Commentary

Contemporary radiation protection in dentistry

Recommendations of National Council on Radiation Protection and Measurements Report No. 177

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Supplemental material is available online.

Radiation protection is not only a matter for science. It is a problem of philosophy, and morality, and the utmost wisdom.

Lauriston S. Taylor, founder of the National Council on Radiation Protection and Measurements[1]

Diagnostic imaging is an essential part of clinical dental practice. Every practitioner wants to use radiation in a safe and effective manner. The National Council on Radiation Protection and Measurements (NCRP), a congressionally chartered nongovernmental agency, has taken the lead in establishing recommendations for radiation protection and safety in the United States, ranging from nuclear power plants to medical imaging, including dental diagnostic imaging. NCRP Report No. 177, *Radiation Protection in Dentistry and Oral & Maxillofacial Imaging*, was published in December 2019,[2] superseding NCRP Report No. 145, *Radiation Protection in Dentistry*, which was published in 2003.[3] In our commentary, we highlight the recommendations that are most immediate and relevant to clinical dental practice.

The major impetus for this new report came from the expansion of digital imaging and the rapid adoption of handheld intraoral imaging and cone-beam computed tomography (CBCT). These technologies were either not being used or were in their infancy at the time NCRP Report No. 145 was written and published. Thus, NCRP Report No. 177 addresses radiation protection issues associated with these 3 modalities and updates material on other topics previously covered in NCRP Report No. 145.

NCRP Report No. 177 makes 62 recommendations; some are technical in nature, but most are applicable to the everyday practice of dentistry (eTable). The recommendations are worded as either imperative "***shall*** or ***shall not***" statements or suggestive "***should*** or ***should not***" statements. Although NCRP recommendations do not have the force of regulations or laws, they are regularly incorporated into most state radiation regulations. In addition, they are incorporated into American Dental Association (ADA) Council on Scientific Affairs recommendations and advisory statements.[5,6] Thus, it is important for dentists and all oral health care practitioners, as well as dental educators, medical physicists, and other radiation regulatory agencies, to be familiar with the recommendations and their roles in protecting patients, operators, and the public.

Several important legacy recommendations are worth revisiting. Applying evidence-based selection criteria when prescribing radiographic imaging is one of the most important and underused techniques for enhancing patient radiation protection (Recommendation 2). If an image is not needed to answer a specific diagnostic question and if that image is not obtained, the patient radiation exposure is zero. Radiographic images are to be obtained only after reviewing the patient's history, conducting a clinical examination, reviewing prior images, and establishing a diagnostic need for imaging (Recommendation 11). Obtaining radiographic images on a fixed time schedule or on the basis of insurance reimbursement is not consistent with contemporary practice.[5,7] NCRP Report No. 177 complements the existing ADA and US Food and Drug Administration (FDA) selection criteria guidelines and expands those guidelines in the area of indications and contraindications of CBCT (Section 9.1.5 in NCRP Report No. 177[2]). When it is necessary to obtain

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imaging, it is incumbent on us to use techniques that render the dose as low as reasonably achievable (ALARA).

Three tried-and-true techniques contribute to ALARA.

- Rectangular collimation of intraoral images, acquired both with fixed and handheld equipment, is a must as it reduces the patient-absorbed dose by some 50% per image (Recommendation 39). With well over 1 billion intraoral images acquired annually in the United States,[8] the potential savings in population-dose is substantial. Rectangular collimation has the added benefit of reducing scatter radiation, resulting in improved image quality[9]—a win-win for the patient and the practitioner.
- The fastest image receptor commensurate with the diagnostic task shall be used—effectively ruling out D-speed radiographic film as an option for modern practice. Given the widespread adoption of digital imaging and the ever-shrinking number of practices still using radiographic film (15% in 2014-2015[6]), D-speed radiographic film is on the path to extinction.
- It is imperative to shield the patient's thyroid when it will not interfere with the examination (Recommendation 19). This is especially true for children, as children are far more sensitive to radiation-induced thyroid cancer than are adults. Although considered controversial by some, lap shielding (with a protective apron) is no longer considered necessary given modern equipment and imaging techniques (such as rectangular collimation and fast image receptors). Lap shielding has been shown not to reduce the tiny dose received by abdominal, thoracic, and gonadal organs during dental imaging procedures, as most of this comes from scattered radiation off of the spine. Indeed, the medical physics and medical imaging communities have reconsidered the alleged benefits of gonadal shielding.[10,11] Of course, all practitioners must comply with the regulations or laws of their states or jurisdictions, even if those regulations and laws do not reflect contemporary evidence and thinking.

NCRP Report No. 177 provides frontline oral health care providers with detailed, evidence-based recommendations, supporting text, and extensive appendixes, to help guide them in providing the best diagnostic imaging for their patients with the utmost protection of patients, staff members, and the public.

Digital imaging is not an imaging modality per se. Rather, it is a nearly ubiquitous alternative to radiographic film for intraoral (including fixed, mobile, and handheld techniques), panoramic, and cephalometric imaging,[8] and it is an integral component of CBCT imaging. Thus, information and recommendations can be found in the sections covering quality assurance and quality control (for example, Table 5.2 in NCRP Report No. 177,[2] delineating the frequency of quality control tests for digital imaging), image receptors, and the various imaging modalities. NCRP Report No. 177 recommends that expert help be sought when converting from film to digital imaging regardless of imaging modality or when any significant changes in existing digital imaging systems are planned (Recommendation 35).

Handheld intraoral dental radiographic equipment is rapidly gaining popularity in the United States. Handheld intraoral imaging is an excellent method, and possibly the only method, for obtaining images from patients in nursing homes, operating rooms without fixed or mobile radiographic units, and other situations in which conventional wall-mounted or mobile radiographic units are not available. However, handheld units have several disadvantages; for example, aligning the unit and image receptor is challenging without a beam-guiding device, increased opportunities for cross-contamination, and, if used improperly, increased dose to the operator. Therefore, handheld units are not a substitute for a fixed wall- or ceiling-mounted unit in a private office setting. There are

units on the market that have not been cleared by the FDA and that pose a marked radiation hazard to the operator and to the patient.[12-14] As with any other intraoral imaging modality, rectangular collimation provides the same radiation protection and image quality benefits with handheld devices (Recommendation 46). When used properly, the operator of an FDA-cleared handheld unit does not need to wear a personal protective radiation garment (Recommendation 45). However, operator (and patient) protection is predicated on the correct positioning of the device, which can be compromised by operator fatigue over the course of multiple exposures owing to the weight of the handheld unit. Therefore, operators need to have the physical strength to maintain proper position of the device when obtaining exposures (Recommendation 43).

When cross-sectional radiographic information is needed, CBCT imaging is often a low-dose alternative to traditional medical multidetector computed tomography (Recommendation 52). Radiation doses from CBCT acquisitions vary widely, depending on the field of view and technique factors. The latter are often determined by the machine, based on preset options such as high, regular, and low resolution. Radiation doses at the high preset values and large fields of view are greater than with any other imaging in dentistry, and can, in fact, exceed radiation doses in medicine when medical multidetector computed tomographic instruments are used.[15] Consistent with the ALARA principle, CBCT images are to be obtained using the smallest field of view and the lowest technique factors commensurate with the diagnostic task (Recommendation 53). Although CBCT is a valuable adjunct to the imaging armamentarium of dentists, it is not to be used as a primary modality to produce simulated bite-wing, panoramic, or cephalometric images (Recommendation 54). Dentists who are not trained in CBCT during their dental education are often trained by salespeople who do not have sufficient knowledge of the radiation safety aspects and indications and limitations of the CBCT instrument. All personnel who use CBCT must be properly educated and trained in the appropriate use of the equipment, especially regarding selection criteria and the ALARA technique protocols for the various imaging studies (Recommendations 60 and 61). The rapid development of new and improved CBCT instruments demands ongoing continuing education in the proper use of the instruments and for the interpretation of the acquired images (Recommendation 62).

NCRP Report No. 177 recognizes and emphasizes that children are at greater risk than adults "due to higher levels of cell proliferation, more cells which are less differentiated, and a much longer proliferative future."[2] Children cannot be treated as small adults. Use of appropriate selection criteria and "child-sized" exposure techniques is essential in this vulnerable population (Recommendation 21), especially with CBCT imaging. More information on pediatric considerations in oral and maxillofacial imaging can be found at the Image Gently Alliance Web site.[16] The ADA is one of the 109 alliance organizations and has been a supporting organization since 2014. The Image Gently Campaign in Dentistry is not known as widely as it should be; only approximately one-third of pediatric dentists are aware of the Image Gently Campaign in Dentistry.[17]

Areas covered in NCRP Report No. 177 that are not specifically discussed in this commentary include shielding, the role of the qualified expert, equipment performance evaluations, diagnostic reference levels and achievable doses, and other technical matters, as well as additional considerations in the areas of intraoral imaging (including handheld equipment), extraoral imaging, CBCT, quality assurance and quality control, education and training, administration and regulations, and other issues that affect dental practice.

CONCLUSION

NCRP Report No. 177 provides frontline oral health care providers with detailed, evidence-based recommendations, supporting text, and extensive appendixes, to help guide them in providing the best diagnostic imaging for their patients with the utmost protection of patients, staff members, and the public. ■

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SUPPLEMENTAL DATA

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eTable. Table 1.1 from the executive summary of National Council on Radiation Protection and Measurement Report No. 177.*

NUMBER	RECOMMENDATION
1	The dentist (or, in some facilities, the designated radiation safety officer) ***shall*** establish a radiation protection program that is subject to periodic review and update. The dentist ***shall*** seek guidance of a qualified expert in this activity.
2	The dentist ***shall*** employ published, evidence-based selection criteria when prescribing radiographic imaging.
3	The qualified expert ***should*** provide guidance for the dentist or facility designer in the layout and shielding design of new or renovated dental facilities, on implementation of a quality control program and on achieving and maintaining radiation doses that are as low as reasonably achievable (the ALARA principle).
4	To avoid unnecessary repeat exposures due to lost images or redundant examinations, the electronic image data management system ***shall*** provide for secure storage, retrieval, and transmission of image data sets.
5	All digital images acquired ***shall*** be retained in the patient's electronic record, which ***should*** be backed up off-site electronically in a separate, safe, and secure location at regular intervals.
6	The qualified expert ***should*** perform a preinstallation shielding design and plan review and postinstallation dose surveys, assessing each installation individually and providing written reports, including consideration of all relevant workloads in rooms with multiple radiograph machines.
7	Acceptance testing ***shall*** be performed by a qualified expert.
8	All new dental radiographic installations ***shall*** have a radiation protection survey and equipment performance evaluation carried out by, or under the direction of, a qualified expert. Subsequently, equipment performance evaluations ***shall*** be performed at regular intervals by a qualified expert.
9	Diagnostic reference levels and achievable dose values ***should*** be developed and regularly updated for intraoral radiography, cephalometric radiography, panoramic radiography, and dental CBCT† imaging and used by all dental facilities.
10	Each dental facility ***should*** record and track indicators of patient dose, such as entrance air kerma and associated technique factors.
11	Radiographic examinations ***shall*** be performed only when patient history and physical examination, prior images, or laboratory findings indicate a reasonable expectation of a health benefit to the patient.
12	For each new or referred patient, the dentist ***shall*** make a good faith attempt to obtain previous, pertinent images before acquiring new patient images.
13	For symptomatic patients, radiologic examinations ***shall*** be limited to those images required for diagnosis and treatment of current disease.
14	For asymptomatic patients, the extent of radiologic examination of new patients, and the frequency and extent for established patients, ***shall*** adhere to current published selection criteria.
15	Administrative use of radiation to provide information that is not necessary for the treatment or diagnosis of the patient ***shall not*** be permitted.
16	Students or candidates for licensure ***shall not*** be compelled or permitted to perform radiographic exposures of humans solely for purposes of education, licensure, credentialing, or other certification.
17	Fluoroscopy ***shall not*** be used for static imaging in dental radiography. If fluoroscopy is used for dynamic imaging, the practices in NCRP Report No. 168‡ ***shall*** be followed.
18	Images ***shall*** be viewed in an environment adequate to ensure accurate interpretation.
19	Thyroid shielding ***shall*** be provided for patients when it will not interfere with the examination.
20	Protective aprons and thyroid shields ***should*** be evaluated for damage (for example, tears, folds, and cracks) quarterly, using visual and manual inspection.
21	Technique factors and selection criteria ***shall*** be appropriate to the age and size of the patient.
22	Adequacy of facility shielding ***shall*** be determined by the qualified expert whenever the average workload increases by a factor of 2 or more from the initial design criteria.
23	In the absence of a barrier in an existing facility, the operator ***shall*** remain at least 2 m, but preferably 3 m, from the x-ray tube head during the exposure. If the 2-m distance cannot be maintained, then a barrier ***shall*** be provided. This recommendation does not apply to handheld units with integral shields.
24	Provision of personal dosimeters for external dose measurement ***should*** be considered for workers who are likely to receive an annual effective dose in excess of 1 mSv. Personal dosimeters ***shall*** be provided for declared pregnant occupationally exposed personnel.

* Source: National Council on Radiation Protection and Measurements.[2] Reproduced with permission of the National Council on Radiation Protection and Measurement (https://ncrponline.org). † CBCT: Cone-beam computed tomography. ‡ Source: National Council on Radiation Protection and Measurements.[4] § ANSI: American National Standards Institute.

eTable. Continued

NUMBER	RECOMMENDATION
25	For new or relocated equipment, facilities ***should*** provide personal dosimeters for at least 1 y to determine and document the doses to personnel, and to determine whether ongoing personnel monitoring is required to be in compliance with applicable state and Occupational Safety and Health Agency regulations.
26	The facility ***should*** provide personal dosimeters for all new operators of handheld dental radiographic equipment for the first year of use to determine whether ongoing personnel monitoring is required to be in compliance with applicable state and Occupational Safety and Health Agency regulations.
27	In dental facilities using large, multipatient open-bay designs, a patient in proximity to another patient being radiographed ***shall*** be treated as a member of the public for radiation protection purposes.
28	When portable or handheld radiography machines are used, all individuals in the area other than the patient and operator ***shall*** be protected as members of the public.
29	Newly purchased radiography machines ***should*** provide a range of exposure times suitable for twice the speed of the fastest available image receptors at the time of purchase.
30	Film-processing quality ***shall*** be evaluated daily, before processing patient films, for each film processor or manual processing system.
31	Image receptors of speeds slower than ANSI[§] speed group E/F ***shall not*** be used for intraoral radiography (that is, D-speed film ***shall not*** be used).
32	Each darkroom and daylight loader ***shall*** be evaluated for fog at initial installation, and then at least quarterly and after any change in room lighting or darkroom safelight lamp or filter.
33	Film ***shall*** be processed with active, properly replenished chemicals, and time-temperature control, according to manufacturers' recommendations.
34	Screen-film systems of speeds slower than ANSI 400 ***shall not*** be used for panoramic or cephalometric imaging. Rare-earth systems ***shall*** be used.
35	The dental practice ***should*** enlist assistance from a qualified expert to ensure each new digital system is properly configured regarding both patient dose and image quality.
36	The operating potentials of intraoral dental x-ray units ***shall not*** be $<$ 60 kVp and ***should not*** be $>$ 80 kVp.
37	Position-indicating devices ***shall*** be open-ended devices and ***should*** provide attenuation of scattered radiation arising from the collimator or filter.
38	Source-to-skin distance for intraoral radiography ***shall*** be at least 20 cm and ***should*** be at least 30 cm.
39	Rectangular collimation of the x-ray beam ***shall*** be used routinely for periapical and bite-wing radiography and ***should*** be used for occlusal radiography when imaging children with size 2 receptors. Receptor-holding devices ***shall*** be used whenever possible.
40	Occupationally exposed personnel ***should not*** routinely restrain patients and ***shall not*** hold the image receptor in place during a radiographic exposure.
41	Comforters and caregivers who restrain patients or hold image receptors during exposure ***shall*** be provided with shielding (for example, radiation protective aprons) and ***should*** hold the image receptor holding device. No unshielded body part of the person restraining the patient ***shall*** be in the primary beam.
42	Only the patient and operator ***shall*** be in the area during an exposure, unless special circumstances do not allow this.
43	Operators of handheld radiographic equipment ***shall*** have the physical ability to hold the system in place for multiple exposures.
44	Operators ***shall*** store handheld radiographic equipment so that it is not accessible to members of the public when not in use.
45	The operator of a US Food and Drug Administration—cleared handheld radiographic unit ***shall not*** be required to wear a personal radiation protective garment.
46	Rectangular collimation ***shall*** be used with handheld devices whenever possible.
47	The x-ray beam for rotational panoramic tomography ***shall*** be collimated such that its vertical dimension is no greater than that required to expose the area of clinical interest and ***shall not*** exceed the size of the image receptor.
48	The fastest imaging system consistent with the imaging task (equal to or faster than ANSI 400 speed or digital) ***shall*** be used for all panoramic radiographic projections.
49	Panoramic machines ***shall*** be on a dedicated electrical circuit.
50	The fastest imaging system consistent with the imaging task (ANSI 400 speed or faster or digital) ***shall*** be used for all cephalometric radiographic projections.

eTable. Continued

NUMBER	RECOMMENDATION
51	Filters for imaging the soft tissues of the facial profile together with the facial skeleton ***shall*** be placed between the patient and the x-ray source rather than at the image receptor.
52	CBCT ***should*** be used for cross-sectional imaging as an alternative to conventional CT when the radiation dose of CBCT is lower and the diagnostic yield is at least comparable.
53	CBCT examinations ***shall*** use the smallest field-of-view and technique factors that provide the lowest dose commensurate with the clinical purpose.
54	CBCT examinations ***shall not*** be obtained solely for the purpose of producing simulated bite-wing, panoramic, or cephalometric images.
55	CBCT examinations ***shall not*** be used as the primary or initial imaging modality when a lower dose alternative is adequate for the clinical purpose and ***shall not*** be used for routine or serial orthodontic imaging.
56	Radiation safety training ***shall*** be provided to all dental staff and other personnel, including secretaries, receptionists, and laboratory technologists, commensurate with the individual's risk of exposure to ionizing radiation.
57	Every person who operates dental radiographic imaging equipment or supervises the use of such equipment ***shall*** have current training in the safe and efficacious use of such equipment.
58	The dentist ***should*** regularly participate in continuing education in all aspects of dental radiology, including radiation protection, and opportunities ***should*** be provided for auxiliary personnel to obtain appropriate continuing education.
59	The predoctoral, postdoctoral, and clinical residency dental curricula ***shall*** provide all information necessary to ensure safe and appropriate use and radiation management in CBCT.
60	Dental practitioners who own CBCT units or use CBCT data sets in their clinical practice and who have not received CBCT education as part of their predoctoral or postdoctoral education ***shall*** acquire equivalent understanding of the basic radiation safety aspects of CBCT imaging and sufficient knowledge of the indications and limitations of CBCT imaging.
61	Dental personnel who operate CBCT units ***shall*** be trained in the proper operation and safety of the units, including complete training on each unit they will use. They ***should*** demonstrate adequate knowledge of different protocols affecting image quality and radiation dose to the patient before performing CBCT on patients.
62	Every person who operates CBCT equipment, supervises the use of CBCT equipment, or tests and evaluates the functions of CBCT equipment ***shall*** have ongoing continuing education in the safe and effective use of that equipment.