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In-Office Cone Beam Computerized Tomography: Technology Review and Clinical Examples

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Computerized tomography (CT) has been utilized in medicine since the early 1970s, but it was not until the late 1980s that it was used in dentistry. The advantages of CT compared with traditional radiographic techniques are numerous, namely, offering a 3-dimensional view with unparalleled accuracy and clinical information.

The benefits of this technology have further clinical practicality when a cone beam computerized tomography (CBCT) machine can be placed in a dental practice, offering immediate results. In-office CT has many clinical applications for implant dental treatment. This article will outline the science of CBCT and provide clinical examples and advantages of an in-office CBCT device.

Available CT Technology

In 1979, G.N. Hounsfield and A.M. Cormack were awarded the Nobel Prize in medicine for the invention of CT. CT is one of the most important methods of radiological diagnosis, delivering non-superimposed cross-sectional images. The American Academy of Oral and Maxillofacial Radiology (AAOMR) “parameters of care” outlines rationalization for diagnosis, treatment planning, and follow-up for different aspects of dental conditions. These conditions include TMJ dysfunction, diseases of the jaw, and dental implant treatment planning. Traditional radiographs can adequately address these parameters, but CT can help to offer improved results due to the enhanced data presented.1

A CT image comprises slices along a plane of the object being viewed. The slices, called voxels, are then reconstructed. The x-ray energy from a CT scan is directed toward an object from multiple orientations, and the decrease in intensity is measured along a series of linear paths. The x-ray intensity reduction is a function of x-ray energy, path length, and the material linear attenuation coefficient. Beers Law characterizes these parameters; an algorithm is then used to reconstruct the distribution of x-ray attenuation.2

For most dental offices CT has not been widely utilized due to the cost of the procedure, radiation dosage, proximity to a CT site, and a dentist’s unfamiliarity with interpreting CT results. The use of CBCT can negate these concerns and allow for improved diagnosis and patient safety.3

The basic components of a CT device consist of an x-ray source, a series of detectors measuring attenuation along multiple beam paths, and a rotation device around the object being measured. There have been 5 generations of CT since Hounsfield’s invention in 1967. Each CT improvement is based on the organization of device parts and physical motion of the beam capturing the data. Currently, a fan beam CT scanner is typically seen in a hospital or CT site setting. With a fan-beam CT, data is acquired using a narrow, fan-shaped beam. The spiral radiation pattern offers information in slices that enlarge the area being targeted. Each slice is slightly overlapped and then reconstructed.4 The image detectors from the fan beam are arranged in an arc around the patient.

A CBCT utilizes a cone beam shape instead of a fan, and is more specifically targeted, allowing a better view of the head and neck. The cone-shaped x-ray beam transmits to a solid-shaped sensor to capture an image in a single rotation, whereas with a conventional CT, multiple slices are stacked. Cone beam technology is quicker and has less radiation due to no overlap of slices.5

The radiation exposure with CBCT is 20% that of a conventional CT and equivalent to a full-mouth series of x-rays.6 The amount of radiation from a CT depends on kVp and mA values. With a full-mouth series of radiographs using 150 µSv, a CBCT can be from 45 µSV to 650 µSv.4

Use of CT for Dental Implant Treatment Planning

Figure 1. *The i-CAT CBCT.*

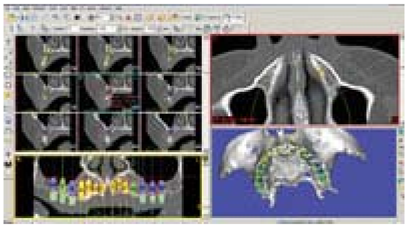

Figure 2. *SimPlant screen showing axial, panograph, cross-sectional, and 3-D views.*

Ideal treatment planning and diagnosis with an in-office CT is a reality with CBCT machines that are readily available for dental practitioners. In-office cone beam CT machines currently available in the United States include the following: i-CAT (Imaging Sciences International; Figure 1), 3-D Accuitomo (J. Morita), ILUMA (Kodak), NewTom VG (Dent-X, parent company AFP Imaging), CB MercuRay (Hitachi), Instrumentarium VT (PaloDEx Group), ProMax 3D (Planmeca), Galileos (Sirona), and PreXion 3D (PreXion).

The small footprint, speed of scans, reduced radiation, and ease of use create a realistic opportunity for dentists to have a CBCT in their offices. Once a CT is taken of a patient, the information is reformatted. Various medical imaging software applications are available to read data from a CBCT. One of the most popular is SimPlant (Materialise Dental), which reads data from a CBCT in DICOM (digital image communication in medicine) format. This is a standard format for medical imaging for any CT scanner and allows the segmentation of anatomical structures. The segmentation allows a 3-D volumetric rendering and navigation between voxels and 3-D panning, rotating, and zooming.7

The interactive nature of a computer-generated CT offers many advantages over a film-based CT. The simultaneous axial, panograph, cross-sectional, and 3-D views allow intuitive planning for dental implants and bone grafting (Figure 2). Utiliz-ing computer-generated CBCT allows for ideal treatment planning for many different aspects of implant dentistry and bone grafting.

Visualization of Anatomy

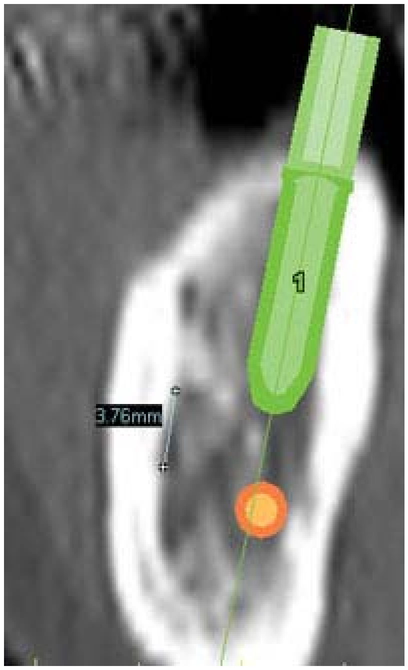

Figure 3a. *Cross-sectional view showing relationship of implant to nerve.*

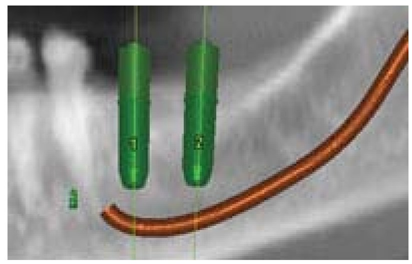

Figure 3b. *Panographic view of implants showing relationship to nerve.*

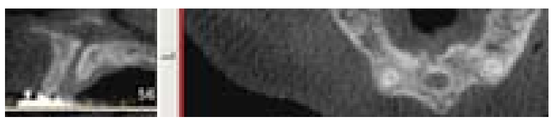

Figure 4. *Axial and cross-sectional view showing large incisal foramen.*

Before any surgical procedure is performed, including implant surgery, there must be an accurate assessment of the patient's anatomy. No technology offers a better view of anatomy than an interactive CT view. Prior to implant placement in the mandible, the inferior alveolar nerve must be visualized. A traditional panograph offers a limited 2-D view, and the relationship buccal or lingual to the inferior alveolar nerve cannot be ascertained. With CBCT, measurements can be made to within one tenth of a millimeter for implant placement8 (Figures 3a and 3b). When placing implants in the anterior maxilla, the incisal foramen can often be enlarged, creating a position problem for implant placement. An axial and cross-sectional view from a CBCT can show this prior to surgery (Figure 4).

Visualization of bone thickness

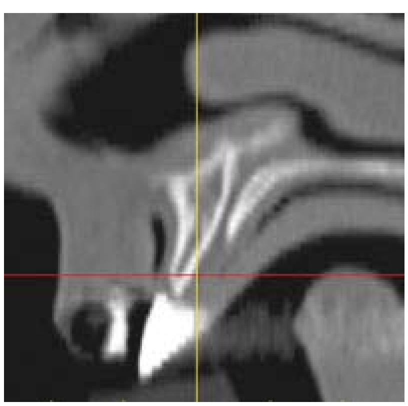

Figure 5. *Cross-sectional view showing thin ridge.*

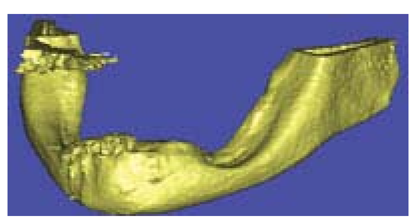

Figure 6. *A 3-D view of atrophic mandible.*

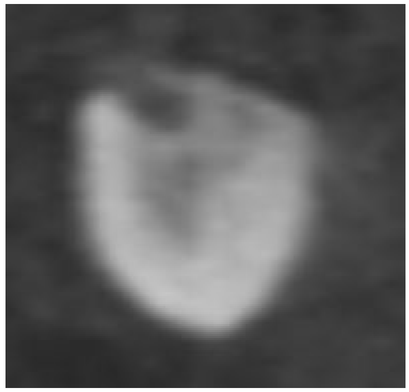

Figure 7. *Cross-sectional view showing mental foramen on superior aspect of ridge.*

The thickness and height of the osseous ridge determines where a dental implant can be placed. Using CBCT, ridge assessment can be performed accurately prior to surgery. If a ridge is thin, then augmentation or ridge splitting might be indicated (Figure 5). If a ridge has reduced height, sometimes soft tissue hides that fact. Through a CBCT the ridge height can be seen in a 3-D view (Figure 6). When there is extreme atrophy of a mandibular ridge, the mental foramen can be found on the superior aspect of the ridge (Figure 7). A CT can define the position of the foramen and avoid iatrogenic damage that can occur during surgical resection.

Visualization for Dental Implant Prosthetics

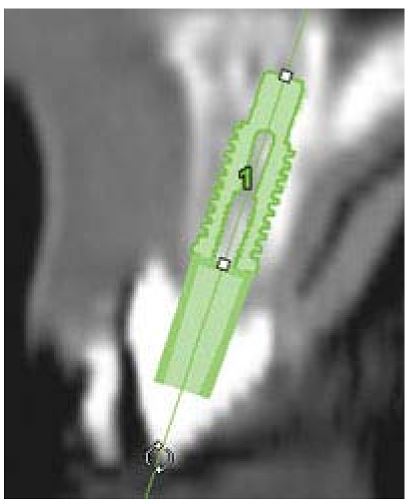

Figure 8a. *Cross-sectional view showing relationship of implant to final prosthetic position.*

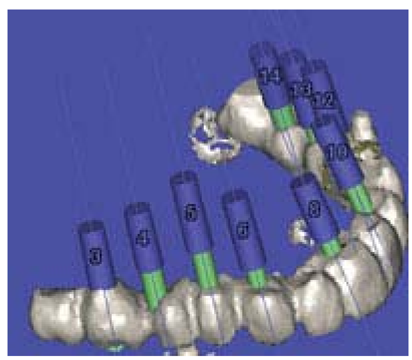

Figure 8b. *A 3-D view showing relationship of implants to prosthetic position for surgical stent.*

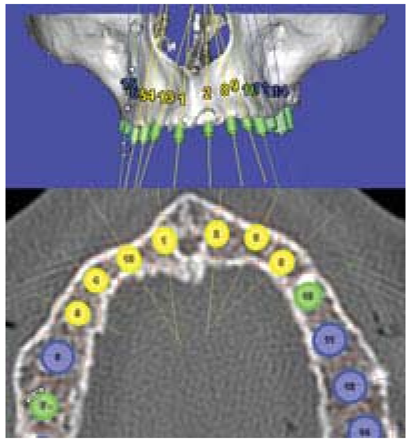

Figure 9. *A 3-D view showing dental implants in parallel position (top). Axial view of full arch showing spacing of implants (bottom).*

With the prosthetic end result dictating the final surgical position for dental implant placement, a CBCT can assist in this process. When a radiopaque marker is used to demark the final tooth position, the data can be seen on a CT (Figures 8a and 8b). The data can then be utilized to create a surgical guide for precise implant placement. By utilizing an interactive program, implants can be virtually placed to assist in planning a case (Figure 9). Information from an interactive program can offer significant information pertaining to implant spacing, angulations, and size of dental implants required.

Visualization for Sinus Grafting and Sinus Anatomy

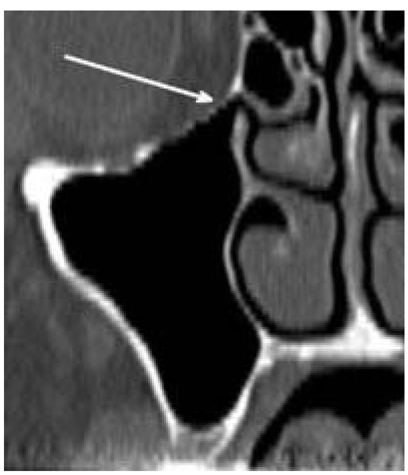

Figure 10. *Cross-sectional view. Arrow showing patency of OM complex.*

Figure 11. *Cross-sectional view showing sinus pathology.*

Figure 12. *Cross-sectional and panographic view showing perforation of sinus membrane.*

Figure 13a. *Cross-sectional view showing cyst in sinus.*

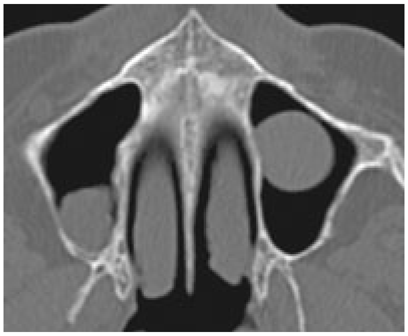

Figure 13b. *Axial sectional view of cysts in sinus cavities.*

Figure 14a. *Cross-sectional view of septae in sinus.*

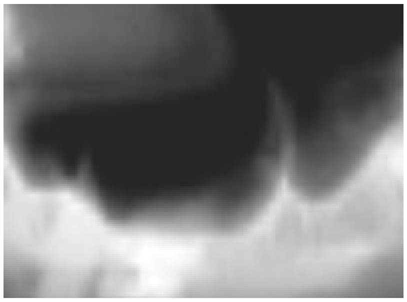

Figure 14b. *Cross-sectional view of septae in sinuses.*

A CT can offer valuable information to aid in successful grafting of the maxillary sinus. One of the first things a clinician should ascertain prior to grafting the maxillary sinus is the patency of the osteomedial complex (OMC; Figure 10). Without the available drainage from the OMC complex, complications could result after a graft. Another presurgical anatomical structure to examine with a CT is the health of the sinus membrane. If thickening of the membrane is observed, then a referral to an ENT specialist should be

done prior to surgery (Figure 11).
Another anatomical variation that is often observed prior to sinus surgery is a perforation of the sinus membrane (Figure 12). This is often due to infection. Thickening of the membrane or cysts are reasons for the clinician to refer a patient to an ENT (Figures 13a and 13b). Septae in the sinus are normal anatomical features, but by utilizing the information provided by a CT, surgical entrance into the sinus can be better planned (Figures 14a and 14b). The range of information gained through a CT can offer the clinician information to improve the success rate of grafting the maxillary sinus.

Visualization for Bone Grafting

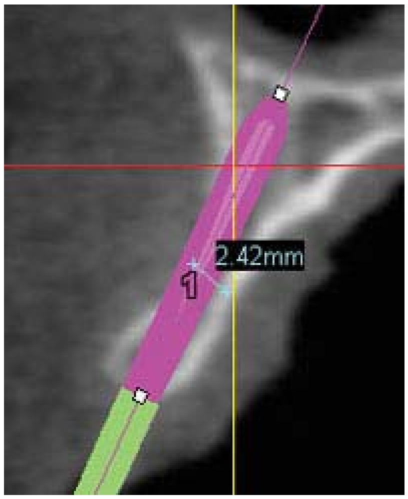

Figure 15. *Cross-sectional view showing where bone needs to be grafted buccal to implant.*

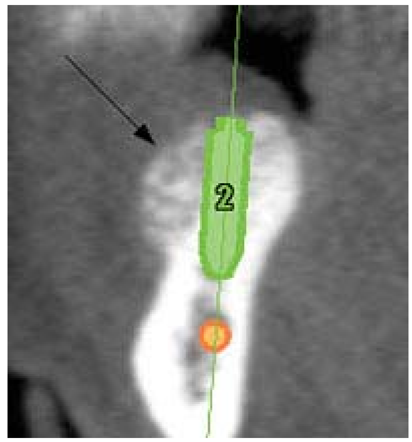

Figure 16. *Cross-sectional view of bone graft. Arrow shows bone formed from graft.*

A CT can identify areas of inadequate bone to support dental implants (Figure 15). A post-graft CT can also show the amount of bone formed and provide information as to bone density (Figure 16). This information is helpful in determining the volume of graft needed prior to surgery and the type of graft material to select.

Conclusion

This article has outlined the fundamental principles of CBCT and presented multiple clinical examples of how it can aid implant and bone grafting treatment planning. The advancements in CBCT allow for its routine use in a private dental practice. The use of an in-office CBCT offers many advantages to a dentist performing implant surgery or bone grafting. The relatively low radiation levels, speed of processing, and clarity of the image are main advantages over traditional radiographs. The 3-D views offer incomparable analysis for treatment planning and pathology detection.

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