Cone Beam Computed Tomography in Dental Education: A Survey of U.S., U.K., and Australian Dental Schools


Abstract: Cone beam computed tomography (CBCT) is an excellent three-dimensional (3D) imaging modality. Traditional dental education has focused on teaching conventional (2D) imaging. The aims of this survey-based study were therefore to evaluate the incorporation of CBCT teaching in both the predoctoral/undergraduate (D.D.S./D.M.D./B.D.S.) and postgraduate/residency specialty training curricula in dental schools in the United States, the United Kingdom, and Australia. A nine-question survey form was electronically mailed to fifty-seven schools in the United States, sixteen schools in the United Kingdom, and seven schools in Australia. Fifty U.S. dental schools (89 percent), ten U.K. dental schools (62.5 percent), and one Australian dental school (14 percent) presently have CBCT equipment. The majority of responding schools do not include instruction in higher level use of this technology for undergraduate/predoctoral students, raising questions as to whether these students are adequately trained on qualification. Larger numbers of schools reported providing this training to residents in specialty programs. A similar trend was noticed in U.S., British, and Australian dental education. If general dentists are to be permitted to purchase and use CBCT equipment, inclusion of CBCT in dental education is an absolute requirement to prepare future dental practitioners to apply 3D imaging appropriately for diagnosis and treatment planning.

Submitted for publication 8/16/11; accepted 1/10/12

Dr. Parashar is Associate Professor, College of Dental Medicine, Midwestern University-Arizona; Dr. Whaites is Senior Lecturer, Department of Dental Radiology, King’s College London Dental Institute, London, United Kingdom; Dr. Monsour is Professor, Dentomaxillofacial Radiology, School of Dentistry, University of Queensland, Brisbane, Australia; Dr. Chaudhry is Assistant Professor, College of Dentistry, The Ohio State University; and Dr. Geist is Professor, Biomedical and Diagnostic Sciences, School of Dentistry, University of Detroit Mercy. Direct correspondence and requests for reprints to Dr. Vijay Parashar, College of Dental Medicine, Midwestern University, 19369 N. 59th Ave., Glendale, AZ 85308; 623-806-7092 phone; 623-806-7037 fax; vparas@midwestern.edu.

Keywords: dental education, graduate dental education, radiology, dental radiology, cone beam computed tomography

One beam computed tomography (CBCT), sometimes referred to as cone beam volumetric imaging (CBVI), is a three-dimensional (3D) dental and maxillofacial imaging modality that has been developed in recent years. The technology essentially involves imaging a volume that allows either the entire maxillofacial skeleton (large field of view) or a restricted dento-alveolar region involving a few teeth (small field of view) to be imaged. Having captured the data, computer software enables the volume to be viewed in the three anatomical orthogonal planes (axial, sagittal, and coronal).

The use of CBCT was independently reported for maxillofacial imaging in 1998 by Mozzo et al. and in 1999 by Arai et al. Since then, there has been a rapidly growing interest in cone beam technology and its maxillofacial imaging applications. The U.S. Food and Drug Administration approved the first CBCT unit (NewTom DVT 9000 Quantitative Radiology, Verona, Italy) for dental use in the United States in 2001. Since 2001, at least two dozen cone beam units have been introduced to the dental community worldwide.

CBCT has been shown to be an excellent modality for maxillofacial imaging, and numerous applications in dentistry have been reported, including evaluation of impacted teeth, supernumerary teeth, dento-alveolar trauma, and root resorption. CBCT is reported to be beneficial in planning oral and orthognathic surgery, evaluating and treating temporomandibular joint disorders, and imaging odontogenic cysts and tumors, cleft lip, and cleft palate. Endodontic evaluation of missed root canals, failing endodontic treatment, and small fractures in the root structure have all been reported to have been facilitated by this technology.

CBCT has also been reported to have an important role in orthodontic treatment planning, airway analysis, cephalometric analysis, and follow-up. In some countries, cone beam 3D images are becoming a standard of care in
planning for implant cases by providing important information such as the amount of available bone, quality of the bone, proximity to vital structures, and disease at the region of the proposed implant site. \(^\text{16}\) CBCT imaging has become a valuable tool for dentists by providing information about the angle of the proposed implant and virtual abutments and helping to plan the restorations. Dental practitioners are also using CBCT scan data in the generation of treatment plans and surgical guided templates to achieve precision implant placement and to avoid implant failure due to incorrect positioning. \(^\text{17,19}\) Graduating dental students and postdoctoral dental residents, especially in periodontics, oral and maxillofacial surgery, prosthodontics, endodontics, and orthodontics, are likely to increasingly utilize 3D images during their professional careers to provide patient care.

However, reliable research evidence for the development of evidence-based selection criteria to provide guidance as to when CBCT should be used to ensure that patients benefit from the new technology is sadly lacking at present. It is clear that this type of imaging can result in exquisite images and can provide considerable beneficial diagnostic information. Unfortunately, the equipment can frequently deliver a radiation dose far in excess of conventional dental imaging.

The extensive range of CBCT units that manufacturers have developed are currently being aggressively marketed into dental hospitals and schools and, more importantly, directly into general dental practices. The clinical use of ionizing radiation (radiographs) is governed by national legislation in most developed countries based on the recommendations of the International Commission on Radiological Protection (ICRP). Dentists, as the professionals responsible for the overall safety of the patient, are usually only allowed to take radiographs of patients once they have been adequately trained. Taking dental radiographs of patients by predoctoral students is usually allowed only under direct supervision. Predoctoral/undergraduate radiography and radiology courses are required to provide this adequate training and have traditionally concentrated on 2D intra-oral and panoramic imaging. As a result, many of the dentists who have already purchased CBCT units (and many of those who may do so in the future) may not have been taught in dental school how to use the equipment or how to interpret the 3D volume and are therefore not adequately trained.

To ensure that CBCT technology is used appropriately in the future and to ensure that the benefits to patients are realized, three questions arise: Have dental schools embraced this new technology? Have they included CBCT image acquisition in their curricula? Have they included CBCT interpretation in their curricula? The aims of this survey-based study were therefore to assess the adoption of CBCT technology in dental schools in the United States, the United Kingdom, and Australia and to evaluate the incorporation of CBCT teaching (both taking the scans and interpreting the images) in both the predoctoral/undergraduate and postdoctoral/postgraduate/residency specialty training curricula in these three countries.

**Methods**

In order to determine the uptake of CBCT equipment and the inclusion of CBCT education in dental curricula, a simple nine-question survey form was created. (The questionnaire is available from the corresponding author.) The questionnaire was formulated to be short and informative with options to choose Yes, No, or Not Applicable as answers. Question 1 assessed the uptake of CBCT equipment within the school. Questions 2, 4, 6, and 8 assessed the inclusion of CBCT in the predoctoral curriculum, including image orientation and the inclusion of CBCT images in the schools’ courses, as well as acquisition and interpretation of the images and application of implant planning software. Questions 5, 7, and 9 assessed the inclusion of CBCT acquisition, interpretation, and implant software application in postdoctoral/residency programs. This project was reviewed by the institution’s director of research and was considered an activity not requiring Institutional Review Board review and approval. This project consisted of collecting and analyzing information regarding current educational trends without reporting any identifiable private information about individual members, employees, or staff of an organization.

Between April and July 2010, the survey form was e-mailed to the instructors responsible for teaching the oral and maxillofacial radiology curriculum in the fifty-seven dental schools listed on the American Dental Association’s website, the sixteen dental schools in the United Kingdom, and the seven dental schools in Australia. Most schools responded immediately with the survey information. Many of the remaining schools responded after a second e-mail request.
Results

Overall, the response rate was remarkable. Fifty-six U.S. schools responded (98 percent response rate); fifteen U.K. schools responded (94 percent response rate); and all seven Australian schools responded (100 percent response rate).

The following reported percentages are all percentages of the responding schools. Fifty dental schools (89 percent) in the United States have a cone beam tomography machine. Ten dental schools (63 percent) in the United Kingdom and one dental school (14 percent) in Australia presently have a CBCT machine. Some of the respondents from dental schools that presently do not have CBCT units mentioned that their schools are actively in process of procuring them. A high number of dental schools teach 3D image orientation in predoctoral oral radiology courses. Forty-seven (84 percent) U.S. dental schools, ten (67 percent) U.K. dental schools, and seven (100 percent) dental schools in Australia teach 3D image orientation to dental students that enables them to view anatomical structures in three dimensions. A large number of dental schools include 3D cone beam tomography images in the predoctoral oral radiology curriculum. Fifty-one (91 percent) U.S. dental schools, twelve (80 percent) U.K. dental schools, and five (71 percent) Australian dental schools include CBCT images in the B.D.S. curriculum in the U.K. and Australia and D.D.S./D.M.D. curriculum in the United States.

When asked if training in acquisition of cone beam scans is provided to predoctoral students, only ten (18 percent) of the oral radiology instructors in the United States responded yes. None of the dental schools surveyed in the U.K. provide training to dental students during the B.D.S. curriculum to acquire the scan, and two out of seven (29 percent) dental schools in Australia provide training to dental students to acquire a CBCT scan on patients. A large number of dental schools do not teach predoctoral dental students to acquire a scan or operate a CBCT machine.

When asked if predoctoral students are educated in the interpretation of CBCT scans, twenty-seven (48 percent) oral radiology instructors in the United States responded yes and twenty-nine (52 percent) responded no. Almost half of the dental schools in the United States thus teach CBCT image interpretation to dental students. Five dental schools in the U.K. (33 percent) and four dental schools (57 percent) in Australia provide training to dental students to interpret a 3D volume acquired by the CBCT machine to prepare them for identifying normal anatomy and abnormal pathology on 3D CBCT images.

Preoperative implant planning is one of the major indications for acquisition of CBCT scan in dental practices. Only eighteen (32 percent) of U.S. dental schools teach predoctoral dental students to apply implant planning software. One dental school in the U.K. (7 percent) and two dental schools in Australia (29 percent) provide training to dental students to apply implant planning software. A large number of dental schools do not provide training to predoctoral dental students to manipulate 3D CBCT images for simulated implant treatment planning.

For postdoctoral dental residency/specialty training in periodontics, prosthodontics, oral surgery, etc., a higher number of dental schools—twenty-three (43 percent) in the United States, one (7 percent) in the U.K., and two (29 percent) in Australia—teach the acquisition of CBCT scans. Even more dental schools prepare their residents in the interpretation of 3D images acquired with a CBCT machine. Fortyfour dental schools (81 percent) in the United States, eight (53 percent) in the U.K., and four (57 percent) in Australia provide training in CBCT scan interpretation. Postdoctoral dental residents at thirty-one dental schools (58 percent) in the United States, six (40 percent) dental schools in the U.K., and four (57 percent) dental schools in Australia receive training in application of implant planning software as part of their postdoctoral dental education.

Discussion

Use of CBCT in dental practice is expanding worldwide as evidence of its efficacy in a variety of diagnostic tasks continues to appear in the literature. The European Academy of Dental and Maxillofacial Radiology has issued guidelines for the use of this technology in Europe. The American Academy of Oral and Maxillofacial Radiology (AAOMR) is in the process of developing position papers on the appropriate use of CBCT with evidence-based guidelines. The AAOMR has stated in an executive opinion that dentists who plan to use CBCT in their practices must have sound knowledge of head and neck anatomy as it appears on the images, as well as the ability to recognize normal variants and disease. It is therefore essential that dental educators begin to include CBCT in their radiology curricula to prepare their students for proper utilization of this technol-
ogy. The use of 3D CBCT images in oral radiology courses will familiarize students with 3D anatomy and prepare them to interpret and analyze 3D images during their dental careers. It is a favorable sign that the large majority of U.S. dental schools now provide instruction on this imaging device, including an understanding of the anatomy of the head and neck as it appears on CBCT.

Slightly less than half of all dental schools in our study teach interpretation of the CBCT images to predoctoral students. Structured 3D radiographic interpretation exercises as part of an oral and maxillofacial radiology course will better prepare dental students to evaluate the complete field of view and identify any unrelated incidental findings that the scan may exhibit. Radiology course directors should be encouraged to add this instruction to their courses.

At the present time, a sizeable majority of dental programs offer no instruction in the techniques of acquiring the images. If graduates of these schools decide to use CBCT technology in their dental practice, they will have to depend on the limited training provided by the CBCT manufacturer or vendor. Hands-on experiences in CBCT image acquisition will help dental students learn various scan acquisition settings and better prepare them to acquire and troubleshoot errors with scan acquisition in their dental practice.

Similarly, only a few dental schools include instruction on using implant treatment planning software, so many graduating dental students will have limited exposure and experience in image planning software. Hands-on exercises in simulated implant planning can be used as a teaching tool prior to actual surgical placement of dental implants. Students will be able to appreciate the dento-alveolar anatomy in relation to the angulation and positioning of proposed implants. Since a fewer number of dental schools in the U.K. and Australia have a CBCT scanner but more are in the process of obtaining them, opportunities should soon exist at all schools for provision of experiences in acquiring images and working with software. We speculate that this will become a more prominent component of the radiology curriculum in the coming years.

Our survey revealed that graduate programs are more likely than predoctoral programs to include instruction in acquisition, interpretation, and software manipulation. Nevertheless, opportunity exists for dental schools to improve the education curriculum for their non-oral and maxillofacial radiology residents/specialty trainees in acquisition and interpretation of CBCT images. It cannot be determined from the data exactly which specialty programs are included in this number. The survey specified non-oral radiology residents like orthodontics, periodontics, prosthodontics, etc. Furthermore, some of the respondents who answered negatively may be located at schools with specialty programs in which CBCT does not play a large role, such as pediatric dentistry or dental public health. The data imply, however, that educational experiences in CBCT technology and interpretation are not yet as widespread as they should be, considering the growing importance of this imaging system in many specialty practices.

Conclusions

Our data show that a large number of dental schools in the United States, the United Kingdom, and Australia have CBCT technology and the rest are in the process of acquiring a CBCT machine. Dental schools recognize the importance of CBCT imaging and its applications in dentistry. Most of the dental schools have adopted CBCT 3D images in oral and maxillofacial radiology courses. Presently, a few dental schools are teaching CBCT scan acquisition and implant planning software application to predoctoral students. Many more dental schools are preparing students for CBCT image interpretation. A higher number of postdoctoral dental residents are receiving training to acquire, interpret, and apply software manipulation to CBCT images.

Inclusion of CBCT imaging in dental education is essential to prepare graduating dental students to perform treatment planning utilizing 3D images to improve the accuracy and reliability of dental treatment planning and outcomes. A follow-up survey will be conducted one year after the original survey to examine the adoption of CBCT technology by the schools presently not teaching CBCT acquisition, interpretation, and implant software application in order to continue to track the development of education in CBCT technology.

Acknowledgments

We sincerely thank all the dental educators who took the time to reply to the survey in order to support this study.

REFERENCES


