Clinical considerations and potential liability associated with the use of ionizing radiation in orthodontics

Ahmad Abdelkarim[a] and Laurance Jerrold[b]
Jackson, Miss, and Brooklyn, NY

Ionizing radiation is a known carcinogen. Its damaging effects can be deterministic or stochastic. Deterministic effects occur only after radiation exposure thresholds are reached, but stochastic effects are random, and there is no known threshold below which harmful effects will not occur. Therefore, the use of ionizing radiation in orthodontic treatment should bring a benefit to the patient that outweighs the risks. No legally binding statutes, rules, or regulations provide explicit radiographic prescription protocols for orthodontic practice. The objective of this article was to discuss guidelines and risk management strategies for appropriate and defensible use of ionizing radiation in orthodontics. Guidelines are discussed for radiographic acquisition at different points along the orthodontic treatment timeline. In addition, risk management strategies and best practices are presented regarding adequate and defensible radiographic interpretation. These guidelines are not rigid and do not establish standards of care; they should be modified as necessary for each patient and each clinical encounter. (Am J Orthod Dentofacial Orthop 2018;154:15-25)

Ionizing radiation is one of the world's most studied carcinogens. Its damaging effects are either deterministic or stochastic. Deterministic effects cause tissue reactions and occur only after certain radiation exposure thresholds are reached. They are not reached for exposure levels used in dentistry, including orthodontics; hence, only stochastic effects can occur. Stochastic effects are random; the main concern is the risk of cancer induction. The likelihood of a stochastic effect is proportional to the dose: the higher the dose, the greater the risk. This risk is also age dependent; it is highest in children and lowest for the elderly.[1]

Children, who comprise most orthodontic patients, are at highest risk because they are sensitive to radiation and have a long life span; therefore, radiation-induced cancer with a long latent period may be expressed later in their lives.[2] In general, the exposure to low-dose radiation during childhood results in a small, insignificant increase in the lifetime risk of fatal cancer.[3,4] Unfortunately, there is no known threshold below which no harmful effect will occur. Therefore, the diagnostic value of a radiographic imaging study needs to be balanced against this risk.[5]

Dental radiography is 1 basic tool for diagnosis; when ionizing radiation is used appropriately, it brings benefits that outweigh the low, future, and theoretical risks of the radiation received.[6] There is no legally binding statute, rule, or regulation that outlines clear radiographic prescription protocols in orthodontic practice, including which radiographs to prescribe or not to prescribe.[7]

The objectives of this article were to review relevant evidence and to discuss general guidelines and practices that can assist orthodontists in evidence-based clinical decision making for justifiable, defensible, and sensible radiographic acquisitions at different points along the orthodontic treatment timeline: initial, progress, and final. Additionally, evidence-based guidelines are presented regarding the acquisition and radiographic interpretation of cone-beam computed tomography (CBCT) scans.

These guidelines are not meant to provide legal advice or establish professional rules or standards of care. They should always be modified as necessary for

[a]Department of Orthodontics, School of Dentistry, University of Mississippi Medical Center, Jackson, Miss.
[b]Division of Orthodontics, Orthodontics and Dentofacial Orthopedics, NYU-Langome Hospital, Brooklyn, NY.
All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
Address correspondence to: Ahmad Abdelkarim, Department of Orthodontics, School of Dentistry, University of Mississippi, 2500 N State St, Jackson, MS 39201 ; e-mail, aabdelkarim@umc.edu.
Submitted, July 2017; revised and accepted, January 2018.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2018.01.005

each patient and each clinical encounter. All guidelines or regulations on the use of ionizing radiation have changed over time and often vary by location and situation in the United States and abroad.

General guidelines for radiographic acquisition

From a purely risk management perspective, not taking a clinically necessary radiograph is worse than taking an unnecessary one. Beyond risk management, it is widely considered beneath the standard of care to initiate orthodontic care without first acquiring proper diagnostic information. A clinician who begins orthodontic treatment without appropriate radiographs necessary for creating an adequate and appropriate diagnosis and treatment plan may be breaching the standard of care.[8]

Radiographic imaging is justified if there is an expected benefit to the patient. No dental organization or any authority can make clear rules on when and which radiographs to take, because each clinical encounter and each patient are different. A minor finding during a clinical examination could make or break the decision on which radiographs to take, if any.

The American Dental Association and the Food and Drug Administration provide general and broad guidelines for dental radiographic examinations and recommendations for patient selection.[9,10] For new adolescent and adult patients with permanent dentition, they advise an "individualized radiographic examination consisting of posterior bitewings with panoramic examination or posterior bitewings and selected periapical images; a full-mouth intraoral radiographic examination is preferred when the patient has clinical evidence of generalized dental disease or a history of extensive dental treatment."[9] These recommendations were made for dentistry overall but not specifically for orthodontics.

The process of prescribing radiographs in orthodontics is based on the practitioner's clinical judgment for a particular patient's presentation, and the ALARA directive—keeping radiation as low as reasonably achievable—should be adhered to.[11] Because most orthodontic patients are children, the ALARA directive is heightened in orthodontics.[12]

In general, the justification for taking radiographs is based on each patient's presentation including considerations of the chief complaint, the medical and dental history, and the requirement to diagnose, monitor, or examine the need, status, or outcome of a procedure or treatment.[13] Radiographs should always be prescribed after (not before) a clinical examination has been performed.[7,10]

Initial radiographic acquisition in orthodontics

After reviewing the patient's health history and completing a clinical examination, radiographs should be considered if they are likely to provide confirming or clarifying information that can affect the diagnosis and treatment.[14] Because each patient is different, there is no indication for taking a standard or the same series of radiographs for all orthodontic patients.[1]

To establish a comprehensive diagnosis for most orthodontic patients, case-specific radiographs are necessary for the patient's benefit.[15] With the ever-increasing quality of radiographic machines and images, the combination of pretreatment panoramic and cephalometric radiographs appears to be appropriate and sufficient in most cases.[15,16]

For initiating orthodontic therapy, a panoramic radiograph has many advantages and provides much information, including the status of dental development.[17] This single image provides an excellent and broad view of a variety of structures, including maxillary and mandibular dentitions, adjacent structures, and temporomandibular joints, and is quite helpful for patients with asymmetry.[18] The panoramic radiograph is simple to obtain and easy to interpret and explain to patients.

Whereas a panoramic radiograph of good quality can show a significant amount of information, it comes with 3 main limitations. First, it lacks the fine detail required to diagnose and monitor carious lesions and periodontal status, and the objects outside the focal trough will not be shown in detail.[19] Second, the panoramic radiograph is not dimensionally accurate and may include geometric distortion and unequal magnification throughout the image.[18] Third, panoramic radiography requires the patient to be positioned accurately in the focal trough.[18] To do so, it is valuable to follow the manufacturer's recommendations for patient positioning, including the appropriate use of light beam markers.[1] Staff members should be able to identify patient positioning errors and optimize the quality of patient positioning during panoramic radiography.

The value of the initial cephalometric radiograph, when appropriately acquired, should not be ignored. It can be useful for assessing growth and dental and skeletal relationships.[10] However, it may not be necessary for some patients who have mild crowding or spacing, or when a limited treatment plan will not change the maxillomandibular relationship.[20] For example, an adult with a chief complaint of mild crowding or spacing of the anterior teeth who requests limited treatment is unlikely to benefit from a cephalometric radiograph; taking this image is unlikely to change the treatment plan or the

final outcome.[20] Generally, when the incisor relationship does not require a significant change, a cephalometric radiograph is not required.[21] Some studies have inferred that cephalometric radiographs do not significantly influence treatment decisions.[22,23] In addition, there is no evidence to support the value of the cephalometric radiograph for predicting facial growth.[24] Therefore, for some patients, if treatment decisions can explicitly be made without the cephalometric radiograph, and this image will not influence treatment decisions, the benefit to the patient becomes questionable, in which case cephalometric acquisition may be unnecessary.

Whereas panoramic and cephalometric radiographs in combination are sufficient for most patients, in some circumstances other imaging techniques should be considered: when more accuracy or information is needed, and when an object needs to be visualized in 3 dimensions. These examples support the contention that the same set of pretreatment radiographs should not be routinely prescribed for every patient.[21,25] In these situations, other radiographic imaging techniques should be considered.

If more accuracy or information is needed, intraoral periapical radiographs should be considered because they are usually more accurate than panoramic radiographs for specific diagnostic tasks such as the evaluation of root resorption, root shape, and status of the alveolar bone.[26,27] Periapical radiographs are also excellent for periodontal and caries diagnoses.[19] The radiographic evaluation of periodontal status, incipient caries, and calculus deposits is best made from periapical and bitewing radiographs. Periapical radiographs will also show areas of bone loss, root anatomy, possible furcation involvements, apical radiolucencies, and widened periodontal ligaments.[19] Therefore, when the panoramic radiograph is insufficient for evaluation of these findings, it can be supplemented with intraoral periapical radiographs.[18]

Because the diagnosis of caries and periodontal disease is best made by periapical and bitewing radiographs, the orthodontist should not rule out incipient interproximal caries or alveolar bone loss by relying only on the panoramic radiograph, even if a high-quality image is available. It is always prudent to inform the patient or the parent that the checkup for carious lesions (or periodontal status) is best made and managed by the general dentist (or a periodontist) who will take intraoral radiographs as needed.

CBCT acquisition in orthodontics

If an object needs to be visualized in 3 dimensions or 2-dimensional (2D) imaging is insufficient for gathering necessary diagnostic data, CBCT imaging may be considered to improve diagnosis. It uses a 2D detector and a divergent and cone-shaped source of ionizing radiation; hence, its name.[28] CBCT imaging can provide accurate submillimeter resolution images in 3 dimensions. These images serve a number of diagnostic purposes in orthodontics.[29]

The acquisition of CBCT imaging can improve the diagnosis in selected orthodontic patients, by providing 3-dimensional evaluation of anomalies in dental position (impacted or ectopic teeth), dental structural anomalies, dentofacial deformities, airway insufficiencies, temporomandibular joints, and pathologies.[30] CBCT can also be used to assess craniofacial anatomy, alveolar boundary conditions, maxillary transverse dimensions, vertical malocclusion, and obstructive sleep apnea.[31] Advanced applications of CBCT imaging in craniofacial orthodontics include the evaluation of skeletal and soft tissue asymmetry, effects of expansion, and bone in a cleft site.[32]

Furthermore, CBCT can alter treatment planning decisions, notably for patients with impacted maxillary canines,[33-36] unerupted teeth with questionable locations or delayed eruption, severe root resorption, or severe skeletal discrepancy.[37] Although the benefits of CBCT in orthodontics cannot be ignored, the orthodontist must be able to justify that CBCT images bring a benefit to the patient over what can be obtained via 2D imaging.[1]

Despite the potential of CBCT to alter treatment planning decisions, some authors believe that CBCT does not necessarily improve the outcome of orthodontic treatment.[38-40] In other words, although CBCT might improve diagnosis and influence treatment planning, the outcome in general may be similar or comparable if 2D radiographic imaging had been used. It is generally difficult to know the value of CBCT imaging in changing treatment outcomes because most of the evidence on its diagnostic performance and efficacy is based on observational studies or those with variable hierarchies of evidence.[41]

Furthermore, for most CBCT examinations, the effective radiation doses are greater than those for conventional radiographic techniques. To estimate the stochastic health risk of any radiographic technique that uses ionizing radiation, a radiation protection quantity known as the effective dose is used.[42] The effective dose is the sum of the equivalent doses to the organs and tissues exposed, multiplied by the risk-tissue weighting factors.[43] The unit of measurement of the effective dose is the sievert, and it is frequently reported in dentistry as microsieverts (μSv). For reference, the average effective dose in the United States from the ubiquitous naturally occurring background radiation

(eg, unavoidable environmental exposures such as radon gas and cosmic rays) is approximately 3000 μSv per year.[6]

Table I presents effective doses of 2D imaging techniques vs those of CBCT. The effective dose of panoramic radiography is estimated to be 6 to 38 μSv[44-50]; the effective dose of cephalometric radiography is approximately 2 to 10 μSv,[49,51,52] whereas the effective dose of an intraoral full-mouth series is approximately 34 to 388 μSv.[53] On the other hand, the wide range of reported effective doses of CBCT acquisitions is 20 to 1025 μSv, which varies between different machines, fields of view, and certain technique factors.[44,46,54-60] Most CBCT scanners use dosages that are within the lower half of this wide range. The high reported values are mostly for older CBCT units with variable settings.[61] Additionally, these values for CBCT are relatively smaller than the effective doses of medical computed tomography head scans, which can be approximately 1000 to 2000 μSv.[6]

One industry response to the concern about the long-term risks of CBCT in orthodontic patients resulted in offering low-exposure alternative scanning options in newer scanner models.[62] This resulted is the availability of small-volume or quick-scan protocols with low radiation doses that rival those of panoramic and cephalometric radiographs.[62] Some authors believe that this development would make the debate about the CBCT radiation dilemma a historical footnote.[63] However, the recently developed quick scans use 180° rotation and result in lower resolution and reduction in image quality compared with standard or high-resolution protocols that use full 360° rotation. The decreased image quality in quick scans may render the image insufficient for specific diagnostic tasks.[36] In addition, the quick scan or low-dose option features are not consistently available in many commercially available CBCT units, which still vary significantly in their radiation dosage ranges and image quality.[16]

Also, the effective doses are averaged across all ages and for both sexes. At all ages, the stochastic health risks for female patients are slightly higher than those for males.[64] More importantly, the theoretical risk of these doses is age-dependent—highest for children and smallest for elderly patients.[64] Table II presents the age-risk relationship based on a 30-year-old adult.[64] If the relative attributable lifetime risk based on a relative risk of 1 is given for the adult at 30 years of age, a patient at age 10 to 20 would have a 2-fold risk because the younger patient has more radiosensitive organs and a longer lifespan.[64] On the other hand, a patient above 80 years of age has a negligible risk because the latent period between the radiographic exposure and the clinical presentation of a tumor formation will far exceed the patient's lifespan.[64] In other words, the cancer risk per unit dose of ionizing radiation is generally higher for younger patients than for adults.[53]

Table I. Effective doses of digital panoramic radiography, cephalometric radiography, and CBCT imaging

Imaging modality	*Estimated range of effective dose (μSv)*
Digital panoramic radiography	6-38
Digital cephalometric radiography	2-10
CBCT	20-1025

Significant variations in effective doses for all radiographic imaging techniques are reported in the literature.

Table II. Age-risk relationship based on a relative risk of 1 for a 30-year-old adult

Age group (y)	*Multiplication factor for risk*
< 10	× 3
10-20	× 2
20-30	× 1.5
30-50	× 0.5
50-80	× 0.3
>80	Negligible risk

The concept of the effective dose becomes more problematic when applied to young orthodontic patients exposed to CBCT, because the tissue-weighting factors used to calculate the effective doses are averaged across all ages, a practice that ultimately results in neglecting the radiosensitivity of children and their long life expectancy.[16,43] Furthermore, with CBCT imaging, several radiosensitive organs receive higher organ and effective doses. This is especially true for small children, because the thyroid gland is closer to the field of view when imaged than that of an adult.[1] Effective dose variations also depend on the child's age. All exposure protocols being equal, a small 10-year-old patient would receive a 30% higher effective dose than an adolescent, because of the 10-year-old's smaller size.[49]

Due to these dilemmas, the evidence on the use of CBCT is inconsistent, including a wide variety of conflicting opinions. Some authors believe that despite the small increase in radiation dose relative to panoramic and cephalometric radiographs, the advantages of CBCT justify prescribing this image for every orthodontic patient.[65] Others believe that the evidence for its efficacy is lacking,[39] and some have questioned the ethics of prescribing CBCT for all orthodontic patients.[66] Conducting randomized controlled trials has been recommended to provide an evidence-based approach for prescribing

CBCT to prove whether it can result in a measurable and meaningful patient outcome.[40]

At present, to aid clinicians in incorporating the strongest evidence into patient care regarding the use of CBCT, it is reasonable and prudent to follow clinical practice guidelines provided by respected dental organizations. These guidelines are defensible and are considered a robust source of evidence. The American Dental Association recommends that CBCT imaging in dentistry should be prescribed only when the diagnostic yield will benefit the patient or improve the clinical outcome significantly.[13] The American Academy of Oral and Maxillofacial Radiology recommends that the use of CBCT imaging in orthodontics should be justified on an individual basis, according to the clinical presentation.[43] Several international organizations have provided similar recommendations. The comprehensive and sensible British Orthodontic Society guidelines suggest that there is no indication for the routine use of CBCT imaging for all orthodontic patients.[1] The Swiss Association of Dentomaxillofacial Radiology recommends that CBCT imaging in orthodontics is justified only if the expected additional information is therapeutically relevant, compared with conventional 2D imaging.[67]

Therefore, if CBCT imaging would benefit the patient or change the outcome of treatment when compared with 2D radiographs (eg, panoramic and cephalometric), then its acquisition is justified. The converse is also true. Furthermore, taking a large field of view CBCT scan merely to synthesize a cephalometric image is not indicated, because a 2D cephalometric radiograph could have been prescribed without exposing the patient to the additional radiation.[16,68] To do so would be at odds with the ALARA directive in radiation protection.[69] It is also unjustified to take CBCT images to merely replace impressions or digital scans that do not use ionizing radiation[43] or to obtain the status of a high-tech orthodontic practice.[16]

Progress radiographic acquisition in orthodontics

To monitor or guide orthodontic care, progress radiographs (midtreatment radiographs) are often necessary. Monitoring the status of the teeth through progress radiographs is usually necessary to detect any adverse occurrences during orthodontic care.[70] For example, root resorption is a common and an unpredictable side effect associated with fixed appliances.[71,72]

Whereas routine radiography is not a recommended practice in dentistry, it is generally an acceptable risk management practice to consider taking a panoramic radiograph or selected intraoral radiographs approximately 6 to 9 months after the start of orthodontic treatment.[70,73] However, each patient is different. For example, taking radiographs at this timeline is especially indicated for traumatized teeth or those with preexisting root resorption.[74] One study showed that teeth with blunt or pipette-shaped roots have significantly greater root resorption than do teeth with normal root forms, and the recommendation was made to take progress radiographs only 3 months after initiating orthodontic treatment in these patients.[75] If there is preexisting or the potential of root resorption, taking appropriate progress radiographs becomes widely justified to monitor the status of the teeth.[76,77] For assessment of root resorption, intraoral periapical radiography is more reliable that panoramic radiography.[27]

It has also been suggested that if root resorption is detected on progress radiographs taken after 6 months, the risk of progressive resorption as treatment proceeds is increased.[75] Therefore, if root resorption is detected on the pretreatment or the progress radiograph, prescribing additional progress radiographs as treatment continues can be clearly justified for the patient's benefit[74] and is a reasonable and prudent practice to monitor the health of teeth and periodontium.[15,78]

Progress radiographs could also help in monitoring root angulations, which can aid clinical decisions regarding bracket repositioning or archwire bending throughout treatment.[76] Progress radiographs are also valuable with significant tooth movements such as monitoring the traction of impacted teeth[79] and to diagnose dental pathology or anomalies that may develop during orthodontic treatment.[15]

In addition, progress radiographs can help to detect any carious lesions developing during treatment.[76] It is valuable to consider collaborating with the referring dentist regarding the acquisition of progress radiographs for patients with a high risk for caries, those with multiple preexisting restorations, or those who, despite serious oral hygiene efforts, have rapidly developing white spot lesions.

In adults with preexisting radiographic bone loss or clinical attachment loss, progress radiographs allow monitoring of the status of the supporting alveolar bone.[76] Progress radiographs also provide information when iatrogenic factors occur during treatment, such as excessive tooth mobility, abnormal tooth pain, or periodontal complications. When these are discovered, timely alteration of the proposed treatment plan can be made.[15] Finally, progress radiographs can be considered to monitor teeth with severe periodontal or pulpal injury during orthodontic treatment.[80]

When progress panoramic radiographs are made, field limitation and collimation of the radiograph to

include the dentition only is possible with selected panoramic units. This practice has the advantage of reducing the radiation dose to the patient and limiting the field of view to the field of interest (the dentition) during image acquisition.

Final radiographic acquisition in orthodontics

In many cases, final radiographs are valuable and can help with appraising the patient of the outcome of the treatment.[15] These radiographs record the final status of treatment and are instrumental for both record keeping and risk management purposes.[15] It can be postulated that the final panoramic radiograph, cephalometric radiograph, or full-mouth survey provides no specific benefit to the patient after the completion of treatment.

However, without being able to evaluate the treatment results of the orthodontic, orthognathic, or orthopedic approaches that were used, the patient's best interests may not be served because the efficacy of the treatment cannot be comprehensively and reliably assessed.[15] Final radiographs could show whether there is any harm to the periodontium or dentition caused by orthodontic therapy, a discovery that places responsibility on the orthodontist to disclose these findings and their clinical implications to the patient.[81] Final radiographs also record the status of the developing third molars and other unerupted teeth. Therefore, the patient has the right to be informed of his or her oral health status and to confirm any expectations associated with orthodontic treatment therapy, which in turn requires the practitioner to conform to this ethical and clinical imperative.[15]

Posttreatment radiographs could affect clinical decision making. For example, if severe root resorption is noted on some incisors and the orthodontist is debating the choice of a fixed or removable retainer, the resorption detected on the final radiographs may alter the decision in favor of the fixed retainer. However, final radiograph acquisition needs to be justified on a case-by-case basis. For example, it is reasonable and prudent to avoid taking posttreatment radiographs for patients undergoing limited treatment of short duration.

To maximize the benefit of the final radiograph, it can be taken a few appointments before the debonding appointment, to obtain information helpful with the patient's finishing and detailing, such as detecting teeth with inappropriate root angulations.[76] If such a radiograph is taken a few months before the debond appointment, a radiograph taken immediately after appliance removal is usually unnecessary and not beneficial to the patient.

Taking a final cephalometric radiograph is also case specific. A cephalometric radiograph taken a few months before completion of active treatment could enable the orthodontist to make certain that treatment targets have been achieved.[1] The final cephalometric radiograph can be taken at the end of functional appliance treatment to evaluate mandibular incisor position, at the end of presurgical treatment in orthognathic patients, and just before the end of active fixed appliance treatment to assess the position of the mandibular incisors.[64]

Unquestionably, taking final radiographs is a great risk management tool, but the controversy will understandably continue about whether patients benefit from these radiographs. Foreseeability of the value of these radiographs is occasionally difficult, because the benefit, or lack thereof, would not be recognized until they are taken. As with numerous clinical circumstances, the clinical presentation alone may not trigger the need for radiographic imaging, but without radiographs, a comprehensive diagnosis may not be possible.[7]

General guidelines for radiographic interpretation

After the acquisition of any radiographs, it is essential to interpret them in their entirety. Whether a panoramic or cephalometric radiograph, a full-mouth survey, or a CBCT scan, the orthodontist cannot interpret only 1 part or aspect of the image.[82]

A comprehensive and successful radiographic interpretation requires the orthodontist to fully understand the radiographic images and recognize what is normal vs abnormal on the images. A systematic approach to reading the entire radiograph should include interpretation of the teeth, apical tissues, periodontium, and all adjacent structures.

In general, the orthodontist should always ensure that any findings are documented in the patient's chart, including abnormal findings and pathologies, and whether these abnormalities require immediate treatment, referral, or observation.[8] In children, it is valuable to include specific notes about the stage of the dental development.[10] In adults, it is valuable to record the status of the periodontium.[10] This is because the incidence of periodontal disease increases with age, and some adults may require selected intraoral radiographs to determine the current status of their periodontium.[83]

Before taking progress radiographs during treatment, it is judicious to examine and interpret any images already in the patient's file, since new radiographs should be expected to provide additional or different information that justifies their acquisition.

Radiographic interpretation of CBCT images

The interpretation of CBCT images poses a distinct liability that is above and beyond that associated with 2D

radiographic imaging. Aside from being the right thing to do for the patient, it is widely considered now that the interpretation of CBCT scans is a legal requirement.[43,84-86] It is the responsibility of the practitioner ordering the CBCT images to ensure that the scans are adequately interpreted.[87] Yet as with any other dental procedure, the orthodontist is not required to perform the radiographic interpretation personally; a referral to a colleague (oral radiologist) who is qualified to complete this task is a viable option.[88]

Interpretation of CBCT scans, especially for large field-of-view scans, may be technically demanding for orthodontists, and one cannot solely interpret volume-rendering views without thoroughly examining axial, coronal, and sagittal views.[89] CBCT volume-rendering views are insufficient for interpretation because they are similar to architectural exemplary illustrations that provide the exterior layout but not the interior details.[11] The general concern for large field-of-view scans is that an inappropriately trained clinician interpreting images produced by advanced imaging systems, such as CBCT, could misinterpret the data with subsequent misdiagnoses or inappropriate patient treatment.[12] Therefore, it would be appropriate to refer to an oral radiologist for radiographic interpretation, especially for large field-of-view CBCT scans that include regions in the head and neck that most dentists are not trained to evaluate.[90,91]

A small field-of-view scan based on the clinical indication could be considered; this could be determined based on the region of interest that triggers the CBCT imaging.[92] Collimating the scan to the minimum coverage consistent with meeting the diagnostic requirements and clinical feasibility protects the patient from unnecessary radiation.[93] Therefore, taking a small field-of-view CBCT scan has 2 advantages. First, it can reduce the effective dose, a major benefit to the patient.[46,59,94] Second, it can shorten the interpretation of the CBCT scan and exclude difficult areas that require a radiologist to evaluate, a major benefit to the orthodontist.[95] However, a small-volume scan should not be overcollimated to where the object of interest is incompletely included, a practice that could require a repeated scan.

If the orthodontist chooses to complete the radiographic interpretation for CBCT scans, a sample form for interpretation is provided in the Appendix. When reviewing the scan, include notations on the image quality and the reason for CBCT acquisition. List the most important findings first, followed by incidental findings.[96] Whenever there is a serious finding, ensure that you quantify it, at least using qualifiers (eg, mild, moderate, or severe), but preferably measuring it using the ruler tool in the CBCT imaging software. For any lesion, indicate the location, shape, margins, density, and relationship to adjacent structures. Be sure to check for symmetry of bilateral structures, areas of higher densities (opacities) or lower densities (lucencies), foreign objects, relationships to contiguous structures, periapical pathoses, continuity of cortical outline, medullary spaces, and bone trabecular pattern.

The best radiographic reports are concise and precise, written in the present tense, and free of vague or redundant statements or words.[96] They include standard language, a structured format, and consistent content.[97] If further investigations such as radiographic or clinical studies are recommended based on the CBCT interpretation, the rationale for their completion should be stated in the report.

If the interpretation of CBCT scans is a challenge even for small-volume scans, a viable alternative to the in-house interpretation of CBCT scans is to consult with another practitioner—specifically an oral and maxillofacial radiologist—to provide a comprehensive interpretation and a written report. This is also valuable if the orthodontist is too busy to read all CBCT volumes and prefers to ask a more qualified colleague to do so.

The process includes uploading images to a secure server with high-speed Internet, or placing in an appropriate medium and sending to the radiologist who will then provide a comprehensive radiographic report. Although this appears to be a simple risk transfer strategy, it comes with 2 concerns and specific risk management strategies to mitigate the risks.

The first concern might involve being exposed to an Internet data security breach or HIPAA violation as the patient's Protected Health Information (PHI) is being transmitted over the Internet to a different location where it may not be secure.[98] To mitigate risks associated with transmitting patient information over the Internet or by e-mail, only HIPAA-compliant servers and cloud storage systems and providers should be used; the minimum of necessary PHI should be sent to the other practitioner, and all PHI should be encrypted appropriately.[99]

The second concern relates to the licensing requirements of the oral radiologist if the patient's recorded health information is sent remotely to a radiologist practicing in another state. This practice is called teleradiology: the transfer of radiographs and patient reports to remote sites. It is critical to verify all rules about teleradiology between the states in which the orthodontist practices, the patient resides, and the radiologist practices.

To interpret the CBCT scans, licensing requirements may vary. It has been suggested that the out-of-state colleague could be required to be licensed in the same state where the orthodontist practices, in his or her state

only, or in both states.[82] In other words, a state dental board may require an out-of-state radiologist interpreting CBCT images for its citizens to be licensed in the state in which the patient resides.[82] In this case, the out-of-state radiologist could be required to obtain a license in the orthodontist's state and carry out-of-state malpractice insurance coverage, because any party (patient, licensing board, or insurance company) could consider teleradiology an out-of-state practice. Failure to verify these requirements could subject both clinicians to disciplinary actions.[82] No orthodontist wants to be involved in referring a patient to a dentist without the required license to practice, since this could generate the charge of having made a negligent referral. Licensing rules apply even if the out-of-state consultation is made without reimbursement.[82]

Some clinicians choose erroneous strategies to limit their liability for the interpretation of CBCT scans, one of which is having the patient sign a waiver of liability for the interpretation. This waiver carries little if any weight and will be deemed null and void in most legal proceedings.[82,100] Another erroneous practice is to inform the patient that an out-of-state radiologist not licensed in the patient's state will read the CBCT scan. This practice does not eliminate possible violations of the licensing laws, future claims, or troubles for both the orthodontist and the out-of-state radiologist.[82]

Therefore, at the present time, due to the ever-changing environment and lack of consistency of regulations between states concerning teleradiology, if such a practice is used, the safest and most defensible strategy is to ensure that the radiologist reviewing the radiographs carries sufficient and appropriate licensing privileges and malpractice insurance.

CONCLUSIONS

In orthodontics, there are no specific standards of care for the acquisition of radiographic imaging before, during, or after treatment. However, the use or the lack of use of ionizing radiation comes with specific potential liability exposure. For instance, failing to take necessary and indicated radiographs cannot be defended by the argument that radiographs were avoided because of the potential harm of ionizing radiation. The benefits of necessary and appropriate diagnostic radiographs should not be ignored but weighed judiciously against the risks.

Every orthodontic patient will benefit differently from ionizing radiation. Its appropriate use in orthodontics requires a sound balance between keeping radiation exposures as low as reasonably achievable—adhering to the ALARA principle in radiation protection—and undertaking excellent risk management. In some instances, the benefit will not be appreciated until the radiograph is taken and interpreted.

Based on the literature and sound risk management practices, the following guidelines can be made for appropriate, defensible, and sensible prescription and use of ionizing radiation in orthodontic practice.

1. Prescribe necessary radiographs after (not before) clinical examination.
2. Prescribe radiographs only when necessary and justified.
3. Choose the most appropriate radiographic examination.
4. Consider CBCT imaging only when it is expected to yield a benefit to the patient or change the outcome of treatment over 2D radiographs.
5. Remember that failing to take necessary and appropriate radiographs based on the well-intentioned concern of irradiating the patient could be considered negligence.
6. Be sure to fully interpret all radiographic images either personally or with an appropriate referral.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.ajodo.2018.01.005.

REFERENCES

1. Isaacson KG, Thom AR, Atack NE, Horner K, Whaites E. Orthodontic radiographs: guidelines for the use of radiographs in clinical orthodontics. 4th ed. London, United Kingdom: British Orthodontic Society; 2015.
2. Applegate KE, Cost NG. Image gently: a campaign to reduce children's and adolescents' risk for cancer during adulthood. J Adolesc Health 2013;52(5 Suppl):S93-7.
3. Brenner D, Elliston C, Hall E, Berdon W. Estimated risks of radiation-induced fatal cancer from pediatric CT. AJR Am J Roentgenol 2001;176:289-96.
4. Slovis TL. Children, computed tomography radiation dose, and the as low as reasonably achievable (ALARA) concept. Pediatrics 2003;112:971-2.
5. Hatcher DC. Operational principles for cone-beam computed tomography. J Am Dent Assoc 2010;141(Suppl 3):3s-6s.
6. McCollough CH, Bushberg JT, Fletcher JG, Eckel LJ. Answers to common questions about the use and safety of CT scans. Mayo Clin Proc 2015;90:1380-92.
7. Jerrold L. Seeing before doing. Am J Orthod Dentofacial Orthop 2014;146:530-3.
8. D'Cruz L. Risk management in clinical practice. Part 1. Introduction. Br Dent J 2010;209:19-23.
9. American Dental Association Council on Scientific Affairs. The use of dental radiographs: update and recommendations. J Am Dent Assoc 2006;137:1304-12.
10. American Dental Association Council on Scientific Affairs, Food and Drug Administration. Dental radiographic examinations: recommendations for patient selection and limiting radiation

exposure: American Dental Association Council on Scientific Affairs; Available at: http://www.fda.gov/downloads/RadiationEmittingProducts/RadiationEmittingProductsandProcedures/MedicalImaging/MedicalX-Rays/UCM329746.pdf; 2012. Accessed September 6, 2017.
11. Abdelkarim A. Myths and facts of cone beam computed tomography in orthodontics. J World Fed Orthod 2012;1:e3-8.
12. Farman AG. ALARA still applies. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100:395-7.
13. 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.
14. Lurie AG. JCO interviews Dr. Alan G. Lurie on risk/benefit considerations in orthodontic radiology. J Clin Orthod 1981;15:469-75: 478-84.
15. Jerrold L. Posttreatment records. Am J Orthod Dentofacial Orthop 2008;133:124-6.
16. Abdelkarim AA. Appropriate use of ionizing radiation in orthodontic practice and research. Am J Orthod Dentofacial Orthop 2015;147:166-8.
17. Nohadani N, Ruf S. Assessment of vertical facial and dentoalveolar changes using panoramic radiography. Eur J Orthod 2008;30: 262-8.
18. Friedland B. Clinical radiological issues in orthodontic practice. Semin Orthod 1998;4:64-78.
19. Baker P, Needleman I. Risk management in clinical practice. Part 10. Periodontology. Br Dent J 2010;209:557-65.
20. Jerrold L. What record is playing? Am J Orthod Dentofacial Orthop 2015;147:627-31.
21. Bruks A, Enberg K, Nordqvist I, Hansson AS, Jansson L, Svenson B. Radiographic examinations as an aid to orthodontic diagnosis and treatment planning. Swed Dent J 1999;23:77-85.
22. Nijkamp PG, Habets LL, Aartman IH, Zentner A. The influence of cephalometrics on orthodontic treatment planning. Eur J Orthod 2008;30:630-5.
23. Devereux L, Moles D, Cunningham SJ, McKnight M. How important are lateral cephalometric radiographs in orthodontic treatment planning? Am J Orthod Dentofacial Orthop 2011;139: e175-81.
24. Houston WJ. The current status of facial growth prediction: a review. Br J Orthod 1979;6:11-7.
25. Atchison KA, Luke LS, White SC. An algorithm for ordering pretreatment orthodontic radiographs. Am J Orthod Dentofacial Orthop 1992;102:29-44.
26. Witcher TP, Brand S, Gwilliam JR, McDonald F. Assessment of the anterior maxilla in orthodontic patients using upper anterior occlusal radiographs and dental panoramic tomography: a comparison. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010; 109:765-74.
27. Sameshima GT, Asgarifar KO. Assessment of root resorption and root shape: periapical vs panoramic films. Angle Orthod 2001;71: 185-9.
28. De Vos W, Casselman J, Swennen GR. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. Int J Oral Maxillofac Surg 2009;38:609-25.
29. Merrett SJ, Drage NA, Durning P. Cone beam computed tomography: a useful tool in orthodontic diagnosis and treatment planning. J Orthod 2009;36:202-10.
30. Scarfe WC, Azevedo B, Toghyani S, Farman AG. Cone beam computed tomographic imaging in orthodontics. Aust Dent J 2017;62(Suppl 1):33-50.
31. Kapila SD, Nervina JM. CBCT in orthodontics: assessment of treatment outcomes and indications for its use. Dentomaxillofac Radiol 2015;44:20140282.
32. Vig KW, Mercado AM. Overview of orthodontic care for children with cleft lip and palate, 1915-2015. Am J Orthod Dentofacial Orthop 2015;148:543-56.
33. Bjerklin K, Ericson S. How a computerized tomography examination changed the treatment plans of 80 children with retained and ectopically positioned maxillary canines. Angle Orthod 2006;76:43-51.
34. Haney E, Gansky SA, Lee JS, Johnson E, Maki K, Miller AJ, et al. Comparative analysis of traditional radiographs and cone-beam computed tomography volumetric images in the diagnosis and treatment planning of maxillary impacted canines. Am J Orthod Dentofacial Orthop 2010;137:590-7.
35. Eslami E, Barkhordar H, Abramovitch K, Kim J, Masoud MI. Cone-beam computed tomography vs conventional radiography in visualization of maxillary impacted-canine localization: a systematic review of comparative studies. Am J Orthod Dentofacial Orthop 2017;151:248-58.
36. Mallya SM. Evidence and professional guidelines for appropriate use of cone beam computed tomography. J Calif Dent Assoc 2015;43:512-20.
37. Hodges RJ, Atchison KA, White SC. Impact of cone-beam computed tomography on orthodontic diagnosis and treatment planning. Am J Orthod Dentofacial Orthop 2013;143:665-74.
38. Kokich VG. Cone-beam computed tomography: have we identified the orthodontic benefits? Am J Orthod Dentofacial Orthop 2010;137(Suppl):S16.
39. Halazonetis DJ. Cone-beam computed tomography is not the imaging technique of choice for comprehensive orthodontic assessment. Am J Orthod Dentofacial Orthop 2012;141:403-11.
40. Hujoel PP, Aps JK, Bollen AM. What are the cancer risks from dental computed tomography? J Dent Res 2015;94:7-9.
41. van Vlijmen OJ, Kuijpers MA, Berge SJ, Schols JG, Maal TJ, Breuning H, et al. Evidence supporting the use of cone-beam computed tomography in orthodontics. J Am Dent Assoc 2012; 143:241-52.
42. International Commission on Radiological Protection. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Ann ICRP 2007;37: 1-332.
43. American Academy of Oral and Maxillofacial Radiology. Clinical recommendations regarding use of cone beam computed tomography in orthodontics [corrected]. Position statement by the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol 2013;116:238-57.
44. Okano T, Harata Y, Sugihara Y, Sakaino R, Tsuchida R, Iwai K, et al. Absorbed and effective doses from cone beam volumetric imaging for implant planning. Dentomaxillofac Radiol 2009; 38:79-85.
45. Garcia Silva MA, Wolf U, Heinicke F, Grundler K, Visser H, Hirsch E. Effective dosages for recording Veraviewepocs dental panoramic images: analog film, digital, and panoramic scout for CBCT. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:571-7.
46. Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. Dentomaxillofac Radiol 2006;35:219-26.
47. Gijbels F, Jacobs R, Bogaerts R, Debaveye D, Verlinden S, Sanderink G. Dosimetry of digital panoramic imaging. Part I: patient exposure. Dentomaxillofac Radiol 2005;34:145-9.

48. Lecomber AR, Yoneyama Y, Lovelock DJ, Hosoi T, Adams AM. Comparison of patient dose from imaging protocols for dental implant planning using conventional radiography and computed tomography. Dentomaxillofac Radiol 2001;30:255-9.
49. Theodorakou C, Walker A, Horner K, Pauwels R, Bogaerts R, Jacobs R. Estimation of paediatric organ and effective doses from dental cone beam CT using anthropomorphic phantoms. Br J Radiol 2012;85:153-60.
50. Gavala S, Donta C, Tsiklakis K, Boziari A, Kamenopoulou V, Stamatakis HC. Radiation dose reduction in direct digital panoramic radiography. Eur J Radiol 2009;71:42-8.
51. Gijbels F, Sanderink G, Wyatt J, Van Dam J, Nowak B, Jacobs R. Radiation doses of indirect and direct digital cephalometric radiography. Br Dent J 2004;197:149-52: discussion, 140.
52. Silva MA, Wolf U, Heinicke F, Bumann A, Visser H, Hirsch E. Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation. Am J Orthod Dentofacial Orthop 2008;133:640.e1-5.
53. White SC, Scarfe WC, Schulze RK, Lurie AG, Douglass JM, Farman AG, et al. The Image Gently in Dentistry campaign: promotion of responsible use of maxillofacial radiology in dentistry for children. Oral Surg Oral Med Oral Pathol Oral Radiol 2014; 118:257-61.
54. Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106: 106-14.
55. Ludlow JB, Davies-Ludlow LE, Brooks SL. Dosimetry of two extraoral direct digital imaging devices: NewTom cone beam CT and Orthophos Plus DS panoramic unit. Dentomaxillofac Radiol 2003;32:229-34.
56. Roberts JA, Drage NA, Davies J, Thomas DW. Effective dose from cone beam CT examinations in dentistry. Br J Radiol 2009;82: 35-40.
57. Tsiklakis K, Donta C, Gavala S, Karayianni K, Kamenopoulou V, Hourdakis CJ. Dose reduction in maxillofacial imaging using low dose cone beam CT. Eur J Radiol 2005;56:413-7.
58. Danforth RA, Dus I, Mah J. 3-D volume imaging for dentistry: a new dimension. J Calif Dent Assoc 2003;31:817-23.
59. Ludlow JB, Timothy R, Walker C, Hunter R, Benavides E, Samuelson DB. Correction to effective dose of dental CBCT—a meta analysis of published data and additional data for nine CBCT units. Dentomaxillofac Radiol 2015;44:20159003.
60. Ludlow JB, Davies-Ludlow LE, White SC. Patient risk related to common dental radiographic examinations: the impact of 2007 International Commission on Radiological Protection recommendations regarding dose calculation. J Am Dent Assoc 2008;139: 1237-43.
61. Carlson SK, Graham J, Mah J, Molen A, Paquette DE, Quintero JC. Let the truth about CBCT be known. Am J Orthod Dentofacial Orthop 2014;145:418-9.
62. Ludlow JB, Walker C. Assessment of phantom dosimetry and image quality of i-CAT FLX cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2013;144:802-17.
63. Hans MG, Palomo JM, Valiathan M. History of imaging in orthodontics from Broadbent to cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2015;148:914-21.
64. European Commission. European guidelines on radiation protection in dental radiology: Radiation protection 136 Luxembourg: Publications Office; Available at: https://ec.europa.eu/energy/sites/ener/files/documents/136.pdf; 2004. Accessed September 6, 2017.
65. Larson BE. Cone-beam computed tomography is the imaging technique of choice for comprehensive orthodontic assessment. Am J Orthod Dentofacial Orthop 2012;141:402-10.
66. Greco PM. Let the truth be known. Am J Orthod Dentofacial Orthop 2013;144:788-9.
67. Dula K, Benic GI, Bornstein M, Dagassan-Berndt D, Filippi A, Hicklin S, et al. SADMFR Guidelines for the use of cone-beam computed tomography/digital volume tomography. Swiss Dent J 2015;125:945-53.
68. Isaacson K. Cone beam CT and orthodontic diagnosis—a personal view. J Orthod 2013;40:3-4.
69. Farman AG, Scarfe WC. Development of imaging selection criteria and procedures should precede cephalometric assessment with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2006;130:257-65.
70. Jerrold L. How to write an expert opinion letter. Am J Orthod Dentofacial Orthop 2014;146:124-6.
71. Segal GR, Schiffman PH, Tuncay OC. Meta analysis of the treatment-related factors of external apical root resorption. Orthod Craniofac Res 2004;7:71-8.
72. Roscoe MG, Meira JB, Cattaneo PM. Association of orthodontic force system and root resorption: a systematic review. Am J Orthod Dentofacial Orthop 2015;147:610-26.
73. Abdelkarim A, Jerrold L. Risk management strategies in orthodontics. Part 1: clinical considerations. Am J Orthod Dentofacial Orthop 2015;148:345-9.
74. Kindelan SA, Day PF, Kindelan JD, Spencer JR, Duggal MS. Dental trauma: an overview of its influence on the management of orthodontic treatment. Part 1. J Orthod 2008;35:68-78.
75. Levander E, Malmgren O. Evaluation of the risk of root resorption during orthodontic treatment: a study of upper incisors. Eur J Orthod 1988;10:30-8.
76. Mizrahi E. Risk management in clinical practice. Part 7. Dentolegal aspects of orthodontic practice. Br Dent J 2010;209: 381-90.
77. Smale I, Årtun J, Behbehani F, Doppel D, van't Hof M, Kuijpers-Jagtman AM. Apical root resorption 6 months after initiation of fixed orthodontic appliance therapy. Am J Orthod Dentofacial Orthop 2005;128:57-67.
78. Jerrold L. Deja vu all over again: continuous treatment and the statute of limitations. Am J Orthod Dentofacial Orthop 2012; 141:814-7.
79. Becker A, Casap N, Chaushu S. Conventional wisdom and the surgical exposure of impacted teeth. Orthod Craniofac Res 2009;12: 82-93.
80. Bauss O, Rohling J, Meyer K, Kiliaridis S. Pulp vitality in teeth suffering trauma during orthodontic therapy. Angle Orthod 2009;79:166-71.
81. Abdelkarim A, Jerrold L. Orthodontic chart documentation. Am J Orthod Dentofacial Orthop 2017;152:126-30.
82. Friedland B. Medicolegal issues related to cone beam CT. Semin Orthod 2009;15:77-84.
83. Hugoson A, Sjodin B, Norderyd O. Trends over 30 years, 1973-2003, in the prevalence and severity of periodontal disease. J Clin Periodontol 2008;35:405-14.
84. Jerrold L. Liability regarding computerized axial tomography scans. Am J Orthod Dentofacial Orthop 2007;132:122-4.
85. Turpin DL. Befriend your oral and maxillofacial radiologist. Am J Orthod Dentofacial Orthop 2007;131:697.
86. Zinman EJ, White SC, Tetradis S. Legal considerations in the use of cone beam computer tomography imaging. J Calif Dent Assoc 2010;38:49-56.

87. Carter L, Farman AG, Geist J, Scarfe WC, Angelopoulos C, Nair MK, 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;106:561-2.
88. Curley A, Hatcher DC. Cone beam CT—anatomic assessment and legal issues: the new standards of care. J Calif Dent Assoc 2009; 37:653-62.
89. Halazonetis DJ. From 2-dimensional cephalograms to 3-dimensional computed tomography scans. Am J Orthod Dentofacial Orthop 2005;127:627-37.
90. Horner K, Islam M, Flygare L, Tsiklakis K, Whaites E. Basic principles for use of dental cone beam computed tomography: consensus guidelines of the European Academy of Dental and Maxillofacial Radiology. Dentomaxillofac Radiol 2009;38:187-95.
91. Brown J, Jacobs R, Levring Jaghagen E, Lindh C, Baksi G, Schulze D, et al. Basic training requirements for the use of dental CBCT by dentists: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology. Dentomaxillofac Radiol 2014;43:20130291.
92. Kapila S, Conley RS, Harrell WE Jr. The current status of cone beam computed tomography imaging in orthodontics. Dentomaxillofac Radiol 2011;40:24-34.
93. Council on Dental Materials, Instruments, and Equipment. Recommendations in radiographic practices: an update, 1988. J Am Dent Assoc 1989;118:115-7.
94. Pauwels R, Beinsberger J, Collaert B, Theodorakou C, Rogers J, Walker A, et al. Effective dose range for dental cone beam computed tomography scanners. Eur J Radiol 2012;81:267-71.
95. Newaz ZA, Barghan S, Katkar RA, Bennett JA, Nair MK. Incidental findings of skull-base abnormalities in cone-beam computed tomography scans with consultation by maxillofacial radiologists. Am J Orthod Dentofacial Orthop 2015;147:127-31.
96. Ridley LJ. Guide to the radiology report. Australas Radiol 2002; 46:366-9.
97. Sistrom CL, Langlotz CP. A framework for improving radiology reporting. J Am Coll Radiol 2005;2:159-67.
98. Andriole KP. Security of electronic medical information and patient privacy: what you need to know. J Am Coll Radiol 2014; 11:1212-6.
99. Kotantoula G, Haisraeli-Shalish M, Jerrold L. Teleorthodontics. Am J Orthod Dentofacial Orthop 2017;151:219-21.
100. Ginsburg WH, Kahn SJ, Thornhill MC, Gambardella SC. Contractual revisions to medical malpractice liability. Law Contemp Probl 1986;49:253-64.