Cone Beam Computed Tomography in Dentistry: What Dental Educators and Learners Should Know


Abstract: Recent advances in cone beam computed tomography (CBCT) in dentistry have identified the importance of providing outcomes related to the appropriate use of this innovative technology to practitioners, educators, and investigators. To assist in determining whether and what types of evidence exist, the authors conducted PubMed, Google, and Cochrane Library searches in the spring of 2011 using the key words “cone beam computed tomography and dentistry.” This search resulted in over 26,900 entries in more than 700 articles including forty-one reviews recently published in national and international journals. This article is based on existing publications and studies and will provide readers with an overview of the advantages, disadvantages, and indications/contraindications of this emerging technology as well as some thoughts on the current educational status of CBCT in U.S. dental schools. It is the responsibility of dental educators to incorporate the most updated information on this technology into their curricula in a timely manner, so that the next generation of oral health providers and educators will be competent in utilizing this technology for the best interest of patients. To do so, there is a need to conduct studies meeting methodological standards to demonstrate the diagnostic efficacy of CBCT in the dental field.

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Note: The authors do not have a declared financial interest in any company manufacturing the types of equipment or products mentioned in this article.

Keywords: dental education, clinical education, oral pathology, information technology, radiology, oral radiology, dental radiography, cone beam computed tomography

Submitted for publication 11/14/11; accepted 4/13/12

Two-dimensional (2D) images have provided diagnostic evidence for dentistry and medicine for many years, and there is little doubt that 2D images will continue to contribute to diagnostic processes for years to come. However, as cone beam computed tomography (CBCT) becomes more commonly used in dentistry, oral health care professionals and dental educators have a responsibility to investigate the applicability of this technology. The use of CBCT raises questions such as the following: Does CBCT offer additional value in the diagnosis and treatment planning of clinical dentistry? Does three-dimensional (3D) evaluation contribute to improved patient care and treatment outcomes? The answers to these questions are important for dental educators who need to understand the advantages, disadvantages, and indications for use of this new imaging modality when teaching future professionals. Educators also need to understand and perform risk vs. benefit assessments prior to the prescription of CBCT examinations to make the best use of this imaging tool.

To assist in determining whether and what types of evidence exist, we conducted PubMed, Google, and Cochrane Library searches in the spring of 2011 using the key words “cone beam computed tomography and dentistry.” This search resulted in over 26,900 entries in more than 700 articles including forty-one reviews recently published in national and international journals. This article is based on existing publications and studies and will provide readers with an overview of the advantages, disadvantages, and indications/contraindications of this emerging technology as well as some thoughts on CBCT education in U.S. dental education.
Technologies in Oral and Maxillofacial Radiology

The American Academy of Oral and Maxillofacial Radiology (AAOMR) developed the rationale for image selection for several areas of the head and neck and clinical applications of cone beam technology in the oral and maxillofacial region.1,2 In dentistry, the conventional panoramic survey and/or full-mouth survey has been the standard of care in the past; however, based upon the patient’s condition, there may be indications that a multiplanar image such as computed tomography (CT) is needed.3

In the last several decades, indications for 3D images in dentistry have been developed. Two types of beams are commonly used in CT: fan beam and cone beam. In fan beam scanners, a narrow fan-shaped ray passes through the axial plan of the body contiguously. The final 3D images are produced by stacking all the 2D axial slices together. One of the most advanced fan beam systems is the multidetector helical CT unit, which can produce sixty-four slices of the 2D images by a single scan of the fan beam, thus reducing exposure time and radiation dosage to the patient.4 A cone beam scanner, on the other hand, uses a cone-shaped beam and a reciprocating detector, which rotates around the patient 360 degrees and acquires projected data. Using sophisticated computer software along with a back-filtered projection, a 3D image is produced that can be viewed in axial, coronal, and sagittal planes.5

All CBCT units produce 3D images although each manufacturer uses slightly different parameters and viewing software. The software reconstructs the sum of the exposures via algorithms specified by the manufacturer into as many as 512 axial slice images. These images are in the Digital Imaging and Communications in Medicine (DICOM) data format. DICOM data enables the dentist to telecommunicate the imaging information. The images can be viewed and measured in a volumetric fashion as well as in all three planes (axial, sagittal, and coronal).5

Advantages of CBCT

CBCT has been available and used for a number of years. However, recent advances in this technology have allowed its commercial production and practical application in today’s patient care and dental education environment. These advances include reduced cost of production for the x-ray source that is not much different from those used in conventional intraoral and panoramic tube heads, a quality detector, advances in software design, and a more powerful computer system.

When one is comparing or evaluating an emerging technology, it is best to compare it to the existing gold standards. Currently, conventional medical CT is the standard for many radiological examinations. Hashimoto et al. have conducted series studies to compare the image performance between CBCT and medical multidetector helical CT for dental use; they concluded that, in terms of image quality, reproducibility, and validity, the CBCT produced superior images to the helical CT, with approximately 400-fold less radiation exposure in the dental radiology field.6,7 Those studies concluded that CBCT technology was useful in maxillofacial radiology, especially for evaluation of hard tissues, although detection and evaluation of soft tissue lesions are not as clear as desired.

Other studies have found that CBCT delivers much lower doses of radiation to patients than conventional CT. One study reported that the average radiation effective dose of CBCT is within 36.9 and 50.3 microsievert, which is up to a 98 percent reduction compared to fan-beam CT systems.8 In addition, Ludlow and Ivanovic conducted comprehensive evaluations of the effective doses of various CBCT units based on the 1990 and 2007 recommendations of the International Commission on Radiological Protection (ICRP).9 They found that calculated doses were much higher when using the new guidelines, which resulted in 68-1073 µSv for large field of view (FOV), 69-560 µSv for medium FOV, and 189-652 µSv for small FOV. This study also confirmed that a similar-FOV medical CT produced a higher dose than CBCT. Based on the 2007 ICRP report, the effective dose from panoramic radiography was approximately 13 µSv, from cephalometric radiography is 1-3 µSv, and from periapical radiography is 1-8 µSv. These researchers found that i-CAT CBCT delivered a higher dose to the patient than a typical panoramic radiography by a factor of 5-16. Overall, the radiation dose from a CBCT is lower than that from a conventional CT, but is significantly higher than traditional dental radiography techniques (see Table 1).10,12

Accuracy is another advantage of CBCT. It can generate a size of voxel (a 3D cuboid unit of images) as small as 0.125 mm in dimension, which contributes to its high resolution and quality. In a study by
different from medicine in that the practicing dentist is often the one who reads the images. Therefore, it is essential that the dentist ensures that radiological equipment is calibrated and has adequate contrast and sufficient brightness along with reduced ambient lighting. Gutierez et al. have argued that the usual desktop computer display is not adequate for accurate diagnostic radiology.

Educators should be aware that referral to an oral and maxillofacial radiologist may be indicated for many cases, not only because of needed expertise but because a proper monitor, ambient lighting, and equipment settings may be available only in a specialist office or department environment.

One major disadvantage of CBCT is that it can only demonstrate limited contrast resolution, mainly due to relatively high scatter radiation during image acquisition and inherent flat panel detector related artifacts. If the objective of the examination is hard tissue only, using a CBCT would not be a problem; however, CBCT is not sufficient for soft tissue evaluation.

Risks have also been noted in the radiation dose needed with CBCT although it is generally believed that the radiation dose of CBCT is significantly lower than a conventional CT. The effective radiation dose of CBCT can be affected to an order of magnitude by the factors of patient size, FOV, region of interest, and resolution. A careful selection of all these parameters is needed to optimize diagnostic information and reduce the patient’s exposure. According to 2009 ICRP reports, the risk of adult patient fatal malignancy related to CBCT is between 1/100,000 and 1/350,000, and when using the technology for children, the risk could be twice as much. Potential benefits of using CBCT in dentistry for assessment and diagnosis of pathologies and presurgical planning are undisputed. However, due to the additional radiation exposure necessary

### Limitations of CBCT

The standard of care for the use of diagnostic monitors has been set by medicine. Dentistry is

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<th>CBCT</th>
<th>Panoramic</th>
<th>Cephalometric</th>
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<td>36.9-50.3 μSv(^a)</td>
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to achieve the desired results, justification of CBCT must be substantiated.

Streaking and motion artifacts are largely limited with current CBCT units; however, they are not completely avoided. Manufacturers have developed their own specific filters to resolve these problems, but it is unclear whether the reconstruction of images will reduce the image quality or quantity. More studies are needed in this area to provide a definitive answer.

Indications and Contraindications for CBCT Use

As with any emerging technology, dental professionals and trainees need adequate education and training to use CBCT effectively and safely. Some consensus has been reached by the American Academy of Oral and Maxillofacial Radiology and the European Academy of DentoMaxilloFacial Radiology that CBCT should be performed by an appropriately licensed practitioner with adequate theoretical and practical training in CBCT. When a certified radiological technician operates the machine, he or she needs to understand how differing operating parameters would affect the image quality and radiation safety. Moreover, each CBCT scan must be accompanied by an imaging report. It is imperative that the interpreter must systematically examine the entire image dataset, instead of just focusing on the region of interest. For CBCT scans that cover only the dento-alveolar region, an adequately trained general dentist may be competent in the imaging interpretation. For images that go beyond the dento-alveolar region, such as those that go above the floor of the nose and include paranasal sinuses and craniofacial structures or go below the inferior border of mandible and include cervical vertebrae and airways, a specially trained oral and maxillofacial radiologist is preferred to interpret and write the imaging report.

CBCT scans should be taken after a history has been done and a clinical exam performed, when CBCT can potentially contribute new information that benefits patient management. Although universally accepted standards of care for CBCT have not been established yet, experience has shown that, in many circumstances, CBCT is superior to conventional 2D images in demonstrating the location and extent of pathos, the quantity and quality of bone, and the spatial relationship of an object relative to the adjacent critical anatomical structures. Applications of CBCT include but are not limited to extraction of an impacted mandibular third molar in close proximity to the inferior alveolar canal; orthodontic traction of an impacted canine into normal occlusion; orthodontic/surgical management of complex skeletal abnormality; endodontic treatment of multirooted teeth when root canal anatomy is not adequately shown on conventional intraoral radiographs; dental trauma (suspected root fracture); implant placement and fabrication of surgical stents; and jaw bone invasion of oral carcinoma. On the contrary, CBCT should not be routinely used for detection of caries, periodontal bone loss, and periapical pathosis or for routine orthodontic diagnosis.

Current Use of CBCT in Dental School Curricula

As CBCT becomes more integrated into private practice as well as in clinical dental education, it is important that dental schools add some fundamental CBCT education for both postdoctoral and predoctoral programs. Reports in 2011 from survey studies indicate that most U.S. dental schools are doing some form of teaching on CBCT for predoctoral as well as postdoctoral students, but schools vary regarding what should be taught and how much the students are expected to learn. Based on our survey of the current literature, we believe the principles of CBCT imaging, varying options for CBCT equipment, radiation doses, risks, protection, normal anatomical structures and variation of normal, imaging artifacts, and radiological interpretation of diseases affecting the teeth and jaws should be covered in predoctoral curricula. As to where to incorporate this content, CBCT anatomy could be integrated into a first-year anatomical course or an introductory oral radiology course starting with intraoral and CBCT images. For postdoctoral curricula, more advanced courses that help students to examine cases with impacted teeth, implant placement, or craniofacial anomalies should be provided.

Since it is a fairly common misconception that the CBCT user has no responsibility for radiological findings beyond those needed for a specific task (e.g., implant treatment planning), it is important to teach our students that the CBCT practitioner is
Conclusions

Studies in the past decade have been encouraging regarding the use of this imaging modality in dentistry. Reviews of recent publications reveal that CBCT is important in the diagnostic process and plays an integral role in treatment planning and outcome assessment. There are ethical and legal considerations for CBCT that are not different from other emerging technological trends such as laser and robotic surgeries in dentistry. CBCT should be prescribed only when its benefits far outweigh the inherent risks. As a general rule, the need for a CBCT scan is indicated if its use will improve treatment planning and oral care outcomes for the patient while keeping the radiation risk as low as possible. Despite the lack of a gold standard, 3D CBCT images for presurgical uses are moving towards being the standard. When challenging diagnostic scenarios such as a suspiciously underdetermined failed root canal therapy or an impacted third molar in approximation of inferior alveolar canal presents, a 3D image capability of CBCT is considered the standard.

Because of the relevance of CBCT to the head and neck region with its complex anatomy and function, oral and maxillofacial radiologists should take the leadership role and facilitate the training and education of dental students and residents. The fundamentals of CBCT should be incorporated into predoctoral and postdoctoral curricula as well as topics related to patient selection and referral.

Finally, although a number of studies have favored the application of CBCT in dentistry, no multicenter double blind clinical trials considered to be the gold standard for evidence-based studies have been conducted. Educators should remain cautious regarding what they endorse or advocate with learners, considering the evidence available. In the meantime, dental educators should be encouraged to conduct research to advance the field of CBCT beyond that at the time of our study.

REFERENCES