wax up using a standard 3/32 drill bit. A 16-mm rod of the same diameter is inserted into the cast.

gous to arriving at a fork in the road with no directional signs leaving the surgeon unable to understand the true treatment plan.

CBCT and Model-based Treatment Plans

Model-based treatment planning with radiographic markers is a successful technique used to merge CBCT images into the surgery and requires absolutely no software. This technique can be used for single tooth (FIGURE 3) or multiple tooth replacement, and will give the clinician valuable information for treatment planning. Several modifications of the original technique have been developed and published.⁶ In brief, diagnostic casts and a wax-up of the proposed site are obtained by the clinician. A vacuform of the wax up is made with thin acrylic material (0.20 thickness) and the site is prepared with a 3/32 standard drill bit. A 16-mm rod with the same diameter as the 3/32 drill bit is inserted into the cast and a second vacuform is pulled over the cast with the 0.20 material (FIGURE 4).

The template is removed from the cast, trimmed, and the tube is filled with radiopaque material (gutta percha or a smaller metal rod)(FIGURE 5). The marker needs to allow the patient to have complete occlusion without distortion in order for the scan to have diagnostic value. The image would show incorrect emergence angle and placement position for the implant if the patient occludes heavily on the marker. A CBCT scan is performed with the patient wearing the radiographic guide; images are then evaluated to determine bone height, width of the mandible and the position of



FIGURE 5. A second vacuform is completed over the small diameter rod. The vacuform is removed, trimmed, and the diameter is filled with gutta percha for radiographic analysis.

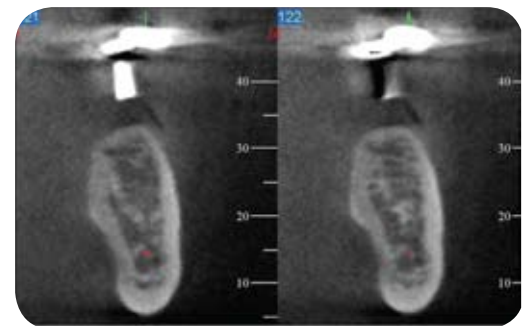


FIGURE 6. NewTom volumetric scan of patient with the radiographic template (sagittal view). The template indicates proper angulation and direction for implant placement. Note the excellent bone volume and position of the mandibular canal.



FIGURE 7. NewTom volumetric scan of patient with the radiographic template (panoramic and axial view).

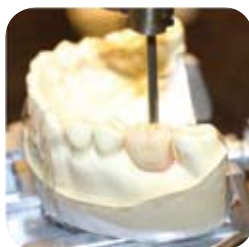


FIGURE 8. Following radiographic confirmation, the cast is prepared for fabrication of the surgical stent. The prepared cast is placed on a surveying table and the initial preparation is enlarged to 9/16 with a drill press. A larger diameter rod is inserted into the cast following enlargement of the preparation with the 9/16 drill bit. A template using 0.060 acrylic material is pulled over the cast with a vacuform.



FIGURE 9. The completed surgical stent. The diameter of the preparation corresponds to the final diameter of the implant to be inserted. Surgical sleeves are utilized for stages of drilling.



FIGURE 10. The completed surgical stent. The diameter of the preparation corresponds to the final diameter of the implant to be inserted. Surgical sleeves are utilized for stages of drilling.

the nerve canal (**FIGURES 6 AND 7**). Measurements are performed to determine the length of the implant and to make any changes in angulation or position for the implant that may be necessary prior to the fabrication of the surgical stent. When the necessary corrections have been made, the cast is brought back to the surveyor, the site is enlarged using a 9/16 drill bit in the drill press. A large-diameter rod with the same diameter as the 9/16 drill bit is inserted into the cast and a vacuform is pulled using 0.60 or 0.80 acrylic material. The thicker material is needed for the fabrication of a rigid surgical stent (**FIGURES 8, 9 AND 10**). A typical clinical case from a model-based treatment plan is shown in **FIGURE 11**.

The Virtual Patient

The limitations of model-based treatment planning has become abundantly clear when directly compared with virtual treatment planning, especially when multiple implants are being placed. Today's clinicians have a number of 3-D treatment planning programs to choose from. For this article, the authors reviewed four of the most commonly used 3-D programs: Materialise's Simplant, Nobel Biocare's Procera, Implant Logic's VIP and iDent's Scan2Guide. Each system has its own protocol and provides the clinician with highly accurate surgical guides. Following the exact protocol of each individual system is essential in the fabrication of surgical guides. Lack of attention to the specific protocols in imaging or the manufacturing of a ra-



FIGURE 11. Clinical presentation for the radiographic images above. The lower left molar (No. 19) will be replaced with an implant restoration. The surgical stent is used for proper implant placement. The photo shows the implant in the correct position as confirmed by the surgical stent. Clinical and radiographic appearance of final implant supported restoration replacing the lower left molar.



FIGURE 12. Diagnostic wax-up. (Image provided by Implant Logic.)



FIGURE 14. Implant Logic computerized milling machine used to manufacture surgical guides. (Image provided by Implant Logic.)



FIGURE 13. Radiographic guide with three reference markers. (Image provided by Implant Logic.)



FIGURE 15. Implant logic Pilot Guide and Compu-Guide. (Image provided by Implant Logic.)

diographic guide will result in the need for repeat CBCT scans, thus unnecessary X-ray exposure and ill-fitting surgical guides.

Five-axis Milling and Virtual Model Treatment Planning

Of the four 3-D programs referenced, only Implant Logic utilizes a five-axis milling technique for manufacturing of its surgical guide. Called Compu-Guide, manufacturing requires the doctor to send diagnostic models to Implant Logic located in Cedarhurst, N.Y. A diagnostic wax-up is used to fabricate the radiographic guide (**FIGURE 12**). The radiographic guide is then fabri-

cated using the barium crowns (which allow the visualization of the crowns in the CBCT scan), along with three radiographic markers that have been triangulated to the outside occlusal surface of the guide (**FIGURE 13**). The guide is returned for imaging, a CBVT scan is taken with the patient wearing the guide. Using the Virtual Implant Placement program, the restorative dentist and surgeon plan the surgery. The radiographic guide, along with the VIP treatment plan, is returned to Implant Logic. Implant Logic then uses the treatment plan with their computer-aided five-axis milling machine

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FIGURE 16. Implant delivery through surgical guide. (Image provided by Implant Logic.)



FIGURE 17. Three-dimensional rendering of the mandible. (Image created in Simplant, C-Dental X-Ray, Inc.)



FIGURE 18. Simplant radiographic guide with barium sulfate. (Image provided by Materialise – Simplant.)

and fabricates Compu-Guide (FIGURE 14). Two types of guides are available, the Pilot Compu-Guide and the Complete Compu-Guide (FIGURE 15). Pilot Compu-Guides start at \$195 with each additional implant site costing \$50. The Complete Compu-Guide starts at \$195 with each addition implants site costing \$75. The Complete Compu-Guide includes both the Pilot Compu-Guide and additional guides needed for remainder of drilling. An important feature of the Complete Compu-Guide is the ability to deliver implants through the guide (FIGURE 16). The cost of the VIP software is \$3,600. From the patient's initial appointment with the doctor, it takes approximately 15 working days to receive their Compu-Guide. For nonaesthetic implant sites, Implant Logic makes a template for the radiographic guide that can be fabricated in the doctor's office. This option can reduce time between the first office visit and receipt of the surgical guide. Additional information about Implant Logic's Compu-Guide can be found at www.implantlogic.com.

Treatment Planning With STL Files

Simplant, Nobel Biocare, and iDent utilize stereolithography files (STL) to manufacture their guides.

An STL is a file format native to the stereolithography CAD software created by 3D-Systems. This file format is supported by many other software packages; it is widely used for rapid prototyping and computer-aided manufacturing. STL machines are basically 3-D printers that can build any volume shape as a series of slices.⁵

Materialise's 3-D Treatment Program

Materialise, a 3-D software and rapid-prototyping company in Belgium, manufactures three different types of surgical guides; bone, mucosa, and tooth-supported. SurgiGuides are manufactured utilizing their 3-D treatment program, Simplant. Simplant exports its proprietary file format into a universal STL file. This file is used to manufacture the SurgiGuide. Bone-supported SurgiGuide's are entirely manufactured from the CBCT data (FIGURE 17). The mucosa-supported guide for fully edentulous patients (enabling a flapless surgery) requires a duplicate of a well-fitting denture or a set of diagnostic models with wax-up. In this case, both the base plate and crowns of radiographic guide must consist of 15 percent barium (BaSo₄) and 85 percent acrylic (FIGURE 18). For tooth-supported guides, the radiographic guide should be fabricated of clear acrylic; the crowns should be made of the same barium-acrylic mixture. The mixture of barium and clear acrylic permits the visualization of the crowns in the treatment planning program. Where prosthetics are of no concern, the scan can be taken with no radiographic guide at all. The manufacturing of the SurgiGuide necessitates the treatment plan and patient models be sent to Belgium. It takes approximately 10 working days for the clinician to receive the surgical guide.

Currently, guides start at \$400 regardless of quantity of sites. This includes a series of three guides. Each additional guide needed for additional drill sizes are \$50. SAFE system guides, which utilize a master sleeve and allow for depth

control, start at \$400 with each additional osteotomy site at \$25. Implants can be delivered through the SAFE system guides. Simplant treatment planning software (Simplant Planner) is priced at \$3,775-\$4,490. A free Simplant viewer is also available for the viewing of treatment plans created in the full version of Simplant Planner. Additional information about Materialise's SurgiGuides can be found at www.materialisedental.com.

Nobel Biocare's 3-D Treatment Program

Nobel Biocare, an implant manufacturer in Sweden, has recently developed 3-D planning software of its own, Procera. The Procera platform utilizes the dual-scan technique. This protocol calls for a radiographic guide fabricated from radio-transparent material (such as clear acrylic) and is marked with 8-10 gutta-percha markers on the lingual or buccal flange of the guide. A patient's well-fitting existing prosthesis can be marked with gutta-percha and also used (FIGURE 19). The patient is scanned wearing the guide and the guide itself is scanned alone. Again, the guide must represent the patient's final prosthetic appliance thus enabling maximum prosthetic planning in the Procera software. The software uses the gutta-perch markers as reference points to merge the two scans. The guide can now be distinguished in the software (FIGURE 20). The treatment plan is rendered in the Procera software.

Once the treatment plan is applied to the virtual guide, an STL file is rendered. This file essentially becomes a digital duplicate of the radiographic



FIGURE 19. Well-fitting hard lined maxillary denture with eight gutta-percha markers. (C-Dental X-Ray, Inc.)

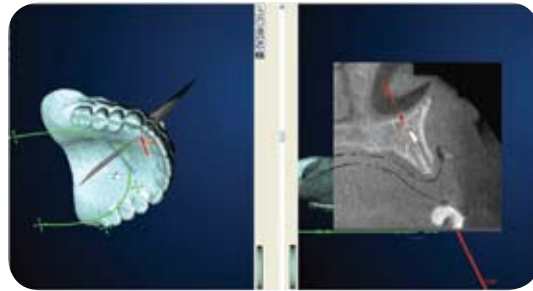


FIGURE 20. Three-dimensional view of surgical guide with implant trajectory and cross sections. (Images created in Nobel Biocare's ProCera Software, C-Dental X-Ray, Inc.)



FIGURE 21. Model and model with radiographic guide. (Images provide by Graham Simpson, DDS.)

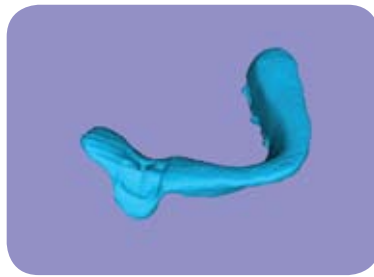


FIGURE 22. Three-dimensional rendering of radiographic guide. (Image created in iDent's Scan2Guide software, provided by McCormack Dental Imaging.)

iDent's Treatment Planning Program

iDent, located in Tel Aviv, Israel, is the maker of the Scan2Guide software. Unlike other manufacturers of surgical guides, they have licensed their technology for manufacturing guides in the United States. This system also utilizes the dual scan technique merging scan data together much like the ProCera system. The radiographic guide required is also similar but requires only six gutta-percha markers. Existing well-fitting prostheses can be used. Accurate representation of the crowns to be restored is critical to utilize the software as a prosthetic planning tool. The radiographic guide can be visualized in all planes of the CT image. From the treatment plan that is rendered, in the software, a STL file of the iGuide is created. The STL file is the 3-D model of the iGuide that will be produced. It is essentially a digital duplicate of the radiographic guide with changes made by the software for the treatment plan the user has rendered. Using rapid prototype printing the guide is fabricated. This guide will be accurate to .2 tenths of a mm and can be used with any implant platform. Generally, the time between the scan of the patient and receipt of the iGuide is four working days. iGuides start at \$200 for a guide with a single site, and \$20 for additional sites. The cost of the Scan2Guide software is \$1,000. For more information on the Scan2Guide system, visit www.ident-surgical.com.

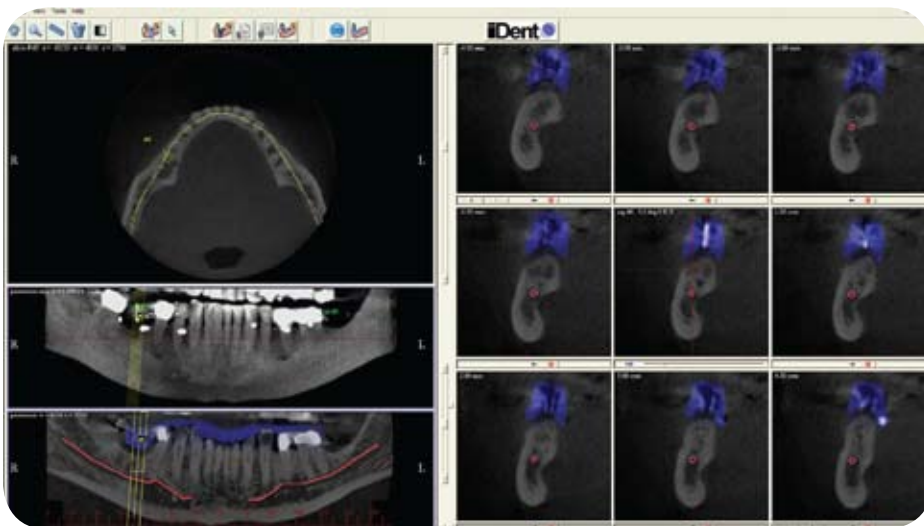


FIGURE 23. Axial, panoramic, and cross-sectional views of patient's CBCT scan with radiographic guide shown in blue. (Images created in iDent's Scan2Guide software, provided by McCormack Dental Imaging.)

guide with the necessary tunnels for the surgery. The surgical guide will fit as well as the radiographic guide. Nobel Guides use a master sleeve system so only one guide is necessary for the surgery. Total time up to receipt of

the surgical guide is 10 working days. Nobel Guides range in price from \$350 to \$600. The ProCera software starts at \$3,500. Additional information about Nobel Biocare's Nobel Guides can be found at www.nobelbiocare.com.

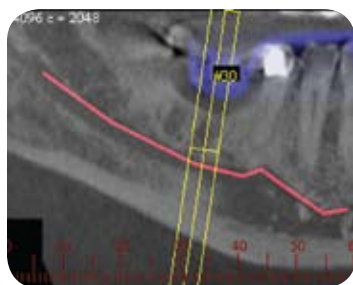


FIGURE 24. Adjustment of implant trajectory in panoramic. (Images created in iDent's Scan2Guide software, provided by McCormack Dental Imaging.)



FIGURE 25. Measurement in the center cross section of the desired implant site from the inferior alveolar nerve canal to the alveolar crest. (Images created in iDent's Scan2Guide software, provided by McCormack Dental Imaging.)

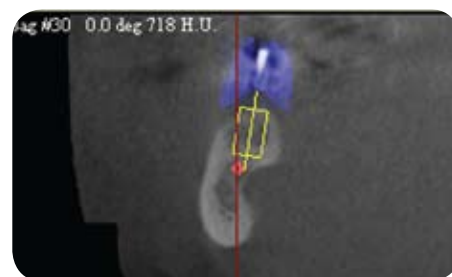


FIGURE 26. Initial placement of implant. (Images created in iDent's Scan2Guide software, provided by McCormack Dental Imaging.)

Illustration Case Using iDent's Scan2Guide

The patient, a 66-year-old male, had been seen by a prosthodontist for the possible placement of an implant for No. 30. The patient was tired of wearing a removable partial and inquired about implant placement. At the consultation, the patient was advised of his choices: a new partial, a three-unit bridge, or an implant. The patient was inclined toward the implant. When the patient was informed of the risks of the procedure, he voiced immediate concern that the nerve canal could be damaged by the placement of the implant and the resulting complications. The decision was made to manufacture a radiographic guide and have the patient imaged using CBVT.

Construction of Radiographic Guide and Image Analysis

The concerns were the proximity of the implant to the inferior alveolar nerve canal, buccal and lingual plates, and the proper emergence profile. Plaster models were fabricated, and, from that, a radiographic guide was fabricated according to the protocols of the 3-D treatment software used for this case (FIGURE 21). The patient was scanned wearing the radiographic guide. According to the radiographic protocol, the guide was scanned alone and now represents the digital duplicate of the radiographic guide (FIGURE 22). The scan

of the patient wearing the radiographic guide and the separate scan of the guide are then fused, allowing the visualization of the guide in the CBVT scan.

In this case (FIGURE 23), the radiographic guide is visualized in blue; the image in the upper left hand corner is the axial view. This view is one of 118 axial slices, each 1 mm thick and spaced .4 mm apart. Scrolling through these slices allows the clinician to visualize the width of the mandible from its inferior border to the occlusal surface. The panoramic directly below the axial image is a maximum intensity projection. The MIP image is a full-surface rendering of anatomical structures. The panoramic image in the lower left hand corner is 1 mm thick. The yellow line in the axial view directly correlates to the delineation of the inferior alveolar nerve canal in the 1 mm panoramic. The yellow line is pushed buccal-lingually until the nerve canal becomes clearly visualized in the panoramic view. A marking tool is used to mark the superior aspect of the canal and the canal's anterior extension. The software automatically designates the location of the nerve in the nine cross sections.

The three yellow lines in the panoramic view represent the anterior-posterior plane of the cross sections and can be adjusted to help determine the proper emergence profile. In this case, the prosthodontist chose a profile parallel to the roots of the adjacent teeth as shown

in (FIGURE 24). Measurements were taken from the superior aspect of the inferior alveolar nerve canal to the alveolar crest to determine the height of bone and the length of implant that can be placed. The software provides an actual 1:1 distance of 10.27 mm (FIGURE 25). Based on the measurements taken, a 4 mm x 4 mm x 8.5 mm implant was chosen (FIGURE 26).

To ensure the optimum position additional measurements were taken showing 1.47 mm from the lingual apex of the implant to the lingual plate and a distance of 1.48 mm from the apex of the implant to the superior aspect of the nerve canal (FIGURE 27). The decision was then made to use a 4 x 4 x 7 mm implant. This produced acceptable distances of 2.64 mm from the apex of the implant to the superior aspect of the canal as well as the distance of the implant to the lingual plate (FIGURE 28).

The implant placement is then analyzed in another dimension by scrolling through the axial slices helping to ensure there is not communication between the implant and the periodontal ligament of the adjacent teeth (FIGURE 29). An additional feature of the software provides the clinician with bone density measurements in Hounsfield units from the apex to the coronal aspect of the implant. The bone density of the planned implant location helps the clinician in determining Type 1, 2, 3, or 4 bone qualities (FIGURE 30).

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FIGURE 27. Measurements taken from the lingual apex of the implant to the lingual plate and from the apex of the implant to superior aspect of the alveolar nerve canal when a 4 mm x 4 mm x 8.5 mm implant is placed. (Images created in iDent's Scan2Guide software, provided by McCormack Dental Imaging.)



FIGURE 28. Measurements taken from the lingual apex of the implant to the lingual plate and from the apex of the implant to inferior alveolar nerve canal when a 4 mm x 4 mm x 7 mm implant is placed. (Images created in iDent's Scan2Guide software, provided by McCormack Dental Imaging.)

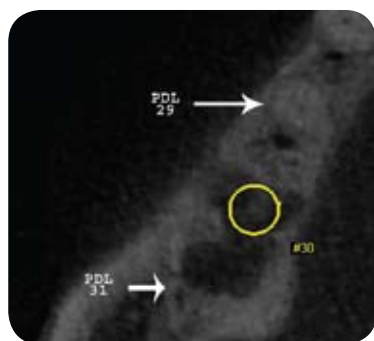


FIGURE 29. Axial view with implant placed showing proximity of adjacent teeth's PDL. (Images created in iDent's Scan2Guide software, provided by McCormack Dental Imaging.)

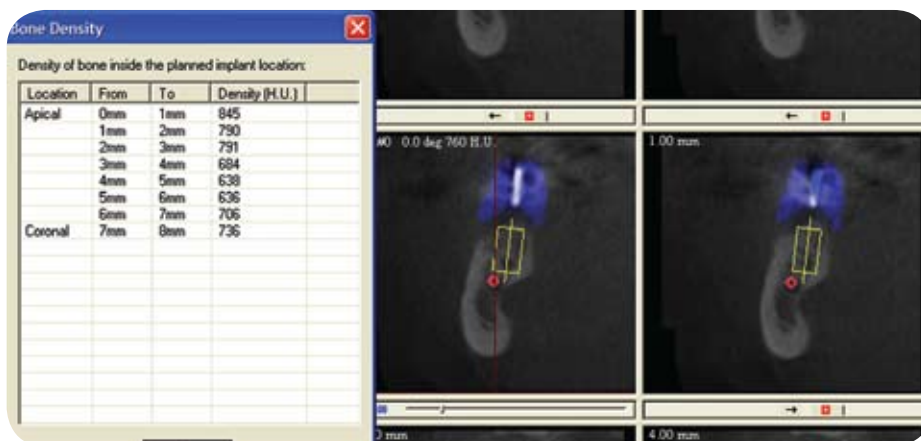


FIGURE 30. Density of bone surrounding planned implant location, provided in Hounsfield units. (Images created in iDent's Scan2Guide software, provided by McCormack Dental Imaging.)



FIGURE 31. Surgical guides with graduated sleeve size to accommodate surgical drills. (Image provide by Graham Simpson, DDS.)



FIGURE 32. Handles tools, which are inserted in master sleeve of the surgical guide according to drill size. (Image provided by Graham Simpson, DDS.)

Application of STL Model and Use of the Surgical Guide

The virtual guide is rendered within the software. Through rapid-prototype printing, a digital duplicate is created from the STL file. The STL file is sent to the rapid prototype printer. The printer lays out 16 micron layers of light-cured acrylic in manufacturing the guide. Titanium sleeves are then placed into the tunnel of the guide. Each guide has a sleeve with one-tenth of a millimeter tolerance for

each drill used in the surgery (FIGURE 31). The cost of multiple guides can be reduced by utilizing a master sleeve. The master sleeve facilitates the placement of handled sleeves, which are custom made to a tolerance of one-tenth of a mm to each individual drill (FIGURE 32). The surgical guide ensures a proper placement of the implant per the virtual treatment plan (FIGURE 33).

A typical clinical case planned from with CBVT and 3D treatment planning would look like FIGURE 34.

Discussion

CBCT and 3-D treatment planning are emerging technologies for dentistry that offer alternative imaging options between 2-D imaging and model-based planning. The case examples illustrate how computer-assisted imaging, with multiplane views, a digitally manufactured surgical guide, with an accuracy of .3 mm, provide the clinician with the necessary information as to the proper prosthetic placement of implants. This .3 mm accuracy is achieved by using a CBCT with a voxel size of .2 mm and a drill sleeve with .1 mm tolerance to the drill. CBCT and 3-D imaging also improve the communication between the surgeon, restorative dentist and patient. Through the 3-D treatment planning the clinician is better able to understand the limitations that may be encountered in surgery before a flap is laid. These imaging and manufacturing capabilities do not exist with 2-D imaging and model-based treatment planning (TABLE 1).



FIGURE 33. Surgical guide in place at time of surgery. (Image provide by Graham Simpson, DDS.)

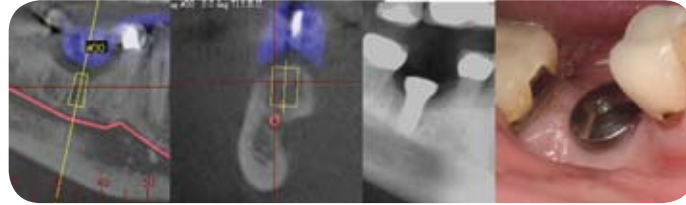


FIGURE 34. A typical clinical case planned from with CBVT and 3-D treatment planning. (Images provide by Graham Simpson, DDS, and McCormack Dental Imaging.)

TABLE 1

Limitations of Model Based Treatment Planning as Compared to 3-D Planning

	Model-based treatment planning with CBCT	3-D treatment planning with CBCT
Ability to visualize the anatomy in the 3 dimensions and determine real relationships between structures	X	X
Ability to accurately apply information and measurement taken from CBCT data to the surgical procedure		X
Ability to accurately choose the best size and placement of dental implants		X
Once implant is virtually placed, 1:1 measurements can be obtained		X
Ensured placement in a compromised ridge situation, such as sinus lifts and ridge augmentation		X
Ability to establish final profile emergence of implant	X	X
Ability to determine proximity of implant to adjacent roots and PDL using panoramic, cross-sectional and axial views		X
Ability to manipulate CBCT data when treatment planning		X
Ability to assess bone density surrounding implant		X
Ability to manufacture surgical guide	X	X
Ability to manufacture guide with accuracy to .3 mm		X
Improved communication between surgeon and restorative dentist through online treatment planning		X

Conclusion

CBCT and 3-D treatment planning are emerging technologies that provide the clinician with the necessary information for routine and complex cases involving the placement of implants in the mandible or maxilla. ■■■■

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