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Dental X-ray Exposure: The Past Has Become the Future

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ABSTRACT Most dental X-ray procedures are delegated to office staff and some recommendations and techniques, such as selection criteria and rectangular collimation for intraoral imaging, have been ignored or forgotten by some dentists. Some of the X-ray exposure recommendations, updated by the American Dental Associtation's Science Institute in June 2018, and the need to adopt guidelines proposed by the public campaign Image Gently are discussed to help the reader develop safe X-ray protocols, from intraorals to CBCT.

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There is no doubt that in our patients' minds exposure to any dental X-ray radiation can be associated with significant health effects. Catering to that concern, media articles are written that actually feed those fears — sometimes unintentionally but sometimes specifically to raise alarms.[1] The dental profession generally attempts to reduce patient X-ray doses and has been guided to do so by the American Dental Association (ADA) for almost 30 years.[2] We have adopted faster receptors, digital imaging modalities such as intraoral solid-state detectors, digital panoramic machines and even low-dose cone beam computed tomography (CBCT) devices. Most dentists use thyroid collars for child X-ray exposures when intraoral images are taken. However, there are several areas in X-ray exposure techniques that could be dramatically improved for any imaging modality. The purpose of this review is to highlight deficiencies that may be present in offices and suggest protocols for improving X-ray techniques and reducing patient dose, especially for children. Many of the suggestions have been taught for decades in dental schools, but unfortunately, many have been forgotten. Because of increasingly stringent state regulations and now even public campaigns, such as Image Gently, these forgotten techniques, protocols and office standards/practices will have to be revisited by dentists and adopted as the new normal.

Effective Use of Radiation

Intraoral X-Ray Practices

The adoption of digital intraoral imaging receptors, solid-state and reusable phosphor plates has been slow but steady in the U.S.[3] These faster receptors have been adopted primarily to reduce patient dose, improve overall image quality by eliminating chemical processing and

TABLE

Types of Collimators

Devices	Manufacturers	How it works	Suggested retail price
RINN universal collimator	Dentsply/Sirona	Plastic adapter snaps into end of round cone	$170.99
DEXshield	Dexis	Attaches to a metal rod that holds image receptor (rods sold separately)	N/A
Rectangular position indicating collimator	Margraf	Round cone is replaced by a long rectangular cone with additional alignment rings that must adapt to the long cone	N/A
XDR ALARA collimator	XDR	Attaches to a metal rod that holds image receptor (rods sold separately)	$75
Tru-Image position locking device (PLD)	Interactive Diagnostic Imaging	Magnetic linkage between receptor and X-ray tube with green LED lights to confirm positioning and linkage	$595
Tru-Align	Interactive Diagnostic Imaging	The predecessor to Tru-Image; no longer available in the U.S.	N/A

increase office productivity, which are all positive goals. It is recommended that all dental practices should adopt digital intraoral X-ray imaging.[2]

Solid-state, intraoral imaging detectors reduce patient X-ray dose the most.[3] Reusable phosphor plates also reduce the dose somewhat compared to conventional X-ray film. However, they do not reduce patient X-ray dose to the same extent as solid-state detectors. Except for endodontic and pediatric use,[2] all dental offices should adopt solid-state detectors over phosphor plates for general dental intraoral imaging.[4] There are also panoramic X-ray machines that can take extraoral bite wings for children, eliminating the need for wired, solid-state intraoral detectors at very low dose.[2] There are questions as to the diagnostic quality of extraoral digital bitewings for proximal lesions that have yet to be resolved, but studies are underway.[2]

Unfortunately, because the images from solid-state detectors can be seen immediately, many operators, primarily dental assistants, often take multiple images in order to present the “best one” to the dentist. This practice defeats the intent of reducing dose to the patient. All dentists in all dental practices must reeducate and instruct their dental assistants on proper positioning technique and safe radiographic imaging practices to eliminate retakes and reduce patient X-ray dose. It is a good practice to keep a retake logbook to keep track of the films that are retaken. In 2006, a National Institute of Dental and Craniofacial Research (NIDCR) committee looking for large data sets for research in osteoporosis estimated that approximately 750 million dental X-rays were performed. It is estimated that the number would be well over 1 billion dental X-rays performed annually at present time. It has also been reported that 7% to 13% of all dental X-rays taken are retakes. That means there are more than 100 million unnecessary dental X-rays taken every year in the U.S. This is a conservative estimate that only documents the known retakes.[2,5] Many of these retakes could be eliminated by the adoption and use of rectangular collimation products (**TABLE**) This concept/technique has been taught in dental schools and in dental auxiliary programs for more than 25 years. Images of these products are shown in **FIGURES 1**. On the other side, the use of intraoral positioning devices must be mandatory when rectangular collimation is in use to avoid cone cuts and unnecessary retakes.[6]

Possible actions to improve intraoral imaging procedures are:

- Adopt the fastest intraoral imaging receptors possible.
- Eliminate as many retakes as possible.
- Adopt and use rectangular collimation devices.

Panoramic X-Ray Practices

In dental practices as well as dental schools, digital panoramic imaging is replacing a full-mouth series of intraoral dental X-rays. The X-ray dose from a single, digital panoramic image is estimated to be 16 microsieverts (μSv). The X-ray dose from a full-mouth series (14 periapicals and four bitewings) of dental images acquired using a solid-state detector or photostimulable phosphor (PSP) plate is reported to be 171 μSv.[2] Thus, the dose to the patient is 100 times less. The patient dose from a full-mouth series of images using conventional D-speed film is 388 μSv.[6] Some practices use a digital panoramic image and intraoral solid-state detector bitewing images as their initial radiographic assessment.

Selected panoramic units offer extraoral bitewing programs that allow for an X-ray beam that is parallel to the interproximal contacts of the teeth and that produces bitewing-like images.[10] Proposed advantages of this system are simplicity in obtaining images, shorter time requirement, greater patient comfort, comparable diagnostics and lower radiation dose.[8] Several studies have confirmed that the highest sensitivity and specificity for detection of interproximal caries is the intraoral bitewing.[7] However, diagnostic quality studies have shown that the improved extraoral bitewing and interproximal panoramic radiograph are superior to conventional panoramic radiographs and

FIGURE 1A.

FIGURE 1B.

FIGURE 1C.

FIGURE 1D.

FIGURE 1E.

FIGURES 1. Types of rectangular collimators for intraoral use: Rinn universal collimator (**1A**), DEXshield (**1B**), Margraf rectangular PID (**1C**), XDR ALARA collimator (**1D**) and Tru-Image PLD (Position Locking Device) (**1E**).

that the sensitivity and specificity of the extraoral bitewing is statistically similar to the intraoral bitewing.[8] Panoramic extraoral bitewing imaging can offer acceptable diagnostic information in certain difficult populations, including pediatrics and the medically compromised, with a relatively low radiation dose (still higher than traditional bitewings) and unfortunately a questionable capacity to asses interproximal caries lesions. **FIGURES 2** is an example of a full digital panoramic image as well as the extraoral bitewing image.

Possible actions to improve panoramic imaging procedures are:

- Consider purchasing or leasing a digital panoramic machine that is full-featured and includes the extraoral bitewing capability for reduced exposure to children and ease-of-use by eliminating wires.
- Consider using a digital panoramic image and digital intraoral bitewings as your initial radiographic examination replacing full-mouth series of images.

CBCT

The adoption of CBCT technology in the dental office is much more rapid than the adoption of intraoral digital X-ray technologies. The reasons for this adoption have been explained more thoroughly elsewhere .[9–11] In terms of exposure to the patient, CBCT is a low-dose imaging modality, especially compared to conventional medical CAT (CT) scanning. Comparing the dose from different CBCT machines is not simple. Many factors such as the field of view (FOV), exposure parameters (kV and especially mA differences) and even machine features can alter the overall patient X-ray exposure dose.[10]

It is now generally accepted that the average dose from typical CBCT machines ranges from approximately 10 to 12 µSv to as high as 132 µSv.[12] By comparison, typical conventional medical CT dose to a patient for a head and neck exam approaches 2,100 µSv. Because of this, there is a concerted effort by the medical and dental professions to reduce true CT dose to children. Image Gently (imagegently.org) is a national awareness campaign for the reduction of radiation exposure in children endorsed by all medical specialties, the ADA, the American Dental Hygiene Association and all dental specialty organizations.[13]

Not every patient who enters your office needs a CBCT examination. Just as we have been teaching in dental schools for more than 40 years, there is the obligation of the dentist to examine the patient clinically, review a complete medical and dental history and then order only those images using the appropriate imaging modalities that are supported by the examination and that are expected to result in positive diagnostic findings. The concept is called selection criteria and has been published multiple times in the *Journal of the American Dental Association (JADA)*.[14]

The adoption of CBCT imaging has been rapidly accepted because of the myriad applications for which this modality is the imaging technique of choice. Once more, the applications for CBCT imaging are discussed completely elsewhere.[15] It should be apparent to the reasonable clinician that more image planning is required than simply ordering a staff member to take a cone beam scan. Considerations for the appropriate scan to be performed include:

- Patient age, especially considerations for exposing children.
- Patient's size or the selection of appropriate kV and especially mA.
- Patient's medical conditions.

FIGURE 2A.

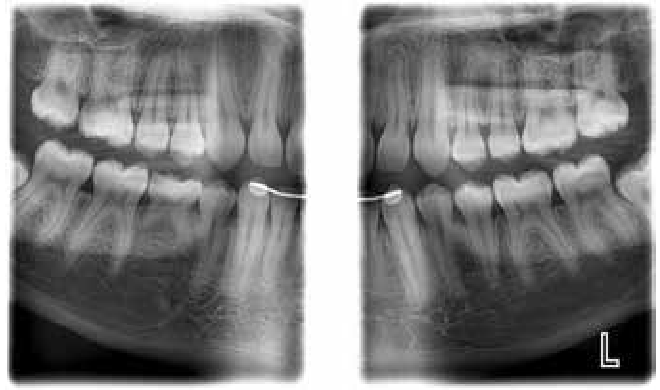

FIGURE 2B.

FIGURES 2. Digital panoramic image (**2A**). Note the overlapped contact points in the bicuspid region. The multiple opacities in the patient's right oropharyngeal airway are tonsilloliths, not plaques. Digital panoramic extraoral "bitewing" image (**2B**). (Image courtesy of Planmeca USA)

- Dental task to be performed, for example, implant site assessment or surgical planning for an impacted tooth.
- Required field of view (FOV).
- Voxel size selection, appropriate to the task.

To illustrate these points, let's examine some case scenarios that all dentists will encounter.

Scenario, case 1. After examination of a healthy 12-year-old male in your operatory, it becomes apparent that the child has missing or unerupted first permanent bicuspids. The patient's permanent second molars are erupted and in a proper occlusion. Which examination would be more appropriate: a 2D digital panoramic image or a CBCT scan?

Possible clinical decision/solution. Even though the dose is low for a CBCT evaluation/scan, the information about the presence, absence and position of the "missing" premolars could probably be evaluated sufficiently with the 2D digital panoramic image. In addition, information about the development of the patient's third molars would also be available. If there were additional findings that required further radiographic evaluation, a follow-up CBCT could be performed. This is appropriate decision-making.

Scenario, case 2. After examination of a healthy 12-year-old female in your operatory, from the clinical symptoms and history present you determine that there may be maxillary sinus inflammation or even infection. She has several grossly carious first molars. After intraoral imaging of the molars, which would be a more appropriate radiographic evaluation, a conventional medical CT scan or a CBCT scan that captures the maxillary antra and nasal cavity regions (typical 8 cm by 8 cm dentoalveolar volume)?

Possible clinical decision/solution. A CBCT dental scan represents a significantly reduced X-ray dose to this child patient. Even though a conventional CT scan has been the gold standard in the past, a CBCT scan would yield significant information about the maxillary sinuses and nasal cavity as well as begin to rule out any odontogenic causes for the maxillary sinus problems. If your scan failed to capture the remainder of the paranasal sinuses and the maxillary antra and/or nasal cavity are significantly involved, you could take an additional scan to capture the ethmoid air cells, frontal sinuses and sphenoid sinus to evaluate all of the paranasal sinus system. Alternatively, you could refer the patient to their primary care provider and/or an otolaryngologist for clinical, endoscopic and radiographic evaluation of all the paranasal sinuses. More frequently, ENT specialists are now using CBCT with larger FOVs to evaluate their child patients in an attempt to reduce the X-ray dose from conventional CT scans. The low-dose dental CBCT scan will help you evaluate both the maxillary sinuses and the role the infected teeth may be playing. This represents good image management and good radiation hygiene.

Scenario, case 3. A 62-year-old white female has come to your office to discuss implants. She has been missing her mandibular first molars for several years. Your clinical examination and medical history review reveal that she has osteoarthritis (OA) in her neck and left knee. You determine that she needs to have implants to replace the mandibular first molars, removed due to dental caries and subsequent apical periodontitis. You decide to perform an 8 cm by 8 cm dental alveolar CBCT scan to assess the implant sites. Is there additional imaging that could be performed because of the patient's history of OA?

Possible clinical decision/solution. Patients with preexisting osteoarthritic changes in other joints should probably have the TMJ region imaged to determine if there are any concomitant OA changes associated with the condylar heads such as osteophyte or subchondral cyst formation. If you restore the patient's bite/dentition to proper form and function, you could stir up preexisting OA that may have affected one or both condyles. It is better to assess the temporomandibular joint complexes before you restore the edentulous spaces and caution the patient that there could be subsequent discomfort due to her preexisting OA. If you do not assess the condyles radiographically using your CBCT device, restore the patient's occlusion and symptoms ensue, you may be seen as the cause of the patient's discomfort because you did not educate them about the relationship between their bite and the TMJ complexes. This could represent a bad outcome for both you and the patient.

Possible actions to improve CBCT imaging procedures are:

- Determine which tasks will require and benefit from CBCT imaging and establish the conditions under which CBCT will be performed.
- Develop an office protocol for the use of CBCT for different tasks. This might include:
  - Recording a diagnosis in the chart for which the CBCT examination is required.
  - Recording why a certain sized FOV was used.
  - Evaluating and recording the voxel size selection depending on the task (smaller voxel size for endodontics and implant assessment and larger voxel size for orthodontic assessment and child imaging). Using smaller voxel size inherently increases the dose to the patient.
  - Identifying the individual in the office who is the primary operator for image acquisition.
  - Recording the exposure factors and dose if possible.
  - Developing a methodology for reviewing the scan data.
  - Establishing a formal way of recording unusual findings that need referral.

Risk and Potential Liability of Using CBCT for You and Your Patients

At first, this may seem like a separate issue to "radiation safety." While extremely unlikely, harm could come to the patient from injudicious use of X-ray modalities. However, there has never been a documented case of dental X-ray exposure from any modality causing serious patient harm or damage. On the other hand, harm to the patient in the form of negligence with resulting injury is documented.[16]

National Campaigns That Have or Will Impact State Dental Acts

The following is a summary of the national campaign called Image Gently that is endorsed by the ADA (2014), the American Dental Hygiene Association (2014) and most of the dental specialty organizations in the U.S. The campaign began as an appeal to both the medical and dental imaging communities to pledge to reduce the number and frequency of conventional CT exams to minimize radiation burden to children.[15,17] It has expanded significantly because of the endorsements of dental organizations to include all types of dental imaging. Although the campaign is aimed at reduction of dose to children, the tenets proposed below could just as easily be adopted for all radiographic exposures performed in the dental office. Following these tenants will allow all of us to take steps in the right direction for minimizing dose to our patients. The six tenets that the Image Gently campaign proposes are:

- *Select X-rays for individual needs, not as a routine*. Use X-rays only when essential for diagnosis and treatment, based on a review of the patient and their dental history.
- *Use the fastest image receptor available*. When film X-ray is used, select E- or F-speed. Set exposure parameters as low as possible for diagnostic digital imaging.
- *Use CBCT only when necessary*. CBCT should be restricted in children to cases where it is essential for diagnosis and treatment planning.
- *Collimate beam to area of interest*. For intraoral X-rays, collimation should be rectangular to match the recording area of detector. For extraoral X-rays, including CBCT, restrict the beam to the area needed for diagnosis.
- *Use thyroid shield always*. The thyroid gland in children is particularly sensitive to radiation. Use of a properly positioned shield significantly reduces the dose to the thyroid.
- *Child-size the exposure time*. Less exposure time is needed for children as oral structures are smaller than in adults.

In dentistry, none of this is new, except for perhaps the addition of guidelines on the use of CBCT. All dental team members who trained in any formal dental program were taught the concept of selection criteria;[14] that is, to examine the patient, determine the need for the X-ray and the modality and only then order those images necessary based on the exam, history and signs and symptoms. The guidelines for this concept have been published multiple times in *JADA*. For the most part, they've been ignored. Unfortunately for us, it is looking more and more likely that these "guidelines" will be mandated into state dental acts in the future. In our opinion, we have done many of our patients a disservice by not following these guidelines.

One only has to look at how HIPAA and OSHA compliance guidelines have impacted dentisty already. The next targets are X-ray and laser compliance issues, and regulations seem to be following. One only has to look at the most recent report from the Texas Department of State Health Services to see the impact currently. This link, dshs.texas.gov/radiation/enforcement.aspx, leads to a report of the enforcement actions taken in the years 2017–18 to date.[18] Average penalties for noncompliance with state regulations with regard to dental X-rays are between $3,000 and $5,000. There are new companies and services being offered to help dentists stay in compliance in these areas (iradconsult.com). Readers of this article would be wise to check out these or other services in their states to find out if they have incurred any risk due to noncompliance. It is imperative that we understand the radiation guidelines in our state as failure to do so could be costly.

Risk and Liability From Poor Radiation Safety/Office Practices

Direct Risk

In general, and despite the public's and media's somewhat inflated concerns over X-radiation, there is very little danger from the judicious use of dental diagnostic X-ray imaging modalities. Just by following the limited guidelines stated from the Image Gently campaign, most patient concerns and probably any harm to the patient would be negligible. Only the developing thyroid of the child needs to be protected from X-radiation because it is a radiosensitive organ. Diagnostic radiographic information is required for many of the tasks we perform in dental offices. The benefits of the value and positive results of the radiographic information need to outweigh the risks of using our intraoral, panoramic and CBCT devices.

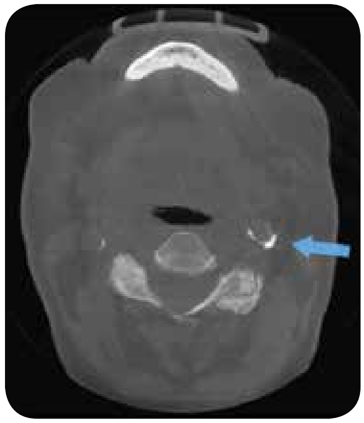

FIGURE 3A. Circumferential carotid plaque, left internal carotid (0.1 mm slice).

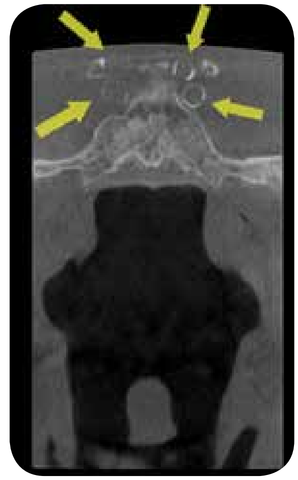

FIGURE 3B. Circumferential carotid plaques, left and right internal carotid arteries (0.1 mm slice).

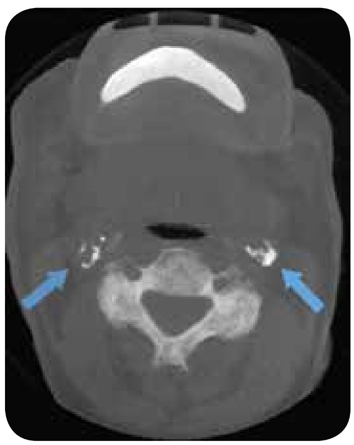

FIGURE 3C.

FIGURE 3D.

FIGURES 3C, 3D. MIP (maximum intensity projection) tool applied making 10 mm slice thickness to show carotids, both right and left internal segments affected. This tool is used by all radiologists to make any calcification more demonstrable.

FIGURE 3E. Circumferential carotid plaques, right paraclinoid and bilateral parasellar segments

FIGURE 3F. Circumferential carotid plaques of the cavernous or parasellar segments (blue arrows).

FIGURE 3G. Medial arterial calcifications lining wall of internal carotid adjacent to the sella turcica (yellow arrows).

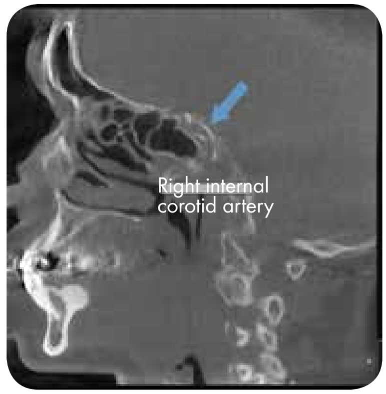

FIGURE 3H. MIP (maximum intensity projection) tool applied making 10 mm slice thickness in a sagittal section showing path/bend in right internal carotid. Blue arrow shows calcifications in the medial walls of this artery (Mönckeberg's calcinosis or MAC).

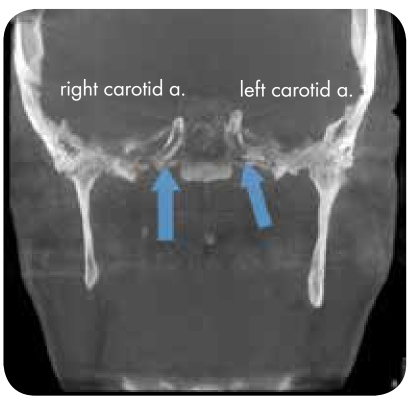

FIGURE 3I. Coronal MIP images of internal carotids, lining the medial wall of the arteries adjacent to the sphenoid sinus after passing through the foramen lacerum (blue arrows).

FIGURE 3J. Sagittal view of same artery.

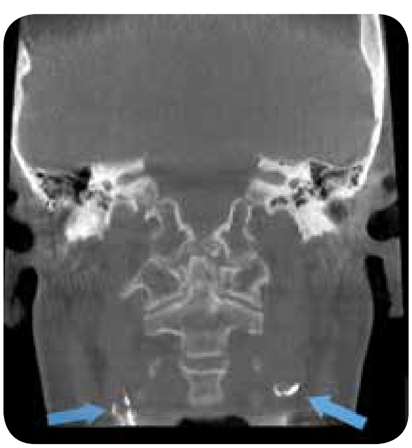

FIGURE 3K. MIP (maximum intensity projection) tool applied making 10 mm slice thickness in a coronal section showing calcifications in the medial wall of the cervical segments of the carotid arteries (Mönckeberg's calcinosis or MAC).

Indirect Risk

On the other hand, there are risks associated with not reviewing or interpreting all the data in all the images produced by these devices. Indirectly, because of the size and content of the CBCT image data sets, dentists' risks are significantly increased from missing something in the scan or failing to refer an abnormality or both. Some dentists think, and indeed have been told by some manufacturers and lecturers, that they do not have to diagnose medical conditions in the scan. Indeed, any radiographic image is just a test or tool to help guide a dentist to a final clinical diagnosis. With very few exceptions, one cannot make a diagnosis of medical conditions solely from radiographic information. That's why the exercise is called "radiographic interpretation." However, this does not abrogate the dentist or dental specialist from their moral and professional obligation to review all of the data set, record any abnormal finding and refer any images made of the finding for a second, often higher-level opinion. This is simply the standard of care. If you identify something different and do not know what it is, there is an obligation to refer the patient and/or the image data for a specialty evaluation — medical or dental.

We take exception to the broad statement that dentists are not responsible for making medical diagnoses. We all take a blood pressure reading prior to an extraction specifically to determine if the patient has high blood pressure, a medical diagnosis that may impact the surgical procedure.

As another example, we may take a patient's history, evaluate their signs and symptoms and correlate this information with clinical findings and radiographic findings in the patient and form a clinical impression of undiagnosed or uncontrolled Type 2 diabetes mellitus.

There are several of these patients with this endocrine problem in our practices who are as yet undiagnosed. The standard of care would dictate we refer this patient to their primary care provider, an endocrinologist, an internist or even a diabetologist for further serologic evaluation and confirmation of our suspicion. **FIGURES 3A–K** show the organized, circumferential calcifications seen in uncontrolled or undiagnosed Type 2 diabetes mellitus in segments of the internal carotid arteries. These are not simple plaques seen in the tunica intima, these are changes in the tunica media or medial layer consistent with medial arterial calcification (MAC). These are significant and must be referred.[19,20]

Almost all dentists in all North American dental programs have been trained to evaluate patient systemic problems and recognize the dental components. If you have a large data set of images from a cone beam evaluation, you have an obligation and responsibility to look at all of the sliced data for radiographic signs of systemic disease. Again, you may not make the final diagnosis but you are reviewing all of the information that you ordered to determine if there is an abnormality. You are responsible for everything in the scan. To reduce this liability, you may decide that because of the time commitment involved to review the scan data or your lack of expertise that you need to have your scans interpreted by an oral maxillofacial radiologist or a medical radiologist specializing in head and neck and/or neuroradiology. Not only will you reduce your risk, you will learn from the reports that you receive from the specialists. This makes you a better clinician, reduces your risk and guarantees that your patient gets the best care possible.

Summary

All X-ray exposures, including those from dental modalities, carry risk. When the diagnostic information from these modalities is expected to benefit the patient, by providing information that leads to a better clinical decision and subsequent better care, there is no reason not to order the appropriate images. The benefit will almost always outweigh any direct harm. If we all adopt faster receptors, prescribe only those radiographs that are necessary, perform those X-ray procedures precisely, use thyroid collars on children for all intraoral procedures, use rectangular collimation for intraoral images and spend more time to interpret the radiographic data we collect, we will serve the patient better and reduce their direct and indirect risk. By adopting all the suggestions in this article, we will most likely be in compliance with any state or federal regulation or recommendation including those contained in our dental acts. If we don't make a better effort to practice radiation safety, it harms us all — our patients and ourselves. ■

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