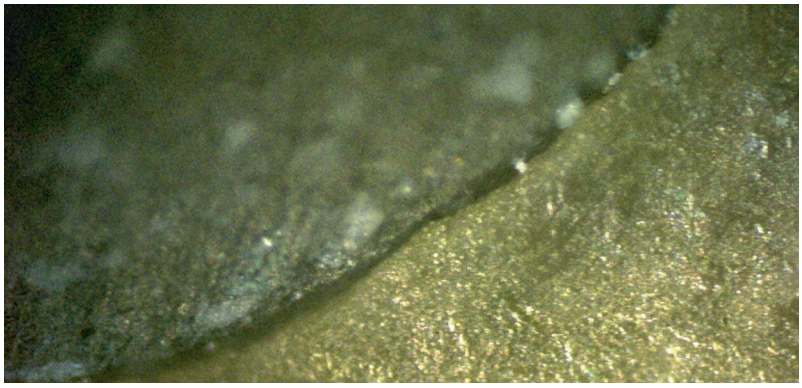
QUINTESSENCE INTERNATIONAL

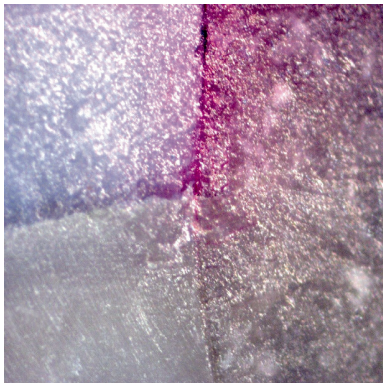
02/19 | February 2019
Volume 50

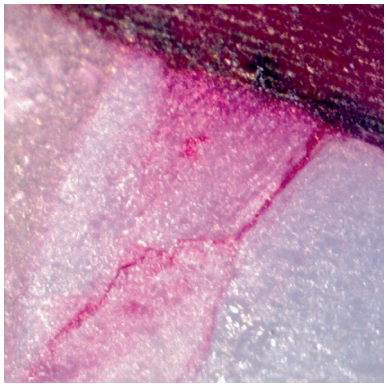
SPECIAL REPRINT

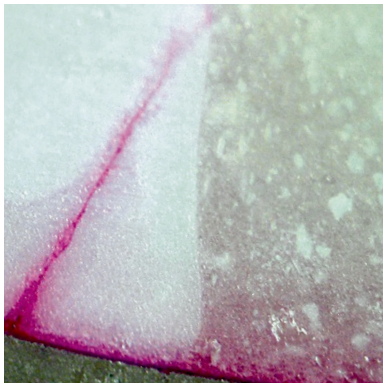
Review of cone beam computed tomography guidelines in North America

Irene H. Kim, Steven R. Singer, Mel Mupparapu









QUINTESSENCE PUBLISHING

Review of cone beam computed tomography guidelines in North America

Irene H. Kim, DMD, MPH/Steven R. Singer, DDS/Mel Mupparapu, DMD, MDS

Objective: The aim of this article is to investigate, study, and summarize cone beam computed tomography (CBCT)-related guidelines offered by relevant organizations and associations within North America to provide the dental practitioner a clearer direction on the practice of CBCT-related procedures in North America. **Data sources:** Scientific databases including PubMed, Science Direct, Scopus, MedLine, and Web of Science were used for the search of relevant literature on the CBCT guidelines developed in North America. In addition, the World Wide Web was searched for comparative CBCT guidelines nationally or internationally using the same search strategies. **Conclusion:** In 1999, the American Dental Association (ADA) recognized Oral and Maxillofacial Radiology as the ninth dental specialty in the United States. The American Academy of Oral and Maxillofacial Radiology (AAOMR) issued their first statement on the use of CBCT in 2008. There have since been several statements issued, independently or jointly with other specialty organizations, related to the use and interpretation of the CBCT volumes. The guidelines identified Oral and Maxillofacial Radiologists (OMR) as providers of interpretative services, portrayed as key players in the dissemination of information related to CBCT, implementation of CBCT-related services and radiation protection, as well as interpretation assistance for CBCT volumes, especially medium to large volumes covering anatomical areas of head and neck, considered beyond the scope of a general dentist. Regulations concerning radiation-producing devices are promulgated through state health codes and practice acts. Selection criteria and interpretation of imaging studies are left to the clinician's choice and abilities. *(Quintessence Int 2019;50:136–145; doi: 10.3290/j.qi.a41332)*

Key words: cone beam computed tomography, guidelines, radiography, selection criteria, x-rays

Medical computed tomography (CT) was first developed by Sir Godfrey Hounsfield in 1967, and since then many advancements have been made involving detectors, beam source, and movement patterns of the detectors and beam sources.[1] Conventional multi-detector computed tomography (MDCT) scanners are too large and expensive for maxillofacial and dental use.[2] Cone beam computed tomography (CBCT) became available for dental and maxillofacial imaging in the United States at the beginning of the new millennium. It was first introduced in Europe in 1996 and in the United States in 2001. The only recommendations for oral and maxillofacial imaging that existed at that time were issued by the American Dental Association Council on Scientific Affairs and the US Department of Health and Human Services. Named as dental radiography guidelines, they did not cover advanced imaging protocols such as CBCT.[3]

CBCT was quickly integrated into dental practice as clinicians started using the technology for skeletal imaging of jaws for a variety of diagnostic and treatment-related tasks.[4] By 1998, Mozzo et al[5] had laid the foundation for the new revolution in three-dimensional (3D) imaging by describing how a volumetric CT machine would be useful for dental imaging. For decades clinicians relied on standard two-dimensional (2D) images that offered little useful information about the z-axis (depth of the anatomical volume). CBCT technology offered a low-dose, high-resolution digital technology providing high-quality and dimensionally accurate imaging for all three reference planes. Oral and maxillofacial surgeons, long users of MDCT technology to visualize the 3D soft and hard tissue structures of the orofacial region, were now able to use CBCT to acquire 3D imaging at significantly lower radiation doses. CBCT also proved to be very useful in pre-implant imaging. In special-

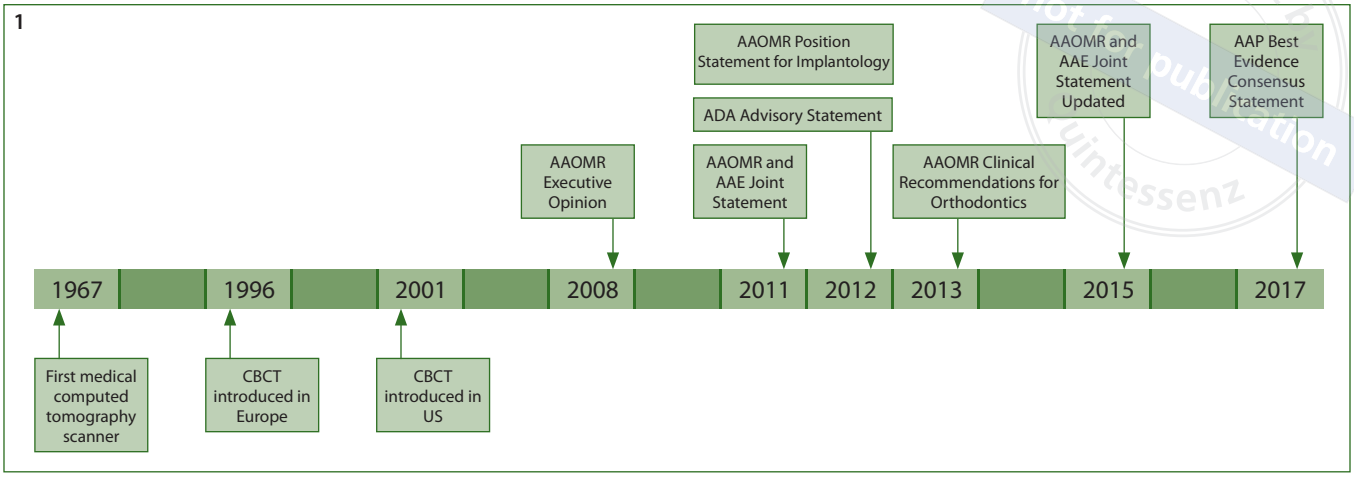


Fig 1 Timeline of CBCT introduction and guideline development in North America. AAP, American Academy of Periodontology; ADA, American Dental Association; AAE, American Association of Endodontists; AAOMR, American Academy of Oral and Maxillofacial Radiology; CBCT, cone beam computed tomography.

ties such as endodontics or periodontics, small volume CBCT imaging using pixels as small as 60 to 70 µm could be used to view periodontal ligament space, furcation defects, root anatomy, fractures, and complex pulp pathways that otherwise would be difficult using 2D imaging alone.[6] In pediatric dentistry, the field of view (FOV) could be tailored in CBCT to suit the imaging needs of children and adolescents, reducing the effective dose when compared to that of MDCT examinations. Collectively, we have an obligation to our patients to reduce the dose to as low as reasonably achievable (ALARA).[7] In the years since its introduction, CBCT technology has advanced due to research and development by the manufacturers of CBCT machines and the competition among them. Better education of dentists, modern flat panel detectors, individualized scanning protocols (selection criteria), and faster scan times all contribute to further reducing the radiation dose.[8]

The first CBCT guideline from organized dentistry in North America came in the form of an executive opinion of the American Academy of Oral and Maxillofacial Radiology (AAOMR).[9] This was followed up by statements addressing CBCT use in various dental specialties, including periodontics, endodontics, and orthodontics, CBCT use in dental implants, and a position statement issued by the American Dental Association Scientific Council.[10-16] In Europe, parallel development of guidelines took place somewhat earlier than in North America, and the European Commission issued evidence-based CBCT guidelines known as the SEDENTEXCT (Safety and Efficacy of a New and Emerging Dental X-Ray Modality) project.[17] National guidance on CBCT has been documented in the United Kingdom, Germany, Norway, Belgium, and Denmark.[17] The time frame for these various statements and guidelines in North America is presented in Fig 1.

Data sources

English language medical and dental literature that was relevant and most recent was reviewed for this study. Scientific databases including PubMed, Science Direct, Scopus, MedLine, and Web of Science were used for the search of relevant literature on the CBCT guidelines pertaining to North America.

Resources selection

All articles were reviewed by at least two authors and duplicates removed from the overall list. Each article was reviewed and discussed by the authors and relevant details were extracted to tables (Tables 1 to 8). Based on the eight selected articles,[9-16] this study investigated the literature for guidelines and position papers since CBCT was introduced to the US market in 2001. The guidelines, principles, and position statements on the use of CBCT in the dental profession studied were limited to organizations and associations within North America. The dental organizations involved in publishing statements included the AAOMR, the American Dental Association (ADA),

Table 1 Summary of the AAOMR executive opinion statement[9]

Recommendations	Details
Use of CBCT	Only performed by licensed practitioner or certified radiologist
	Only for valid diagnostic or treatment reasons
	With minimum exposure necessary for adequate imaging
1. Practitioner responsibilities	Must have a valid license, held to the same standards as oral and maxillofacial radiologists
	Must interpret CBCT findings with a thorough understanding of CT anatomy in the entire image dataset, systematically reviewing for disease
	Should be familiar with alternative and complementary imaging and diagnostic procedures to correlate CBCT findings
	Have a thorough understanding of operating parameters, effects of parameters on image quality, and radiation safety
	Properly prepare, position, monitor, and comfort the patient
	Perform calibration and quality control testing regularly
	Confirm legal authority in specific locality
2. Documentation	Provide evidence of diagnostic or treatment need for CBCT
	Provide appropriate demographic, clinical, and case history information to allow proper performance and interpretation of CBCT exam
	Obtain separate patient consent for CBCT to support diagnostic need and facilitate patient understanding
	Store dataset in compliance with legal and regional stipulations
	Dataset should be exportable in ISO-referenced DICOM standard format
	Images are part of the permanent record and should be stored in proper archival format
	Interpretation should be included in patient record
3. Radiation safety and quality assurance	Facilities should have specific policies and procedures for dose optimization (ie, custom exposure protocols based on patient body size, field limitation to region of interest, lead aprons, etc)
	Procedures should follow all pertaining regulations
	Documentation of performance calibration tests, log of results of equipment performance, facility dosimetry results, chart of patient, and task-specific technique exposure parameters

CBCT, cone beam computed tomography; CT, computed tomography; DICOM, Digital Imaging and Communications in Medicine; ISO, International Standards Organization.

the American Academy of Oral and Maxillofacial Pathology (AAOMP), the American Academy of Pediatric Dentistry (AAPD), the American Association of Endodontists (AAE), the American Association of Oral and Maxillofacial Surgeons (AAOMS), the American Association of Orthodontists (AAO), and the American Academy of Periodontology (AAP). The non-dental organizations included the American Association of Physicists in Medicine (AAPM), the Conference of Radiation Control Program Directors (CRCPD), the National Council on Radiation Protection and Measurements (NCRP), and the United States Food and Drug Administration (FDA). The history of the guidelines and statements were studied, reviewed, and summarized.

Review and discussion

Since the introduction of CBCT technology to the profession at the turn of the new millennium, there has been a marked increase in the use of CBCT. The North American CBCT dental imaging market is expected to reach USD 360.44 million in the year 2023, up from USD 172.31 million in 2016. The market is expected to grow at a compound annual growth rate (CAGR) of 11.1% for the forecasted period.[18] This is a clear indicator of the growth of the use of CBCT among dentists in North America. Although education and training are key pieces for the appropriate use of CBCT technology, development and regulation of clinical guidelines are even more important for radiation dose reduction and patient safety. Commercialization and excessive use of CBCT imaging should be avoided, especially when not indicated.

The Executive Council of the AAOMR published an executive opinion statement performing and interpreting diagnostic CBCT in 2008.[9] Their opinion document outlined recommendations based on CBCT use, practitioner responsibilities, documentation, and radiation safety and quality assurance. A summary of the guidelines is presented in Table 1. The goal of the executive statement was to help dental practitioners provide the best CBCT imaging to their patients based on radiographic selection criteria, dose, technique, and diagnostic or treatment needs.

Table 2 Summary of the joint position statement of AAOMR and AAE[10]

Joint statement	Details
1. Volume – limited volume CBCT preferred for most endodontic applications	Increased spatial resolution improves accuracy of visualization of small features (ie, accessory canals, root fractures, apical deltas, etc)
	High spatial resolution provides diagnostically acceptable signal-to-noise ratio
	Less radiation exposure to patient
	Smaller volume to interpret saves time
2. Dose considerations – reduce to lowest effective radiation	Smallest possible FOV
	Smallest voxel size
	Lowest mA setting
	Shortest exposure time in conjunction with pulsed exposure mode
	Case-by-case analysis for larger FOV if systemic or non-endodontic etiology is suspected (with interpretation of entire acquired volume)
3. Patient selection criteria	Must not be used routinely in the absence of clinical signs and symptoms
	Patient history and clinical exam must justify CBCT, where benefits outweigh risks
	CBCT use only when clinical questions cannot be answered by lower dose conventional dental radiography or alternate imaging modalities
4. Patient consent	Patients should receive disclosure and education on the risks, benefits, and alternatives
	Consent documented in patient record
	Patients should be informed that CBCT is not reliable for soft tissue lesions and possible artifacts make interpretation difficult
	If the patient still refuses, certain states recognize "informed refusal"
	Informed refusal should be documented in the chart and signed by the legally responsible individual
5. Interpretation	Ordering clinician is responsible for entire CBCT image volume interpretation, as with all other radiographs
	No informed consent for interpreting only a specific area of image volume
	Clinician is liable for missed diagnosis even if it is outside their area of practice
	Any questions should be referred to a specialist in OMR
6. Protection of patients and office personnel	Extra practical protection measures are needed for office personnel due to the higher dose levels and beam energies of CBCT compared to conventional dental radiography
	Qualified experts should be consulted prior to and after installation to meet state and federal requirements
	Manufacturer recommended calibration routines should be conducted regularly

AAE, American Association of Endodontists; AAOMR, American Academy of Oral and Maxillofacial Radiology; FOV, field of view; OMR, oral and maxillofacial radiology.

In 2011, the AAOMR and the AAE issued a joint position statement on the use of CBCT in endodontics.[10] The joint statement, summarized in Table 2, provided guidelines based on volume, dose consideration, patient selection criteria, patient consent, interpretation, and protection of patients and office personnel. The statement also recommended that the use of CBCT in endodontics be limited to certain complex conditions (Table 3).

In 2012, the AAOMR addressed the use of CBCT in dental implantology with a position statement on radiographic selection criteria, with an emphasis on CBCT for dental implants.[11] These recommendations were evidence-based on peer-reviewed research, as well as consensus. They offered guidelines and advice on the use of CBCT, as well as other planar modalities such as intraoral, panoramic, and cephalometric imaging. Clinical considerations on selection criteria, radiation dose considerations, and principles of imaging for dental implantology were also discussed in the position paper. A summary of the AAOMR recommendations for CBCT is presented in Table 4. In summary, it was recommended to perform cross-sectional imaging in the preoperative diagnostic phase. CBCT imaging would remain the method of choice, as it provides the most diagnostic information at an acceptable radiation dose risk. Postoperative implants may be monitored with periapical and, in some cases, panoramic imaging. Practitioners should always clinically justify the use of CBCT (as well as all imaging modalities) and properly maintain all equipment to minimize radiation exposure to the patient. The report added that all CBCT

Table 3 Summary of the use of CBCT in endodontics, AAE/AAOMR[10]

Use of CBCT in endodontics should be limited to assessment and treatment of complex conditions	
To identify potential accessory canals in teeth with suspected complex morphology as revealed by conventional imaging	
To identify root canal system anomalies and determination of root curvature	
To diagnose dental periapical pathosis in patients:	with contradictory or nonspecific clinical signs and symptoms
	with poorly localized symptoms associated with no evidence of pathosis by conventional imaging
	where anatomical superimposition of roots or areas of the maxillofacial skeleton are needed for task-specific procedures
To diagnose pathosis of non-endodontic origin in order to determine the extent of a lesion and its effect on surrounding structures	
To assess intra- or postoperative endodontic treatment complications	Overextended root canal obturation material
	Separated endodontic instruments
	Calcified canals
	Perforations
To diagnose and manage dentoalveolar trauma	Root fractures
	Luxation and/or displacement of teeth
	Alveolar fractures
To localize and differentiate:	external from internal root resorption
	invasive cervical resorption from other conditions
For presurgical case planning:	to determine the exact location of root apex/apices
	to evaluate proximity to anatomical structures
For implant case planning where cross-sectional imaging is necessary based on clinical evaluation of the edentulous ridge	

AAE, American Association of Endodontists; AAOMR, American Academy of Oral and Maxillofacial Radiology.

Table 4 AAOMR recommendations for radiology in implantology with emphasis on CBCT[11]

Assessment	Recommendation	
Initial examination	1. Panoramic radiography is the imaging modality of choice in the initial evaluation	
	2. Intraoral periapical radiography to supplement panoramic radiography	
	3. Do not use cross-sectional imaging, including CBCT, as an initial diagnostic exam	
Preoperative site-specific imaging	4. Radiographic examination of a potential implant site should include cross-sectional imaging orthogonal to the site of interest	
	5. CBCT should be considered as the imaging modality of choice for preoperative cross-sectional imaging of potential implant sites	
	6. CBCT should be considered when there is a clinical need for augmentation procedures or site development before implant placement:	Sinus augmentation
		Block of particulate bone grafting
		Ramus or symphysis grafting
		Assessment of impacted teeth in the field of interest
		Evaluation of prior traumatic injury
	7. CBCT should be considered if bone reconstruction and augmentation procedures (ie, ridge preservation or bone grafting) have been performed to treat bone volume deficiencies before implant placement	
Postoperative imaging	8. Use intraoral periapical radiography in the absence of clinical signs or symptoms. Panoramic radioagraphs may be used for extensive implant cases.	
	9. Use cross-sectional imaging (CBCT) immediately postoperatively only if the patient presents with implant mobility or altered sensation, especially if fixture in the posterior mandible	
	10. Do not use CBCT imaging for periodic review of clinically asymptomatic implants	
	11. Cross-sectional imaging (CBCT) should be considered if implant retrieval is anticipated	

AAOMR, American Academy of Oral and Maxillofacial Radiology.

Table 5 The American Dental Association Council of Scientific Affairs[12]

Summary of principles for the safe use of dental and maxillofacial CBCT
Principle for safe use of dental and maxillofacial CBCT
– After careful review of patient's health and imaging history, and complete and thorough clinical exam
– After professional justification that potential clinical benefits outweigh risks of ionizing radiation exposure
– Prescribe only if diagnostic yield will benefit patient care, enhance patient safety, significantly improve clinical outcomes, or all of these
– May be used to diagnose, monitor, treat, or manage oral conditions if the practitioner determines that the structures of interest may not be captured by conventional radiography
– ALARA, the radiation dose should be optimized to achieve the lowest practical level to address a specific clinical situation (use the smallest FOV with the lowest combination of tube output and scan time)
– Use every precaution to reduce radiation dose and ensure patient safety, thyroid collars, and lead aprons when they do not interfere with the examination
– Prescribed by a dentist with appropriate training and education in CBCT imaging, including an understanding of CBCT selection and imaging findings
– CBCT images of the oral and maxillofacial structures should be evaluated by a dentist with appropriate training and education in CBCT interpretation
– The complete image set must be interpreted by an appropriately qualified health care provider (dentist or physician) and the prescriber should receive a thorough radiologic report. If the prescriber also interprets, the findings should be entered into the patient record and communicated to the patient
– Dental practitioners using CBCT devices must receive appropriate training. The Council recommends continuing education courses to maintain adequate knowledge
– Dentist must abide by applicable federal and state regulations including safe working environments for both staff and the public. CBCT operators should contact state and local radiation control programs for any additional requirements for licensure or accreditation
– Dentist should use professional judgment in prescribing and performing CBCT exams by consulting guidelines and keeping abreast of scientific literature using an evidence- and science-based approach
– Call for appropriate agencies in ADA and dental community to develop and implement recommendations and criteria for adequate CBCT training and education
– Facilities considering installation of CBCT devices should consult a health physicist to perform a shielding analysis based on NCRP reports 145 and 147
– Facilities using CBCT devices should consult a health physicist to perform equipment performance and evaluations at installation and then follow a schedule in compliance with local, state, and federal requirements
– Staffs of CBCT facilities should establish a quality control program based on manufacturer's recommendations or can be established, implemented, and monitored by a qualified expert

ADA, American Dental Association; ALARA, as low as reasonably achievable; FOV, field of view; NCRP, National Council on Radiation Protection and Measurements.

volumes should also be systematically reviewed for any abnormalities and a report generated for all CBCT examinations.

In 2012, the ADA Council on Scientific Affairs issued an advisory statement on the use of CBCT in dentistry.[12] The council reviewed the current research literature, and also received input from various stakeholder organizations. These organizations included dental associations such as the AAOMR, the AAOMP, the AAPD, the AAE, the AAOMS, and the AAO. In addition to these dental organizations, the AAPM, the CRCPD, the NCRP, and the United States FDA were also included. This collaborative effort resulted in the Council recommending adherence to principles for the safe use of dental and maxillofacial CBCT. The results are summarized in Table 5. In summary, the council recommended that CBCT use for dental and maxillofacial imaging should be based on sound professional judgment, including weighing patient risk against potential benefits, using the ALARA principle to protect the patient and staff, justifying the use of CBCT for diagnosis using all precautions such as protective aprons and collars when possible, and optimizing technical factors such as the smallest FOV for diagnosis. The council also stressed the importance of proper CBCT education and training for all staff and clinicians, as well as proper maintenance and evaluation of the CBCT equipment.

In 2013, the AAOMR published a position statement on clinical recommendations for the use of CBCT in orthodontics.[13] A panel of board-certified orthodontists and oral and maxillofacial radiologists convened to reach a consensus on all aspects of the use of CBCT in orthodontic practice, based on a review of the literature on clinical efficacy and radiation dose. The clinical recommendations are summarized in Table 6. The panel agreed with the principles put forth by the ADA Scientific Council in 2012. It was concluded that the use of CBCT in orthodontics should be determined individually based on clinical presentation, assessment of radiation dose risk, and minimizing patient exposure. In addition, the orthodontist should maintain professional competency in performing and interpreting CBCT studies through continuing education courses.

An update of the AAE and AAOMR joint position statement was issued in 2015.[14] It reiterates that CBCT should only be used when indicated by the patient's complaint, history, and clinical findings, and that the smallest applicable FOV with the lowest radiation dose should be used. In addition, any questions regarding interpretation of the images should be referred to an oral and maxillofacial radiologist. The position paper outlined each recommendation and provided a rationale for each recommendation. Table 7 summarizes the updated recommendations of the AAE and AAOMR.

Table 6 Summary of guidelines for CBCT in orthodontics[13]

Guideline	Details	
1. Image appropriately according to clinical condition	1.1 Base the decision to use CBCT imaging on patient history, clinical exam, available radiographs, and presence of a clinical condition where the benefits to the diagnosis/treatment outweigh the potential risks of exposure to radiation, especially in children and young adults	
	1.2 Use CBCT imaging if the clinical question cannot be answered by lower-dose conventional dental radiography or alternate non-ionizing radiation	
	1.3 Avoid using CBCT to obtain data that can be provided by alternate non-ionizing modalities (ie, to produce virtual orthodontic study models)	
	1.4 Use a CBCT protocol that restricts the FOV, minimizes exposure (mA, kVp), the number of basis images, and resolution that permits adequate visualization of the ROI	
	1.5 Avoid CBCT to solely produce a lateral cephalogram and/or panoramic view if the CBCT results in a higher radiation exposure that conventional imaging	
	1.6 Avoid taking conventional 2D radiographs if the clinical examination indicates that a CBCT study is indicated for proper diagnosis and/or treatment planning, or if a recent CBCT study is available	
2. Assess the radiation dose	2.1 Consider the relative radiation level designations for children and adults for orthodontic imaging as recommended by the American College of Radiology when assessing imaging risk over the course of orthodontic treatment	
	2.2 Explain and disclose to patients (especially pregnant and younger patients) the risks of CBCT ionizing radiation, as well as its benefits and alternate imaging modalities. Document in patient records.	
3. Minimize patient radiation exposure	3.1 Perform CBCT imaging with acquisition parameters adjusted to the normal settings consistent with providing appropriate task-specific diagnostic quality for desire diagnostic information:	Use pulsed exposure mode of acquisition
		Optimize exposure setting (mA, kVp)
		Reduce number of basis projection images
		Employ dose reduction protocols (ie, reduced resolution) when possible
	3.2 When all factors remain the same, reduce the size of the FOV to match the ROI. However, selection of FOV may result in default changes in other technical factors (ie, mA) that should be considered because of the resulting increase in dose	
	3.3 Use protective shielding when possible to minimize exposure to radiosensitive organs outside the FOV of exposure	
	3.4 Ensure all CBCT equipment is properly installed, routinely calibrated, and updated, and meets all government requirements and regulations	
4. Maintain professional competency in performing and interpreting CBCT studies	4.1 Clinicians have an obligation to attain and improve their professional skills through lifelong learning in performing CBCT exams and interpreting resultant images	
	4.2 Clinicians have a legal responsibility when operating CBCT equipment and interpreting images and are expected to comply with all government and third party payer regulations	
	4.3 Patients and guardians should know about the limitations of CBCT regarding visualization of soft tissue, artifacts and noise	

FOV, field of view; ROI, region of interest.

In 2016, a task force was appointed by the AAOMS to study the indications, safety, and clinical patterns of CBCT in oral and maxillofacial surgery.[15] A global study of the CBCT literature was performed and a national survey of academic thought leaders and practicing oral surgeons to determine how CBCT is used and adopted in academic and private practice settings. It was concluded that there is much confusion associated with the indications, authorizations, and payment policies of CBCT use. After reviewing the literature and survey results, the authors proposed an industry guideline to help reach a consensus on the clinical indications of CBCT, as well as offer guidance on third-party payment policies. Based on majority expert opinion, CBCT is usually indicated in oral and maxillofacial pathology, orthognathic surgery, maxillofacial trauma, foreign body evaluations, reconstructive surgery planning, supernumerary teeth, impacted teeth, dental implant evaluation, and sinus elevation planning. CBCT might be indicated in craniofacial surgery, maxillofacial infections, salivary gland pathology, temporomandibular joint evaluations, and facial pain.

In 2017, the AAP issued a best evidence consensus statement on selected oral applications for CBCT.[16] The panel of experts addressed the application of CBCT in three specific clinical therapies: placement of implants, interdisciplinary dentofacial therapy involving orthodontic tooth movement in the management of malocclusion with associated risk to the supporting periodontal tissues, and management of periodontitis.

Table 7 Updated AAOMR and AAE recommendations for CBCT use[14]

Treatment stage		Recommendation
Diagnosis		1. Intraoral radiographs should be the imaging modality of choice in the evaluation.
		2. Limited FOV CBCT should be considered for diagnosis in patients with contradictory or nonspecific clinical signs and symptoms associated with untreated or previously endodontically treated teeth.
Initial treatment	Preoperative	3. Limited FOV CBCT should be considered for initial treatment of teeth with the potential for extra canals, suspected complex morphology, and dental anomalies.
	Intraoperative	4. If preoperative CBCT was not taken, limited FOV CBCT should be considered for identification and localization of calcified canals.
	Postoperative	5. Intraoral radiographs should be considered for immediate postoperative imaging.
Nonsurgical treament		6. Limited FOV CBCT should be considered if the clinical exam and 2D intraoral radiography are inconclusive in the direction of the vertical root fracture.
		7. Limited FOV CBCT should be used to evaluate the non-healing of previous endodontic treatment to help determine the need for further treatment (ie, nonsurgical, surgical, or extraction)
		8. Limited FOV CBCT should be used for nonsurgical retreatment to asses endodontic treatment complications (ie, overextended root canal obturation material, separated endodontic instruments, localization of perforations).
Surgical retreatment		9. Limited FOV CBCT should be considered for presurgical treatment planning to localize root apex/apices and to evaluate proximity to adjacent anatomy.
Special conditions	Implant placement	10. Limited FOV CBCT should be considered for surgical placement of implants.
	Traumatic injuries	11. Limited FOV CBCT should be considered for diagnosis and management of limited dentoalveolar trauma, root fractures, luxation, and/or displacement of teeth and localized alveolar fractures in the absence of other maxillofacial or soft tissue injury that required advance imaging modalities.
	Resorptive defects	12. Limited FOV CBCT should be used in the localization and differentiation of external and internal resorptive defects and to determine the appropriate treatment and prognosis.

AAE, American Association of Endodontists; AAOMR, American Academy of Oral and Maxillofacial Radiology; FOV, field of view.

A literature search was performed for each therapy, and the benefits, limitations, and risks were discussed by the panel. A summary of their consensus conclusions is presented in Table 8. The panel concluded that while there is a critical mass of evidence, there is not enough evidence to support periodontal clinical practice guidelines.

SEDENTEXCT, the European evidence-based CBCT guidelines, were initially developed in 2009 and led to the development of national guidelines within the European Union.[17] A final guideline document that was based on a sound systematic review based on established methodology was developed and published in 2012. The project included dentists, dental radiologists, medical physicists, and other dental specialists, including oral and maxillofacial surgeons, orthodontists, periodontologists, and restorative dentists. The guidelines were essentially developed for dentists and all specialists using the technology in Europe. Although there are no definitive published numbers of actual users of CBCT in the United States, it is believed that general dentists comprise the majority of users. CBCT technology is currently used in various clinical radiographic tasks including endodontics, where higher resolutions are needed due to the nature of the diagnostic tasks involved.[19] A survey conducted among endodontic practitioners who were members of the AAE in the United States revealed that about a third of those surveyed used CBCT technology in their practice.[20]

Conclusions

CBCT guidelines in the United States were developed through cooperative efforts of the AAOMR and other US-based dental specialty groups. The guidelines are generally focused on the appropriate use of CBCT technology for diagnostic and treatment planning applications in both specialty care and general dental practice. The guidelines are also focused on the concept of ALARA and the recommendations are very specific to the situations in dental practice where the tasks on hand cannot be completed using 2D imaging alone. If a CBCT is indicated, the FOV selected is an important consideration to reduce to dose to the patient.

Table 8 American Academy of Periodontology consensus conclusions of selected oral applications of CBCT[16]

Question	Conclusion	
Should CBCT replace 2D radiographic analysis of regional anatomy in surgical management of patients requiring implants?	Evaluation of root morphology and associated pathology for extractions and reconstruction	
	Location on relevant anatomical structures and their relation to implant placement	
	Sinus grafting pre-implant evaluation	
	Evaluation of autogenous bone donor site	
	Fabrication of static surgical guides and dynamic navigation of implant placement	
	Post-bone augmentation implant planning	
	Complications with previously placed implants	
	Team communication with implant restorative colleagues	
Is CBCT imaging useful in determining risk to periodontal structures in patients requiring tooth movement?	Skeletally mature orthodontic patient with malocclusion that requires a fixed orthodontic appliance for decompensation	
	Orthodontic patient with a thin dentoalveolar phenotype and dentoalveolar bone deficiencies are suspected	
	Malocclusion patient requiring advanced tooth movement and there is an increased risk for positioning the roots outside the orthodontic boundary	
	Skeletally immature orthodontic patient requiring interdisciplinary approach (ie, periodontal-orthodontic-restorative or multi-specialist care)	
	Orthodontic patient with concomitant mucogingival deformities (recession)	
	Patient presenting with other specific treatment considerations requiring global analysis	Temporomandibular disorders
		Dentofacial disharmonies requiring orthodontic-periodontal-orthognathic approaches for management
		Congenitally missing teeth
		Requirement for skeletal anchorage
Does CBCT imaging add clinical value in diagnostic assessment and treatment planning for the management of periodontis?	When an advanced furcation lesion has been detected and dental implants are being considered as an alternative treatment option	
	When advanced bone loss has encroached on anatomical structures such as sinus cavities or the inferior alveolar nerve	
	When there is a questionable root fracture, root resorption, or periodontal-endodontic lesion present that could not be identified by 2D imaging and/or clinical evaluation	
	In retreatment of cases that don't respond favorably to localized periodontal therapy	
	To enhance the diagnosis and management of peri-implantitis when determined necessary	

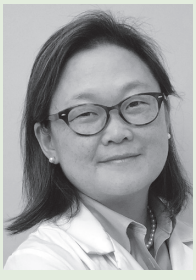
Summary of recommendations

The guidelines can be summarized for clinical care as below:

- CBCT is a new and emerging technology that has the potential for use and application in a variety of clinical tasks, both diagnostic and prognostic.
- 2D radiography or plain radiography is the first choice of imaging in many clinical scenarios, and CBCT should be used when 2D imaging alone cannot answer the question on hand. When using CBCT, published criteria should be used for selection of the appropriate FOV.
- A thorough clinical examination must precede the use of CBCT, as is the case with any other radiation-based examination. CBCT is a higher x-ray dose modality, and hence caution should be exercised while selecting the FOV to be scanned. Large FOV should not be used when a small or medium FOV can be adequate for the task.
- Pre-implant imaging using CBCT is more useful than post-implant imaging.
- The effective doses for dentoalveolar CBCT range from 11 to 674 µSv. The effective doses for craniofacial CBCT range from 30 to 1,073 µSv.
- CBCT is indicated in situations where a tooth is impacted, infected, or missing, and 2D radiography did not reveal the pathoses. Pre-implant planning, preoperative evaluation, postsurgical evaluation in a variety of oral surgical, periodontal, endodontic, restorative, and prosthodontic conditions can be performed using CBCT.
- Dose sparing techniques must be used in children and adolescents to minimize the effective doses using the ALARA principle.

References

1. Beckmann EC. CT scanning the early days. Br J Radiol 2006;79(937):5–8.
2. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc 2006;72:75–80.
3. Kim IH, Mupparapu M. Dental radiographic guidelines: a review. Quintessence Int 2009;40:389–398.
4. Hatcher DC. Operational principles for cone-beam computed tomography. J Am Dent Assoc 2010;141(Suppl 3):3S.
5. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol 1998;8:1558–1564.
6. Mupparapu M, Nadeau C. Oral and maxillofacial imaging. Dent Clin North Am 2016;60:1–37.
7. Mupparapu M, Singer SR. Dose reduction and cone beam CT: perception is reality. Quintessence Int 2011;42:279.
8. Baba R, Ueda K, Okaba M. Using a flat-panel detector in high resolution cone beam CT for dental imaging. Dentomaxillofac Radiol 2004;33:285–290.
9. Carter L, Farman AG, Geist J, et al. American Academy of Oral and Maxillofacial Radiology executive opinion statement on performing and interpreting diagnostic cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:561–562.
10. American Association of Endodontists; American Academy of Oral and Maxillofacial Radiology. Use of cone beam computed tomography in endodontics. Joint Position Statement of the American Association of Endodontics and the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111:234–237.
11. Tyndall D, Price J, Tetradis S, Ganz S, Hildebolt C, Scarfe W. Position statement of the American Academy of Oral and Maxillofacial Radiology on the selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2012;113:817–826.
12. The American Dental Association Council on Scientific Affairs. The use of cone-beam computed tomography in dentistry, an advisory statement from the American Dental Association Council on Scientific Affairs. J Am Dent Assoc 2012;143:899–902.
13. American Academy of Oral and Maxillofacial Radiology. Clinical recommendations regarding use of cone beam computed tomography in orthodontics. Position statement by the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2013;116:238–257.
14. American Association of Endodontists; American Association of Oral and Maxillofacial Radiology. AAE and AAOMR Joint Position Statement: Use of Cone Beam Computed Tomography in Endodontics 2015 Update. Oral Surg Oral Med Oral Pathol Oral Radiol 2015;120:508–512.
15. Carter JB, Stone JD, Clark RS, Mercer JE. Applications of cone-beam computed tomography in oral and maxillofacial surgery: an overview of published indications and clinical usage in the United States academic centers and oral and maxillofacial surgery practices. J Oral Maxillofac Surg 2016;74:688–679.
16. Mandelaris GA, Scheyer ET, Evans M, et al. American Academy of Periodontology Best Evidence Consensus Statement on selected oral applications for cone-beam computed tomography. J Periodontol 2017;88:939–945.
17. Radiation Protection No. 172. Cone Beam CT for dental and maxillofacial Radiology. www.sedentexct.eu/files/radiation_protection_172.pdf. Accessed 20 September 2018.
18. North America CBCT Dental Imaging Market Research Report - Forecast to 2023. https://www.marketresearchfuture.com/reports/north-america-cbct-dental-imaging-market-5320. Accessed 20 September 2018.
19. Cohenca N, Shemesh H. Clinical applications of cone beam computed tomography in endodontics: a comprehensive review. Quintessence Int 2015;46:657–668.
20. Setzer FC, Hinckley N, Kohli MR, Karabucak B. A survey of cone-beam computed tomographic use among endodontic practitioners in the United States. J Endod 2017;43:699–704.



Irene H. Kim

Irene H. Kim Attending Staff, Department of Dentistry, Morristown Medical Center, Morristown, New Jersey, USA.

Steven R. Singer Professor and Chair, Department of Diagnostic Sciences, Rutgers School of Dental Medicine, Newark, New Jersey, USA.

Mel Mupparapu Professor of Oral Medicine, Director of Radiology, Department of Oral Medicine, University of Pennsylvania School of Dental Medicine, Philadelphia, Pennsylvania, USA.

Correspondence: Professor Mel Mupparapu, Robert Schattner Center, Suite #214, 240 S 40th Street, Philadelphia, PA, USA.
Email: mmd@upenn.edu