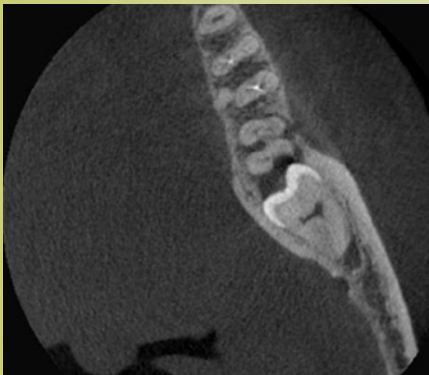
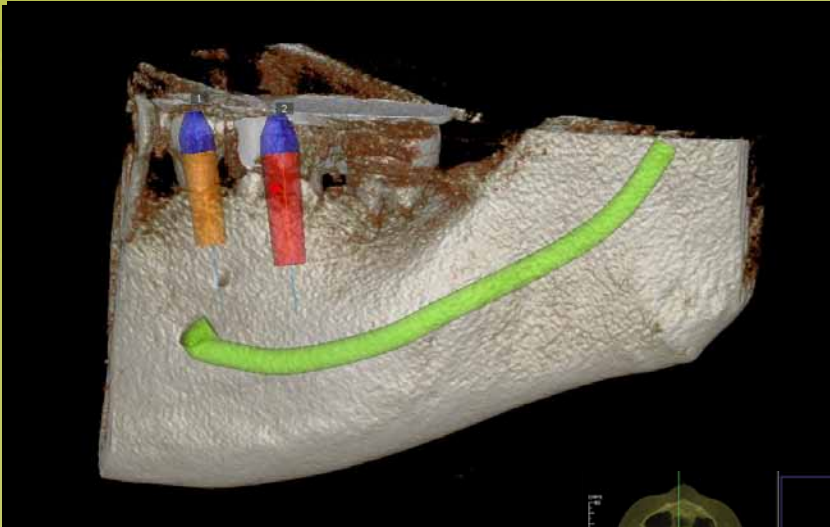


Earn

4 CE credits

This course was written for dentists, dental hygienists, and assistants.



The Genesis and Development of CBCT for Dentistry

A Peer-Reviewed Publication

Written by James Mah, DDS, DMSc, MS, BSc

ADA CERP® Continuing Education Recognition Program
PennWell is an ADA CERP Recognized Provider



inedce.com
The Academy of Dental Therapeutics and Stomatology®

suni
MEDICAL IMAGING INC

Go Green, Go Online to take your course

This course has been made possible through an unrestricted educational grant from Suni Medical Imaging Inc. The cost of this CE course is \$59.00 for 4 CE credits.
Cancellation/Refund Policy: Any participant who is not 100% satisfied with this course can request a full refund by contacting PennWell in writing.

Educational Objectives

The overall goal of this article is to provide dental professionals with information on the introduction of radiographic imaging to dentistry and the more recent evolution of dental imaging towards 3-dimensional imaging with cone-beam CT. Upon completion of this course, the participant will be able to do the following:

1. List the principles of cone beam computerized tomography (CBCT)
2. State the dosage considerations and the comparative doses with traditional radiographs and computerized tomography (CT)
3. List the indications for which CBCT offers enhanced imaging and aids in the identification of anatomical structures and oral-maxillofacial conditions
4. List the considerations in deciding whether to purchase a CBCT device or refer patients to imaging centers

Abstract

Cone beam computerized technology (CBCT) offers 3-dimensional visualization and more complex and more accurate imaging compared to analog and digital radiographs. It is an accurate tool for many clinical oral-maxillofacial indications, with lower radiation doses than computerized tomography. The clinician must determine the risk:benefit of imaging for each patient. Clinicians are rapidly realizing the significant advantages of CBCT imaging. Factors to consider in determining whether to purchase a CBCT device or to refer patients to imaging centers include cost, training, time required to generate images and reports, data transmission and storage, and responsibility for interpretation and pathology review.

Introduction

“I have discovered something interesting, but I do not know whether my observations are correct,” stated Wilhelm Conrad Roentgen (Figure 1) in 1895 after he saw the bones of his hand clearly displayed in an outline of flesh when he held it between a cathode ray tube and a barium-coated screen. In December 1895 he reported this to the Wurzburg Physical-Medical Society with a radiograph of his wife’s hand (Figure 2), and within weeks of Roentgen’s report, newspapers and professional journals exploded with descriptions of his finding. By February 1896, most cities and small towns in the United States had seen demonstrations of the “new light.”

Figure 1.
Wilhelm Conrad Roentgen



Figure 2.
Radiograph of Mrs. Roentgen’s hand



Health care professionals immediately recognized the tremendous benefits of this discovery, and within a year, X-rays were being used in diagnosis and therapy, and radiographic images of foreign bodies, fractures, and stones were being taken. The importance of X-rays was also recognized in dentistry—only 14 days after Roentgen published his discovery, Dr. Walkhoff, a dentist in Braunschweig, Germany, produced images of teeth. These intraoral X-rays were produced with small glass photographic plates wrapped in sheets of black paper and rubber. By 1900, about a dozen dentists in the United States were using X-rays in their practices. After a period of skepticism and debate over the benefits of radiographs compared to transillumination, dentists began to routinely use X-rays in routine dental examinations. Dental clinicians came to rely greatly on radiograph and scanning technology for the diagnosis of disease and for the identification of anatomical structures for treatment planning. The number of radiographs taken by private practitioners, excluding those taken in hospital and academic settings, has steadily increased (Table 1).

Table 1. Use of X-rays in dentistry

Number of radiographs		
	1999	1990
Bitewing	112,836,100	95,618,400
Periapical	80,259,100	NA
Complete series	17,024,800	14,510,400
Panoramic films	20,845,900	15,389,500

Source: American Dental Association. The 1999 survey of dental services rendered.

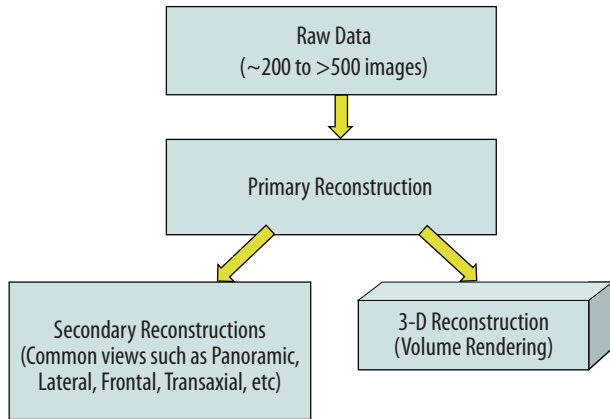
Although the basic technology of dental radiography has remained unchanged for conventional imaging, a significant development was the introduction of faster films, which reduced radiation doses to patients. This development was furthered by the introduction of digital radiography. With digital radiography, radiation doses generally are lower than with conventional dental radiographs. They offer quicker image taking and accuracy, the ability to store the images indefinitely in computer archives without deterioration, and the ability to send them to other clinicians as a digital file when required.

Cone Beam Computerized Tomography

From the early days of dental radiographs, the concepts did not change significantly until 3-dimensional imaging was introduced. Computed tomography was available for 3-dimensional dental imaging in the 1980s, but due to the high cost, limited access, and radiation exposure, utilization was limited to management of craniofacial anomalies, complex surgeries, and other unique dental situations. In 1988, cone beam computerized tomography (CBCT) was introduced to dentistry. This technology offered 3-dimensional visualization and more complex and more accurate imaging compared to analog and digital radiographs. CBCT is not a new concept and was originally devised as a cost-effective and efficient

method for obtaining cross-sectional 3-dimensional images for radiotherapy, and later for angiography.^{1,2} Conventional medical computerized tomography (CT) devices image patients in a series of axial plane slices that are captured as individual stacked slices or from a continuous spiral motion over the axial plane. Conversely, CBCT presently uses one or two rotation sweeps of the patient similar to that for panoramic radiography. Image data can be collected for a complete dental/maxillofacial volume or limited regional area of interest. Scan times for these vary from approximately 5 to 90 seconds. The X-ray energy of CBCT is similar to that of panoramic radiography with a typical operating range of 1-15 mA at 90-120 kVp, while that of medical CT is significantly higher at 120-150 mA, at 220 kVp. These operational differences are some of the most significant differences between the two technologies, although there is often confusion since both provide 3-dimensional visualization and include “computed tomography” in their description.

Figure 3. Scan to raw data to reconstruction



Radiation Doses for X-ray Technologies

CBCT technology allows scan times to vary, typically from 5.7 to 40 seconds, with an exposure dose typically in the range of 40 to 135 μ SV, a fraction of the radiation dose of an equivalent CT scan. The effective absorbed radiation dose for a complete cone beam volume tomographic image of the maxillofacial area is within the range of a full-mouth dental periapical survey.^{3,4} For the purposes of comparison, the effective absorbed radiation doses for dental images are listed in Table 2. One must bear in mind that one cone beam volumetric imaging session can provide all of the other dental images with the exception of the full-mouth series, although this capability seems to be in the near future. CBCT offers accurate 3-dimensional scanning with radiation doses that are lower than those of computerized tomography and enable its use in a normal clinical dental setting.^{5,6} As a result, CBCT scanning for accurate diagnosis and planning can be performed in-office or referred out. Since the systems and software are specifically developed for dental applications, the images are superior to those of medical CT for dental uses.

Table 2. Effective doses from dental imaging

Panoramic film	3-11 μ S
Lateral cephalograph	5-7 μ S
PA cephalograph	5-7 μ S
Occlusal film	5 μ S
Full mouth series	30-80 μ S
TMJ series	20-30 μ S
CBCT	18-135 μ S

Ranges above are for traditional and digital imaging combined

CBCT Indications and Accuracy

A basic principle of diagnostic imaging is that a specific clinical indication calls for selected diagnostic imaging to better plan treatments. CBCT is an accurate and useful tool for many clinical oral-maxillofacial indications, including the identification of anatomical structures and locations prior to implant placement and other oral surgery procedures, prior to and during endodontic procedures and when planning treatment for orthodontics. Recently, CBCT scans have also been studied for their ability to noninvasively measure the thickness of palatal mucosa in different locations, and have been found to be accurate.⁷

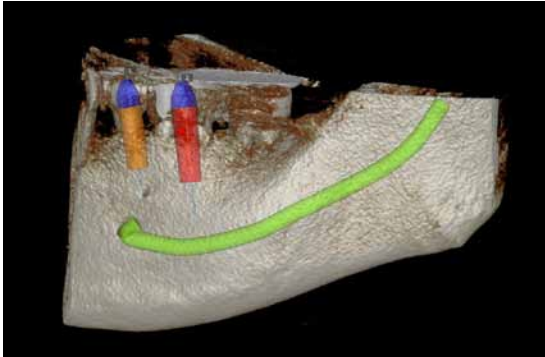
CBCT also plays a role in the identification, diagnosis, and determination of the severity of diseases. A retrospective assessment in Germany found that 90% of referrals for CBCT scanning were largely for identification and examination of structures prior to oral and maxillofacial surgery or implant placement, and to enable treatment planning and preparation. Reasons for referrals were mainly related to wisdom tooth anatomy, cystic lesions, and the positioning of mediodents and impacted canines and premolars.⁸ The majority of CBCT users in dentistry in the United States are clinicians placing dental implants.

Dental Implants

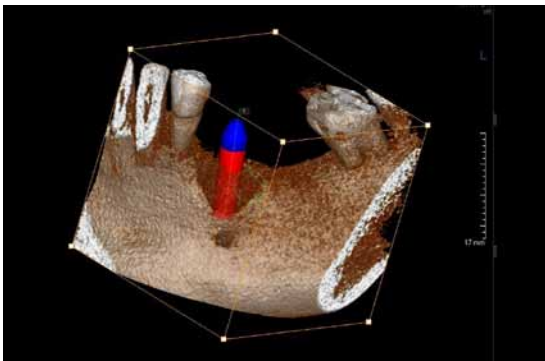
Information about bone height, regional width, bone ridge thickness and morphology, and inferior alveolar nerve canal location (if applicable) is essential for selection of the correct dental implant size and length.⁹ Implant planning using a surgical guide stent and CBCT will provide information that results in a safe clinical procedure that avoids inferior alveolar nerve trauma, maxillary sinus penetration, and other iatrogenic sequelae of dental implant placement. CBCT provides the clinician with more precise and accurate imaging, providing better preoperative information and thereby helping avoid problems associated with any surgery in sites close to these structures or where compromising factors are present (Table 3). The importance of such accuracy should not be underestimated. Researchers have found that CBCT accurately detects differences in the loop length and diameter of mandibular canals in the interforaminal region, and that large variations in these structures occur between individuals. Investigators concluded that CBCT scans offer important preoperative

information for patients receiving implants in the interforaminal region (Figure 4).¹⁰ In addition, CBCT scans can detect accessory mental foramina.¹¹

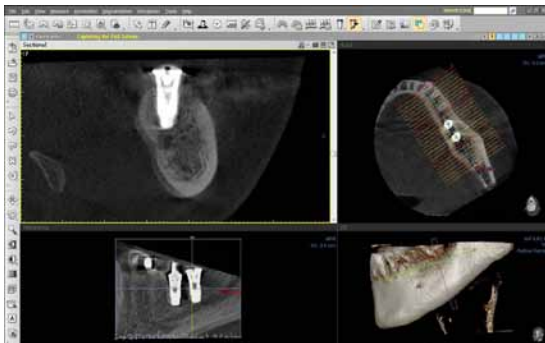
Figure 4. CBCT views for implant treatment planning



Canal draw for implant planning using CBCT



Treatment planning with a sectional implant image



Cross-sectional view of a case after implant placement

Bone quality is one of the factors responsible for primary implant stability and can be difficult to assess using traditional techniques. Song et al. found that bone thickness as determined by CBCT scans in 61 patients was accurate and predictive for primary implant stability.¹² These collective advantages of CBCT led the authors to conclude, "This imaging technology provides 3-D and cross-sectional views of the jaws. It is obvious that this hardware is not in the same class as CT machines in cost, size, weight, complexity, and radiation dose. It is thus considered to be the examination of choice when making a risk-benefit assessment."¹³

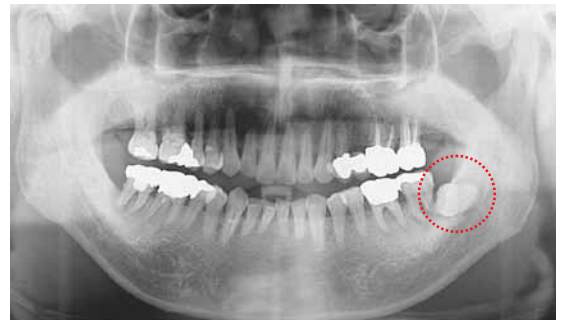
Table 3. Implant planning and anatomical considerations

Planning of exact implant position
Sinus lift
Intra-alveolar distraction osteogenesis
Reduced vertical bone height
Reduced horizontal bone width
Anatomical variations of the alveolar nerve
Preparation of templates

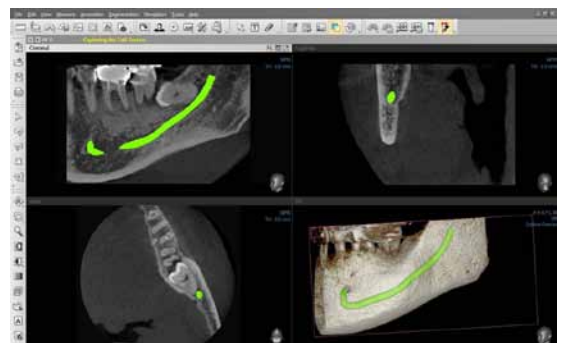
Oral Surgery

CBCT imaging offers improved intra- and inter-observer reliability for the identification of some facial anatomical features. Safe and optimal removal or transplantation of impacted wisdom teeth and localization of impacted canines are enhanced with the use of CBCT. In oral surgery, CBCT is superior in generating images to locate root position and proximity of impacted third molars to the inferior alveolar nerve, compared to 2-dimensional cephalographs (Figure 5) as well as other structures such as the infra-orbital artery (Figure 6).¹⁴

Figure 5. Mandibular CBCT views of impacted third molar

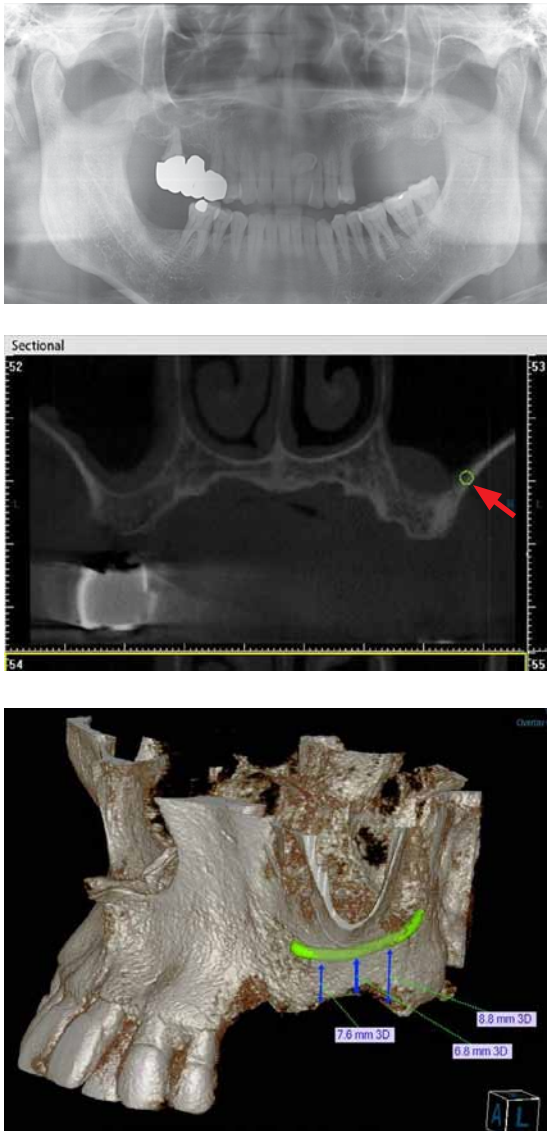


3rd molar in the Axial View (checking the root direction)



Coloring on the mandibular canal and diagnosis of the impacted tooth and location of the mandibular canal

Figure 6. Maxillary CBCT views with infra-orbital artery



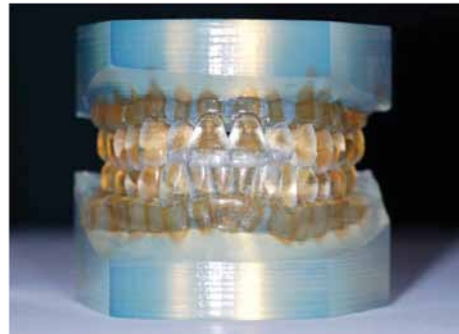
Note the ability to measure available bone to plan the surgery to avoid the infra-orbital artery

As an illustration of the accuracy of CBCT, bifid (bifurcated) mandibular canals are one of many considerations when planning mandibular surgery, and have been reported to be present in less than 1% of the population based on studies using panoramic radiographs. However, a recent study of more than 100 patients found bifid canals in 65% of patients when CBCT scanning was used.¹⁵ In a study correlating intra-operative surgical findings of impacted third molars and their relationship to the inferior alveolar dental canal, use of conventional imaging had 66% sensitivity as far as its ability to determine if the impacted third molar was in contact with the IDC, and 74% specificity to eliminate this possibility. This study underscores the limitations of conventional imaging approaches to evaluation of relatively common dental situations.¹⁶

Orthodontics

For orthodontics, one single CBCT scan can effectively generate all the images needed for orthodontic diagnosis including the lateral cephalograph, the panoramic radiograph, the antero-posterior cephalogram, temporo-mandibular joint tomograms, and many other oblique/cross-sectional slices previously unavailable in flat planar films,¹⁷ at a relatively equivalent radiation dose for a set of orthodontic X-ray initial records. In addition, leading technological developments are allowing for the production of virtual orthodontic study models from the same data set (Figure 7).¹⁸

Figure 7. Rapid prototyped anatomical models from CBCT



Many published articles have validated the use of CBCT images in orthodontics, including measurement accuracy, comparisons between 2-D and 3-D images for diagnosis and treatment planning, and the clinical use of native 3-D information from the DICOM data set. As Dr. B. Holly Broadbent's standardization of 2-D lateral cephalometric parameters has led to numerous orthodontic analyses, many research groups are in the process of developing new 3-D norms using anatomic landmarks previously unavailable on 2-D images. 3-D imaging allows for accurate and reliable assessment of the positions of impacted canines and supernumeraries (Figure 8) as well as of the adjacent teeth for resorption and surrounding soft and hard tissues.¹⁹ Serial CBCT scans can also measure and quantify volumetric changes of craniofacial structures using superimposition techniques.

Figure 8. 3-D view of a supernumerary



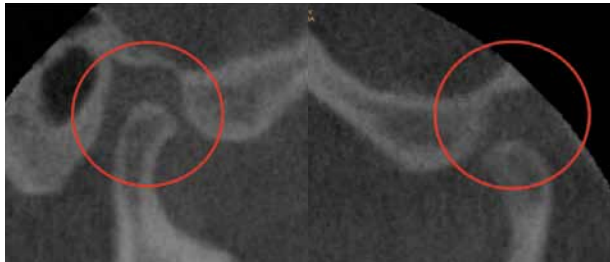
Advancements in software also allow analysis of skeletal structures, dental structures, and soft tissue structures in the same instance. Moving forth into the 4th and 5th dimension, many groups are also using these 3-D structures to study movement²⁰, e.g., TMJ function, occlusion (Figure 9a,b), and to develop finite element models (muscle attachment, bone biology with tooth movement). Furthermore, novel computer algorithms have been created to allow for voxel-based superimposition of 3-D data sets (Figure 10a,b). A voxel is a volume element or “volume cell”, representing a value on a grid in 3-dimensional space. It is analogous to a pixel or “picture cell” which represents 2D image data in a bitmap.

Figure 9a. Assessment of the TMJ and occlusion



Note: Occlusal pattern and condylar positions

Figure 9b. Close up of condylar positions



Note: Condyles are unseated revealing an anterior mandibular shift

This approach utilizes information from thousands of voxels in two-image sets to obtain the best possible superimposition. In contrast, conventional methods using landmark and/or anatomic structure identification, subsequent labeling, and matching create a significant chain of events that contain margins of error within each step.

Table 4. Orthodontic views and considerations

Panoramic views
Lateral cephalographs
Impacted canines
Planning of orthodontic anchorage implants/pins
Supernumerary teeth
Periodontal bone support

Figure 10a. Frontal superimposition to highlight orthodontic outcomes following functional appliance therapy

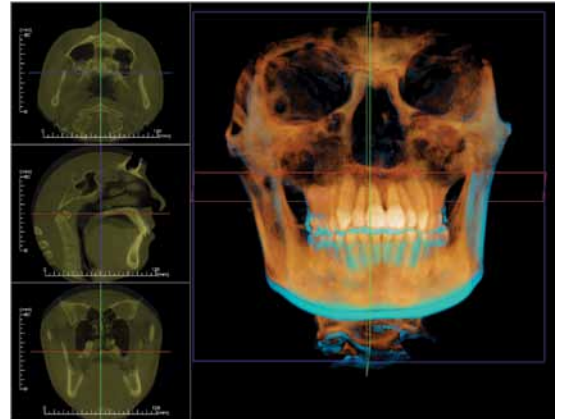
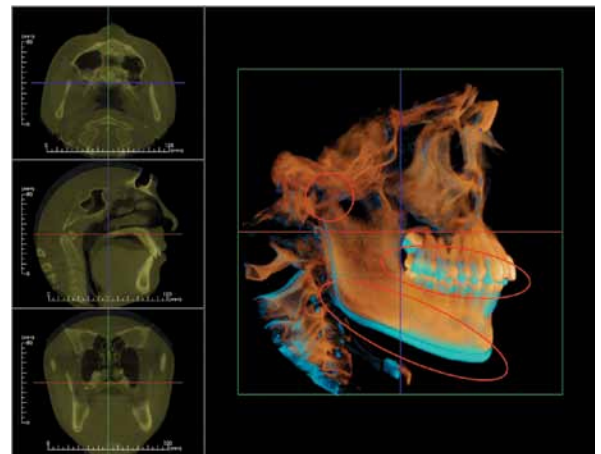


Figure 10b. Lateral superimposition to highlight orthodontic outcomes following functional appliance therapy



Endodontics

CBCT scans offer increased accuracy for the identification of root canals, and their location, prior to endodontic therapy.²¹ When compared with 2-dimensional digital radiographs, CBCT enables clinicians to identify more canals in multi-canal teeth that can then be instrumented and obturated, thereby increasing the likelihood of a successful outcome.²² CBCT scans were found in an *in vitro* study to be more accurate in showing apical periodontitis than were periapical radiographs. The CBCT scans detected these 84% of the time compared to 71% for apical radiographs, while apical periodontitis was found histologically 93% of the time. Periapical radiographs were concluded to be more likely to miss apical periodontitis and to be less accurate than CBCT scans.²³ One study found that artificially created voids larger than 300 μm in root canal sealers were detected using CBCT, standard radiographs (analog), and digital radiographs, while for smaller voids digital radiograph techniques were best.²⁴ CBCT scans have also been found to increase accuracy in identifying horizontal

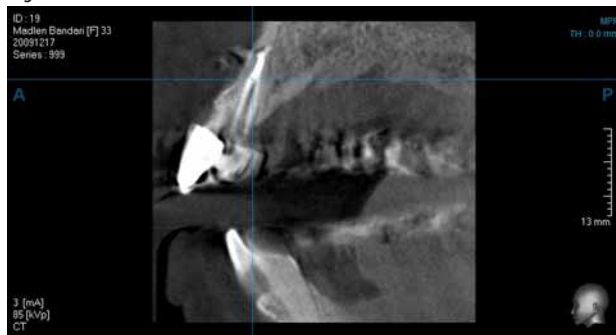
and vertical root fractures, which can be difficult to definitively diagnose using traditional methods (Figure 11). Hassan et al. found that CBCT offered greater sensitivity (80% versus 37%) compared to periapical radiographs for detecting vertical root fractures, with a specificity that was only slightly lower (92% versus 95%). It was also found that the presence of root canal fillings reduced accuracy. Overall, the accuracy of CBCT was 86% compared to 66% for periapical radiographs.²⁵

In one study in which radiographs led to the conclusion that the periapical tissues were healthy, CBCT scans detected apical periodontitis in a high percentage of cases. Furthermore, while the investigators found periapical healing with radiographs, the CBCT scans showed evidence of enlarged radiolucencies, indicating disease. They concluded that evaluation of long-term longitudinal studies using CBCT, and stricter criteria, were required to determine endodontic outcomes and success rates.²⁶ CBCT can also be used to help rule out endodontic pathology in cases of referred pain due to sinus infection.

Table 5. Endodontics and CBCT uses

Root morphology—shape, number of canals
Pathways of infection
Quality of root canal filling
Rule out referred pain (sinus)

Figure 11. Root fracture



Other Oral Pathological Conditions

CBCT scans are useful in cases where orofacial pain exists, and for the detection and/or diagnosis of osteoarthritis, osteoarthritis, hypoplasia, hyperplasia, aplasia, loose bodies, and neoplasia of the temporomandibular joints. Figure 12 shows the phenomenon of enostosis of the TMJ. CBCT scanning has also been used to assess the severity of TMJ osteoarthritis,²⁷ as well as to detect various oral pathological conditions such as apical cysts, fibrous dysplasia, and cementomas. Other dental applications include visualization of cleft palate cases in craniofacial anomalies, assessment of pharyngeal airway patency or obstruction, and sinus evaluation.^{28,29}

Figure 12a. Traditional panoramic unable to reveal enostosis in mandible



Figure 12b. Enostosis (bone locule) evident on CBCT image



Risk-Benefit

An important aspect of the diagnostic imaging using radiation is risk-benefit determination. This relies on less tangible information such as estimation of risk of populations and other generic information. In addition, each patient has a specific risk-benefit depending on the nature of his or her problems, history, and treatment plan. For X-rays, the principle of ALARA (As Low As Reasonably Achievable) applies; however, it can often be very difficult to specifically define this for a given patient, particularly if the patient's problem is atypical. For this reason, the American Dental Association has published general guidelines on the use of X-ray imaging in dentistry. There is very little if any information available to address the risks to patients if the imaging views are insufficient. The National Radiological Protection Board (NRPB) estimates risk of X-ray imaging as the additional risk of cancer due to exposure. On average, humans have a one in three chance of getting some type of cancer. Dental X-ray imaging is typically in the range of 10 to 100 μ Sv. At 10 μ Sv, the NRPB estimates the additional risk of cancer is negligible and is equivalent to a day or two of natural background radiation with some variation due to geographic location. On average, the daily exposure from naturally occurring sources such as the sun and earth is 8 μ Sv. At 100 μ Sv, the NRPB estimates that the additional risk, above the baseline of one in three, is minimal (1:100,000 to

1:1,000,000 chance) and equivalent to a few days or weeks of background radiation, depending on geographic location. Given these estimates of risk, the clinician must arrive at a risk:benefit determination for every diagnostic imaging session. While the risks of X-ray imaging are not to be ignored, the risks of misdiagnosis, and treatment complications and benefit to the patient, must also be weighed in.

Considerations for CBCT Ownership or CBCT Procedure Referral

Considering the modest diagnostic specificity and sensitivity of traditional dental imaging and recent scientific evidence strongly supporting 3-dimensional imaging, clinicians are rapidly realizing the significant advantages of CBCT imaging. However, they are still unsure how to integrate it into their private practice. Factors to consider include the initial cost of the scanner, training, relatively higher annual maintenance fees, the radiation exposure dictated by the field of view/kV/mA settings, primary reconstruction time, secondary reconstruction focus, image reformatting and report generation, data transmission and storage, and responsibility for interpretation and pathology review.

Individual Ownership

Initial and operational costs:

While the purchase cost of CBCT devices has dropped, it is still in the range of \$90,000 to \$250,000 depending largely upon the field of view, with many also requiring an annual maintenance agreement with fees ranging from \$8,000 to \$20,000 annually. Total cost analysis must include installation of adequate protective shielding such as lead walls and glass; electrical and computer requirements; and manpower to perform the tasks of scanning, image reformatting, and data management. In addition to the initial up-front cost of the purchase price and maintenance fee, other initial costs may include a requirement for computer hardware upgrades in the office in order to support the heavy graphics and processor demand of the 3-D imaging software and networking to link multiple computers for data access and processing. Facilities build-out costs may also be needed to support the physical accommodation of the CBCT unit. Recurring costs of CBCT unit ownership include the cost of the technician or assistant hired to take the scan and possibly that of generating the reports, tracing the lateral cephalogram, and printing the reports. The qualification of the technician varies from state to state. Depending on the output, the costs of photo-quality paper and inkjet printer and ink can also factor significantly into each patient scan workup.

Sensor type and size:

Many of the newer CBCT devices marketed toward the dental implant sector need only a limited field of view, and are installed with smaller sensors. Therefore, in order to capture all of the anatomical structures that are needed for orthodontic diagnosis (sella to nasion to pogonion to basion as a rough

perimeter outline), it is necessary to increase the field of view. This can be done via two methods: (1) a larger sensor, which will increase purchase cost; or (2) a greater scan time with two scan passes that are subsequently “stitched together” for the 3-D image; this method increases operational costs.

Primary/secondary reconstruction:

There is considerable variation in the time required to process the raw image captures and reconstruct this data into a format that can be visualized and manipulated on screen, depending on the specific CBCT device. During the active capture phase in which the X-ray generator rotates or moves around the patient’s head in approximately 10, 20 or 40 seconds, the device is capturing hundreds of raw X-ray images (e.g., the Hitachi MercuRay captures 288 raw images in a 9.8-sec pass and the Suni captures 280 raw images in 8.3 seconds). Using computer mathematical algorithms, these images are then pieced together and reconstructed into a 3-D volume. This process can take anywhere from 5 or 6 minutes to 30 minutes, depending on the device and amount of image data generated during the scan. Some systems allow the operator to perform a quick reconstruction for previewing the data and return later to perform a much higher resolution reconstruction taking a significantly longer time. This “downtime” is especially important if there is a high patient volume scan throughput, because during this reconstruction phase the scanner/computer is busy and cannot be used for other purposes. Recent developments allow for batching of patient scans so that they may be reconstructed at a later time when the computer is not occupied with image acquisition.

Image formatting/reports:

After the secondary reconstruction in which the 3-D volume is exported as a series of small Digital Imaging and Communications in Medicine (DICOM) files, similar to those of conventional medical CT slices, the 3-D volume is available for analysis. All CBCT devices come with imaging software for capturing and analyzing the information. Some are simple and user friendly for easy visualization of the 3-D object, while others are more complex but more powerful in the ability to measure distances, angles, and object segmentation. This is a consideration for the clinician, as staff training is required for extraction of useful information from the DICOM data. Generating a standard report with volumetric images, dentition views, panoramic radiograph, lateral cephalogram, and cephalometric analysis, in addition to any cross-sectional views necessary to view anomalous conditions, such as impacted canines or root resorption, becomes the crux of CBCT implementation in an orthodontic practice. Just as important is the amount of time needed to generate this report, because streamlining of the CBCT process from image capture to report output will dictate its success in the clinical private practice. Recently, service bureaus have emerged that offer to perform the reformatting for dental offices, thus providing high-level reformatted images while saving the office valuable clinical time.

Cost Sharing

The acquisition and operational costs of a CBCT device often exceed the budget for an individual clinician. Cost sharing is a feasible alternative when there is a group of clinicians who can provide the internal referrals required to support the use of a CBCT device. Many dental groups include providers for oral surgery, periodontics, pedodontics, endodontics, and orthodontics. While the demand for CBCT imaging is increasing, each specialty has certain specific needs from its CBCT images. A ready example is the difference between a dental implant clinician and an orthodontist or an endodontist. For placing dental implants, the usual region of interest is limited to a single arch or quadrant, and the resolution should be high enough to trace the inferior alveolar canal. However, for orthodontic purposes, a larger field of view is necessary to capture all the necessary sites of growth and development. Since orthodontists are looking at larger skeletal structures, resolution in the range of 300-400 μm is very acceptable, while an implantologist may prefer resolution in the range of 200-300 μm , and further, an endodontist may call for resolution in the range of <100-200 μm . Therefore, the selection of the CBCT machine becomes critical to the provision of information to all the clinical users. The ability of the CBCT device to store and transmit data must be considered in this shared ownership model. Newer CBCT softwares operate on a partial download platform, server-based software system, or a data compression system to expedite the DICOM information transfer. Recurring costs of technician salary and generation of report outputs are still applicable in this ownership model.

X-Ray Imaging Labs

The third option is to outsource this 3-D imaging, and it is rapidly becoming popular. Many 3-D X-ray imaging labs are opening as CBCT technology gains popularity and momentum. The cost of the scan is usually paid for by the patient in the form of an X-ray records fee, and most imaging centers are willing to work with the referring doctor to develop a customized report template to be delivered directly to the doctor's office. Advantages of this include no initial overhead, no operational costs, no investment for staff training, and no data communication/storage issues. However, this option is only available if there is a physical 3-D imaging center in the vicinity of the office. There is also the turnaround time between giving the patient the referral form, the patient actually getting the scan at the 3-D imaging center, and then the report being mailed back to the doctor's office. Most of the lag time in this situation is the patient actually making an appointment at the 3-D X-ray lab, possibly due to the associated inconvenience. As we become more aware of patient information privacy, The Health Insurance Portability and Accountability Act (HIPAA) becomes more of a concern in this emerging medical information field. There is usually a consent form signed by the patient giving permission to release information to the 3-D imaging centers. With outsourcing, the obvious limitation is

the availability of these services. In many urban communities, X-ray imaging labs have started to provide these 3-D imaging services, and almost all academic dental institutions in the United States have acquired a CBCT device.

Summary

The benefits of 3-D imaging apply to every dental discipline, and there is a corresponding trend toward integrating it into dental offices. Whether a clinician decides to buy a CBCT device, share the purchase with other colleagues, or refer the patient to an imaging center, this powerful technology will shape the future of dental diagnosis and treatment planning. Of particular note, malpractice litigation cases are already starting to cite the availability of this technology to provide additional and more accurate information obtained from CBCT scans compared to traditional 2-D planar radiography. Therefore, risk-management issues present the question of whether it is a liability if a clinician does not use this technology in diagnosis and treatment planning. However, it is also very important to emphasize that the use of 3-D imaging in itself does not preclude litigation issues. The 3-D data needs to be adequately interpreted. There are advantages and disadvantages of having a static printed report generated by a technician versus active manipulation of the 3-D data set by the trained clinician. Interpretative radiology reports provided by board-certified oral and maxillofacial radiologists can become important in the identification of other incidental or pathological findings within the 3-D data set.

There are numerous factors and issues involved with the use of CBCT. It is important for the private practice clinician not to shy away but rather to embrace this new concept of craniofacial diagnosis. Searching out as much information as possible about this technology is the first step toward successfully implementing it into private practices.

References

- 1 Harrison RM, Farmer FT. The determination of anatomical cross-sections using a radiotherapy simulator. *Br J Radiol.* 1978;51:448-53.
- 2 Cho PS, Johnson RH, Griffin TW. Cone-beam CT for radiotherapy applications. *Phys Med Biol.* 1995;40:1863-83.
- 3 Mah JK, Danforth RA, Bumann A, Hatcher D. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2003;96(4):508-13.
- 4 Ludlow JB, Davies-Ludlow LE, Brooks SL. Dosimetry of two extraoral direct digital imaging devices: NewTom cone beam CT and Orthophos Plus DS panoramic unit. *Dentomaxillofac Radiol.* 2003;32(4):229-34.
- 5 Eggers G, Senoo H, Kane G, Mühling J. The accuracy of image guided surgery based on cone beam computer tomography image data. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2009;107(3):e41-8.
- 6 Liang X, Jacobs R, Hassan B, Li L, Pauwels R, et al. A comparative evaluation of Cone Beam Computed Tomography (CBCT) and Multi-Slice CT (MSCT) Part I. On subjective image quality. *Eur J Radiol.* 2009 Apr 30. [Epub ahead of print]
- 7 Barriviera M, Duarte WR, Januário AL, Faber J, Bezerra AC. A new method to assess and measure palatal masticatory

- mucosa by cone-beam computerized tomography. *J Clin Periodontol.* 2009;36(7):564-8.
- 8 Rugani P, Kimbauer B, Armetzl GV, Jakse N. Cone beam computerized tomography: basics for digital planning in oral surgery and implantology. *Int J Comput Dent.* 2009;12(2):131-45.
 - 9 Hatcher DC, Dial C, Mayorga C. Cone beam CT for presurgical assessment of implant sites. *J Calif Dent Assoc.* 2003;31:825-33.
 - 10 Uchida Y, Noguchi N, Goto M, Yamashita Y, Hanihara T. Measurement of anterior loop length for the mandibular canal and diameter of the mandibular incisive canal to avoid nerve damage when installing endosseous implants in the interforaminal region: a second attempt introducing cone beam computed tomography. *J Oral Maxillofac Surg.* 2009;67(4):744-50.
 - 11 Naitoh M, Hiraiwa Y, Aimiya H, Gotoh K, Ariji E. Accessory mental foramen assessment using cone-beam computed tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2009;107(2):289-94. Epub 2008 Dec 13.
 - 12 Song YD, Jun SH, Kwon JJ. Correlation between bone quality evaluated by cone-beam computerized tomography and implant primary stability. *Int J Oral Maxillofac Implants.* 2009;24(1):59-64.
 - 13 Guerrero ME, Jacobs R, Loubele M, Schutyser F, Suetens P, et al. State of the art on cone beam CT imaging for preoperative planning of implant placement. *Clin Oral Investig.* 2006;10(1):1-7.
 - 14 Chien PC, Parks ET, Eraso F, Hartsfield JK, Roberts WE, et al. Comparison of reliability in anatomical landmark identification using two-dimensional digital cephalometrics and three-dimensional cone beam computed tomography in vivo. *Dentomaxillofac Radiol.* 2009;38(5):262-73.
 - 15 Naitoh M, Hiraiwa Y, Aimiya H, Ariji E. Observation of bifid mandibular canal using cone-beam computerized tomography. *Int J Oral Maxillofac Implants.* 2009;24(1):155-9.
 - 16 Bell GW, Rodgers JM, Grime RJ, Edwards KL, Hahn MR, et al. The accuracy of dental panoramic tomographs in determining the root morphology of mandibular third molar teeth before surgery. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2003 Jan;95(1):119-25.
 - 17 Huang JC, Bumann A, Mah J. 3-Dimensional Radiographic Analysis for Orthodontics. *J Clinical Orthod.* 2005;39(7):421-8.
 - 18 Mah J, Redmond R. The evolution of digital study models. *J Clin Orthod.* 2007;XLI (9):557.
 - 19 Walker L, Enciso R, Mah J. Three-dimensional localization of maxillary canines with cone-beam computed tomography. *Am J Orthod Dentofacial Orthoped.* 2005;128:418-23.
 - 20 Enciso R, Memon A, Fidaleo DA, Neumann U, Mah J. The virtual craniofacial patient: 3D jaw modeling and animation. *Studies in Health Technology & Informatics.* 2003;94:65-71.
 - 21 Baratto Filho F, Zaitter S, Haragushiku GA, de Campos EA, Abuabara A, et al. Analysis of the internal anatomy of maxillary first molars by using different methods. *J Endod.* 2009;35(3):337-42.
 - 22 Matherne RP, Angelopoulos C, Kulild JC, Tira D. Use of cone-beam computed tomography to identify root canal systems in vitro. *J Endod.* 2008;34(1):87-9.
 - 23 de Paula-Silva FW, Wu MK, Leonardo MR, da Silva LA, Wesselink PR. Accuracy of periapical radiography and cone-beam computed tomography scans in diagnosing apical periodontitis using histopathological findings as a gold standard. *J Endod.* 2009;35(7):1009-12.
 - 24 Huybrechts B, Bud M, Bergmans L, Lambrechts P, Jacobs R. Void detection in root fillings using intraoral analogue, intraoral digital and cone beam CT images. *Int Endod J.* 2009;42(8):675-85.
 - 25 Hassan B, Metska ME, Ozok AR, van der Stelt P, Wesselink PR. Detection of vertical root fractures in endodontically treated teeth by a cone beam computed tomography scan. *J Endod.* 2009;35(5):719-22.
 - 26 Wu MK, Shemesh H, Wesselink PR. Limitations of previously published systematic reviews evaluating the outcome of endodontic treatment. *Int Endod J.* 2009;42(8):656-66. Epub 2009 Jun 22.
 - 27 Alexiou K, Stamatakis H, Tsiklakis K. Evaluation of the severity of temporomandibular joint osteoarthritic changes related to age using cone beam computed tomography. *Dentomaxillofac Radiol.* 2009;38(3):141-7.
 - 28 Tsiklakis K, Syriopoulos K, Stamatakis HC. Radiographic examination of the temporomandibular joint using cone beam computed tomography. *Dentomaxillofac Radiol.* 2004;33:196-201.
 - 29 Aboudara CA, Hatcher D, Nielsen IL, Miller A. A three-dimensional evaluation of the upper airway in adolescents. *Orthod Craniofac Res.* 2003;6(Suppl 1):173-5.

Author Profile



James Mah, DDS, DMSc, MS, BSc

Dr. James Mah obtained his Bachelor of Science, Doctorate of Dental Surgery, Master of Science degrees and his Certificate of Specialization in Orthodontics from the University of Alberta, Canada. Subsequently, he graduated from Harvard Medical School with a Doctorate of Medical Science degree and completed a Post-Doctoral Fellowship in the Department of Orthopaedics at Children's Hospital, Boston. He was a full-time faculty member in the Department of Orthodontics at Harvard School of Dental Medicine.

Dr. Mah is an Associate Clinical Professor at the University of Southern California and the University of Nevada, Las Vegas. At USC he is the Director of Redmond Imaging Center and the Director of the Craniofacial Virtual Reality Laboratory.

Dr. Mah is a recognized expert in 3-Dimensional imaging, visualization and modelling. He serves as an editor for the *Journal of Clinical Orthodontics* and is a reviewer for the *American Journal of Orthodontics & Dentofacial Orthopedics*, *Journal of Clinical Orthodontics*, *Korean Orthodontic Journal*, the *International Journal of Oral Maxillofacial Surgery and Oral Surgery*, *Oral Medicine*, *Oral Pathology*, *Oral Radiology*, & *Endodontics and Dentomaxillofacial Radiology*.

Dr. Mah has authored over 80 publications, 4 textbooks and several book chapters.

Dr. Mah is a recognized expert in 3-Dimensional imaging, visualization and modelling. He serves as an editor for the *Journal of Clinical Orthodontics* and is a reviewer for the *American Journal of Orthodontics & Dentofacial Orthopedics*, *Journal of Clinical Orthodontics*, *Korean Orthodontic Journal*, the *International Journal of Oral Maxillofacial Surgery and Oral Surgery*, *Oral Medicine*, *Oral Pathology*, *Oral Radiology*, & *Endodontics and Dentomaxillofacial Radiology*.

Dr. Mah has authored over 80 publications, 4 textbooks and several book chapters.

Disclaimer

The author of this course has no commercial ties with the sponsors or the providers of the unrestricted educational grant for this course.

Reader Feedback

We encourage your comments on this or any PennWell course. For your convenience, an online feedback form is available at www.ineedce.com.

Online Completion

Use this page to review the questions and answers. Return to www.ineedce.com and sign in. If you have not previously purchased the program select it from the "Online Courses" listing and complete the online purchase. Once purchased the exam will be added to your Archives page where a Take Exam link will be provided. Click on the "Take Exam" link, complete all the program questions and submit your answers. An immediate grade report will be provided and upon receiving a passing grade your "Verification Form" will be provided immediately for viewing and/or printing. Verification Forms can be viewed and/or printed anytime in the future by returning to the site, sign in and return to your Archives Page.

Questions

- The first radiographs by Wilhelm Roentgen used a _____.
 - diode ray tube and a barium-coated screen
 - cathode ray tube and a helium-coated screen
 - cathode ray tube and a barium-coated screen
 - none of the above
- The number of radiographs taken by private practitioners, excluding those taken in hospital and academic settings, has steadily increased.
 - True
 - False
- Radiation doses with digital radiography generally are _____ with conventional dental radiographs, and they offer _____.
 - lower than; slower image taking
 - the same as; quicker image taking
 - lower than; quicker image taking
 - none of the above
- Cone beam computerized tomography was introduced to dentistry in _____.
 - 1978
 - 1988
 - 1998
 - 2008
- Using CBCT, image data can be collected for a complete dental/maxillofacial volume or limited regional area of interest.
 - True
 - False
- The X-ray energy of CBCT is similar to that of panoramic radiography with a typical operating range of _____.
 - 1-10 mA at 60-90 kVp
 - 1-15 mA at 90-120 kVp
 - 1-20 mA at 120-150 kVp
 - none of the above
- CBCT technology allows scan times to vary, typically from 5.7 to 40 seconds, with an exposure dose typically in the range of 40 to 135 μ SV.
 - True
 - False
- The effective absorbed radiation dose for a complete cone beam volume tomographic image of the maxillofacial area is within the range of a full-mouth dental periapical survey.
 - True
 - False
- The majority of CBCT users in dentistry in the United States are _____.
 - clinicians removing lower wisdom teeth
 - clinicians placing stents
 - clinicians placing dental implants
 - clinicians removing tori
- Researchers have found that CBCT accurately detects differences in the loop length and diameter of mandibular canals in the interforaminal region.
 - True
 - False
- Bone thickness determined from CT scans was found in one study to be accurate and predictive for primary implant stability.
 - True
 - False
- Safe and optimal removal or transplantation of impacted wisdom teeth and localization of impacted canines are enhanced with the use of CBCT.
 - True
 - False
- 3-D imaging allows for accurate and reliable assessment of the positions of _____.
 - impacted canines
 - trephines
 - supernumeraries
 - a and c
- A single CBCT scan can effectively generate all the images needed for orthodontic diagnosis.
 - True
 - False
- Serial CBCT scans can measure and quantify volumetric changes of craniofacial structures using _____ techniques.
 - bilateral
 - superimposition
 - trigonal
 - none of the above
- Virtual orthodontic study models can be created from CBCT scans.
 - True
 - False
- In one in vitro study, CBCT scans detected apical periodontitis _____ of the time compared to _____ of the time using apical radiographs.
 - 65%; 51%
 - 73%; 56%
 - 78%; 67%
 - 84%; 71%
- CBCT scans increase accuracy in identifying horizontal and vertical root fractures.
 - True
 - False
- Hassan et al. found that CBCT offered greater sensitivity (80% versus 37%) compared to periapical radiographs for detecting vertical root fractures.
 - True
 - False
- Dental applications of CBCT scans include _____.
 - the detection of various oral pathological conditions such as apical cysts
 - visualization of cleft palate cases
 - sinus evaluation
 - all of the above
- Recent developments allow for batching of patient scans so that they may be reconstructed at a later time.
 - True
 - False
- Piecing together raw X-ray images and reconstructing these into a 3-D volume can take anywhere from 5 or 6 minutes to 30 minutes, depending on the manufacturer.
 - True
 - False
- The clinician must arrive at a risk:benefit determination for every diagnostic imaging session.
 - True
 - False
- Only some CBCT devices come with imaging software for capturing and analyzing the information.
 - True
 - False
- Cost sharing is a feasible option when there is a group of clinicians who can provide the internal referrals required to support the use of a CBCT device.
 - True
 - False
- Annual maintenance agreements for CBCT machines have fees ranging from _____ annually.
 - \$4,000 to \$10,000
 - \$8,000 to \$20,000
 - \$12,000 to \$30,000
 - none of the above
- Since orthodontists are looking at larger skeletal structures, resolution in the range of _____ is very acceptable.
 - 100-200 μ m
 - 200-300 μ m
 - 300-400 μ m
 - none of the above
- An implantologist may prefer resolution in the range of 200-300 μ m, while an endodontist may call for resolution in the range of <100-200 μ m.
 - True
 - False
- X-ray imaging labs are only an option if there is a physical 3-D imaging center in the vicinity of the office.
 - True
 - False
- The benefits of 3-D imaging apply to every dental discipline.
 - True
 - False

The Genesis and Development of CBCT Technology for Dentistry

Name: _____ Title: _____ Specialty: _____

Address: _____ E-mail: _____

City: _____ State: _____ ZIP: _____ Country: _____

Telephone: Home () _____ Office () _____

Requirements for successful completion of the course and to obtain dental continuing education credits: 1) Read the entire course. 2) Complete all information above. 3) Complete answer sheets in either pen or pencil. 4) Mark only one answer for each question. 5) A score of 70% on this test will earn you 4 CE credits. 6) Complete the Course Evaluation below. 7) Make check payable to PennWell Corp. **For Questions call 216.398.7822**

Educational Objectives

- List the principles of cone beam computerized tomography (CBCT)
- State the dosage considerations and the comparative doses with traditional radiographs and computerized tomography
- List the indications for which CBCT offers enhanced imaging and aids in the identification of anatomical structures and oral maxillofacial conditions
- List the considerations in deciding whether to purchase a CBCT device or refer patients to imaging centers

Course Evaluation

Please evaluate this course by responding to the following statements, using a scale of Excellent = 5 to Poor = 0.

- | | | | | | | |
|---|-------------------|-----|-------------------|----|---|---|
| 1. Were the individual course objectives met? | Objective #1: Yes | No | Objective #3: Yes | No | | |
| | Objective #2: Yes | No | Objective #4: Yes | No | | |
| 2. To what extent were the course objectives accomplished overall? | 5 | 4 | 3 | 2 | 1 | 0 |
| 3. Please rate your personal mastery of the course objectives. | 5 | 4 | 3 | 2 | 1 | 0 |
| 4. How would you rate the objectives and educational methods? | 5 | 4 | 3 | 2 | 1 | 0 |
| 5. How do you rate the author's grasp of the topic? | 5 | 4 | 3 | 2 | 1 | 0 |
| 6. Please rate the instructor's effectiveness. | 5 | 4 | 3 | 2 | 1 | 0 |
| 7. Was the overall administration of the course effective? | 5 | 4 | 3 | 2 | 1 | 0 |
| 8. Do you feel that the references were adequate? | | Yes | | No | | |
| 9. Would you participate in a similar program on a different topic? | | Yes | | No | | |
| 10. If any of the continuing education questions were unclear or ambiguous, please list them. | _____ | | | | | |

11. Was there any subject matter you found confusing? Please describe.
- _____
- _____
12. What additional continuing dental education topics would you like to see?
- _____
- _____

If not taking online, mail completed answer sheet to
Academy of Dental Therapeutics and Stomatology,
 A Division of PennWell Corp.

P.O. Box 116, Chesterland, OH 44026
 or fax to: (440) 845-3447

For IMMEDIATE results, go to www.ineedce.com and click on the button "Take Tests Online." Answer sheets can be faxed with credit card payment to (440) 845-3447, (216) 398-7922, or (216) 255-6619.

Payment of \$59.00 is enclosed.
(Checks and credit cards are accepted.)

If paying by credit card, please complete the following: MC Visa AmEx Discover

Acct. Number: _____

Exp. Date: _____

Charges on your statement will show up as PennWell

- | | |
|---------------------|---------------------|
| 1. (A) (B) (C) (D) | 16. (A) (B) (C) (D) |
| 2. (A) (B) (C) (D) | 17. (A) (B) (C) (D) |
| 3. (A) (B) (C) (D) | 18. (A) (B) (C) (D) |
| 4. (A) (B) (C) (D) | 19. (A) (B) (C) (D) |
| 5. (A) (B) (C) (D) | 20. (A) (B) (C) (D) |
| 6. (A) (B) (C) (D) | 21. (A) (B) (C) (D) |
| 7. (A) (B) (C) (D) | 22. (A) (B) (C) (D) |
| 8. (A) (B) (C) (D) | 23. (A) (B) (C) (D) |
| 9. (A) (B) (C) (D) | 24. (A) (B) (C) (D) |
| 10. (A) (B) (C) (D) | 25. (A) (B) (C) (D) |
| 11. (A) (B) (C) (D) | 26. (A) (B) (C) (D) |
| 12. (A) (B) (C) (D) | 27. (A) (B) (C) (D) |
| 13. (A) (B) (C) (D) | 28. (A) (B) (C) (D) |
| 14. (A) (B) (C) (D) | 29. (A) (B) (C) (D) |
| 15. (A) (B) (C) (D) | 30. (A) (B) (C) (D) |

AGD Code 731

PLEASE PHOTOCOPY ANSWER SHEET FOR ADDITIONAL PARTICIPANTS.

AUTHOR DISCLAIMER
 The author of this course has no commercial ties with the sponsors or the providers of the unrestricted educational grant for this course.

SPONSOR/PROVIDER
 This course was made possible through an unrestricted educational grant from SUNI Medical Imaging, Inc. No manufacturer or third party has had any input into the development of course content. All content has been derived from references listed, and/or the opinions of clinicians. Please direct all questions pertaining to PennWell or the administration of this course to Machele Galloway, 1421 S. Sheridan Rd., Tulsa, OK 74112 or macheleg@pennwell.com.

COURSE EVALUATION and PARTICIPANT FEEDBACK
 We encourage participant feedback pertaining to all courses. Please be sure to complete the survey included with the course. Please e-mail all questions to: macheleg@pennwell.com.

INSTRUCTIONS
 All questions should have only one answer. Grading of this examination is done manually. Participants will receive confirmation of passing by receipt of a verification form. Verification forms will be mailed within two weeks after taking an examination.

EDUCATIONAL DISCLAIMER
 The opinions of efficacy or perceived value of any products or companies mentioned in this course and expressed herein are those of the author(s) of the course and do not necessarily reflect those of PennWell.

Completing a single continuing education course does not provide enough information to give the participant the feeling that s/he is an expert in the field related to the course topic. It is a combination of many educational courses and clinical experience that allows the participant to develop skills and expertise.

COURSE CREDITS/COST
 All participants scoring at least 70% (answering 21 or more questions correctly) on the examination will receive a verification form verifying 4 CE credits. The formal continuing education program of this sponsor is accepted by the AGD for Fellowship/Mastership credit. Please contact PennWell for current term of acceptance. Participants are urged to contact their state dental boards for continuing education requirements. PennWell is a California Provider. The California Provider number is 4527. The cost for courses ranges from \$49.00 to \$110.00.

Many PennWell self-study courses have been approved by the Dental Assisting National Board, Inc. (DANB) and can be used by dental assistants who are DANB certified to meet DANB's annual continuing education requirements. To find out if this course or any other PennWell course has been approved by DANB, please contact DANB's Recertification Department at 1-800-FOR-DANB, ext. 445.

RECORD KEEPING
 PennWell maintains records of your successful completion of any exam. Please contact our offices for a copy of your continuing education credits report. This report, which will list all credits earned to date, will be generated and mailed to you within five business days of receipt.

CANCELLATION/REFUND POLICY
 Any participant who is not 100% satisfied with this course can request a full refund by contacting PennWell in writing.

© 2009 by the Academy of Dental Therapeutics and Stomatology, a division of PennWell