Clinical recommendations regarding use of cone beam computed tomography in orthodontics. Position statement by the American Academy of Oral and Maxillofacial Radiology

American Academy of Oral and Maxillofacial Radiology

Aims. To summarize the potential benefits and risks of maxillofacial cone beam computed tomography (CBCT) use in orthodontic diagnosis, treatment and outcomes and to provide clinical guidance to dental practitioners.

Methods. This statement was developed by consensus agreement of a panel convened by the American Academy of Oral and Maxillofacial Radiology (AAOMR). The literature on the clinical efficacy of and radiation dose concepts associated with CBCT in all aspects of orthodontic practice was reviewed.

Results. The panel concluded that the use of CBCT in orthodontic treatment should be justified on an individual basis, based on clinical presentation. This statement provides general recommendations, specific use selection recommendations, optimization protocols, and radiation-dose, risk-assessment strategies for CBCT imaging in orthodontic diagnosis, treatment and outcomes.

Conclusions. The AAOMR supports the safe use of CBCT in dentistry. This position statement is periodically revised to reflect new evidence and, without reapproval, becomes invalid after 5 years. (Oral Surg Oral Med Oral Pathol Oral Radiol 2013;116:238-257)

Malocclusions and craniofacial anomalies adversely affect quality of life. Orthodontics and dentofacial orthopedic treatment address the correction of malocclusions and facial disproportions due to dental/skeletal discrepancies to provide esthetic, psychosocial, and functional improvements. For almost a century, two-dimensional (2D) planar radiographic imaging and cephalometry have been used to assess the interrelationships of the dentition, maxillofacial skeleton, and soft tissues in all phases of the management of orthodontic patients, including diagnosis, treatment planning, evaluation of growth and development, assessment of treatment progress and outcomes, and retention. However, the limitations of 2D imaging have been realized for decades as many orthodontic and dentofacial orthopedic problems involve the lateral or "third dimension."[1-3] For instance, relapse of and unfavorable responses to orthodontic therapy remain poorly understood despite implications that considerations in the transverse plane are important factors in stability.[4] For years, multiple radiographic projections were obtained to attempt to display complex anatomic relationships and surrounding structures; however, interpreting multiple-image inputs is challenging. With the increasing availability of multi-slice computed tomography (CT) and, more recently, cone beam computed tomography (CBCT), visualization of these relationships in three dimensions is now feasible.

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SCOPE AND PURPOSE OF THE RECOMMENDATIONS AND CONCLUSIONS

This position statement was developed by board-certified orthodontists and oral and maxillofacial radiologists convened by the American Academy of Oral and Maxillofacial Radiology (AAOMR). Their objectives were to 1) review and evaluate critically the current science, guidance and other resources available from professional organizations on the clinical benefits and potential limitations of the use of CBCT in orthodontics, and 2) develop consensus derived, orthodontic-specific clinical guidelines. Imaging selection recommendations, optimization protocols and radiation-dose, risk-assessment strategies were developed to assist professional clinical judgment on the use of CBCT in orthodontics. The panel concluded that there is no clear evidence to support the routine use of ionizing radiation in standard orthodontic diagnosis and treatment planning, including the use of CBCT.

BACKGROUND

Imaging considerations in orthodontic therapy

One purpose of radiographic imaging in orthodontics is to supplement clinical diagnosis in the pretreatment assessment of the orthodontic patient. Radiographic imaging may also be performed during treatment to assess the effects of therapy and posttreatment to monitor stability and outcome. Imaging for a specific orthodontic patient occurs in at least three 3 stages: 1) selection of the most appropriate radiographic imaging technique, 2) acquisition of appropriate images, and 3) interpretation of the images obtained. In some instances, these steps need to be repeated. Selection of the appropriate radiographic imaging technique (or techniques) is based on the principle that practitioners who use imaging with ionizing radiation have a professional responsibility of beneficence—that imaging is performed to "serve the patient's best interests." This requires that each radiation exposure is justified clinically and that procedures are applied that minimize patient radiation exposure while optimizing maximal diagnostic benefit. The extension of this principle, referred to as the "as low as reasonably achievable" (ALARA),[5] to CBCT imaging is supported by the American Dental Association.[6] Justification of every radiographic exposure must be based primarily on the individual patient's presentation including considerations of the chief complaint, medical and dental history, and assessment of the physical status (as determined with a thorough clinical examination) and treatment goals.[6]

In 1987, a panel of representatives from general dentistry and various academic disciplines in the United States was convened by the Food and Drug Administration. This panel published broad selection recommendations for intraoral radiographic examinations.[7] These were updated in 2004.[8,9] The guidelines suggest that for monitoring growth and development of children and adolescents, "clinical judgment be used in determining the need for, and type of radiographic images necessary for, evaluation and/or monitoring of dentofacial growth and development." In both the European Union[10-12] and the United Kingdom[13] orthodontic imaging guidelines state that there is neither an indication for taking radiographs routinely before clinical examinations nor for taking a standard series of radiographic images for all orthodontic patients. The latter document provides clinical decision algorithms based on the ages of the patients (less than or over 9 years of age) and clinical presentation (delayed or ectopic eruption, crowding, or anteroposterior discrepancies such as overjet or overbite, etc.).

CBCT imaging in orthodontics

There has been a dramatic increase in the use of CBCT in dentistry over the last decade. This technology has found particular applications in orthodontics for diagnosis and treatment planning for both adult and pediatric patients.[14-20] CBCT imaging provides two unique features for orthodontic practice. The first is that numerous linear (e.g., lateral and posteroanterior cephalometric images) or curved planar projections (e.g., simulated panoramic images) currently used in orthodontic diagnosis, cephalometric analysis, and treatment planning can be derived from a single CBCT scan. This provides for greater clinical efficiency. The second, and most important, is that CBCT data can be reconstructed to provide unique images previously unavailable in orthodontic practice. Innately CBCT data are presented as inter-relational undistorted images in three orthogonal planes (i.e., axial, sagittal, and coronal); however, software techniques are readily available (e.g., maximum intensity projection and surface or volumetric rendering) that provide three-dimensional visualization of the maxillofacial skeleton, airway space and soft tissue boundaries such as the facial outline. The current diagnostic uses of CBCT are summarized in Appendix A.[21-158]

Evidence based assessments

The potential for extracting additional diagnostic information from volumetric imaging and the technical ease of obtaining scans has led some clinicians and manufacturers to advocate the replacement of current conventional imaging modalities with CBCT for standard orthodontic diagnosis and treatment.[15,18,159,160] Although CBCT imaging increases clinician confidence in orthodontic diagnosis[161] and has demonstrated clinical efficacy in altering treatment planning for impacted maxillary canines,[37,43,161] unerupted teeth, severe root resorption, and severe skeletal discrepancies,[161] no benefit has been demonstrated for patients specifically referred for abnormalities of the temporomandibular joint, airway assessment or dental crowding.[161] Despite the number of publications on the use of CBCT for specific orthodontic applications, most are observational studies of diagnostic performance and efficacy with wide ranging methodological soundness.[162] Few authors have presented higher levels of evidence and measured the impact of CBCT on orthodontic diagnosis and treatment planning decisions.

Fundamentals to guideline development are systematic reviews of the published literature. Systematic reviews use well-defined and reproducible literature search strategies to identify evidence focused on a specific research question. Evidence is graded according to its level of methodological rigor (or quality), relevance and strength. There is a lack of CBCT-orthodontic systematic reviews. There is a need for rigorous investigation on the efficacy of CBCT imaging for all aspects of orthodontics related to its influence on therapy decisions and ultimately patient outcome.[163] Because of the lack of CBCT-orthodontic systematic reviews, the panel used consensus and published criteria.[164-168] to develop three hierarchical recommendations for CBCT imaging in orthodontics (Table I). An important consideration in the use of CBCT is that ionizing radiation is a risk to patient health.

Radiation dose considerations in orthodontics

There are two broad potential harmful effects of ionizing radiation in orthodontics. The first is deterministic effects that cause the death of cells from high doses over short periods of time and usually occur only after thresholds are reached. Below these thresholds no clinical change has been reported. These levels are never reached for a single exposure in the diagnostic range

Table I. Panel consensus recommendations for use of CBCT imaging*

Recommendation	*Consensus level*	*Definition*
Likely indicated	I	The use of CBCT imaging is indicated in most circumstances for this clinical condition. There is an adequate body of evidence to indicate a favorable benefit from the procedure relative to the radiation risk in the majority of situations.
Possibly indicated	II	The use of CBCT imaging may be indicated in certain circumstances for this clinical condition. There is a sufficient body of evidence to indicate a possible favorable benefit from the procedure relative to the radiation risk in many situations.
Likely not indicated	III	The use of CBCT imaging is not indicated in the majority of circumstances for this clinical condition. There is an insufficient body of evidence to indicate a benefit from the procedure relative to the radiation risk in most situations.

*In the future, if CBCT imaging radiation levels are equivalent to conventional modalities, this table may be less relevant.

used in conventional oral and maxillofacial radiology. They do, however, occur in dental patients who have cancer and undergo radiotherapy to the head and neck region. One example of this is radiation-induced oral mucositis. The second effect is a stochastic effect that irreversibly alters the cells, usually by damaging cellular DNA. Such damage can result in cancer. The long-term risk associated with diagnostic radiographic imaging is radiation-induced carcinogenesis. Unlike deterministic effects, stochastic effects can result from low levels of radiation that are cumulative over time.

Assessment of the risks associated with the use of ionizing radiation for diagnostic imaging is an important public health issue. Recent reports have increased concerns over the potential association between radiation exposure and cancer. In one article, a relationship was found between intracranial meningiomas and dental radiographic procedures[169]; however, numerous rebuttal articles have highlighted limitations in this study.[170-173] Most recently, the results of a retrospective cohort study provide evidence of a link between exposure to radiation from medical CT and cancer risk in children.[174] It was found that children and young adults who received radiation doses from the equivalent of 2 or 3 medical CT scans of the head have almost triple the risk of developing leukemia or brain cancer later in life. Medical CT head scans may have an effective dose of up to 2000 μSv[175]; however, for CT examinations with dental protocols, substantial reductions to less than 1000 μSv have been reported.[159,176-184] Most CBCT examinations impart a fraction of medical CT effective dose; however, doses vary considerably among CBCT units.[90,137,159,176-196]

Low-dose radiographic procedures (including maxillofacial CBCT) are those that result in doses below about 1,00,000 μSv. The risk of cancer induction caused by low-dose radiographic procedures is difficult to assess. While there is lack of agreement among radiation epidemiologists and radiobiologists, there is consensus among the four authoritative agencies in the United States responsible for developing public-health, radiation-safety directives that for stochastic risks, such as carcinogenesis, the risks should be considered to be linearly related to doses, down to the lowest doses.[197-200] The assessment of risk is, however, confounded in that people are exposed to background radiation, including cosmic radiation from airline flights and/or living at high altitudes. For this position statement, the panel reviewed information on the potential health effects of exposure to diagnostic ionizing radiation. There is neither convincing evidence for carcinogenesis at the level of dental exposures, nor the absence of evidence of such damage. This situation is unlikely to change in the near future. In the absence of evidence of a threshold dose, it is prudent, from a patient-policy perspective, to assume that such a risk exists. This implies that there is no safe limit or "safety zone" for ionizing radiation exposure in diagnostic imaging. Every exposure cumulatively increases the risk of cancer induction. Consequently, to be cautious, the guidelines presented in this position statement are focused on minimizing or eliminating unnecessary radiation exposure in diagnostic imaging.

The overall biological effect of exposure to ionizing radiation, expressed as the risk of cancer development over a lifetime, is determined from absorbed radiation dose to specific organs in combination with weighting factors that account for differences in exposed-tissue sensitivity and patient susceptibility factors such as gender and age. For this position statement, the International Commission on Radiological Protection (ICRP)'s effective dose (E) method was used to estimate whole body dose and measure stochastic radiation risks to patients based on evidence of biological effects currently available.[201] Effective dose is calculated by multiplying organ doses by risk weighting factors (which are the organs' relative radiosensitivities to developing cancers). The sum of the products for all of the organs is the effective whole-body dose (effective dose).[201] The estimated risk weighting factors have recently been revised, and a number of additional tissues found in the head and neck region have been included (most importantly the salivary glands, lymphatic nodes, muscle, and oral mucosa).[197] These modifications have resulted in substantial increases (ranging from 32% to 422%) in effective doses for specific maxillofacial radiographic procedures.[177]

The effective dose for CBCT radiographic imaging used for orthodontic records is of particular concern, especially as the modal age for initiating orthodontic treatment represents a pediatric population. The radiation risk to ionizing radiation is greater for young children than for adolescents and adults because: 1) the rate of cellular growth and organ development (when radiosensitivity is highest) is greater in young children; 2) children have longer life expectancies, so the cumulative effects of radiation exposures have longer time periods in which they can cause cancers; 3) with CBCT imaging, specific organ and effective doses, (particularly the salivary glands) are, on average, 30% higher for young children than for adolescents[183]; and 4) unless specific, pediatric, exposure−reduction techniques are incorporated, the radiation doses for children (small patients) may exceed typical adult radiation levels (with some currently available CBCT units, it is not possible to implement exposure−reduction techniques). In sum, it is estimated that children may be two to ten times or more prone to radiation-induced carcinogenesis than mature adults.[175,200-202] Because it is important to consider the increased risks associated with exposing children to ionizing radiation, the American College of Radiology (ACR) has incorporated pediatric, effective-dose estimates in relative radiation level (RRL) designations for specific imaging procedures (Table II).[203] In addition, there are at least two national radiation safety initiatives to raise awareness of using lower radiation doses to image children: Image Gently[204] and the National Children's Dose Registry.[205] The AAOMR sought, and received, permission to adopt the ACR, relative-radiation-level designations for several reasons: First, this scheme provides a relative assessment of radiation dose risk based on the premise that with an exposure of 10,000 μSv, there is a risk of 1 in 1000 individuals developing cancer; second, the risk is related to diagnostic imaging only (and is unrelated to considerations of background radiation exposure); and three, risk assessment incorporates increased pediatric radiation sensitivity considerations.

For all imaging procedures using ionizing radiation, the clinical benefits should be balanced against the potential radiation risks, which are determined by the relative radiosensitivity of those being imaged and the abilities of the operators to control radiation exposures.

Table II. Estimations of relative radiation level designations for children and adults for orthodontic imaging (*with permission from* ACR,* 2011)

	Effective dose estimate range (μSv)	
Relative radiation level	*Adult*	*Child*[†]
0	0	0
☢	<100	<30
☢☢	100-1000	30-300
☢☢☢	1000-10,000	300-3000
☢☢☢☢	10,000-30,000	3,000-10,000

*Some of the information in this document was provided with permission from the American College of Radiology (ACR) and taken from the ACR Appropriateness Criteria. The ACR is not responsible for any deviations from original ACR Appropriateness Criteria content.
†Child is defined as any individual less than 18 years of age.

GUIDELINES FOR CBCT IN ORTHODONTICS

The choice of modality used for imaging an orthodontic patient is based on a risk/benefit assessment (i.e., the risk to the patient attributable to radiation exposure in relationship to the benefit to the patient from imaging procedure). Assessment of clinical benefit is primarily patient and practitioner dependent but should be based on the application of sound imaging selection principles. As part of this position statement, the following guidelines are suggested for the use of CBCT in orthodontics:

1. Image appropriately according to clinical condition
2. Assess the radiation dose risk
3. Minimize patient radiation exposure
4. Maintain professional competency in performing and interpreting CBCT studies

1. Image appropriately according to clinical condition

Recently the American Dental Association Council on Scientific Affairs issued an advisory statement on the use of CBCT in dentistry. The AAOMR contributed to the statement,[6] which is based on the ALARA principle and acknowledges the increased sensitivity of pediatric patients to ionizing radiation and recognizes that patients present with varying degrees of orthodontic complexity. The panel recommends the following general strategies for the use of CBCT in orthodontics:

Recommendation 1.1. The decision to perform a CBCT examination is based on the patient's history, clinical examination, available radiographic imaging, and the presence of a clinical condition for which the benefits to the diagnosis and/or treatment plan outweigh the potential risks of exposure to radiation, especially in the case of a child or young adult.

Recommendation 1.2. Use CBCT when the clinical question for which imaging is required cannot be answered adequately by lower-dose conventional dental radiography or alternate non-ionizing imaging modalities.

Recommendation 1.3. Avoid using CBCT on patients to obtain data that can be provided by alternate non-ionizing modalities (e.g., to produce virtual orthodontic study models).

Recommendation 1.4. Use a CBCT protocol that restricts the field of view (FOV), minimizes exposure (mA and kVp), the number of basis images, and resolution yet permits adequate visualization of the region of interest.

Recommendation 1.5. Avoid taking a CBCT scan solely to produce a lateral cephalogram and/or panoramic view if the CBCT would result in higher radiation exposure than would conventional imaging.

Recommendation 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.

To assist clinicians in defining the scope of orthodontic conditions and the most appropriate CBCT imaging in each circumstance, specific imaging selection recommendations for the use of CBCT in orthodontics are given in Table III. The proposed recommendations include the phase of treatment (pre-, during-, or post-treatment), the treatment difficulty and the presence of additional skeletal and dental conditions. The table rows list orthodontic phases of treatments and treatment difficulty categories and columns list dental and skeletal clinical conditions. Within each cell, the overall suitability of the CBCT procedure (Table I) and most appropriate FOV are provided. Table IV describes the three FOV ranges most commonly encountered in orthodontic imaging. The concerns in selecting a CBCT FOV are the inclusion of the region of clinical importance and the collimation of the radiation beam to that specific region. The rational for orthodontic image selection recommendations is in Appendix B.

2. Assess the radiation dose risk

Orthodontists must be knowledgeable of the radiation risk of performing CBCT and be able to communicate this risk to their patients. Radiation risk has most often been estimated by calculating the effective dose[201] of a CBCT scan and comparing this value to; 1) measurements obtained from comparable imaging modalities (e.g., multiples of typical panoramic images or a multi-slice medical CT), 2) background equivalent radiation time (e.g., days of background), or 3) radiation detriment [e.g., probability of x cancers per million scans (stochastic-cancer rate)]. Often the base unit of these comparisons (typical panoramic dose, background radiation, weighted probabilities of fatal and nonfatal cancers) is variable and not absolute. This means, for example, that depending on the panoramic

Table III. Imaging selection recommendations for the use of cone beam computed tomography in orthodontics

Presentation		*Dental and skeletal clinical conditions*								
Primary	*Treatment difficulty*	*None*	*Dental structure anomalies*	*Anomalies in dental position*	*Compromised dento-alveolar boundaries*	*Asymmetry*	*Anteroposterior discrepancies*	*Vertical discrepancies*	*Transverse discrepancies*	*TMJ signs and/or symptoms*
Pretreatment	Mild	III	FOV_S (I)	FOV_S (I)	$FOV_{s,m}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{s,m}$ (III)
	Moderate	$FOV_{m,l}$ (II)	FOV_S (I)	FOV_S (I)	$FOV_{s,m}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)
	Severe	FOV_l (II)	FOV_S (I)	FOV_S (I)	$FOV_{s,m}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)
During treatment		III	FOV_S (III)	FOV_S (II)	$FOV_{s,m}$ (II)	Presurgical $FOV_{m,l}$ (I)	Presurgical $FOV_{m,l}$ (II)	Presurgical $FOV_{m,l}$ (II)	Presurgical $FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)
Posttreatment		III	FOV_S (III)	FOV_S (III)	$FOV_{s,m}$ (III)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)	$FOV_{m,l}$ (II)

CBCT, cone beam computed tomography; Field of View (FOV): FOV_s = Small FOV CBCT imaging; FOV_m = Medium FOV CBCT imaging; FOV_l = Large FOV CBCT imaging. Consensus Recommendations: I = Likely Indicated; II = Possibly Indicated; III = Likely Not Indicated.

Table IV. Definition of cone beam computed tomography field of view (FOV) ranges for orthodontic imaging

FOV	*Abbreviation*	*Definition*
Small	FOV_s	A region of radiation exposure that is limited to a few teeth, a quadrant, and up to two dental arches and that has a spherical volume diameter or cylinder height ≤10 cm.
Medium	FOV_m	A region of radiation exposure that includes the dentition of at least one arch up to both dental arches and that has a spherical volume diameter or cylinder height >10 cm and ≤15 cm.
Large	FOV_l	A region of radiation exposure that includes the TMJ articulations and anatomic landmarks necessary for quantitative cephalometric and/or airway assessment and that has a spherical volume diameter or cylinder height >15 cm.

image dose used for the comparison (e.g., equipment manufacturer and model, film vs. digital acquisition) the risk for CBCT may be reported either conservatively or liberally compared to panoramic radiography.

To standardize comparison of radiation dose risk between various imaging procedures, this position statement recommends the use of RRLs (Table II). The RRL for various imaging examinations used either as an isolated procedure or for a course of orthodontics can be determined for adults and children using published effective dose calculations (Table VI).[90,159,176-196,206,207] Calculations of RRL levels in millisieverts (mSv; 1mSv = 1000 μSv) were made with methods described elsewhere,[197] and data from the 7th Biological Effects of Ionizing Radiation report.[208] The estimate in the report, and the basis for subsequent levels of radiation risk, is that approximately 1 in 1000 individuals develop cancer from an exposure of 10,000 μSv.[197] RRL assignments are based on reviews of current literature. These assignments are revised periodically, as practice evolves and further information becomes available.

Based on these considerations, the following recommendations are suggested for assessing patient radiation dose risk for CBCT in orthodontics:

Recommendation 2.1. Consider the RRL (Table II) when assessing the imaging risk for imaging procedures over a course of orthodontic treatment. Table V contains the effective doses for specific orthodontic protocols and various modalities. Appendix C provides an example of the calculation of RRL for Orthodontic Imaging.

Recommendation 2.2. Because CBCT exposes patients to ionizing radiation that may pose elevated risks to some patients (pregnant or younger patients), explain and disclosure to patients radiation exposure risks, benefits and imaging modality alternatives and document this in the patients' records.

3. Minimize patient radiation exposure

Depending on the equipment type and operator preferences, operators can alter radiation doses to patients by adjusting various exposure (e.g., milliamperage, kilovoltage), image-quality (e.g., number of basis images, resolution, arc of trajectory) and beam-collimation (e.g., FOV) settings. CBCT units from different manufacturers vary in dose by as much as 10-fold for an equivalent FOV examination (Table V).[184] In addition, adjustments of exposure factors to improve image quality are available in many CBCT units and can cause as much as 7-fold differences in patient doses (Table V).[184] If CBCT imaging is warranted, appropriate selection of the FOV to match the region of interest (ROI) may provide a substantial dose savings.

Based on these considerations, the following specific recommendations are made to minimize patient radiation exposure for CBCT in orthodontics:

Recommendation 3.1. Perform CBCT imaging with acquisition parameters adjusted to the nominal settings consistent with providing appropriate images of task-specific diagnostic quality for the desired diagnostic information required: 1) Use a pulsed exposure mode of acquisition, 2) Optimize exposure settings (mA, kVp), 3) Reduce the number of basis projection images, and 4) Employ dose reduction protocols (e.g., reduced resolution) when possible.

Recommendation 3.2. When other factors remain the same, reduce the size of the FOV to match the ROI; however, selection of FOV may result in automatic or default changes in other technical factors (e.g., mAs) that should be considered because these concomitant changes can result in an increase in dose.

Recommendation 3.3. Use patient protective shielding (such as, lead torso aprons and consider the use of thyroid shields) when possible (e.g., maxillary only scan), to minimize exposure to radiosensitive organs outside the FOV of the exposure.

Recommendation 3.4. Ensure that all CBCT equipment is properly installed, routinely calibrated and updated, and meets all governmental requirements and regulations.

Appendix C provides an example of the calculation of the RRL for both adults and children with and

Table V. Selected published effective doses ($E_{ICRP,\ 2007}$) in microSieverts [μSv] for various field of view (FOV) cone beam computed tomography devices used in orthodontics in comparison with multi-slice computed tomography (MSCT), rotational panoramic and cephalometric radiography

Examination	*CBCT unit*	*Scanning volume (cm²)*	*Protocol*	E (*μSv*)[*Reference*]
Large FOV CBCT (>15 cm height/diameter)	3DeXAM	17 × 23	0.4 mm resolution	72[196]
	3D Accuitomo 170	17 × 12	Adolescent; 10 years old	216[183]; 282[183]
	CB MercuRay	15 × 15	Maxillofacial/TMJ	436[184]; 569[184]; 680[195]; 511[180]/436[90]
		20 × 20	SR/HR/TMJ	558[177]; 761[195]/1025[177]; 1073[184]/916[90]
	Galileos	15 × 15	High/low dose	128[184]/70[184]
	Galileos Comfort	15 × 15	Adult; adolescent; 10 years old	84[191]; 71[183]; 70[183]
	i-CAT Classic	16 × 22	Low/high resolution	65-69[192]; 193[177]; 82[178]; 206[186]; 110[181]/127-131[192]
	i-CAT Next Generation	23 × 17		74[184]; 78[190]
	Iluma	19 × 19	Standard/ultra	98[184]/498[184]
	Iluma Elite	21 × 14		368[191]
	KODAK 9500	18 × 20	With; without filtration	136[191]; 166[188]/260[188]
	NewTom 3G	15 × 15/20 × 20		57[178]/59[177]; 68[184]
	NewTom 9000	15 × 15		56[159]; 95[193]; 52[184]
	Newtom VGi	15 × 15		194[191]
	Skyview 3D	17 × 17	Adult; adolescent; 10 years old	87[191]; 90[183]; 105[183]
Medium FOV CBCT (>10 cm and ≤15 cm height/diameter)	3DeXAM	13 × 16	0.3 mm resolution	107[196]
	3D Accuitomo 170	10 × 14	Adolescent; 10 years old	188[183]; 237[183]
	CB Mercuray	10 × 10	Maxillofacial/TMJ imaging	283[177]; 407[184]; 603[195]/283[90]
	i-CAT Classic	13 × 16		61[159]; 105[177]; 134[186]; 69[184]
	i-CAT Next Generation	13 × 16	Adult; adolescent; 10 years old	87[184]; 83[191]; 77[190]; 82[183]; 134[183]
	NewTom VG	11 × 15	Adult; adolescent; 10 years old	83[191]; 81[183]; 114[183]
	Scanora 3D	13.5 × 14.5	Adult; adolescent; 10 years old	68[191]; 74[183]; 85[183]
Small FOV CBCT (≤10 cm height/diameter)	3DeXAM	5 × 10	Man	111[182]
		8 × 16	0.25; 0.30 resolution	170[196]; 45[196]
		4 × 16	Max 0.125 mm; 0.3 mm resolution/man 0.125 mm; 0.3 mm resolution	68[196]; 33[196]/76[196]; 38[196]
		8 × 8	0.125 mm; 0.3 mm resolution	122[196]; 62[196]
	3D Accuitomo IID	3 × 4		27[179]
	3D Accuitomo FPD	4 × 4/6 × 6		102[180]; 20[185]/43[185]; 50[180]; 166[179]

Table V. Continued

Examination	*CBCT unit*	*Scanning volume (cm^2)*	*Protocol*	E (*μSv*)*Reference*
	3D Accuitomo 170	4 × 4	Man adult; adolescent; 10 year old	43[191]; 32[183]; 28[183]
		5 × 10	Max	54[191]
		5 × 14	Max adolescent; 10 years old	70[183]; 214[183]
	AZ3000CT	7.9 × 7.1		333[182]
	i-CAT Classic	6 × 16	Man SR; HR/Mx SR; HR	96[186]; 189[186]/59[186]; 93[186]
	i-CAT Next Generation	6 × 16	Man SR; HR/Max SR; HR	74[184]; 45[191]; 58[190]; 113[190]/32[190]; 60[190]
		6 × 16	Max adolescent; 10 year old/man adolescent; 10 year old	33[183]; 43[183]/49[183]; 63[183]
	Implagraphy	5 × 8		83[182]
	KODAK 9500	5 × 15/9 × 15	Without; with filtration	93[188]; 76[188]/92[191]; 163[188]; 98[188]
	KODAK 9000 3D	5 × 3.7	Max anterior adult; 10 years old/man molar adult; adolescent	19[191]; 16[183]/40[191]; 24[183]
	Newtom VGi	8 × 12		265[191]
	Pan eXam Plus 3D	4.1 × 6.1	Max 0.133 mm; 0.2 mm resolution/man 0.133 mm; 0.2 mm resolution	79[196]; 40[196]/115[196]; 49[196]
		7.8 × 6.4	Max 0.2 mm; 0.3 mm resolution/man 0.2 mm; 0.3 mm resolution	125[196]; 79[196]/184[196]; 110[196]
	Picasso Trio	7 × 12	Low/high dose	81[191]/123[191]
	PreXion	8.1 × 7.6	High/standard resolution	388[184]/189[184]
		6 × 16	Max adolescent; 10 years old/man adolescent, 10 years old	33[183]; 43[183]/49[183]; 63[183]
	ProMax 3D	8 × 8	High/standard/low	674[179]; 652[184]; 122[191]; 306[193]/197[193]/488[184]; 30[187]; 28[191]
		8 × 8	Adolescent; 10 years old	18[183]; 28[183]
	Pax-Uni3D	5 × 5	Max anterior	44[191]
	Scanora 3D	6 × 6		91[179]
		7.5 × 10	Max/man/both	46[191]/47[191]/45[191]
		7.5 × 10	Adolescent; 10 year old	52[183]; 67[183]
	Veraviewepocs 3D	4 × 4/4 × 8/6 × 6/8 × 8		31[185]/40[185]/40[185]/73[191]

(*continued on next page*)

Table V. Continued

Examination	*CBCT unit*	*Scanning volume (cm²)*	*Protocol*	E (μSv)[Reference]
MSCT	Siemens Somatom	Lower jaw/head	Head sensation 16; volume zoom 4	474[178]; 494[178]/995[178]; 1110[178]
		Lower jaw	Sensation 10; emotion 6	426[182]; 199[182]
		10 × 12	Sensation 64	430[159]; 860-534[177]
		20 × 12.8/11.7	Sensation 64 adolescent; 10 years old	1047[183]; 605[183]
	Philips Mx8000IDT		Lower jaw; head	541[178]; 1160[178]
	GE 4 Slice CT	34.8 × 25		685[179]
	GE 64 Slice CT	25 × 41.25		1410[179]
	Toshiba Aquilion 64	9 × 4		990[181]
	HiSpeed QX/I	7.7 × 15		769[180]
Panoramic	Planmeca Promax	N/A	Film; CCD	26[207]; 24.3[184]
	Planmeca PM Proline 2000	N/A	High; low dose	38[207]; 12[207]
	Veraviewepocs	15 × 10	Adolescent	6[183]
	Sirona Orthophos	DS 15 × 11; XGplus 23 × 15		10[159]; 50[181]
	Instrumentarium OP100	30 × 15		21.5[192]
Cephalometric	PSP	N/A	Lat ceph	5.6[184]
	Orthophos DS	18 × 15	Lat ceph	10[159]
	Instrumentarium OC 100	24 × 18	Lat ceph	4.5[192]
	Veraviewepocs 2D	20 × 20	Lat ceph	2[183]
	Planmeca Promax PA	N/A	PA	5.1[184]

CBCT, cone beam computed tomography; *PSP*, photo-stimulable phosphor; *CCD*, charged coupled device-based technology; *Max*, maxillary; *Man*, mandibular; *TMJ*, temporomandibular joint; *MSCT*, multi-slice computed tomography; *HR*, high resolution; *SR*, standard resolution; *Lat ceph*, lateral cephalometric image; *PA*, posteroanterior cephalometric image; *N/A*, not available.

Product/Manufacturer details: 3DeXAM (KaVo Dental GmbH, Biberach/Riβ, Germany); 3D Accuitomo 170 (J. Morita Mfg. Corp., Kyoto, Japan); CB Mercuray (Hitachi Medical Systems, Kyoto, Japan); Galileos (Sirona Dental Systems GmbH, Bensheim Germany); Galileos Comfort (Sirona Dental Systems GmbH, Bensheim Germany); i-CAT Classic (Imaging Sciences International, Hatfield, PA); i-CAT Next Generation (Imaging Sciences International, Hatfield, PA); Iluma (Imtec (3M), Ardmore, OK); Iluma Elite (Imtec (3M), Ardmore, OK); KODAK 9500 (Kodak Dental Systems, Carestream Health, Rochester, NY); NewTom 3G (Quantitative Radiology, Verona, Italy); NewTom 9000 (Quantitative Radiology, Verona, Italy); Newtom VGi (Quantitative Radiology, Verona, Italy); Skyview 3D (MyRay, Cefla Dental Group, Imola, Italy); 3DeXAM (KaVo Dental GmbH, Biberach/Riβ, Germany); 3D Accuitomo 170 (J. Morita Mfg. Corp., Kyoto, Japan); CB Mercuray (Hitachi Medical Systems, Kyoto, Japan); i-CAT Classic (Imaging Sciences International, Hatfield, PA); i-CAT Next Generation (Imaging Sciences International, Hatfield, PA); NewTom VG (Quantitative Radiology, Verona, Italy); Scanora 3D (Soredex, Tuusula, Finland); 3DeXAM (KaVo Dental GmbH, Biberach/Riβ, Germany); 3D Accuitomo IID (J. Morita Mfg. Corp., Kyoto, Japan); 3D Accuitomo FPD (J. Morita Mfg. Corp., Kyoto, Japan); 3D Accuitomo 170 (J. Morita Mfg. Corp., Kyoto, Japan); AZ3000CT (Asahi Roentgen, Kyoto, Japan); i-CAT Classic (Imaging Sciences International, Hatfield, PA); i-CAT Next Generation (Imaging Sciences International, Hatfield, PA); Implagraphy (Vatech, E-WOO Technology Co, Ltd. Republic of Korea); KODAK 9500 (Kodak Dental Systems, Carestream Health, Rochester, NY); KODAK 9000 3D (Kodak Dental Systems, Carestream Health, Rochester, NY); Newtom VGi (Quantitative Radiology, Verona, Italy); Pan eXam Plus 3D (PaloDEx Group Oy, Tuusula, Finland); Picasso Trio (Vatech, Co, Ltd. Republic of Korea); PreXion 3D (PreXion Inc., San Mateo, CA); ProMax 3D (Planmeca OY, Helsinki, Finland); Pax-Uni3D (Vatech, Technology Co, Ltd. Republic of Korea); Scanora 3D (Soredex, Tuusula, Finland); Veraview epocs 3D (J. Morita Mfg. Corp., Kyoto, Japan); Siemens Somatom (Siemens Medical Solutions USA, Malvern, PA); Philips Mx8000IDT (Philips Medical Systems, Best, the Netherlands); GE 4 slice CT (GE Medical Systems, Little Chalfont, UK); GE 64 slice CT (GE Medical Systems, Little Chalfont, UK); Toshiba Aquilion 64 (Toshiba Medical Systems Corporation, Tochigi, Japan); HiSpeed QX/I (GE Medical Systems, Little Chalfont, UK); Planmeca Promax (Planmeca, Helsinki, Finland); Planmeca PM Proline 2000 (Planmeca, Helsinki, Finland); Veraview epocs (J. Morita Mfg. Corp., Kyoto, Japan); Sirona Orthophos (Sirona Dental Systems GmbH, Bensheim Germany); Instrumentarium OP100 (Instrumentarium Dental, Tuusula, Finland); Orthophos DS (Sirona Dental Systems GmbH, Bensheim Germany); Instrumentarium OC 100 (Instrumentarium Dental, Tuusula, Finland); Veraview epocs 2D (J. Morita Mfg. Corp., Kyoto, Japan); Planmeca Promax PA (Planmeca OY, Helsinki, Finland).

Table VI. Examples of the calculation of the RRL associated with specific imaging protocols used in orthodontics

		Stage of treatment			*Dose (μSv)*		*Relative radiation level**	
Protocol	*Modality*	*Initial diagnostic*	*Mid-treatment*	*Post-treatment*	*Sub-total*	*Total*	*Child*	*Adult*
Conventional imaging	Panoramic[†]	+	+	+	36	47.2	☢☢	☢
	Lateral cephalogram[‡]	+	−	+	11.2			
Conventional + small FOV CBCT	Panoramic[†]	+	+	+	36	107.2	☢☢	☢
	Lateral cephalogram[‡]	+	−	+	11.2			
	Small FOV CBCT[§]	+	−	−	60			
Large FOV CBCT + conventional imaging	Panoramic[†]	−	+	+	24	112.6	☢☢	☢☢
	Lateral cephalogram[‡]	−	−	+	5.6			
	Large FOV CBCT[‖]	+	−	−	83			
Large FOV CBCT	Large FOV CBCT[‖]	+	+	+	249	249	☢☢	☢☢

CBCT, cone beam computed tomography; *FOV*, field of view; *CCD*, charged coupled device technology; *Sub-total*, product of the times when the modality is used at each stage over a course of treatment by the average effective dose per modality exposure; *Total*, sum of subtotals for a particular orthodontic imaging protocol.

*American College of Radiology relative radiation level[203]; ☢, child (<30 μSv), adult (<100 μSv); ☢☢, child (<30-300 μSv), adult (100-1000 μSv).

[†]Planmeca PM Proline 2000 (low dose) − charged coupled device (12 μSv).[207]

[‡]Photostimulable storage phosphor (5.6 μSv).[177]

[§]i-CAT Next Generation − Maxilla 6 cm FOV height, high resolution (60 μSv).[190]

[‖]i-CAT Next Generation − 16 × 13 cm (83 μSv).[191]

without CBCT imaging for representative orthodontic imaging protocols (Table VI).

4. Maintain professional competency in performing and interpreting CBCT studies

Orthodontists must be able to exercise judgment by applying professional standards to all aspects of CBCT. Any radiographic image prescribed and/or performed by a dental practitioner may contain information that is important to the management or general health of the patient. Incidental findings in CBCT images of orthodontic patients are common,[209-213] and some are critical to patient health.[214] Clinicians who order or perform CBCT for orthodontic patients are responsible for interpreting the entire image volumes, just as they are responsible for interpreting all regions of other radiographic images that they order.[215,216]

Based on these considerations, the following recommendations are related to performing and interpreting CBCT studies:

Recommendation 4.1. Clinicians have an obligation to attain and improve their professional skills through lifelong learning in regards to performing CBCT examinations as well as interpreting the resultant images. Clinicians need to attend continuing education courses (such as those offered by the American Dental Association Continuing Education Recognition Program) to maintain familiarity with the technical and operational aspects of CBCT and to maintain current knowledge of scientific advances and health risks associated with the use of CBCT.

Recommendation 4.2. Clinicians have legal responsibilities when operating CBCT equipment and interpreting images and are expected to comply with all governmental and third party payer (e.g., Medicare) regulations.

Recommendation 4.3. It is important that patients/guardians know about the limitations of CBCT with regard to visualization of soft tissues, artifacts and noise.

EMERGING DEVELOPMENTS

CBCT acquisition technology continues to develop and a number of innovations are proposed to improve image quality, increase utility and reduce radiation output. These include the use of automatic exposure control with photon counting, added filtration, flat panel detectors with greater photon sensitivity, customizable FOV collimation, variable exposure parameters (mA, kVp) and image quality settings (e.g., scan trajectory options and number of basis images). The image quality and dose reductions purported by such innovations should be assessed critically and verified by independent published research.

SUMMARY

The recommendations provided for the use of CBCT in orthodontics are neither rigid guidelines nor do they represent or imply a standard of care. While it is the responsibility of each practitioner to make a decision, along with the patient/family, as to what imaging is considered to be in the patient's best interest, this position statement is intended to assist the clinician in the decision making process.

This position statement supports and affirms the position of the American Dental Association Council on Scientific Affairs in that the selection of CBCT imaging should be based on initial clinical evaluation and must be justified based on individual need.[6] The perceived or actual benefits to the patient must outweigh the radiation risks. Exposure of patients to ionizing radiation must never be considered "routine." It is important to perform a thorough clinical examination prior to performing or ordering any radiographic study. This position statement provides four guidelines for CBCT use in orthodontic practice: 1) Image appropriately by applying imaging selection recommendations, 2) Assess the radiation dose risk, 3) Minimize patient radiation exposure and, 4) Maintain professional competency in performing and interpreting CBCT studies.

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APPENDIX A: DIAGNOSTIC USES OF CBCT IN ORTHODONTICS

Dental structural anomalies

These comprise assessments of variations in tooth morphology, hypodontia, retained primary teeth, supernumeraries/gemination/fusion, root abnormalities, and external and internal resorption.[21-32]

Anomalies in dental position

These include dental impactions, presence of unerupted and impacted supernumeraries, locations of molars in relation to the inferior alveolar canals, anomalies in eruption sequences, and ectopic eruptions (including teeth in clefts).[14,22,27,33-50]

Compromised dento-alveolar boundaries

The assessment of dento-alveolar volume (in addition to that which can be determined by clinical examination and study models) is needed when there is reduced buccal/lingual alveolar width, bimaxillary protrusion, compromised periodontal status, and/or clefts of the alveolus.[51-56]

Asymmetry

Clinically, asymmetry presents as chin or mandibular deviation, dental midline deviation, and/or occlusal cant discrepancies as well as other dental and craniofacial asymmetries.[57-64]

Anteroposterior discrepancies

These are skeletally based Class II and Class III malocclusions.[59,60,62,65-73]

Vertical discrepancies

Initial facial patterns assessed clinically or radiographically may suggest skeletal discrepancies related to vertical maxillary deficiency or excess and may present as anterior open bite or deep overbite.[67,74]

Transverse discrepancies

These anomalies may be present as either skeletal lingual or buccal crossbites or discrepancies without the presence of crossbites in which there is excessive dental compensation of the bucco-lingual inclination of posterior teeth.[67,75,76]

Temporomandibular joint (TMJ) signs and/or symptoms

TMJ pathoses that result in alterations in the size, form, quality and spatial relationships of the osseous joint components may lead to skeletal and dental discrepancies in the three planes of space. In affected condyles, perturbed resorption and/or apposition can lead to progressive bite changes and compensations in the maxilla. In addition, tooth position, occlusion and the articular fossa of the non-affected side of the mandible can become involved. The sequelae of these changes are unpredictable orthodontic outcomes. Such TMJ conditions include developmental disorders such as condylar hyperplasia, hypoplasia, or aplasia, arthritic degeneration, persistently symptomatic joints, and bite changes including progressive bite opening and limitation or deviation upon opening or closing.[77-96]

Dentofacial deformities and craniofacial anomalies

CBCT imaging can facilitate analysis of these conditions and be used to simulate virtual treatments and plan orthopedic corrections and orthognathic surgeries. Computer-aided jaw surgery is increasing in use clinically because virtual plans accurately represent surgical procedures in the operating room.[65,66,68-73,97-109]

Conditions that affect airway morphology

A number of authors have used CBCT imaging to measure airway dimensions and reported changes over time with specific therapies including orthognathic surgery and particularly obstructive sleep apnea.[18,111-131] There are challenges in the use of CBCT clinically as the validity of such measurements may vary.[132,133] The boundaries of the nasopharynx with the maxillary/paranasal sinuses and of the oropharynx with the oral cavity are often not consistent among subjects and image acquisitions, and airway shapes and volumes vary markedly with dynamic processes such as breathing and head postures.

In addition, CBCT has been reported useful in preoperative assessment and/or postoperative evaluation of treatment outcomes for specific research applications including:

Specific surgical procedures

Research in the areas of craniofacial growth and development as well as assessments of the short- and long-term outcomes of various treatment regimens has the potential to benefit from CBCT assessments of longitudinal changes and diagnostic characterization of tooth and facial morphology of hard and soft tissues. Studies on the morphological basis for craniofacial growth and response to treatment can help elucidate clinical questions on variability of outcomes of treatment, as well as clarify treatment effects and areas of bone remodeling and displacement.

Orthodontic mini-implants used as temporary anchorage devices

Numerous authors have identified CBCT imaging as being clinically useful in identifying optimal site location for placement of orthodontic mini-implants.[67,75,134-151]

Maxillary expanders

CBCT imaging of maxillary transverse deficiencies treated with fixed and removable expanders has been reported of benefit in characterizing appliance specific skeletal displacement, associated dental effects and quantifying changes in skeletal dimensions of the nasal cavity and maxillary sinus volume.[51,152-158]

APPENDIX B: RATIONAL FOR ORTHODONTIC IMAGE SELECTION RECOMMENDATIONS

The recommendations in Table III are based upon the complexity of the orthodontic case. The following were considered in developing the recommendations.

Selection of clinical conditions for indications of CBCT use

The most common clinical dental and skeletal conditions in the orthodontic patient are presented as column headings in Table III.

Definition of orthodontic treatment difficulty criteria

The panel acknowledges the uniqueness of the facial form of each patient and the inherent difficulty in attempting to assess the severity of malocclusion and quantifying and categorizing orthodontic treatment need. For patients with severe malocclusions, there are, however, more choices with regard to appropriate orthodontic treatments, and there is an increased need for radiographic diagnostic input. For Table III, malocclusion severity was categorized and anticipated appropriateness of CBCT imaging was listed according to three levels of patient presentation:

Mild. Patients present with dental malocclusions, with or without minimal anteroposterior, vertical, or transverse skeletal discrepancies. These patients are treated usually with conventional biomechanics (with or without extraction). CBCT imaging is likely inappropriate for these patients unless they present with the additional clinical conditions noted.

Moderate. Patients present with dental and skeletal discrepancies that are treated orthodontically and/or orthopedically only. These discrepancies include bimaxillary proclination, open bite, and compensated Class III malocclusion. CBCT imaging is possibly indicated for many of these patients as indicated.

Severe. Patients present with skeletal conditions including, but not limited to complicated skeletal discrepancies, craniofacial anomalies (e.g., cleft lip and palate, craniofacial synostosis, etc.), sleep apnea, speech disorders, and post oncology/trauma/resection/pathology. For patients in this group, a team approach for treatment is used including speech therapy, clinical psychology, orthodontic and surgical interventions. Advanced imaging, including CBCT, may be indicated for many of these patients.

Selection of FOV

There is limited published research on the many and varied technical issues associated with CBCT imaging in orthodontics including optimal fields of view (image sizes) for specific diagnostic tasks, optimal exposure settings (some tasks may require lower exposures than others), and variations in the levels of ionizing radiation used (for similar tasks) with various CBCT systems. More specific and additional issues and controversies related to CBCT use include: 1) the necessary diagnostic quality of images[205]; 2) imperfect superimposition of CBCT and surface-scan data; 3) differing levels of exposure needed to determine root and bone morphology related to appliance construction or for the diagnosis of pathology; 4) indications for use of multiple CBCT scans; 5) lack of and utility of 3D norms; 6) impact of CBCT for the assessment of treatment outcome; 7) responsibility for the identification of clinically significant incidental pathology; and 8) responsibility for calibration and maintenance of the equipment.[203]

Assessment of progress and treatment outcomes

In complex cases, follow-up CBCT acquisitions for growth observation, assessment of treatment progress, and posttreatment analysis may be helpful. Any imaging protocol for the longitudinal quantitative assessment of the craniofacial complex requires methods to: 1) minimize the radiation dose from sequential multiple CBCT exposures; 2) construct accurate three-dimensional surface models; 3) reliably image registration (non-rigid, elastic and deformable; or rigid registration) using stable structures of reference for cranial base or regional superimpositions; and 4) quantify changes over time.

Age considerations

The choice of radiographic imaging method of a patient with clinically determined dental and/or skeletal modifying factors is dependent on the stage of growth of the individual and age-related presentation of the condition; therefore, recommendations for CBCT for some dental/skeletal conditions are age dependent. These conditions include:

Tooth structural anomalies. A CBCT examination may be indicated when other diagnostic modalities indicate a problem with root morphology or resorption in the mixed and permanent dentitions.

Tooth positional or eruption anomalies. A possible indication for a CBCT examination (in addition to periapical, occlusal and/or panoramic images) exists when interceptive orthodontic treatment is being considered for children between the ages of 5-11. In such cases, a small FOV should be used. Another possible indication for a CBCT examination (usually restricted or small FOV) is for children more than 11 years of age if surgical exposure is being considered as a treatment option and the location of the crown cannot be determined clinically or with conventional 2D images (e.g., panoramic, occlusal and/or periapical images).

Craniofacial anomalies. An additional possible indication for CBCT is in children (0-4 years) prior to mandibular distraction or other craniofacial surgical treatments if the children can remain motionless during the scans. For children between 5 and 11 years of age, CBCT is useful for locating developing teeth prior to alveolar bone grafting and Phase I orthodontic treatment for children with oral clefts. For these cases, limited fields of views may suffice. For patients older than 11 and comprehensive orthodontic treatments are required in preparation for craniofacial surgical procedures, CBCT may provide a benefit at the diagnostic stage of orthodontic treatment as well as immediately before the surgical procedures. Such decisions are case specific.

APPENDIX C: CALCULATION OF RRL FOR ORTHODONTIC IMAGING

Table VI provides four orthodontic imaging protocols and provides RRLs[168,203] and published effective doses. For example, if a typical imaging protocol incorporates three digital (Planmeca PM Proline 2000 [low dose]) panoramic images (initial- diagnostic-, mid- and post-treatment; 12 μSv[207] for each exposure = 36 μSv) and two digital (photo-stimulable storage phosphor) lateral cephalometric images (initial- and post-treatment; 5.6 μSv[177] for each exposure = 11.2 μSv) the total equivalent dose for the orthodontic series is 47.2 μSv. For an adult this represents an RRL of ☢ whereas for a child this represents an RRL of ☢☢. This can be compared to orthodontic imaging series incorporating a large FOV CBCT (i-CAT Next Generation [16 × 13 cm]) image (initial; 83 μSv[191]), two digital (Planmeca PM Proline 2000 [low dose][206]) panoramic images (mid- and post-treatment; 12 μSv[207] for each exposure = 24 μSv) and one digital (photo-stimulable storage phosphor) lateral cephalometric image (post-treatment; 5.6 μSv[177]). The equivalent dose for this orthodontic imaging series is 112.6 μSv. While radiation risk (RRL) using CBCT in this example is for both the adult and child is the same (☢☢), this protocol provides over twice the absolute dose than the conventional imaging series and elevates the risk of the adult into a higher category.

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