Iowa Dental Board
Dental Assistant
Radiography Exam Study Guide

Updated: June 2024

Introduction

This manual has been designed to help dental assisting applicants prepare for their dental radiography exam. Prospective dental assistants are required to take the radiography exam only if they wish to apply for a radiography qualification issued by the Iowa Dental Board.

A dental assisting registration (R.D.A.) permits you to practice dental assisting; however, it does not authorize you to participate in dental radiography. To be legally authorized to participate in dental radiography, you must have a radiography qualification. A radiography qualification will be noted on your certificate in the upper left-hand corner with a number starting with a “Q”, or “X” in the cases of licensed nurses who obtain a dental radiography qualification.

Note: A dental assistant can participate in radiography only if on trainee status, holds a current dental radiography qualification issued by the board, or is in the process of training in dental radiography

To qualify for a dental radiography qualification, a dental assistant or licensed nurse must have completed training, or have clinical experience taking dental x-rays in another state, within five (5) years of the date of application.

The Board strongly encourages dental assistant trainees to complete the training and exam requirements while on trainee status. Dental assistant trainees who have successfully completed training and the radiography examination can apply for radiography qualification at the same time as registration, saving the trainee from submitting a separate application and separate application fee at a later date.

If you do not successfully pass the radiography exam on the first try, you may retake the test on the next calendar day. You may take the exam as many times as needed in order to pass.

The radiography exam consists of 50 questions and is divided into three parts:

1. The legal requirements for taking radiographs;
2. Infection control requirements when taking radiographs; and
3. Clinical competencies.

The radiography exam consists of a combination of true or false and multiple-choice questions. A minimum score of 75 percent (38 correct answers) is required to pass the exam.

Legal Requirements

Applicants should be familiar with the requirements for being legally authorized to take radiographs in dental offices. Please refer to the following information for more details.

Identify the Agencies that Oversee Dental Radiography

DHHS Radiological Health

The Iowa Department of Health and Human Services' (DHHS) Radiological Health program is designated as the state radiation control agency. This agency is responsible for licensing and inspecting facilities using radioactive materials. DHHS also requires that all dental x-ray machines be registered. Questions regarding radiation-emitting equipment, radiation badges and other related topics can be directed to DHHS. For more information visit their website at https://hhs.iowa.gov/public-health/radiological-health.

Dental Board

The Iowa Dental Board is responsible for ensuring that dental assistants meet minimum training standards in the area of dental radiography. Dental assistants may not participate in dental radiography unless they have been issued a qualification in dental radiography by the board, is authorized to train in dental radiography while on trainee status, or otherwise engaged in the training of dental radiography as permitted by board rules.

Iowa Administrative Code 650 (Board rules)—Chapter 22 specify three primary requirements for obtaining a dental radiography qualification:

1. Clinical training, including taking dental radiographs with patients;
2. Examination: and
3. Submitting a completed application with fee.

Discuss the Requirements for a Dental Assistant to Participate in Dental Radiography

Training

To be eligible for dental radiography qualification, a dental assistant must complete training that includes taking dental x-rays of patients. Training must be completed within five (5) years of application for a radiography qualification. The training may be completed on-the-job as a dental assistant trainee, at a board-approved postsecondary school, at another program prior-approved by the board, or other training as permitted by board rule.

Examination

Proof of successful completion of a board-approved dental radiography examination is required for a dental radiography qualification. The board accepts the following dental radiography examinations:

- The board's examination for dental assistants, which includes sections on infection control/hazardous materials, radiography, and jurisprudence;
- A board-approved examination in the area of dental radiography;
- The Dental Assisting National Board's (DANB) Radiation Health and Safety (RHS) Examination;
- An examination in the area of dental radiography developed and administered by accredited dental assisting programs; or
- A board-approved continuing education course in the area of dental radiography, which includes a posttest examination at the conclusion of the course.

Additional information on the DANB exam is available at www.danb.org.

Application

Successful completion of the training, and the radiography exam alone does not qualify a dental assistant to take x-rays. The dental assistant must apply for and receive a radiography qualification from the Iowa Dental Board. To obtain the qualification from the board, a dental assistant must comply with the following:

1. Be at least 18 years of age.
2. Completion of board-approved training in dental radiography, which may include:

a. On-the-job training;
b. Education at an accredited dental assisting program; or
c. Practice as a dental assistant in another state which included clinical experience taking dental radiographs within the previous five (5) years.

3. Evidence of successful completion of a board-approved examination in dental radiography.
4. Submit an application for a qualification in dental radiography.
5. Submit the application fee.
6. Any additional information required by the board relating to the character, education, and experience of the applicant as may be necessary to evaluate the applicant's qualifications.

Dental assistant trainees can apply for radiography qualification using the combined application for dental assistant registration and radiography qualification. The dental assistant's supervising dentist will need to attest to the dental assistant's clinical proficiency in radiography on the appropriate application form.

Renewal

Once issued, radiography qualification must be renewed at the time as the dental assistant registration. Registration and qualification expire on August 31 of odd-numbered years. To renew a radiography qualification, a dental assistant must obtain a minimum of two (2) hours of continuing education in the subject area of dental radiography, complete the application for renewal, and submit the renewal fee.

Failure to renew by November 1 of the renewal year causes the qualification to lapse and become invalid for practice. If a qualification has lapsed, the dental assistant cannot take dental radiographs until the qualification is reinstated. Reinstatement requires evidence of continuing education, an application for reinstatement, payment of the applicable fees, and/or examination.

Iowa law requires registrants to display the current renewal in conjunction with the registration certificate at each permanent practice location. Dental assistants who maintain a current qualification will have the words, "Added qualification: dental radiography" printed on the renewal card. Possible penalties for violating the law include criminal and civil actions, as well as disciplinary action by the board.

A copy of all rules governing radiography are copied below.

CHAPTER 22
DENTAL ASSISTANT RADIOGRAPHY QUALIFICATION

[Prior to 5/18/88, Dental Examiners, Board of[320]]

650—22.1(136C,153) Qualification required. A person who is not otherwise actively licensed by the board shall not participate in dental radiography unless the person holds a current registration certificate or active nursing license and holds an active radiography qualification issued by the board, and a dentist provides general supervision.

[**ARC 8369B**, IAB 12/16/09, effective 1/20/10]

650—22.2(136C,153) Definitions. As used in this chapter:

"Dental radiography" means the application of X-radiation to human teeth and supporting structures for diagnostic purposes only.

"Radiography qualification" means authorization to engage in dental radiography issued by the board.

650—22.3(136C,153) Exemptions. The following individuals are exempt from the requirements of this chapter.

22.3(1) A student enrolled in an accredited dental, dental hygiene, or dental assisting program, who, as part of the student's course of study, applies ionizing radiation.

22.3(2) A dental assistant pursuant to 650—Chapter 20, or an Iowa-licensed nurse, who is engaging in on-the-job training in dental radiography.

[**ARC 6673C**, IAB 11/16/22, effective 12/21/22]

650—22.4(136C,153) Application requirements for dental radiography qualification. Applicants must apply for registration as a dental assistant or hold an active license issued by the board of nursing. Applications for dental radiography qualification must be filed on official board forms and include the following:

22.4(1) Evidence of one of the following requirements:

a. The applicant is a dental assistant trainee who has completed on-the-job training or registered dental assistant with an active registration status;

b. The applicant is a graduate of an accredited dental assisting program;

c. The applicant is a nurse who holds an active Iowa license issued by the board of nursing and has completed on-the-job training; or

d. The applicant practiced as a dental assistant in another state within the previous five years, and that practice included clinical experience taking dental radiographs.

22.4(2) The fee as specified in 650—Chapter 15.

22.4(3) Evidence of successful completion, within the previous five years, of education, clinical training and examination in the area of dental radiography. The education and clinical

training may be completed on the job as a dental assistant, as part of an accredited dental assisting program, or through the Dental Assisting National Board (DANB).

22.4(4) Any additional information required by the board relating to the character, education, and experience of the applicant as may be necessary to evaluate the applicant's qualifications.

[**ARC 6673C**, IAB 11/16/22, effective 12/21/22]

650—22.5(136C,153) Examination requirements. An applicant for dental assistant radiography qualification shall successfully pass an examination in dental radiography.

22.5(1) Examination may be completed as part of one of the following:

a. The board's examination for dental assistants, which includes sections on infection control/hazardous materials, radiography, and jurisprudence;

b. A board-approved examination in the area of dental radiography;

c. The DANB's Radiation Health and Safety (RHS) Examination;

d. An examination in the area of dental radiography administered by accredited dental assisting programs; or

e. A board-approved continuing education course in the area of dental radiography, which includes a posttest examination at the conclusion of the course.

22.5(2) A score of 75 percent or better on a board-approved examination shall be considered successful completion of the examination. The board accepts the passing standard established by the DANB for applicants who take the DANB's RHS Examination.

22.5(3) A dental assistant must meet such other requirements as may be imposed by the board's approved dental assistant testing centers.

[**ARC 3143C**, IAB 6/21/17, effective 7/26/17; **ARC 4948C**, IAB 2/26/20, effective 4/1/20; **ARC 6673C**, IAB 11/16/22, effective 12/21/22]

650—22.6(136C,153) Penalties.

22.6(1) Any individual except a licensed dentist or a licensed dental hygienist who participates in dental radiography in violation of this chapter or Iowa Code chapter 136C shall be subject to the criminal and civil penalties set forth in Iowa Code sections 136C.4 and 136C.5.

22.6(2) Any licensee who permits a person to engage in dental radiography or a registrant who engages in dental radiography contrary to this chapter or Iowa Code chapter 136C shall be subject to discipline by the board pursuant to 650—Chapter 30.

[**ARC 0265C**, IAB 8/8/12, effective 9/12/12]

These rules are intended to implement Iowa Code section 136C.3 and chapter 153.

CHAPTER 14
RENEWAL AND REINSTATEMENT

[Prior to 5/18/88, Dental Examiners, Board of[320]]

650—14.3(136C,153) Renewal of dental assistant radiography qualification. A certificate of radiography qualification must be renewed biennially. Radiography qualification certificates shall expire on August 31 of every odd-numbered year.

14.3(1) *Renewal procedures.*

a. *Renewal notice.* The board office will send a renewal notice by regular mail or email to each registrant at the registrant's last-known mailing address or email address. The board will notify each registrant by mail or email of the expiration of the radiography qualification.

b. *Registrant obligation.* The registrant is responsible for renewing the radiography qualification prior to its expiration. Failure of the registrant to receive the notice does not relieve the registrant of the responsibility for renewing that radiography qualification if the registrant wants to continue taking dental radiographs in the state of Iowa.

c. *Renewal application form.* Application for renewal must be made in writing on forms provided by the board office before the current radiography qualification expires. Registrants may renew their radiography qualification online or via paper application.

d. *Complete and timely filed application.* No renewal application shall be considered timely and sufficient until received by the board office and accompanied by all material required for renewal and all applicable renewal and late fees. Incomplete applications will not be accepted. For purposes of establishing timely filing, the postmark on a paper submittal will be used, and for renewals submitted online, the electronic timestamp will be deemed the date of filing.

14.3(2) *Application fee.* The appropriate fee as specified in 650—Chapter 15 must accompany the application for renewal. A penalty shall be assessed by the board for late renewal, as specified in 650—Chapter 15.

14.3(3) *Continuing education requirements.* In order to renew a radiography qualification, the dental assistant shall obtain at least two hours of continuing education in the subject area of dental radiography. Proof of attendance shall be retained by the dental assistant and must be submitted to the board office upon request.

14.3(4) *CPR certification.* In order to renew a radiography qualification, an applicant must submit a statement:

a. Confirming that the applicant possesses a valid certificate from a nationally recognized course in cardiopulmonary resuscitation (CPR) that included a "hands-on" clinical component;

b. Providing the expiration date of the CPR certificate; and

c. Acknowledging that the CPR certificate will be retained and made available to board office staff as part of routine auditing and monitoring.

This rule is intended to implement Iowa Code chapters 136C and 153.

[**ARC 0265C**, IAB 8/8/12, effective 9/12/12]

650—14.4(147,153,272C) Grounds for nonrenewal. The board may refuse to renew a license, registration or radiography qualification on the following grounds:

14.4(1) After proper notice and hearing, for a violation of these rules or Iowa Code chapter 147, 153, or 272C during the term of the last license, registration or radiography qualification or renewal of license, registration or radiography qualification.

14.4(2) Failure to pay required fees.

14.4(3) Failure to obtain required continuing education.

14.4(4) Failure to provide a statement of current certification in cardiopulmonary resuscitation in a course that includes a clinical component.

14.4(5) Receipt of a certificate of noncompliance from the child support recovery unit of the department of human services in accordance with 650—Chapter 33.

This rule is intended to implement Iowa Code section 153.23 and chapters 147, 252J, and 272C.

[**ARC 0265C**, IAB 8/8/12, effective 9/12/12; **ARC 4747C**, IAB 11/6/19, effective 12/11/19]

650—14.5(147,153,272C) Late renewal.

14.5(3) *Failure to renew radiography qualification.* Failure to renew a radiography qualification prior to November 1 following expiration shall cause the radiography qualification to lapse and become invalid. A dental assistant whose radiography qualification is lapsed is prohibited from engaging in dental radiography until the qualification is reinstated in accordance with rule 650—14.7(136C,153).

This rule is intended to implement Iowa Code sections 147.10, 147.11, and 272C.2.

650—14.7(136C,153) Reinstatement of lapsed radiography qualification. A dental assistant who allows a radiography qualification to lapse by failing to renew may have the radiography qualification reinstated at the discretion of the board by submitting the following:

14.7(1) A completed application for reinstatement of the dental assistant radiography qualification.

14.7(2) Payment of the radiography reinstatement application fee and the current renewal fee, both as specified in 650—Chapter 15.

14.7(3) Proof of current registration as a dental assistant or proof of an active Iowa nursing license.

14.7(4) If the radiography qualification has been lapsed for less than five years, proof of two hours of continuing education in the subject area of dental radiography, taken within the previous two-year period.

14.7(5) If the radiography qualification has been lapsed for more than five years, the dental assistant shall be required to retake and successfully complete an examination in dental radiography. A dental assistant who presents proof of a current radiography qualification

issued by another state and who has engaged in dental radiography in that state is exempt from the examination requirement.

This rule is intended to implement Iowa Code section 136C.3 and chapter 153.

[**ARC 0265C**, IAB 8/8/12, effective 9/12/12; **ARC 6303C**, IAB 4/20/22, effective 5/25/22]

TITLE V

PROFESSIONAL STANDARDS

CHAPTER 25
CONTINUING EDUCATION

[Prior to 5/18/88, Dental Examiners, Board of[320]]

650—25.2(153) Continuing education administrative requirements.

25.2(1) Each person licensed to practice dentistry or dental hygiene in this state shall complete during the biennium renewal period a minimum of 30 hours of continuing education approved by the board.

25.2(2) Each person registered to practice dental assisting in this state shall complete during the biennium renewal period a minimum of 20 hours of continuing education approved by the board.

25.2(3) Each person who holds a qualification in dental radiography in this state shall complete during the biennium renewal period a minimum of two hours of continuing education in the area of dental radiography.

25.2(4) The continuing education compliance period shall be the 24-month period commencing September 1 and ending on August 31 of the renewal cycle.

25.2(5) Hours of continuing education credit may be obtained by attending and participating in a continuing education activity either previously approved by the board or which otherwise meets the requirements herein and is approved by the board pursuant to rule 650—25.5(153).

25.2(6) It is the responsibility of each licensee or registrant to finance the costs of continuing education.

[**ARC 3489C**, IAB 12/6/17, effective 1/10/18]

Dental Radiography & Infection Control

Applicants should be familiar with the CDC's infection control requirements for dental radiography, which are discussed below. Additional information about infection control standards that are required in dental offices is available in the CDC MMWR Dec 19, 2003.

When taking radiographs, if aseptic technique is not practiced the potential to cross-contaminate equipment and environmental surfaces with blood or saliva is high. Gloves should be worn when taking radiographs, and if applicable handling contaminated film packets. Other personal protective equipment (PPE) (e.g. masks, protective eyewear, and gowns) should be used if spattering of blood or other body fluids is likely (11, 13, 367).

Heat-tolerant versions of intraoral radiograph accessories are available. Semi-critical items such as positioning and/or film-holding devices, should be heat sterilized before each patient use.

After exposure of the radiograph and before glove removal, the positioning devices and/or film should be dried with disposable gauze or a paper towel to remove blood or excess saliva, and in the case of film, placed in a container (e.g. disposable cup) for transport to the developing area.

- Alternatively, if FDA-cleared film barrier pouches are used, the film packets should be carefully removed from the pouch to avoid contamination of the outside film packet and placed in the clean container for transport to the developing area.

Various methods have been recommended for aseptic transport of exposed films, if applicable, to the developing area, and for removing the outer film packet before exposing and developing the film. Other information regarding dental radiography infection control is available (260,367,368).

Care should be taken to avoid contamination of the developing equipment. Protective barriers should be used, or any surfaces that become contaminated should be cleaned and disinfected with an EPA-registered hospital disinfectant of low- (i.e. HIV and HBV claim) to intermediate-level (i.e. tuberculocidal claim) activity.

Radiography equipment, including the radiograph tubehead and control pane, should be protected with surface barriers that are changed after each patient. If barriers are not used,

equipment that has come into contact with DHCP's gloved hands or other contaminated items should be cleaned and then disinfected after each patient use.

Digital radiography sensors and other high-technology instruments, such as an intraoral camera, electronic periodontal probe, occlusal analyzers, and lasers, come into contact with mucous membranes and are also considered semi-critical devices. They should be cleaned and heat-sterilized, or high-level disinfected between each patient.

- The ability of these items to be sterilized or high-level disinfected vary by manufacturer or type of device. Be aware of the manufacturer's recommendations for sterilization or disinfection.

Semi-critical items that cannot be reprocessed by heat sterilization or high-level disinfection should, at a minimum, be barrier protected by using an FDA-cleared barrier to reduce gross contamination during use.

Important! Use of a barrier does not always protect from contamination (369– 374).

- One study determined that a brand of commercially-available plastic barriers used to protect dental digital radiography sensors failed at a substantial rate (44%). This rate dropped to 6% when latex finger cots were used in conjunction with the plastic barrier (375).
- To minimize the potential for device-associated infections, after removing the barrier, the device should be cleaned and disinfected with an EPA-registered hospital disinfectant after each patient. (i.e. Intermediate level disinfectant)
- Manufacturers should be consulted regarding appropriate barrier and disinfection and sterilization procedures for digital radiography sensors, high-technology intraoral devices, and other computer components.

Clinical Competencies

Applicants should be familiar with the practical application of radiography. This instruction should be provided by your supervising dentist or educators. Licensed dental hygienists or registered dental assistants may assist in providing training in dental radiography as delegated by the supervising dentist.

Reminder! Training in dental radiography must be completed under personal supervision, which requires that another licensee or registrant be present in the treatment room.

Clinical Competencies

Applicants should know and understand the following:

- The clinical practice of taking x-rays;
- All aspects of using x-ray equipment;
- Proper use of sensor positioning devices;
- Basic anatomy and position of x-rays;
- Rationale for utilizing certain types of x-rays;
- Ability to identify radiographic errors;
- Radiation safety standards for the patient, self and others;
- Hazards associated with radiation and how to prevent over-exposure;
- ALARA (as low as reasonably achievable) concept; and
- Patient care related to radiography procedures.

Commonly Asked Questions

1. Can a trainee take x-rays?

Yes. A trainee can take x-rays under the personal supervision of a dentist. Alternatively, the supervising dentist can delegate the personal supervision requirement to another licensed dental hygienist or registered dental assistant.

2. How do I renew my radiography qualification?

The Dental Board will email you a notice of renewal approximately 60 days before the date of expiration. The radiography qualification must be renewed prior to November 1 of a renewal year to continue taking x-rays.

3. How many times can I take the radiography exam?

You can take the radiography exam an unlimited number of times; however, you are limited to one attempt per calendar day. If you take the test more than once on the same date, only the first result will be accepted.

Note: Remediation is not required for re-testing.

4. When can I take the exam?

You can take the exam at your convenience, and feel prepared. You are not required to wait a set amount of time prior to attempting the exam.

5. Where do I take the exam?

Approximately 20 Iowa community college testing centers are authorized to administer the dental assisting exams. The list of testing centers is available on the website.

6. What does it cost?

The Iowa Dental Board does not charge a fee to take the examination; however, the testing centers may charge a proctoring fee. This varies based on the testing site.

7. How many questions are on the exam?

There are 50 questions, multiple choice and true/false.

8. What kind of questions are on the exam?

The information included in the radiography exam are primarily addressed earlier in this study guide. They include legal requirements, infection control standards, and clinical questions.

9. What is considered a passing score? How will I know if I passed?

You must obtain a 75 percent or greater to pass the exam. This means you must get at least 38 questions correct.

You will see your score on the screen at the end of the test, and it will be automatically sent to the Dental Board. Written score results are not provided. You will have the opportunity to review your answers at the end of the exam.

10. If I don't pass the exam, can I retake it?

You can retest the next calendar day. If multiple attempts on the same day, only the first result is valid.

11. Do I have to know about film to pass the exam?

No. The questions are global to either digital images or film.

12. Are online exams available?

All board exams are online but must be proctored at an approved testing site.

13. What documentation do I need in order to take the exam?

No documentation or authorization is required. Schedule your testing appointment directly with the testing center.

The testing center may have additional requirements. You may want to ask if there are any additional requirements, such as verifying your identity with a copy of your driver’s license.

14. Do I have to take all three exams (jurisprudence, infection control, and radiography) at the same time?

No. You can schedule any of the exams to be done at your convenience.

15. Who can I ask if I have additional questions?

Additional questions can be directed to Stephanie.Bowers@dia.iowa.gov or IDB@Iowa.gov.

Additional Resources

- American Dental Association (ADA) – “Optimizing radiation safety in dentistry: Clinical recommendations and regulatory considerations”, JADA 155(4), April 2024.
- ADA – “Patient shielding during dentomaxillofacial radiography: Recommendations from the American Academy of Oral & Maxillofacial Radiology”, JADA 154(9), August 2023.
- ADA, Food & Drug Administration (FDA) – “Dental Radiographic Examinations: Recommendations for Patient Selection & Limiting Radiation Exposure, Revised 2012.

Important! The ADA issued updated recommendations for radiography in 2023 and 2024, and may differ from the recommendations that were revised in 2012.

Cover Story

Optimizing radiation safety in dentistry

Clinical recommendations and regulatory considerations

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Supplemental material is available online.

ABSTRACT

Background. The value of dental radiographs to oral health care decision making must be balanced with radiation safety to minimize patient exposure and occupational risk of oral health care providers. This review summarizes recommendations and regulatory guidance regarding dental radiography and cone-beam computed tomography. An expert panel presents recommendations on radiation safety, appropriate imaging practices, and reducing radiation exposure.

Types of Studies Reviewed. A systematic search run in Ovid MEDLINE, Embase, and Cochrane Database of Systematic Reviews identified relevant topical systematic reviews, organizational guidelines, and regulatory reviews published in the peer-reviewed literature since 2010. A supplemental search of the gray literature (eg, technical reports, standards, and regulations) identified topical nonindexed publications. Inclusion criteria required relevance to primary oral health care (ie, general or pediatric dentistry).

Results. A total of 95 articles, guidance documents, and regulations met the inclusion criteria. Resources were characterized as applicable to all modalities, operator and occupational protection, dose reduction and optimization, and quality assurance and control.

Practical Implications. Understanding factors affecting imaging safety and applying fundamental principles of radiation protection consistent with federal, state, and local requirements are essential for limiting patient ionizing radiation exposure, in conjunction with implementing optimal imaging procedures to support prudent use of dental radiographs and cone-beam computed tomographic imaging. The regulatory guidance and best practice recommendations summarized in this article should be followed by dentists and other oral health care providers.

Key Words. Dental radiography; radiography; dentistry; radiation protection; computer tomography; CBCT; x-ray; panoramic; digital radiograph; radiographic film.

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In 2012, the American Dental Association (ADA) and the US Food and Drug Administration (FDA) published *Dental Radiographic Examinations: Recommendations for Patient Selection and Limiting Radiation Exposure*,[1] and the ADA Council on Scientific Affairs issued an advisory statement on the use of cone-beam computed tomography (CBCT) in dentistry.[2] This article provides updated evidence-based recommendations, consistent with ADA methodology, on components of the 2012 publications related to dental radiation safety, appropriate imaging practices, recommendations to reduce radiation exposure to patients and personnel, and adherence to relevant regulatory requirements.

These recommendations are based on a comprehensive review of dental radiation safety research, guidance from national and international agencies, and regulatory standards. These broadly applicable recommendations aim to help clinicians develop and implement safety practices that will provide optimal diagnostic value while minimizing radiation risks to patients or personnel. This

article also provides an overview of regulatory standards that clinicians may need to consult when conducting radiographic imaging studies in clinical practice, including installation and use of imaging equipment, and training of staff members. The recommendations were developed for dental practitioners and their support teams, public health dentists, dental staff members (including dental hygienists and dental assistants), dental students, and community oral health coordinators.

METHODS

A library informationist (K.K.O.) developed a search strategy to identify systematic reviews, organizational guidelines, and regulatory reviews addressing dental imaging modalities (2-dimensional radiographs [bite-wing, periapical, occlusal, panoramic] and 3-dimensional images [CBCT]) used in general dentistry or recognized dental specialties, with a primary focus on digital imaging modalities. The strategy was built in Ovid MEDLINE, and searches were run in August 2020 in Ovid MEDLINE 1946-, Embase 1947-, and Cochrane Database of Systematic Reviews. The Scottish Intercollegiate Guidelines Network systematic reviews filter was modified to include guideline language and applied to the MEDLINE and Embase searches.[3]

Publications to be included were limited to articles published from 2010 onward. The original search was augmented with an updated search in April 2022, and an EndNote file of 1,476 records was exported into DistillerSR (DistillerSR Inc) and duplicates were removed. After duplicate removal and screening at the abstract and full-text level, 95 articles were included. Further manual screening for duplicates and exclusion criteria resulted in 74 articles available for qualitative synthesis. The full search strategies are provided in the Appendix, available online at the end of this article.

Concurrent with the primary search, nonindexed publications were identified with a systematic search of the gray literature and regulatory literature to retrieve technical reports, white papers, position and consensus statements, and regulations (primarily federal, eg, *Code of Federal Regulations* [CFR]) addressing dental imaging considerations and other documents from professional organizations or government agencies in the United States or internationally. A total of 22 citations were identified using this methodology. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram of the search strategy and article screening process is presented in the eFigure, available online at the end of this article.[4]

An expert panel composed of general, public health, and pediatric dentists (M.A.K., A.K.M., M.-L.D.); oral and maxillofacial radiologists (E.B., T.A., A.B.); and a patient representative (M.J.A.-B.) was convened by the ADA Council on Scientific Affairs. A designated writing group composed of expert panel members, including 3 oral and maxillofacial radiologists (E.B., T.A., A.B.), 1 health physicist (D.S.), and 2 ADA Science and Research Institute staff members (J.R.K., R.T.C.), was charged with developing the imaging safety recommendations presented in this report, which was subsequently reviewed and approved by the expert panel.

RESULTS

Radiation exposure and use of ionizing radiation in dentistry

Radiographic imaging procedures used in dental practice are collectively among the most frequently performed in the United States in healthy people[5] and one of the most common radiographic examinations performed worldwide.[6,7] In a 2023 report, a scientific committee of the National Council on Radiation Protection and Measurements (NCRP) estimated that 320 million dental imaging procedures (including intraoral, panoramic, and CBCT) were conducted in the United States in 2016, comprising more than 46% of diagnostic imaging and nuclear medicine procedures nationwide.[5]

Exposure to any amount of ionizing radiation can increase the risk of adverse health effects.[8-14] Adverse effects associated with ionizing radiation exposure are commonly grouped in 2 categories: tissue reactions (also known as deterministic effects [eg, skin burns, cataracts, or cellular death after an acute radiation exposure $\geq$100 mGy]) and stochastic (random) effects.[7,15] Although direct association between low-dose cumulative exposure and eventual adverse outcomes has remained elusive,[13,16-20] tissue reactions from exposure to ionizing radiation may occur in patients who receive an acute exposure at high doses (ie, > 100 mGy threshold level).[15] Although dental imaging exposure levels are typically well below this threshold, patients often undergo multiple radiographic examinations throughout life,[21,22] and studies have shown that cumulative low-level

ABBREVIATION KEY

ADA:	American Dental Association.
ALARA:	As low as reasonably achievable.
CBCT:	Cone-beam computed tomography.
CT:	Computed tomographic.
CDC:	Centers for Disease Control and Prevention.
CFR:	*Code of Federal Regulations*.
FDA:	US Food and Drug Administration.
FOV:	Field of view.
NCRP:	National Council on Radiation Protection and Measurements.
OSHA:	Occupational Safety and Health Administration.
PSP:	Photo-stimulable phosphor.
QA:	Quality assurance.
QC:	Quality control.

Table 1. Effective dose and equivalent background radiation exposure time for selected dental and medical radiographic examinations and procedures.

TYPE OF EXAMINATION	EFFECTIVE DOSE, AVERAGE OR RANGE,* μSv	AVERAGE BACKGROUND RADIATION EQUIVALENT, D†
Dental Radiograph Examination Exposure		
Full-mouth series—18 images, adult[34,35]		
PSP‡ or F-speed film and rectangular collimation	34.9	4
PSP or F-speed film and round collimation	170.7	20
Full-mouth series—12 images, pediatric[36]		
PSP or F-speed film and rectangular collimation	44 (44-85)	5
PSP and round collimation	89.0	11
Bite-wing		
Digital, single[37]	0.3 (premolar), 1.4 (molar)	< 1
4 images with PSP or F-speed film and rectangular collimation[34,37]	3.4-5.0	< 1§
Extraoral radiographs		
Panoramic charge-coupled device[34,37]	14.2-30.0	2-3.5
Panoramic PSP[37]	19.0-75.0	2-9
Cephalometric[34,38]	2.0-10.0	< 1-1.3§
Cone-beam computed tomography—adult[35]		
Small FOV¶	19-652	2-77
Medium FOV	45-860	5-101
Large FOV	68-1,073	8-126
Cone-beam computed tomography—pediatric[31,39]		
Small FOV	7-521	1-61§
Medium or large FOV	13-769	1.5-91§
Comparative Effective Dose From Medical Examinations		
Conventional head CT scan#,[35]	860-1,500	101-177
Low-dose protocol head CT scan[35]	180-534	21-63
Brain CT scan[38]	1,600	188§
Abdominal and pelvic CT[38]	7,700	905

* All values follow International Commission on Radiation Protection 103[34] methodology unless otherwise noted. † National Council on Radiation Protection and Measurements 177[35] estimates unless otherwise noted. ‡ PSP: Photo-stimulable phosphor. § Estimated per capita based on average natural background radiation 3.1 mSv per year. ¶ FOV: Field of view. # CT: Computed tomographic.

radiation exposure may be associated with triggering oxidative stress or potentially inducing damage to cellular DNA[23,24] or oral epithelium,[22,25] increasing the risk of carcinogenesis.[13,14,18,20-23] In addition, the risk for children may be augmented due to longer cumulative exposure over the life span[14,25-27] as well as higher organ radiosensitivity.[14,24,26-30]

Radiation Dose in Dental Imaging

The radiation doses associated with the main imaging modalities used in dental practices range from low-dose intraoral digital radiographs to higher-dose imaging procedures using CBCT. Typical effective doses associated with these modalities are generally low when compared with other medical diagnostic imaging. Table 1 presents a summary of typical effective dose values for dental imaging procedures as well as comparative effective doses from nondental radiographic procedures. The wide range of reported radiation doses from CBCT examinations is a result of differences among models or scanner types, field of view options, exposure parameters, and other protocols used.[31-33]

Recommendations to minimize exposure to ionizing radiation in dentistry

Ionizing radiation exposure is a known carcinogen. The risks associated with the use of ionizing radiation in dentistry, however, can be mitigated by following recommended procedures, in addition

to selection criteria and recall interval guidance as provided by professional societies such as the ADA and relevant specialty organizations. The guiding principle for the safe use of radiograph-based imaging states the needed clinical benefit should be obtained at a radiation dose level that is as low as reasonably achievable (ALARA)[40] and, following the increased use of CBCT, as low as diagnostically acceptable.[41]

Priority recommendations

To emphasize the significance of practice-level considerations to reduce exposure to ionizing radiation while optimizing diagnostic quality, recommendations of critical importance are listed as priority recommendations in Box 1. When these recommendations are followed, exposure to ionizing radiation can be reduced substantially for both patients and staff members.

Regulatory oversight and nongovernmental guidance

Distinguishing Between Regulations and Recommendations

Guidance and recommendations from the ADA and other organizations and agencies, such as the Centers for Disease Control and Prevention (CDC), provide a basis for professional clinical judgment and are not regulatory in nature. Federal, state, and local agencies or health departments may choose to enforce some aspects of clinical guidance. At the federal level, the Occupational Safety and Health Administration (OSHA) regulates the workplace environment (ie, dental health care professional staff members), and the FDA develops and enforces regulatory performance requirements for clinical medical and dental radiograph systems. Those requirements include the provision of device features that address safety for the patient and user, acceptable imaging performance at minimal radiation doses, and instructions for use that document relevant device performance characteristics, as specified in federal regulations. The FDA also promulgates various guidance documents to assist manufacturers and users and releases specific guidance on handheld dental radiograph devices.[42]

ADA policies (available to ADA members on ADA.org) recognize the importance of work practice controls, OSHA recommendations,[43] and guidance from the CDC that support safe delivery of care in dental settings.[44] Regulatory oversight of the use of ionizing radiation in dentistry is based on ALARA principles of radiation safety and image optimization,[45] and, therefore, the first general (and a priority) recommendation is that dentists adhere to all applicable federal, state, and local regulations (Box 1, recommendation 1.0.1). Table 2 lists additional federal and international guidance that is within the dentist's responsibility to be aware of in addition to local regulatory oversight.

NCRP and International Radiation Protection Agencies

The NCRP is a US-chartered scientific advisory agency that develops radiation safety recommendations used by US government agencies (eg, Environmental Protection Agency) and various professional organizations.[56] The NCRP also evaluates recommendations from the International Commission on Radiation Protection to consider their applicability to various domestic radiologic health activities. The International Commission on Radiation Protection and NCRP are not regulatory agencies, but both develop recommendations that serve as a basis for radiation protection standards and legislation. The International Atomic Energy Agency also provides a range of resources that promote optimization of patient protection in dental radiology.[7]

The NCRP developed several reports addressing radiation safety in dental imaging procedures.[56,57] NCRP report 177, *Radiation Protection in Dentistry and Oral and Maxillofacial Imaging*,[35] provides recommendations for practicing dentists that serve as a foundation for these recommendations, which were developed as a component of an update to the 2012 ADA-FDA recommendations for dental radiographic examinations.[1]

Occupational Radiation Safety

OSHA sets statutes, standards, and regulations pertaining to workplace safety and workers' rights. OSHA's Standard on Ionizing Radiation (29 CFR 1910.1096)[58] includes regulatory oversight of the storage, labeling, and testing of radiologic equipment as well as personnel monitoring (dosimetry) and recordkeeping. OSHA ionizing radiation standards relevant to the practice of dentistry are incorporated into NCRP report 177 recommendations[35] as well as the recommendations regarding

Box 1. Priority recommendations.*

RECOMMENDATION

1. Familiarity with and adherence to all applicable local, state, and federal laws (recommendation 1.0.1)
2. Radiographs should be ordered based on diagnostic and treatment planning needs, and dentists shall make a good-faith attempt to obtain radiographs from previous dental examinations (recommendation 3.0.1)
3. Use digital receptors instead of film for intraoral, panoramic, and cephalometric imaging (recommendation 3.1.1.0)
4. Use rectangular collimation whenever possible for intraoral imaging (recommendation 3.1.2)
5. Use cone-beam computed tomography only when lower-exposure options will not yield the needed diagnostic information (recommendation 3.2.1)

*See Box 2 for a full list of recommendations.

occupational protection we present (Box 2, Section 2). OSHA also regulates hazard communication and infection control in the workplace.

Infection Control

OSHA's Bloodborne Pathogens Standard[47] provides regulatory guidance in workplace infection control. The CDC provides nonregulatory infection control protocols for the dental setting, which includes specific recommendations for radiographic equipment.[46] Infection control in radiography is beyond the scope of this article, which is focused on radiation protection, but is included in Section 5.3 of NCRP report 177.[35]

Recommendations applicable to all radiographic modalities (Box 2, Section 1)

Section 1 of Box 2 contains recommendations applicable to all radiographic imaging modalities and patients. In addition to following local, state, and federal regulations, protective measures should be implemented carefully before, during, and after the provision of dental and maxillofacial imaging procedures, including proper radiographic equipment installation, structural shielding, periodic testing of radiographic imaging equipment, and proper training of personnel qualified to operate radiographic equipment. It is also necessary to follow the manufacturer's instructions for the operation and maintenance of equipment, in addition to following recommendations for safe and optimal use. Manufacturers who market radiographic systems in the United States are required to provide that user documentation. Structural considerations and barrier protection, typically regulated by state and local agencies, are beyond the scope of this article.

Recommendations for occupational and operator use of ionizing radiation (Box 2, Section 2)

Recommendations for the reduction of radiation exposure to dental staff members and operators of radiographic equipment can be found in Box 2, Section 2. Every dental practice should have a radiation protection program that specifies occupational radiation exposure limits and includes requirements for barrier shielding where possible and guidance regarding personnel dosimeters for monitoring to minimize the risk of exceeding the limits. These recommendations are supported by NCRP report 177.[35] Barrier protection and structural shielding are covered in detail in NCRP report 147[49] (Table 3 in that NCRP report). When barrier protection is not available, the operator shall stand at least 2 meters from the primary beam path (recommendation 2.0.1). NCRP report 177 further recommends standing at an angle of 90 to 135° to the beam path.[35]

Dosimetry

Dental staff members who may be exposed to an annual effective dose that may exceed 1 mSv, or as otherwise determined by state or local guidance, should consider wearing dosimeters. Using data from United Nations Scientific Committee on the Effects of Atomic Radiation,[59] NCRP report 177 noted that a dental health care worker receives on average an effective dose of 0.06 mSv per year, which is 6% of the recommended threshold for radiation monitoring.[35] Although it is unlikely that

Table 2. List of external resources.*

EXTERNAL RESOURCE	TYPE	AUDIENCE
Infection Control		
Centers for Disease Control and Prevention, Summary of infection prevention practices in dental settings: basic expectations for safe care[46]	Health guidance	Dental office staff members
United States Department of Labor, Occupational Safety and Health Administration, Standard 1910.1030: bloodborne pathogens[47]	Regulatory	Dental office staff members
Occupational Risks		
United States Nuclear Regulatory Commission, Standards for Protection Against Radiation: Subpart C—Occupational Dose Limits. Code of Federal Regulations 10 CFR part 20[48]	Regulatory	Industry
Structural Shielding and Protection		
National Council on Radiation Protection and Measurements Report 147, *Structural Shielding Design for Medical X-Ray Imaging Facilities*[49]	Guidance	Facility-level
Quality Control and Quality Assurance		
National Council on Radiation Protection and Measurements Report 177, *Radiation Protection in Dentistry and Oral & Maxillofacial Imaging: Recommendations of the National Council on Radiation Protection and Measurements*[35]	Guidance	Dental office staff members
American National Standards Institute and American Dental Association Standard No. 1094, *Quality Assurance for Digital Intra-Oral Radiographic Systems*[50]	Standards	Dental office staff members
American National Standards Institute and American Dental Association Standard No. 1099, *Quality Assurance for Digital Panoramic and Cephalometric Radiographic Systems*[51]	Standards	Dental office staff members
American Association of Physicists in Medicine Report No. 175, *Acceptance Testing and Quality Control of Dental Imaging Equipment*[52]	Guidance	Quality assurance and quality control experts
Conference of Radiation Control Program Directors, Technical white paper: cone beam computed tomography (CBCT) for dental applications[53]	Guidance	State and local governments, regulators, inspectors
International Guidance		
International Atomic Energy Agency, *Radiation Protection in Dental Radiology*[7]	Guidance	Dental office staff members; national, local and professional agencies
International Electrotechnical Commission International Standard 60601-2-63:2012, Medical electrical equipment, part 2-63: particular requirements for the basic safety and essential performance of dental extra-oral x-ray equipment[54]	Standards	Manufacturers
International Electrotechnical Commission International Standard 61223-3-7:2021, Evaluation and routine testing in medical imaging departments, part 3-7: acceptance and constancy tests—imaging performance of X-ray equipment for dental cone beam computed tomography[55]	Standards	Manufacturers

* Consult local and state regulatory agencies for local radiation protection standards. Additional external guidance is referred to in the article.

a dental health care worker will approach the exposure limit of 1 mSv per year, it is recommended that operators of radiographic equipment who are pregnant firmly adhere to shielding procedures as specified in the facility's radiation protection documentation and always use dosimeters to monitor exposure.

Recommendations for patient safety and protection (Box 2, Section 3)

General Recommendations to Limit Radiation Exposure to Patients

The ADA recommends that clinicians should perform radiographic imaging, including CBCT, only after reaching the professional judgment that there is a clear clinical benefit from the imaging examination and that this benefit outweighs the risks associated with exposure to ionizing radiation.[2] The benefits and associated risks of the dental imaging examination should be discussed clearly with the patient. Justification also should be based on consultation of evidence-based selection and recall criteria balanced with risks of exposure.[7,8,25,33,35,60-63]

Before performing a radiographic examination, dentists should perform a clinical examination of the patient and consider the patient's medical and dental history. In addition, when previous radiographs and images exist, a good-faith effort should be made to obtain them. CBCT examinations

Box 2. Recommendations for the safe and appropriate use of ionizing radiation in dentistry.

1. General Recommendations for All Modalities

1.0 Regulatory and Industry Oversight

1.0.1 The practice shall comply with all applicable local, state, and federal regulatory requirements regarding the safe and effective use of radiography-based imaging modalities, including installation, usage, optimization, patient and operator protection, infection control, maintenance and training for radiographic equipment and procedures.

1.0.2 New facilities, or facilities installing or relocating radiographic and CBCT* equipment must follow state and local regulations pertaining to radiation safety in effect at the time of construction or renovation.

1.0.3 Follow manufacturer's provided documentation for safe and proper operation, maintenance, and infection control procedures for radiographic, CBCT, and related radiographic imaging equipment.

1.1 Radiation Safety Programs and Training

1.1.1 The dental practice shall develop and implement a radiation safety program that provides all staff members with instructions and guidance for maintaining a safe radiographic imaging program. The program should be consistent with nationally established recommendations for the radiation protection of both patients and staff members and adhere to all applicable state and local requirements, be developed and implemented under the guidance of a qualified expert, and should be regularly reviewed and updated to be current with applicable established guidance and regulations.

1.1.2 Personnel performing radiography-based dental and maxillofacial imaging shall have the qualifications, education, training, and licensure as required by relevant federal, state, and local regulations.

2. Occupational and Operator Use of Ionizing Radiation

2.0 Operator Training Requirements and Performance

2.0.1 When barrier protection or shielding is not available for intraoral imaging, the operator shall stand at least 2 meters from the tube head and out of the primary beam path.

2.0.2 Access to radiation-producing devices shall be restricted, and handheld and portable devices shall be safely secured to prevent unauthorized use.

2.1 Dosimetry

2.1.1 Dental staff members who may be exposed to an annual effective dose that may exceed 1 mSv, or as otherwise determined by state or local guidance, should consider wearing dosimeters.

2.1.2 Pregnant dental personnel who operate radiographic imaging equipment shall adhere to the relevant recommendations set forth in the facility's radiation safety program, including the limitation of occupational exposure, and the use of protective barriers and personal dosimeters regardless of anticipated exposure levels.

3. Patient Safety and Protection

3.0 General Recommendations for Patient Safety and Protection

3.0.1 Before conducting any type of radiographic examination, clinicians should complete a comprehensive clinical examination and patient assessment, with consideration of the patient's oral and medical histories, including previous radiographs as well as the patient's specific oral disease risk.

3.0.2 Clinicians should prescribe dental radiographs and CBCT scans only when they expect that the diagnostic yield will benefit patient care, enhance patient safety, or substantially improve clinical outcomes.

*CBCT: Cone-beam computed tomography.

Box 2. Continued.

3.0.3 The clinical prescription of radiographic imaging, including CBCT, should be supported by professional judgment that is based on current, established selection and recall criteria to ensure that the benefit of the radiographic imaging procedure outweighs the associated radiation risk.

3.0.4 Where possible the x-ray imaging equipment shall be configured to optimize imaging and dosimetric performance specific to the size and age of the patient.

3.0.5 Abdominal and thyroid shielding during diagnostic intraoral, panoramic, cephalometric, and CBCT imaging is no longer recommended, and the use of these forms of protective shielding should be discontinued as routine practice.

3.1 Radiation Dose Minimization and Image Optimization for Traditional Modalities

3.1.1.1 Digital rather than film-based imaging should be used because digital imaging allows for lower patient radiation exposure.

3.1.1.2 If film is used, only E- or F-speed film shall be used because they require substantially lower patient radiation exposure compared with D-speed film. D-speed film shall be eliminated from clinical use.

3.1.1.3 If film is used for panoramic or cephalometric imaging, rare-earth screens and high-speed film of 400 are recommended.

3.1.2 The x-ray beam should be collimated to the receptor size and shape wherever possible, and rectangular collimation should be used for intraoral imaging.

3.1.3 The intraoral radiograph system shall be configured so that the distance from the x-ray tube focal spot to the skin entrance surface (source-to-skin distance) is not < 20 cm.

3.1.4 Intraoral radiography units should be operated at a minimum of 60 kV and not exceed 80 kV.

3.1.5 Intraoral image receptor holders including beam-guiding devices should be used when possible.

3.1.6 Handheld radiographic devices for intraoral imaging must be cleared by the US Food and Drug Administration, used according to manufacturer's instructions, and restricted to use only by authorized operators with appropriate training in device use.

3.2 Radiation Dose Minimization and Image Optimization for CBCT

3.2.1 CBCT imaging should not be used routinely. CBCT examinations shall not be used as the primary or initial imaging modality when a lower dose alternative is adequate for diagnosis and treatment planning.

3.2.2 Use the smallest field of view necessary for imaging the specific anatomical area of interest consistent with the diagnostic and treatment planning needs.

3.2.3 CBCT shall be conducted using technique factors and imaging protocols that are optimized to produce diagnostically acceptable images with the lowest radiation dose to the patient.

3.3 Special Considerations for Pediatric Patients for All Modalities

3.3.1 Pediatric patients shall be imaged using radiographic device configurations as labeled by the manufacturer and optimized specifically for such patients.

4. Quality Assurance and Quality Control

4.0 General Recommendations for Staff Members and Equipment

4.0.1 Staff members of facilities using radiographic imaging equipment shall establish a quality assurance and quality control program, implemented and monitored by a qualified expert and following updated quality assurance and quality control guidance (see Table 2 for list of external guidance).

4.0.2 A qualified expert should survey all conventional radiography units at the time of installation, and should survey the equipment at least every 4 years, after any changes that may affect the radiation exposure to patients and staff members, or in accordance with state and local law, whichever is more stringent.

Box 2. Continued.

4.1	**Equipment- and Modality-Specific Image Quality and Dose Optimization**
4.1.1	The operator's manual for all radiographic systems including applicable computer hardware and software systems must be readily available to the user. All imaging equipment shall be operated and maintained following the manufacturer's instructions, including any appropriate adjustments for optimizing dose and image quality and quality control and quality assurance testing frequency.
4.1.2	CBCT imaging and dosimetry performance shall be evaluated by a qualified expert at least every 2 years, but preferably annually.
4.1.3	Special considerations for receptors
4.1.3.1	Image receptor devices for film-based and digital systems shall undergo initial acceptance testing and be evaluated either monthly (film-based) or annually (digital), as recommended by relevant American National Standards Institute and American Dental Association standards.
4.1.3.2	The film processor and phosphor plate scanners should be evaluated at initial installation and regularly afterward, according to the manufacturer's instructions.
4.1.3.3	Film shall be processed with active, properly replenished chemicals. Chemical solutions should be replenished daily and replaced when depleted. Film processor performance should be checked daily before developing the first patient radiograph, and each type of film should be evaluated monthly or when a new box or batch of film is opened.
4.2	**Technique Charts**
4.2.1	A radiograph exposure factors chart shall be developed for each type of intraoral image receptor and radiograph unit combination and posted near the control panel of the radiographic unit. The charts and recommended exposure factors shall be updated when a different type of receptor or new radiograph unit are used.
4.2.2	Technique charts for intraoral radiography should list the exposure settings based on the type of examination, the type of receptor, and the patient size (small, medium, large) for adults and pediatric settings.

should not be merely routine and should not be for screening purposes.[1] The size and age of the patient need to be considered when applying selection criteria and selecting dose-optimization procedures.[2,7,35,64,65]

Dose Reduction and Optimization

Using digital sensors instead of film for intraoral imaging (3.1.1.0, a priority recommendation) can decrease substantially radiation dose per acquired image. The level of dose reduction varies according to the imaging modality used. If film is used, use the fastest speed possible (E or F). High-speed film can provide a dose reduction similar to digital imaging,[66-68] with F-speed film showing a 60% reduction in dose compared with (now obsolete) D-speed film.[35,69] NCRP report 177 indicates that D-speed film shall not be used for intraoral imaging.[35] Rare-earth, high-speed film is recommended for panoramic and cephalometric radiographs.

Collimating the x-ray beam to the specific region of interest, including using rectangular collimation whenever possible (3.1.2, a priority recommendation),[7,35] has been shown to reduce dose consistently by more than 40%.[66,70] Additional intraoral radiographic measures can reduce radiation exposure substantially, including the use of long position-indicating devices to maximize the distance between the radiation source and the skin of patient to decrease the divergence of the beam, using appropriate operating potentials (60-80 kVp) (3.1.4), and, when digital images are not possible, using E-speed or faster film (3.1.1.2) and using a receptor holder with a beam-guiding device (3.1.5).[35]

Handheld dental intraoral radiographic devices must be FDA-cleared (meaning the FDA has found the device to be substantially equivalent to another legally marketed device that already has FDA clearance). These devices are cleared for a specific clinical intended use and should be used only in accordance with that declaration. Special considerations should be given to the use of handheld intraoral radiographic devices, and the operator should review referenced guidance

documents.[42] Due to the portable nature of handheld devices, they should be stored securely, outside of public reach. Because the operator is essentially holding a radiographic system while it is producing x-rays, facility staff members should be trained in proper holding of these devices to maximize protection from the backscatter shield.[35]

Special Considerations for CBCT

Dentists should never use CBCT routinely, when any other lower-dose radiographic modality may yield adequate diagnostic information[2,8,11,32,33,35,61,71-81] (recommendation 3.2.1). CBCT can deliver a substantially higher dose than traditional radiography (as much as 10-15 times the dose)[25,30,31,35,61,62,82,83] but provides 3-dimensional images of teeth and surrounding structures that can be valuable for certain indications.[7,8,35,39,76,78,81,84-89] CBCT should be used only after a determination is made that other lower-dose imaging methods would not be expected to provide the required diagnostic information. Most newer systems provide clinical scanning protocols that include lower-dose settings[87,88,90,91]; however, operators also can reduce patient radiation dose via using the smallest possible field of view needed for the clinical purpose (recommendation 3.2.2) and manually adjusting the combination of tube output and scan time where possible (recommendation 3.2.3).[12,75,77,79,86,87,92-94]

Special Considerations for Pediatric Patients

Children and young adults are more susceptible to the effects of radiation exposure due to a higher sensitivity of organs as well as the longer expected life span, resulting in a greater cumulative effect.[7,12,27,29,30,95] In accordance with recommendation 3.0.4, the size and age of the patient, especially eruption sequence and spacing in children (recommendation 3.3.1), must be taken into account when prescribing radiographic examinations.

Radiographic imaging using any modality should be justified clinically.[2,7,8,25,35,64,95,96] Of particular concern is exposure of the thyroid to the x-ray beam,[11,29] and, therefore, careful patient positioning and application of dose-reduction measures, including rectangular collimation for intraoral radiographs, are essential.

Patient Protection and Shielding

Although the ADA had previously recommended that the thyroid gland should be shielded with a protective collar during intraoral radiography in children,[1] thyroid collars are no longer recommended for any imaging modality.[97] Thyroid collars and abdominal (gonadal) shielding can introduce artifacts by blocking the primary beam,[33,98] potentially resulting in additional radiographs being taken, and do not protect against internal scatter radiation.[97] Patient radiation doses can be minimized most effectively with proper use of rectangular collimation, optimal patient positioning during imaging procedures,[35,97] and implementing appropriate dose-reduction procedures as presented in Box 2 (eg, sections 3.1 and 3.2).

In dentistry, appropriate selection of patients for imaging[1] and rectangular collimation when taking intraoral radiographs[99] offer the best protection against radiation exposure to the thyroid, when combined with guiding principles of radiation safety.[35,100] Patient thyroid shielding during diagnostic intraoral, panoramic, cephalometric, and CBCT imaging no longer should be used in routine practice for pediatric or adult patients. As necessary, federal, state, and local regulations and guidance should be revised to remove any actual or implied requirement for routine protective shielding for intraoral, panoramic, cephalometric, and CBCT imaging.

Quality assurance and quality control (Box 2, Section 4)

Quality assurance (QA) in dental and maxillofacial radiography are the specific steps taken to produce images with necessary diagnostic information with the lowest radiation exposure to the patient, in accordance with manufacturer and regulatory guidance for device use.[35,101] Quality control (QC) is the component of QA focused on tests and measurements of radiographic devices, image receptors, scanners, display devices, and other technical components and parameters.[98] The primary goal of QC is to ensure that the complete imaging system remains at an acceptable level of performance as established by QA activities. American Association of Physicists in Medicine report 175, NCRP report 177, and American National Standards Institute/ADA standard no. 1094 provide detailed guidance on QA and QC procedures for dental and maxillofacial imaging systems, equipment performance evaluation,

and shielding design.[35,50,52] They underscore the responsibility of the dentist to establish and implement protocols for the safe and effective use of diagnostic radiographic equipment in the office. This includes optimization and maintenance of dental imaging equipment and QC of the components of digital imaging systems and film processing (for those using film).[35] For CBCT imaging devices, the European Federation of Organizations for Medical Physics and the International Atomic Energy Agency have established a detailed quality-control protocol for CBCT, available online.[101]

Dental facilities should have a designated, locally licensed clinician who is responsible for the radiation safety program.[35] The program should include procedures that limit patient exposure, guidance about application of appropriate dose-reduction techniques, protective devices that minimize radiation exposure to the patient, and QA practices as well as protocols for ensuring the proper functioning, calibration, and use of dental imaging equipment.[35,98] For CBCT, the FDA requires manufacturers to provide QA and QC recommendations, including a schedule of the frequency that various tests should be performed and who should perform them (21 CFR 1020.33).[102]

The NCRP recommendations strongly encourage dentists to establish and implement robust QA and QC processes as part of a complete quality program of radiographic imaging. Although clinical staff members should ensure that radiographic equipment produce consistent output of clinically acceptable images, a qualified physics professional such as a medical or health physicist should conduct periodic evaluations of the complete program of radiographic imaging to ensure the production of high-quality dental images at the lowest possible patient radiation dose and that risks of radiation-induced injury to personnel are mitigated.[35] The QA program should specify a complete physics survey at recommended intervals that includes assessment of patient radiation dose, clinical image quality, and x-ray output levels as appropriate to evaluate compliance with manufacturer-recommended values.[35,71,103] In addition to recommendation 1.0.3, the dental practice should follow the manufacturer's instructions and guidance for routine maintenance of imaging equipment and infection-control procedures for radiographic, CBCT, and related radiographic imaging equipment. Recommendations for QA and QC are presented in Box 2, Section 4.

DISCUSSION

This review of radiation safety and protection recommendations and regulatory oversight has established several critical recommendations that significantly reduce patient dose and occupational risk from radiographic and CBCT imaging. These priority recommendations include adherence to local, state, and federal regulations; a good-faith attempt to obtain images from previous examinations; using digital receptors rather than film; using rectangular collimation; and using CBCT only as an adjunct.

Dental practice continues to evolve, with use of electronic dental records, precision dental medicine, imaging equipment advancements, and artificial intelligence applications driving the way dentistry is practiced. Trends in technology use likely are affected not only by its availability but also the frequency with which patients seek routine care as well as available treatment options. Nevertheless, foundational compliance with radiation-protection regulations and best-practice recommendations is a core component of quality dentistry. Regulatory compliance is essential, as is the appropriate and safe use of radiographic imaging systems.

Although CBCT can provide enhanced visualization of dental and related structures beyond that provided with conventional 2-dimensional imaging, its misuse results in ionizing radiation exposure to the patient that is not justified. It is incumbent on the influencers of clinical practice, including academics and journal editors, to consult the latest professional recommendations regarding the clinical indications for CBCT to ensure that such imaging is appropriate and justified.

CONCLUSIONS

The concept of ALARA, introduced in 1977,[40] is firmly entrenched as an overarching principle for radiation protection in dental and medical imaging guidance and regulatory standards. With the increasing availability of CBCT and digital-based imaging, the panel recommends that dental office staff members integrate the recommendations presented here, weigh the benefits of newer imaging technologies against radiation-specific risks (particularly for children), and conduct imaging procedures with an aim of obtaining optimal image quality at radiation doses that are as low as diagnostically acceptable.[41] ■

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APPENDIX: LIBRARY SEARCH STRATEGIES

Ovid MEDLINE search strategy

1 exp Radiography, Dental/
2 ((radiograph$ or x-ray$ or radiation or radiology or radiolucency or radiopacity or radiopaque or radiolucent or imaging or bitewing or CBCT or "Cone-beam CT" or "cone beam computed tomography" or "Computerized tomography" or panoramic or orthopantomograph$) adj5 (dent$ or tooth or teeth or orthodont$ or mouth or maxillofacial or endodont$ or periodont$ or root or maxillary or gingiv$ or intraoral or periapical or alveolar or molar or premolar or cuspid or incisor or canine or temporomandibular or furcation or 'intrabony defect' or 'dental caries' or 'carious lesion')).ab,kw,ti.
3 1 or 2
4 adverse effects.fx.
5 exp Risk Factors/
6 Safety/
7 exp Risk Assessment/
8 radiation effects.fx.
9 exp Radiation Protection/
10 exp Radiation Effects/
11 (risk or exposure or damage or radiosensitivity or safe or safety or mortal$ or threat$ or "adverse effect" or "adverse effects" or "adverse event" or "adverse events" or "side effect" or "side effects" or protection$ or protect or dosimetry or regulatory or regulation or regulations or rules or "as low as reasonably achievable" or ALARA or ALADA or dose or doses or dosing or phantom or phantoms).ab,kw,ti.
12 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11
13 3 and 12
14 Meta-Analysis as Topic/
15 meta analy$.tw.
16 metaanaly$.tw.
17 Meta-Analysis/
18 (systematic adj (review$1 or overview$1)).tw.
19 exp "Review Literature as Topic"/
20 review.pt.
21 14 or 15 or 16 or 17 or 18 or 19 or 20
22 cochrane.ab.
23 embase.ab.
24 (psychlit or psyclit).ab.
25 (psychinfo or psycinfo).ab.
26 (cinahl or cinhal).ab.
27 science citation index.ab.
28 bids.ab.
29 cancerlit.ab.
30 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29
31 reference list$.ab.
32 bibliograph$.ab.
33 hand-search$.ab.
34 relevant journals.ab.
35 manual search$.ab.
36 31 or 32 or 33 or 34 or 35
37 exp guideline/
38 (guideline or guidelines).ab,kw,ot,ti.
39 ('consensus statement' or 'consensus statements').ab,kw,ot,ti.
40 37 or 38 or 39

41 selection criteria.ab.
42 data extraction.ab.
43 41 or 42
44 "Review"/
45 43 and 44
46 Comment/
47 Letter/
48 Editorial/
49 exp Animals/
50 exp Humans/
51 49 and 50
52 49 not 51
53 46 or 47 or 48 or 52
54 21 or 30 or 36 or 40 or 45
55 54 not 53
56 13 and 55

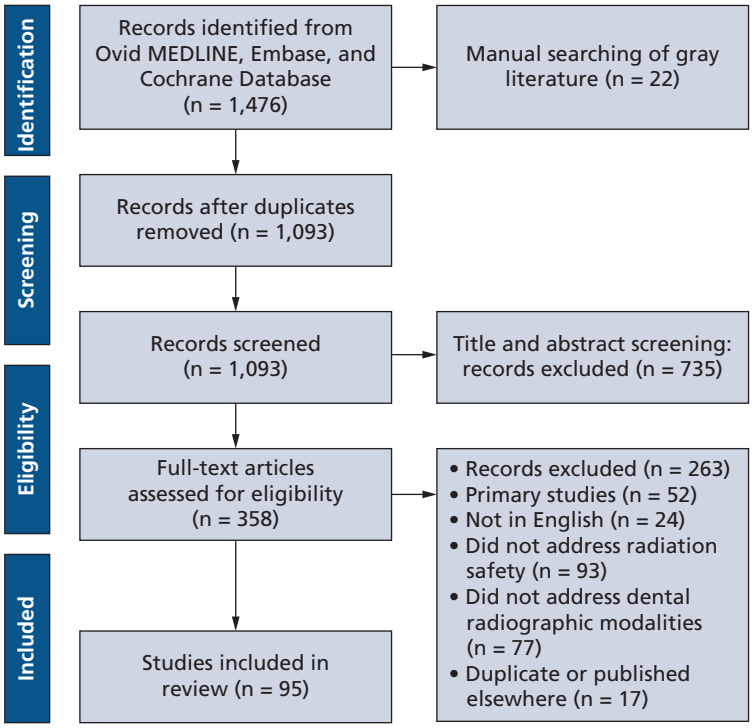
Embase search strategy

1 'dental x ray system'/exp
2 'dental radiology'/exp
3 ((dent* OR tooth OR teeth OR orthodont* OR mouth OR maxillofacial OR endodont* OR periodont* OR root OR maxillary OR gingiv* OR intraoral OR periapical OR alveolar OR molar OR premolar OR cuspid OR incisor OR canine OR temporomandibular OR furcation OR 'intrabony defect' OR 'dental caries' OR 'carious lesion') NEAR/5 (radiograph* OR 'x ray*' OR radiation OR radiology OR radiolucency OR radiopacity OR radiopaque OR radiolucent OR imaging OR bitewing OR cbct OR 'cone-beam ct' OR 'cone beam computed tomography' OR 'computerized tomography' OR panoramic OR orthopantomograph*)):ab,ti,kw
4 #1 OR #2 OR #3
5 'adverse event'/exp
6 'adverse drug reaction':lnk
7 'unexpected outcome of drug treatment':lnk
8 'adverse device effect':lnk
9 'risk factor'/exp
10 'safety'/exp
11 'risk assessment'/exp
12 'radiation response'/exp
13 'radiation protection'/exp
14 'radiation injury'/exp
15 risk:ti,ab,kw OR exposure:ti,ab,kw OR damage:ti,ab,kw OR radiosensitivity:ti,ab,kw OR safe:ti,ab,kw OR safety:ti,ab,kw OR mortal*:ti,ab,kw OR threat*:ti,ab,kw OR 'adverse effect':ti,ab,kw OR 'adverse effects':ti,ab,kw OR 'adverse event':ti,ab,kw OR 'adverse events':ti,ab,kw OR 'side effect':ti,ab,kw OR 'side effects':ti,ab,kw OR protection*:ti,ab,kw OR protect:ti,ab,kw OR dosimetry:ti,ab,kw OR regulatory:ti,ab,kw OR regulation:ti,ab,kw OR regulations:ti,ab,kw OR rules:ti,ab,kw OR 'as low as reasonably achievable':ti,ab,kw OR alara:ti,ab,kw OR alada:ti,ab,kw OR dose:ti,ab,kw OR doses:ti,ab,kw OR dosing:ti,ab,kw OR phantom:ti,ab,kw OR phantoms:ti,ab,kw
16 #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15
17 #4 AND #16
18 'meta analysis'/exp OR 'review'/exp OR 'review':it OR 'systematic review'/exp OR 'systematic review':it
19 (meta NEXT/1 analy*) OR metaanalys*
20 systematic* NEAR/5 (review* OR overview*)
21 #18 OR #19 OR #20
22 guideline:ti,ab,kw OR guidelines:ti,ab,kw

23 'practice guideline'/exp
24 'consensus statement':ti,ab,kw OR 'consensus statements':ti,ab,kw
25 #22 OR #23 OR #24
26 'cancerlit':ab
27 'cochrane':ab
28 'embase':ab
29 'psychlit':ab OR 'psyclit':ab
30 'psychinfo':ab OR 'psycinfo':ab
31 'cinahl':ab OR 'cinhal':ab
32 'science citation index':ab
33 'bids':ab
34 #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33
35 'reference lists':ab
36 'bibliograph*':ab
37 'hand-search*':ab
38 'manual search*':ab
39 'relevant journals':ab
40 #35 OR #36 OR #37 OR #38 OR #39
41 'letter':it
42 'editorial':it
43 'animal'/exp
44 'human'/exp
45 #43 NOT (#43 AND #44)
46 #41 OR #42 OR #45
47 #21 OR #25 OR #34 OR #40
48 #47 NOT #46
49 #17 AND #48

Cochrane Database of Systematic Reviews search strategy

1 MeSH descriptor: [Radiography, Dental] explode all trees
2 ((radiograph* OR x-ray* OR radiation OR radiology OR radiolucency OR radiopacity OR radiopaque OR radiolucent OR imaging OR bitewing OR CBCT OR "Cone-beam CT" OR "cone beam computed tomography" OR "Computerized tomography" OR panoramic OR orthopantomograph*) NEAR/5 (dent* OR tooth OR teeth OR orthodont* OR mouth OR maxillofacial OR endodont* OR periodont* OR root OR maxillary OR gingiv* OR intraoral OR periapical OR alveolar OR molar OR premolar OR cuspid OR incisor OR canine OR temporomandibular OR furcation OR 'intrabony defect' OR 'dental caries' OR 'carious lesion')):ti,ab,kw
3 #1 OR #2
4 MeSH descriptor: [] explode all trees and with qualifier(s): [adverse effects - AE]
5 MeSH descriptor: [Risk Factors] explode all trees
6 MeSH descriptor: [Safety] explode all trees
7 MeSH descriptor: [Risk Assessment] explode all trees
8 MeSH descriptor: [] explode all trees and with qualifier(s): [radiation effects - RE]
9 MeSH descriptor: [Radiation Protection] explode all trees
10 MeSH descriptor: [Radiation Effects] explode all trees
11 (risk OR exposure OR damage OR radiosensitivity OR safe OR safety OR mortal* OR threat* OR "adverse effect" OR "adverse effects" OR "adverse event" OR "adverse events" OR "side effect" OR "side effects" OR protection* OR protect OR dosimetry OR regulatory OR regulation OR regulations OR rules OR "as low as reasonably achievable" OR ALARA OR ALADA OR dose OR doses OR dosing OR phantom OR phantoms):ti,ab,kw
12 #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11
13 #3 AND #12



eFigure. Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram of the search strategy and article screening process.[4]

Supplemental material is available online.

Patient shielding during dentomaxillofacial radiography

Recommendations from the American Academy of Oral and Maxillofacial Radiology

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ABSTRACT

Background. The American Academy of Oral and Maxillofacial Radiology established an ad hoc committee to draft evidence-based recommendations and clinical guidance for the application of patient contact shielding during dentomaxillofacial imaging.

Types of Studies Reviewed. The committee reviewed monographs and reports from radiation protection organizations and studies that reported radiation dose to gonads, breasts, and thyroid gland from dentomaxillofacial imaging.

Results. Considering the absence of radiation-induced heritable effects in humans and the negligible dose to the gonads and fetus from dentomaxillofacial imaging, the committee recommends discontinuing shielding of the gonads, pelvic structures, and fetuses during all dentomaxillofacial radiographic imaging procedures. On the basis of radiation doses from contemporaneous maxillofacial imaging, the committee considered that the risks from thyroid cancer are negligible and recommends that thyroid shielding not be used during intraoral, panoramic, cephalometric, and cone-beam computed tomographic imaging.

Practical Implications. This position statement informs and educates the reader on evolving radiation protection practices and provides simple, unequivocal guidance to dental personnel to implement these guidelines. State and local authorities should be contacted to update regulations to reflect these recommendations.

Key Words. Radiation effects; radiation shielding; radiation protection; thyroid collar; lead apron.
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Dentists use x-rays to obtain radiographs of the dentomaxillofacial region. Radiographs may be obtained to evaluate a symptom or to screen for occult disease in asymptomatic patients. Point-of-care imaging in dental offices includes intraoral, panoramic, cephalometric, and cone-beam computed tomographic (CBCT) imaging. In addition, dentists may prescribe multidetector computed tomography (CT), for example, to evaluate pathoses in the jaws and soft tissues. When prescribing imaging, dentists must consider the advantages and limitations of different imaging techniques and customize the radiographic examination to meet the diagnostic needs of each patient scenario. Although diagnostic objectives are situation-specific, the following principles that guide prescription of radiologic imaging are the same

- Imaging will likely provide answers to the diagnostic questions at hand.
- Imaging techniques will minimize patient radiation dose and provide the necessary diagnostic information.
- Benefits from imaging should vastly outweigh the estimated radiation-associated risks.

Appropriate application of these principles ensures the safety and efficacy of radiographic imaging. To assist dentists in this task, the American Academy of Oral and Maxillofacial Radiology

This article has an accompanying online continuing education activity available at: http://jada.ada.org/ce/home.

and other organizations have developed guidance documents that describe the selection of patients for radiologic examinations and implementation of radiation safety practices.[1-7]

RADIATION EFFECTS

Radiation-induced effects are categorized as stochastic effects and tissue reactions. Stochastic effects result from DNA sequence variations—misrepair of radiation-induced DNA damage. The paradigm considers that stochastic effects occur without a threshold, emphasizing the need to minimize dose to minimize radiation-associated risks. DNA sequence variations that occur in somatic cells may manifest as neoplasia, and there is strong evidence of radiation-induced neoplasia in humans exposed to ionizing radiation.[8] In contrast, DNA sequence variations that occur in germ cells may result in heritable effects that are manifested in the exposed patient's progeny. Unlike radiation-induced cancer, there is no evidence of radiation-induced heritable effects in humans.[9] Tissue reactions, previously termed deterministic effects, occur only when the dose exceeds a threshold. This threshold dose (that is, the minimum dose to induce a manifestable effect in 1% of the irradiated group) varies with effect and tissue of occurrence. Doses from dentomaxillofacial radiography are several thousand-fold below threshold doses for occurrence of tissue reactions. Therefore, there is no risk of tissue reactions from dentomaxillofacial radiography.

PATIENT DOSE REDUCTION

Radiation protection practices are targeted to minimize risks of cancer induction and heritable effects and to eliminate the risk of tissue reactions. With dose-reduction efforts in place, as summarized in the following section, radiation doses from dentomaxillofacial imaging carry negligible risk.

Selection criteria

The most effective approach to eliminating unnecessary radiation is appropriate radiographic prescription through the use of selection criteria. Published guidance assists dentists in the selection of patients for intraoral, panoramic, cephalometric, and CBCT imaging.[1-7] In a study of radiographic prescription patterns, researchers found that most providers followed radiographic prescription guidelines,[10] emphasizing the feasibility of this simple, effective practice.

Collimation

Limiting the radiation field to the region of interest eliminates unnecessary radiation exposure. For intraoral radiography, rectangular collimation limits the beam to the size of the image receptor and reduces patient dose by 60%.[11,12] With CBCT imaging, using the smallest field of view that encompasses the anatomy of interest allows patient dose reduction.

Image receptors and exposure optimization

The use of digital receptors for intraoral, panoramic, and cephalometric radiography reduces radiation exposure. Results of a survey of US dental practices estimated that for intraoral radiography, dental offices use direct digital sensors (68%), photostimulable storage phosphor digital technology (18%), and silver halide film-based imaging (14%).[13] Most intraoral imaging is performed using direct digital sensors, which offer the highest dose reduction. Likewise, almost 80% of panoramic radiographic units in dental offices use digital receptors.[13]

Dental offices should optimize radiation exposure protocols to ensure adequate diagnostic quality with the least amount of radiation. The American National Standard Institute/American Dental Association Standard 1094 provides guidance to establish optimal exposure settings for intraoral imaging considering patient age and size.[14] Some CT units allow automatic exposure control to customize the radiation exposure for each patient.

Shielding

This approach is targeted to reduce exposure of sensitive tissues to external radiation. Gonadal shielding is a long-standing practice during radiographic imaging in general and is mandated by law in many US states. The rationale for gonadal shielding is to reduce the risk of radiation-caused hereditary effects. However, the scientific rationale of this practice has been challenged, and organizations have recommended that routine gonadal shielding during radiography be

ABBREVIATION KEY

ALARA:	As low as reasonably achievable.
ATA:	American Thyroid Association.
CBCT:	Cone-beam computed tomography.
CT:	Computed tomography.
FMX:	Full-mouth radiographic examination.
NA:	Not applicable.
NCRP:	National Council on Radiation Protection and Measurements.

Table 1. Effects of prenatal radiation exposure.

EFFECT	THRESHOLD DOSE, mGy*	SENSITIVE GESTATION PERIOD*	RISK FROM ORAL AND MAXILLOFACIAL IMAGING†
Prenatal Death	100	< 10 d	None; fetal dose approximately 10,000-fold lower than threshold
Microcephaly	100	2-15 wk	None; fetal dose approximately 10,000-fold lower than threshold
Growth Retardation	100	2-15 wk	None; fetal dose approximately 10,000-fold lower than threshold
Intellectual Disability	300	8-15 wk	None; fetal dose approximately 30,000-fold lower than threshold
Radiation-Induced Cancer	None‡	Throughout pregnancy‡	Negligible, approximately 1 in 1.7 million§

* Data from the International Commission on Radiological Protection.[26] † Fetal dose from dentomaxillofacial imaging, including cone-beam computed tomography, estimated at 0.01 mGy.[22] ‡ Radiation-induced cancer is considered a stochastic risk[26]; however, cancer induction in utero is not observed with doses less than 10 mGy.[26] § Cancer risk calculated on the basis of linear no-threshold model[27] and an excess absolute risk of 6% per Gy.[28]

discontinued.[15,16] This position statement summarizes scientific evidence for these changing practices and provides guidance to implement new practices in the dental office. Thyroid shielding seeks to reduce the risk of radiation-induced thyroid cancer—a risk corroborated by classic and contemporary evidence.[17] This position statement summarizes scientific evidence for radiation-induced thyroid neoplasia and provides recommendations and guidance to implement new practices in the dental office.

GONADAL SHIELDING DURING DENTOMAXILLOFACIAL RADIOGRAPHY

Practice of using gonadal shielding in dentomaxillofacial radiography

Gonadal shielding during dental imaging is controversial and was implemented to optimize patient protection during radiography imaging procedures. In 1950, the International Commission on Radiological Protection "strongly recommended that every effort be made to reduce exposures to all types of ionizing radiations to the lowest possible level."[18] In 1966, the International Commission on Radiological Protection introduced the concept of as low as is readily achievable,[19] which was subsequently shortened to the acronym ALARA (which now stands for as low as reasonably achievable).[20] The ALARA principle reinforced the concept of using time, distance, and shielding to reduce patient radiation dose.[20] Technical enhancements to all dental radiographic modalities have substantially decreased patient dose over the years. Nevertheless, the use of gonadal aprons is common practice, and patients expect and often request shielding when dental radiographs are obtained. This long-standing practice reflects public perception of radiation risk and the ease of use of aprons. Many practices offer gonadal shields to alleviate patients' apprehension, and many state regulations require the use of gonadal shielding during dental radiography. However, the decrease in gonad radiation dose from shielding is negligible, and the scientific rationale for its continued use has been questioned.

Absence of heritable effects in humans

Stochastic effects of radiation result from sequence variations. When these sequence variations occur in germ cells, they could potentially manifest as disease in the exposed person's offspring. Although reported in animal studies, there is no evidence of radiation-induced heritable disease in humans.[9,21] Thus, the risk of radiation-induced heritable effects is practically nonexistent with diagnostic imaging, and data do not support routine use of gonadal shielding.

Lead aprons do not protect against internal scatter radiation and radiation doses to the gonads and fetus due to scattered radiation from dental diagnostic imaging have been reduced to negligible levels.[22] With dentomaxillofacial imaging, lead shielding provides no decrease in radiation absorbed by reproductive organs outside of the primary field.[23,24] Overall, scientific evidence does not identify a need to protect against radiation-induced heritable effects, and, thus, gonadal shielding during dentomaxillofacial imaging is deemed unnecessary.

Table 2. Median breast-absorbed doses from dental maxillofacial imaging.*

PROCEDURE	BREAST-ABSORBED RADIATION DOSES,† mGy	
	Unshielded	Shielded
Intraoral Radiography	< 0.1	< 0.1
Panoramic Radiography	< 0.1	< 0.1
Cephalometric Radiography	< 0.1	< 0.1
Cone-Beam CT‡	< 0.1	< 0.1
Mammography, Range	1.4-3.1	NA¶
Head CT	0.3	NA
Chest CT, Lung Cancer Screening, Mean (SD)	15 (0.5)	NA

* Published studies used to compile these data are provided in eTable 1 (available online at the end of this article). † Doses less than 0.1 mGy are reported as a single category. This dose is 500- through 1,000-fold smaller than the lowest doses with demonstrable carcinogenic effects in humans. The committee considered that risk reduction is insignificant when other dose reduction practices, such as fast receptors and rectangular collimation, are implemented. ‡ CT: Computed tomography. ¶ NA: Not applicable.

Radiation exposure of the embryo and fetus: imaging the pregnant patient

Researchers have reported tissue reactions and stochastic cancer induction from in utero irradiation of the human embryo and fetus. Table 1 lists the tissue reactions associated with radiation exposure of the human embryo or fetus and the period of sensitivity during the gestational period. The threshold doses for causation of these tissue reactions are several thousand-fold higher than the estimated fetal doses from dentomaxillofacial imaging.[22] Thus, diagnostic imaging of a pregnant patient poses no risk of occurrence of prenatal death, growth retardation, microcephaly, and intellectual disability. This is consistent with the American College of Radiology's practice parameter for imaging pregnant patients; when the radiologic examination will not directly expose the fetus or gravid uterus, verification of pregnancy status is not needed and is not part of the preparatory questionnaire.[25]

Shielding breast tissue

Although originally intended to shield the gonads, lead aprons also shield the breasts, a sensitive tissue for radiation-induced cancer in women. We reviewed reported breast radiation doses from intraoral, panoramic, and CBCT imaging to derive median breast radiation doses from contemporary dentomaxillofacial radiologic imaging. Table 2 summarizes breast-absorbed doses according to imaging procedure. Published studies used to derive these summary data are listed in eTable 1 (available online at the end of this article).

Breast doses from intraoral, panoramic, and cephalometric radiography and CBCT imaging are less than 0.1 mGy. The median breast-absorbed dose from CBCT imaging is approximately 0.034 mGy, approximately 10-fold lower than the breast dose from multidetector CT imaging of the head.[22] Overall, breast radiation dose and the subsequent risk of breast cancer are negligible, and the added benefit from shielding is insignificant. Thus, there is no evidence to require the use of breast shielding during dentomaxillofacial radiography. This includes the use of cape aprons that have been marketed for use during panoramic imaging.

Practical issues related to gonadal shielding during dentomaxillofacial imaging

Effectiveness in Reducing Gonadal Radiation Exposure

Two sources of radiation exposure to organs outside the anatomic region imaged are internal scattered radiation originating from the anatomic region imaged and traversing internally through the body and external scattered radiation originating from off-focus radiation.

Lead shielding can only decrease external scattered radiation. When using a lead apron for pediatric chest CT, the mean percentage dose reduction outside the region scanned is approximately 19.1%, 10.1%, and 4.3% at 1, 5, and 10 cm from the edge of the scan, respectively.[29] Likewise, lead shielding did not substantially decrease organ-absorbed doses from panoramic radiography and CBCT imaging, especially in organs outside the primary beam.[23,24]

Potential Artifacts

The lead apron may be inadvertently placed too close to the mandible during intraoral imaging or too high on the neck during panoramic imaging, thus blocking the primary beam, obscuring anatomy, decreasing diagnostic value, and potentially requiring retakes.

Infection Control

The lead apron may get contaminated with saliva, particularly during intraoral imaging. Failure to properly disinfect the lead apron may result in patient cross-contamination.

Selected published statements and guidance documents

National Council on Radiation Protection and Measurements

The National Council on Radiation Protection and Measurements (NCRP) Statement No. 13[15] concludes that, in most circumstances, the use of gonadal shielding does not contribute substantially to reducing risks from exposure and may have the unintended consequences of increased exposure and loss of valuable diagnostic information.[16] The NCRP recommends that gonadal shielding not be used routinely during abdominal and pelvic radiography, and that federal, state, and local regulations and guidance be revised to remove any actual or implied requirement for routine gonadal shielding. The NCRP recognizes that gonadal shielding use may remain appropriate in some limited circumstances. NCRP Report No. 177 specifically identified that technological and procedural improvements incorporated into its recommendations have practically eliminated the requirement for the gonadal shield.[7]

American Association of Physicists in Medicine

Patient gonadal and fetal shielding during radiography-based diagnostic imaging should be discontinued as routine practice.[15] Use of these shields during radiography-based diagnostic imaging may obscure anatomic information or interfere with the automatic exposure control of the imaging system.[15]

The British Institute of Radiology

The key recommendation in The British Institute of Radiology's report,[30] "Guidance on Using Shielding on Patients for Diagnostic Radiology Applications," is that all optimization approaches should be considered and applied in the first instance, and that the use of patient shielding during CT is not generally advised. The prime reasons against the use of patient protection are the effects on image quality and interference with automatic exposure control settings for in-beam protection and, for out-of-beam, the potential for artifacts from misplaced protection. Considerations for reassurance of the patient or caregiver suggest that the use of patient protection may either reassure or frighten and, therefore, strong, informed guidance from the radiology professionals is required, while bearing in mind the perspective of each patient.

The European consensus on patient contact shielding does not recommend the use of gonadal shielding or breast shielding during radiologic imaging.[31]

RECOMMENDATIONS

Patient gonadal and fetal shielding during diagnostic intraoral, panoramic, cephalometric, and CBCT imaging should be discontinued as routine practice. Federal, state, and local dental regulations and guidance should be revised to remove any actual or implied requirement for routine gonadal shielding for intraoral, panoramic, cephalometric, and CBCT imaging.

Special considerations

In light of these new recommendations that counter long-standing and well-accepted practices, special considerations must be given to populations such as pregnant, apprehensive, and pediatric patients.

Pregnant Patients

Table 1 lists the effects from radiation exposure on the fetus and embryo. Loss of pregnancy, growth retardation, and congenital malformations only occur at doses higher than 100 mGy.[26] With technology, diagnostic-level doses in dentistry are tens of thousands-fold below these thresholds.

As a comparison, when the fetus is positioned directly within the primary beam during a CT examination, the dose rarely exceeds from 15 through 20 mGy and is even lower for planar radiography. In all modalities of dentomaxillofacial imaging, including CBCT, the fetus is well outside the field of imaging and radiation dose is less than 0.01 mGy,[22] contributed by means of internal scatter radiation that is not attenuated by external shielding.[22-24] There is no evidence to indicate that a single imaging examination poses any risk to a fetus.[31]

Pregnant patients may question this lack of fetal shielding. The oral health care team must effectively communicate the absence of substantial risks and the lack of any benefit from such shielding. Eventually, it remains the responsibility of the health care provider to address the patient's concerns and increase their confidence in the evidence-based care provided.

Pediatric Patients (Parent Considerations)

Oral health care providers who treat pediatric patients may lack specific knowledge about radiation risk in this group of patients. It is essential that these providers be familiar with the background information related to pediatric populations to be able to communicate effectively with them and their parents or caregivers. This includes the understanding that off-focus, external scattered radiation is considerably limited by beam collimation and that the primary source of radiation to the child is internal scattered radiation within the body. The lead apron does not reduce dose from internal scattered radiation.[22-24] Furthermore, lead aprons can be heavy and uncomfortable for the pediatric patient, leading to motion during imaging. Many national and international organizations, including the Society for Pediatric Radiology and the Image Gently Alliance, support discontinuing routine shielding.

In summary, for organs positioned outside the imaged field, most radiation exposure results from internal scattered radiation and shielding provides negligible protection to the patient. For dentomaxillofacial imaging, this applies to exposure of the gonads, fetuses, and breasts and is applicable to all patients, including pregnant and pediatric patients. Of prime importance in all patients is adherence to the ALARA principles. This includes appropriate patient selection and procedure optimization, including collimation and periodic quality assurance. These dose-reduction procedures adequately decrease radiation risks. It is important for the clinician to emphasize the benefit and safety of dentomaxillofacial imaging procedures and the need for imaging to facilitate diagnosis and timely treatment. Particularly in the case of pregnancy, failure to provide proper patient care for dental disease is much more harmful to the fetus than any risk that might be associated with radiation exposure.

THYROID SHIELDING DURING DENTOMAXILLOFACIAL RADIOGRAPHY

Practice of using thyroid shielding in dentomaxillofacial radiography

Thyroid shielding is a long-standing dental radiation safety recommendation. Via our article, we sought to provide oral health care teams with contemporary understanding on why this may be unnecessary during dentomaxillofacial radiography. Recommendations for thyroid shielding are provided in NCRP Report No. 177[7] and from the American Thyroid Association (ATA).[32] The recommendations are based on risks of radiation-induced thyroid cancer at doses of approximately 50 mGy and higher[33] and on the linear no-threshold model—the accepted approach to model radiation risks from low doses.[34] In dentistry, appropriate selection of patients for imaging[6] and rectangular collimation[11] offers the best protection to the thyroid when combined with guiding principles of radiation safety.

Evidence for radiation-induced thyroid cancer

In numerous studies, researchers have identified radiation exposure as a strong risk factor for inducing benign and malignant tumors of the thyroid gland. These researchers have included survivors of the atomic bomb explosion, cohorts irradiated for medical purposes, and populations exposed to radioactive iodine, including populations affected via the fallout of the nuclear accident at Chernobyl, Ukraine. Overall, data from the diverse population sources consistently support radiation as a substantial thyroid carcinogen. These data are summarized in detail in NCRP Report No. 159.[17] A consistent trend in all studies is the higher sensitivity to thyroid cancer induction in children and adolescents; relative to adults, the risk is 3-fold higher when exposed from ages

Table 3. Median thyroid-absorbed doses from dental maxillofacial imaging.*

PROCEDURE	THYROID-ABSORBED RADIATION DOSES,† mGy	
	Unshielded	Shielded
Intraoral Radiography, FMX,‡ Round Collimation, F-Speed Radiograph or Photostimulable Storage Phosphor	0.8	0.5
Intraoral Radiography, FMX, Rectangular Collimation, F-Speed Radiograph or Photostimulable Storage Phosphor	0.4	0.3
Intraoral Radiography, FMX, Rectangular Collimation, Complementary Metal-Oxide Semiconductor Sensors§	0.2	0.1
Intraoral Radiography, Bite-Wing Radiographs	0	NA¶
Panoramic Radiography	< 0.1	< 0.1
Cephalometric Radiography	< 0.1	< 0.1
Cone-Beam CT#	0.3	0.1**
Head and Craniofacial CT, Range	0.6-8.7	NA
Mammography, Range	0.4-0.8	NA
Chest CT, Mean (SD)	18 (8)	NA

* Published studies used to compile these data are provided in eTable 2 (available online at the end of this article). † Doses less than 0.1 mGy are reported as a single category. This dose is 500- through 1,000-fold less than the lowest doses with demonstrable carcinogenic effects in humans. ‡ FMX: Full-mouth radiographic examination. § Dose reduction with use of direct digital sensors is estimated at 50% on the basis of the published literature. ¶ NA: Not applicable. # CT: Computed tomography. ** Dose reduction with thyroid shield is estimated on the basis of the dose reduction factor computed from published reports as listed in eTable 2 (available online at the end of this article).

10 through 19 years and is 10-fold higher when age at exposure is younger than 10 years.[17,35,36] Thus, efforts to reduce thyroid radiation dose are especially important for children and adolescents younger than 19 years. However, the risk when exposed after age 30 years is small to none.[9] There is some, but inconsistent, evidence that female patients appear to be at greater risk, but this is complicated, given their greater risk of developing spontaneous thyroid cancer.

Thyroid dose from dentomaxillofacial imaging

It is estimated that more than 380 million intraoral radiographic examinations are performed annually in the United States.[13] Approximately 20% of these examinations are performed in pediatric patients, the sensitive subpopulation for thyroid cancer induction.[13] More than 86% of dental offices use digital imaging, which allows for considerable dose reduction in intraoral imaging. Data from the Nationwide Evaluation of X-ray Trends highlight an almost 40% reduction in dose used to obtain intraoral radiographs since the group's previous survey.[13] This trend emphasizes continued evolution of dental imaging with better safety.

The thyroid gland is exposed via the primary beam and internal scatter. The anticipated doses to the thyroid gland are minimal relative to other imaging procedures (Table 3) (published reports used to compile the data in Table 3 are provided in eTable 2, available online at the end of this article). Thyroid dose estimates are based on use of F-speed radiograph or storage phosphor plates. Digital imaging with complementary metal-oxide semiconductor sensors further reduces the dose by 50% (Table 3). Furthermore, rectangular collimation decreases thyroid dose approximately 50%, and is more effective at reducing thyroid dose than thyroid shielding.[11] The extent of the intraoral radiographic examination strongly influences thyroid dose; doses with bite-wing radiographs and periapical radiographs are below detection levels.[37] In children, bite-wing and selected periapical radiographs are obtained more frequently than full-mouth examinations.[13] Thus, the committee considered that the overall population radiation exposure with intraoral radiography has negligible effects on thyroid carcinogenesis.

Panoramic imaging uses a collimated narrow radiography beam and produces little scatter. Similar to intraoral imaging, more than 80% of panoramic units use digital imaging receptors. Thyroid gland–absorbed doses are less than 0.1 mGy.[37-43] Thyroid shields could cause artifacts that degrade image quality and negatively affect diagnostic evaluation.

Cephalometric imaging uses standardized projection geometry. Some digital cephalometric units use a narrow, collimated beam that scans across the patient's craniofacial structures—this will decrease scatter radiation and subsequent dose. Other digital units image the entire field with a single exposure. Nevertheless, the thyroid radiation dose from cephalometric imaging is less than 0.1 mGy.[37,44-46] Although shields may be placed to reduce thyroid gland dose, their placement could cause artifacts that degrade image quality and negatively affect diagnostic evaluation. Considering the already low dose to the thyroid gland, added benefits from shielding are questionable.

Radiation doses from CBCT imaging vary depending on the exposure settings, the size of the imaged field, and the device model and manufacturer. CBCT scans of the maxilla deliver less dose to the thyroid than mandibular CBCT scans. Thyroid doses from CBCT imaging[38,44,45,47-58] are within the range of those from intraoral imaging[12,41,59] and are considerably lower than doses from head and neck multidetector CT examinations (Table 3).

Practical issues related to thyroid collar use during dentomaxillofacial imaging

Blocking the Useful Primary Beam

With panoramic and some CBCT devices, the primary radiography beam is projected with a negative angulation. When obtaining a panoramic radiograph, the image of a thyroid shield may be projected onto and obscure anatomy of the mandible and often the anterior maxilla. Thyroid-absorbed dose from panoramic imaging is less than 0.1 mGy (Table 3). It is challenging to place a thyroid shield to yield effective radiation dose reduction without creating artifacts. With CBCT imaging, the artifacts are pronounced and spread over a large area of the scan. Such artifacts may manifest even when the thyroid shield is placed outside the field of view. This is often the case with mandibular scans.

Infection Control

The thyroid shield is likely to become contaminated with saliva, particularly during intraoral imaging. Failure to properly disinfect the thyroid shield may result in patient cross-contamination.

Selected published statements and guidance documents

NCPR Report No. 177 is the most contemporary document that provides guidance for radiation safety and protection in dentistry and oral and maxillofacial imaging.[7] Recommendation No. 19 of this report states: "Thyroid shielding shall be provided for patients when it will not interfere with the examination."[7]

In 2012, the American Dental Association's Council on Scientific Affairs published guidance for patient selection and dose limitation.[6] Thyroid shielding was discussed as

> The thyroid gland is more susceptible to radiation exposure during dental radiographic exams given its anatomic position, particularly in children. Protective thyroid collars and collimation substantially reduce radiation exposure to the thyroid during dental radiographic procedures. Because every precaution should be taken to minimize radiation exposure, protective thyroid collars should be used whenever possible.[6]

In 2013, the ATA published a policy statement on thyroid shielding during diagnostic imaging.[32] These quotations are specific references to dental diagnostic imaging

- "With regards to dental x-rays, the ATA recommends the reduction of thyroidal radiation exposure as much as possible without compromising the clinical goals of dental examinations."[32]
- "The ATA also recommends that efforts be made to encourage and monitor compliance with the American Dental Association (ADA) and NCRP guidelines and to reduce, as much as possible, the areas of ambiguity in them."[32]

The European consensus on patient contact shielding was published in 2022.[31] For intraoral, cephalometric, and CBCT imaging, the committee recommendation was thyroid contact shielding may be used.[31] This category indicates "general agreement favours usefulness of patient contact shielding in some circumstances."[31] The European consensus group did not recommend thyroid shielding for mammography and CT, both procedures when the thyroid-absorbed doses are equal to or exceed those from dentomaxillofacial imaging.[60,61]

RECOMMENDATIONS

Patient thyroid shielding during diagnostic intraoral, panoramic, cephalometric, and CBCT imaging should be discontinued as routine practice. As necessary, federal, state, and local regulations and guidance should be revised to remove any actual or implied requirement for routine thyroid shielding for intraoral, panoramic, cephalometric, and CBCT images. ■

SUPPLEMENTAL DATA

Supplemental data related to this article can be found at: https://doi.org/10.1016/j.adaj.2023.06.015.

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eTable 1. List of published studies of breast-absorbed dose from dentomaxillofacial imaging.

STUDY	MODALITY	BREAST DOSE,* mGy	
		Unshielded	Shielded
Ludlow, 2009[62]	Bite-wing	0.001	0
Ludlow, 2009[62]	Full-mouth intraoral radiographs, rectangular collimation	0.000	0
Ludlow, 2009[62]	Full-mouth intraoral radiographs, round collimation	0.002	0.001
Ludlow, 2009[62]	Panoramic	0.002	0
Ludlow, 2009[62]	Cephalometric, lateral	0.001	0
Ludlow, 2009[62]	Cephalometric, anteroposterior	0.001	0
Okano and Colleagues, 2009[63]	CBCT†	0.01-0.03	NA‡
Okano and Colleagues, 2012[64]	CBCT	0.013-0.034	NA
Rottke and Colleagues, 2013[24]	CBCT	0.002-0.084	0.037-0.093
Kelaranta and Colleagues, 2016[22]	Periapical, mandibular incisor	0.001	0.000
Kelaranta and Colleagues, 2016[22]	Periapical, maxillary premolar	0.001	0.001
Kelaranta and Colleagues, 2016[22]	Occlusal, maxilla	0.002	0.001
Kelaranta and Colleagues, 2016[22]	Panoramic	0.004	0.001
Kelaranta and Colleagues, 2016[22]	Cephalometric, lateral	0.004	0
Kelaranta and Colleagues, 2016[22]	CBCT	0.0-0.076	0.00-0.011
Rottke and Colleagues, 2017[23]	CBCT	0.221-0.278	0.203
Rottke and Colleagues, 2017[23]	CBCT	0.278	0.261
Rottke and Colleagues, 2017[23]	CBCT	0.263	0.263
Schulze and Colleagues, 2017[65]	Panoramic	0.004	0
Franck and Colleagues, 2018,[60] **Mean (SD)**	Chest computed tomography	15 (0.5)	NA
Li and Colleagues, 2020[38]	Intraoral radiograph	0.002	NA
Li and Colleagues, 2020[38]	Panoramic	0.006-0.009	NA
Li and Colleagues, 2020[38]	CBCT	0.025	NA
Perez Fuentes and Colleagues, 2022[59]	Mammography	1.360-3.080	NA

* Individual data were compiled and used to calculate median doses. Doses are rounded to the nearest microgray (0.001 mGy) and doses less than 0.001 mGy are reported as 0. † CBCT: Cone-beam computed tomography. ‡ NA: Not applicable.

eTable 2. List of published studies of thyroid-absorbed dose from dentomaxillofacial imaging.

STUDY	MODALITY	THYROID DOSE,* mGy	
		Unshielded	Shielded
Tsiklakis and Colleagues,[47] 2005	CBCT[†]	0.320	0.180
Ludlow and Colleagues,[37] 2008	Intraoral, full-mouth examination, PSP,[‡] rectangular collimation	0.117	NA[§]
Ludlow and Colleagues,[37] 2008	Intraoral, bite-wings, rectangular collimation	0	NA
Ludlow and Colleagues,[37] 2008	Intraoral, full-mouth examination, PSP, round collimation	0.550	NA
Ludlow and Ivanovic,[48] 2008	Cephalometric	0.030-0.045	NA
Ludlow and Ivanovic,[48] 2008	CBCT	0.333-1.733	NA
Ludlow,[49] 2011	CBCT	0.835	NA
Grunheid and Colleagues,[44] 2012	Cephalometric	0.030	NA
Grunheid and Colleagues,[44] 2012	CBCT	0.150-0.367	NA
Pauwels and Colleagues,[50] 2012	CBCT	0.474	NA
Qu and Colleagues,[45] 2012	CBCT	1.895	0.625-0.768
Qu and Colleagues,[45] 2012	CBCT	2.700	0.695-0.740
Al-Okshi and Colleagues,[51] 2013	CBCT	0.050	NA
Goren and Colleagues,[52] 2013	CBCT	0.470-1.780	0.280-1.200
Han and Colleagues,[39] 2013	Panoramic	0.028-0.068	0.025-0.056
Ludlow and Walker,[53] 2013	CBCT	0.183-0.301	NA
Morant and Colleagues,[54] 2013	CBCT	0.050	NA
Kim and Colleagues,[55] 2014	CBCT	0.533	NA
Hildalgo and Colleagues,[56] 2015	CBCT	1.620	0.940-1.050
Hoogeveen and Colleagues,[46] 2015	Cephalometric	0.004	0.004-0.005
Ludlow and Colleagues,[57] 2015	CBCT	0.345	NA
Ludlow and Colleagues,[57] 2015	CBCT	0.162-1.374	NA
Lukat and Colleagues,[58] 2015	CBCT	0.023	NA
Granlund and Colleagues,[40] 2016	Cephalometric	0.040-0.048	NA
Benchimol and Colleagues,[41] 2018	Panoramic	0.040	NA
Lee and Colleagues,[42] 2019	Panoramic	0.024-0.036	NA
Johnson and Colleagues,[12] 2020	Intraoral, full-mouth examination, PSP, rectangular collimation	1.086	0.448
Johnson and Colleagues,[12] 2020	Intraoral, full-mouth examination, PSP, rectangular collimation	0.366-1.027	0.266-0.428
Li and Colleagues,[38] 2020	Panoramic	0.054-0.064	NA
Li and Colleagues,[38] 2020	CBCT	0.453-0.476	NA

* Individual data were compiled and used to calculate median doses. Doses are rounded to the nearest microgray (0.001 mGy) and doses less than 0.001 mGy are reported as 0. † CBCT: Cone-beam computed tomography. ‡ PSP: Photostimulable storage phosphor. § NA: Not applicable.

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FDA

DENTAL RADIOGRAPHIC EXAMINATIONS: RECOMMENDATIONS FOR PATIENT SELECTION AND LIMITING RADIATION EXPOSURE

REVISED: 2012

AMERICAN DENTAL ASSOCIATION
Council on Scientific Affairs

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Food and Drug Administration

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DENTAL RADIOGRAPHIC EXAMINATIONS: RECOMMENDATIONS FOR PATIENT SELECTION AND LIMITING RADIATION EXPOSURE

BACKGROUND

The dental profession is committed to delivering the highest quality of care to each of its individual patients and applying advancements in technology and science to continually improve the oral health status of the U.S. population. These guidelines were developed to serve as an adjunct to the dentist's professional judgment of how to best use diagnostic imaging for each patient. Radiographs can help the dental practitioner evaluate and definitively diagnose many oral diseases and conditions. However, the dentist must weigh the benefits of taking dental radiographs against the risk of exposing a patient to x-rays, the effects of which accumulate from multiple sources over time. The dentist, knowing the patient's health history and vulnerability to oral disease, is in the best position to make this judgment in the interest of each patient. For this reason, the guidelines are intended to serve as a resource for the practitioner and are not intended as standards of care, requirements or regulations.

The guidelines are not substitutes for clinical examinations and health histories. The dentist is advised to conduct a clinical examination, consider the patient's signs, symptoms and oral and medical histories, as well as consider the patient's vulnerability to environmental factors that may affect oral health. This diagnostic and evaluative information may determine the type of imaging to be used or the frequency of its use. Dentists should only order radiographs when they expect that the additional diagnostic information will affect patient care.

Based on this premise, the guidelines can be used by the dentist to optimize patient care, minimize radiation exposure and responsibly allocate health care resources.

This document deals only with standard dental imaging techniques of intraoral and common extraoral examinations, excluding cone-beam computed tomography (CBCT). At this time the indications for CBCT examinations are not well developed. The ADA Council on Scientific Affairs has developed a statement on use of CBCT.[1]

INTRODUCTION

The guidelines titled, "The Selection of Patients for X-Ray Examination" were first developed in 1987 by a panel of dental experts convened by the Center for Devices and Radiological Health of the U.S. Food and Drug Administration (FDA). The development of the guidelines at that time was spurred by concern about the U.S. population's total exposure to radiation from all sources. Thus, the guidelines were developed to promote the appropriate use of x-rays. In 2002, the American Dental Association, recognizing that dental technology and science continually advance, recommended to the FDA that

the guidelines be reviewed for possible updating. The FDA welcomed organized dentistry's interest in maintaining the guidelines, and so the American Dental Association, in collaboration with a number of dental specialty organizations and the FDA, published updated guidelines in 2004. This report updates the 2004 guidelines and includes recommendations for limiting exposure to radiation.

PATIENT SELECTION CRITERIA

Radiographs and other imaging modalities are used to diagnose and monitor oral diseases, as well as to monitor dentofacial development and the progress or prognosis of therapy. Radiographic examinations can be performed using digital imaging or conventional film. The available evidence suggests that either is a suitable diagnostic method.[2-4] Digital imaging may offer reduced radiation exposure and the advantage of image analysis that may enhance sensitivity and reduce error introduced by subjective analysis.[5]

A study of 490 patients found that basing selection criteria on clinical evaluations for asymptomatic patients, combined with selected periapical radiographs for symptomatic patients, can result in a 43 percent reduction in the number of radiographs taken without a clinically consequential increase in the rate of undiagnosed disease.[6,7] The development and progress of many oral conditions are associated with a patient's age, stage of dental development, and vulnerability to known risk factors. Therefore, the guidelines in Table 1 are presented within a matrix of common clinical and patient factors, which may determine the type(s) of radiographs that is commonly needed. The guidelines assume that diagnostically adequate radiographs can be obtained. If not, appropriate management techniques should be used after consideration of the relative risks and benefits for the patient.

Along the horizontal axis of the matrix, patient age categories are described, each with its usual dental developmental stage: child with primary dentition (prior to eruption of the first permanent tooth); child with transitional dentition (after eruption of the first permanent tooth); adolescent with permanent dentition (prior to eruption of third molars); adult who is dentate or partially edentulous; and adult who is edentulous.

Along the vertical axis, the type of encounter with the dental system is categorized (as "New Patient" or "Recall Patient") along with the clinical circumstances and oral diseases that may be present during such an encounter. The "New Patient" category refers to patients who are new to the dentist, and thus are being evaluated by the dentist for oral disease and for the status of dental development. Typically, such a patient receives a comprehensive evaluation or, in some cases, a limited evaluation for a specific problem. The "Recall Patient" categories describe patients who have had a recent comprehensive evaluation by the dentist and, typically, have returned as a patient of record for a periodic evaluation or for treatment. However, a "Recall Patient" may also return for a limited evaluation of a specific problem, a detailed and extensive evaluation for a specific problem(s), or a comprehensive evaluation.

Both categories are marked with a single asterisk that corresponds to a footnote that appears below the matrix; the footnote lists “Positive Historical Findings” and “Positive Clinical Signs/Symptoms” for which radiographs may be indicated. The lists are not intended to be all-inclusive, rather they offer the clinician further guidance on clarifying his or her specific judgment on a case.

The clinical circumstances and oral diseases that are presented with the types of encounters include: clinical caries or increased risk for caries; no clinical caries or no increased risk for caries; periodontal disease or a history of periodontal treatment; growth and development assessment; and other circumstances. A few examples of “Other Circumstances” proposed are: existing implants, other dental and craniofacial pathoses, endodontic/restorative needs and remineralization of dental caries. These examples are not intended to be an exhaustive list of circumstances for which radiographs or other imaging may be appropriate.

The categories, “Clinical Caries or Increased Risk for Caries” and “No Clinical Caries and No Increased Risk for Caries” are marked with a double asterisk that corresponds to a footnote that appears below the matrix; the footnote contains links to the ADA Caries Risk Assessment Forms (0 – 6 years of age and over 6 years of age). It should be noted that a patient’s risk status can change over time and should be periodically reassessed.[8]

The panel also has made the following recommendations that are applicable to all categories:

1. Intraoral radiography is useful for the evaluation of dentoalveolar trauma. If the area of interest extends beyond the dentoalveolar complex, extraoral imaging may be indicated.
2. Care should be taken to examine all radiographs for any evidence of caries, bone loss from periodontal disease, developmental anomalies and occult disease.
3. Radiographic screening for the purpose of detecting disease before clinical examination should not be performed. A thorough clinical examination, consideration of the patient history, review of any prior radiographs, caries risk assessment and consideration of both the dental and the general health needs of the patient should precede radiographic examination.[9-15]

In the practice of dentistry, patients often seek care on a routine basis in part because oral disease may develop in the absence of clinical symptoms. Since attempts to identify specific criteria that will accurately predict a high probability of finding interproximal carious lesions have not been successful for individuals, it was necessary to recommend time-based schedules for making radiographs intended primarily for the detection of dental caries. Each schedule provides a range of recommended intervals that are derived from the results of research into the rates at which interproximal caries progresses through tooth enamel. The recommendations also are modified by criteria that place an individual at an increased risk for dental caries. Professional judgment

should be used to determine the optimum time for radiographic examination within the suggested interval.

RECOMMENDATIONS FOR PRESCRIBING DENTAL RADIOGRAPHS

These recommendations are subject to clinical judgment and may not apply to every patient. They are to be used by dentists only after reviewing the patient's health history and completing a clinical examination. Even though radiation exposure from dental radiographs is low, once a decision to obtain radiographs is made it is the dentist's responsibility to follow the ALARA Principle (As Low as Reasonably Achievable) to minimize the patient's exposure.

Table 1.

<table>
<tr><th rowspan="2">TYPE OF ENCOUNTER</th><th colspan="5">PATIENT AGE AND DENTAL DEVELOPMENTAL STAGE</th></tr>
<tr><th>Child with Primary Dentition (prior to eruption of first permanent tooth)</th><th>Child with Transitional Dentition (after eruption of first permanent tooth)</th><th>Adolescent with Permanent Dentition (prior to eruption of third molars)</th><th>Adult, Dentate or Partially Edentulous</th><th>Adult, Edentulous</th></tr>
<tr><td>New Patient*
being evaluated for oral diseases</td><td>Individualized radiographic exam consisting of selected periapical/occlusal views and/or posterior bitewings if proximal surfaces cannot be visualized or probed. Patients without evidence of disease and with open proximal contacts may not require a radiographic exam at this time.</td><td>Individualized radiographic exam consisting of posterior bitewings with panoramic exam or posterior bitewings and selected periapical images.</td><td colspan="2">Individualized radiographic exam consisting of posterior bitewings with panoramic exam or posterior bitewings and selected periapical images. A full mouth intraoral radiographic exam is preferred when the patient has clinical evidence of generalized oral disease or a history of extensive dental treatment.</td><td>Individualized radiographic exam, based on clinical signs and symptoms.</td></tr>
<tr><td>Recall Patient* with clinical caries or at increased risk for caries**</td><td colspan="3">Posterior bitewing exam at 6-12 month intervals if proximal surfaces cannot be examined visually or with a probe</td><td>Posterior bitewing exam at 6-18 month intervals</td><td>Not applicable</td></tr>
<tr><td>Recall Patient* with no clinical caries and not at increased risk for caries**</td><td colspan="2">Posterior bitewing exam at 12-24 month intervals if proximal surfaces cannot be examined visually or with a probe</td><td>Posterior bitewing exam at 18-36 month intervals</td><td>Posterior bitewing exam at 24-36 month intervals</td><td>Not applicable</td></tr>
</table>

TYPE OF ENCOUNTER (continued)	**Child with Primary Dentition** (prior to eruption of first permanent tooth)	**Child with Transitional Dentition** (after eruption of first permanent tooth)	**Adolescent with Permanent Dentition** (prior to eruption of third molars)	**Adult, Dentate and Partially Edentulous**	**Adult, Edentulous**
Recall Patient* with periodontal disease	Clinical judgment as to the need for and type of radiographic images for the evaluation of periodontal disease. Imaging may consist of, but is not limited to, selected bitewing and/or periapical images of areas where periodontal disease (other than nonspecific gingivitis) can be demonstrated clinically.				Not applicable
Patient (New and Recall) for monitoring of dentofacial growth and development, and/or assessment of dental/skeletal relationships	Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development or assessment of dental and skeletal relationships		Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development, or assessment of dental and skeletal relationships. Panoramic or periapical exam to assess developing third molars	Usually not indicated for monitoring of growth and development. Clinical judgment as to the need for and type of radiographic image for evaluation of dental and skeletal relationships.	
Patient with other circumstances including, but not limited to, proposed or existing implants, other dental and craniofacial pathoses, restorative/endodontic needs, treated periodontal disease and caries remineralization	Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of these conditions				

***Clinical situations for which radiographs may be indicated include, but are not limited to:**

A. Positive Historical Findings

1. Previous periodontal or endodontic treatment
2. History of pain or trauma
3. Familial history of dental anomalies

4. Postoperative evaluation of healing
5. Remineralization monitoring
6. Presence of implants, previous implant-related pathosis or evaluation for implant placement

B. Positive Clinical Signs/Symptoms

1. Clinical evidence of periodontal disease
2. Large or deep restorations
3. Deep carious lesions
4. Malposed or clinically impacted teeth
5. Swelling
6. Evidence of dental/facial trauma
7. Mobility of teeth
8. Sinus tract ("fistula")
9. Clinically suspected sinus pathosis
10. Growth abnormalities
11. Oral involvement in known or suspected systemic disease
12. Positive neurologic findings in the head and neck
13. Evidence of foreign objects
14. Pain and/or dysfunction of the temporomandibular joint
15. Facial asymmetry
16. Abutment teeth for fixed or removable partial prosthesis
17. Unexplained bleeding
18. Unexplained sensitivity of teeth
19. Unusual eruption, spacing or migration of teeth
20. Unusual tooth morphology, calcification or color
21. Unexplained absence of teeth
22. Clinical tooth erosion
23. Peri-implantitis

****Factors increasing risk for caries may be assessed using the ADA Caries Risk Assessment forms (0 – 6 years of age and over 6 years of age).**

EXPLANATION OF RECOMMENDATIONS FOR PRESCRIBING DENTAL RADIOGRAPHS

The explanation below presents the rationale for each recommendation by type of encounter and patient age and dental developmental stages.

New Patient Being Evaluated for Oral Diseases

Child (Primary Dentition)

Proximal carious lesions may develop after the interproximal spaces between posterior primary teeth close. Open contacts in the primary dentition will allow a dentist to visually inspect the proximal posterior surfaces. Closure of proximal contacts requires radiographic assessment.[16-18] However, evidence suggests that many of these lesions will remain in the enamel for at least 12 months or longer depending on fluoride exposure, allowing sufficient time for implementation and evaluation of preventive interventions.[19-21] A periapical/anterior occlusal examination may be indicated because of the need to evaluate dental development, dentoalveolar trauma, or suspected pathoses. Periapical and bitewing radiographs may be required to evaluate pulp pathosis in primary molars.

Therefore, an individualized radiographic examination consisting of selected periapical/occlusal views and/or posterior bitewings if proximal surfaces cannot be examined visually or with a probe is recommended. Patients without evidence of disease and with open proximal contacts may not require radiographic examination at this time.

Child (Transitional Dentition)

Overall dental caries in the primary teeth of children from 2-11 years of age declined from the early 1970s until the mid 1990s.[22-24] From the mid 1990s until the 1999-2004 National Health and Nutrition Examination Survey, there was a small but significant increase in primary decay. This trend reversal was larger for younger children. Tooth decay affects more than one-fourth of U.S. children aged 2–5 years and half of those aged 12-15 years; however, its prevalence is not uniformly distributed. About half of all children and two-thirds of adolescents aged 12–19 years from lower-income families have had decay.[25]

Children and adolescents of some racial and ethnic groups and those from lower-income families have more untreated tooth decay. For example, 40 percent of Mexican American children aged 6–8 years have untreated decay, compared with 25 percent of non-Hispanic whites.[25] It is, therefore, important to consider a child's risk factors for caries before taking radiographs.

Although periodontal disease is uncommon in this age group,[26] when clinical evidence exists (except for nonspecific gingivitis), selected periapical and bitewing radiographs are indicated to determine the extent of aggressive periodontitis, other forms of uncontrolled periodontal disease and the extent of osseous destruction related to metabolic diseases.[27,28]

A periapical or panoramic examination is useful for evaluating dental development. A panoramic radiograph also is useful for the evaluation of craniofacial trauma.[15,29,30] Intraoral radiographs are more accurate than panoramic radiographs for the evaluation of dentoalveolar

trauma, root shape, root resorption[31,32] and pulp pathosis. However, panoramic examinations may have the advantage of reduced radiation dose, cost and imaging of a larger area.

Occlusal radiographs may be used separately or in combination with panoramic radiographs in the following situations: 1. unsatisfactory image in panoramic radiographs due to abnormal incisor relationship, 2. localizations of tooth position, and 3. when clinical grounds provide a reasonable expectation that pathosis exists.[32-34]

Therefore, an individualized radiographic examination consisting of posterior bitewings with panoramic examination or posterior bitewings and selected periapical images is recommended.

Adolescent (Permanent Dentition)

Caries in permanent teeth declined among adolescents, while the prevalence of dental sealants increased significantly.[35] However, increasing independence and socialization, changing dietary patterns, and decreasing attention to daily oral hygiene can characterize this age group. Each of these factors may result in an increased risk of dental caries. Another consideration, although uncommon, is the increased incidence of periodontal disease found in this age group compared to children.[36]

Panoramic radiography is effective in dental diagnosis and treatment planning.[30,37,38] Specifically, the status of dental development can be assessed using panoramic radiography.[39] Occlusal and/or periapical radiographs can be used to detect the position of an unerupted or supernumerary tooth.[40-42] Third molars also should be evaluated in this age group for their presence, position, and stage of development.

Therefore, an individualized radiographic examination consisting of posterior bitewings with panoramic examination or posterior bitewings and selected periapical images is recommended. A full mouth intraoral radiographic examination is preferred when the patient has clinical evidence of generalized oral disease or a history of extensive dental treatment.

Adult (Dentate or Partially Edentulous)

The overall dental caries experience of the adult population has declined from the early 1970s until the most recent (1999-2004) National Health and Nutrition Examination Survey.[43] However, risk for dental caries exists on a continuum and changes over time as risk factors change.[44] Therefore, it is important to evaluate proximal surfaces in the new adult patient for carious lesions. In addition, it is important to examine patients for recurrent dental caries.

The incidence of root surface caries increases with age.[45] Although bitewing radiographs can assist in detecting root surface caries in proximal areas, the usual method of detecting root surface caries is by clinical examination.[46]

The incidence of periodontal disease increases with age.[47] Although new adult patients may not have symptoms of active periodontal disease, it is important to evaluate previous experience with periodontal disease and/or treatment. Therefore, a high percentage of adults may require selected intraoral radiographs to determine the current status of the disease.

Taking posterior bitewing radiographs of new adult patients was found to reduce the number of radiological findings and the diagnostic yield of panoramic radiography.[48,49] In addition, the following clinical indicators for panoramic radiography were identified as the best predictors for useful diagnostic yield: suspicion of teeth with periapical pathologic conditions, presence of partially erupted teeth, caries lesions, swelling, and suspected unerupted teeth.[50]

Therefore, an individualized radiographic examination, consisting of posterior bitewings with selected periapical images or panoramic examination when indicated is recommended. A full mouth intraoral radiographic examination is preferred when the patient has clinical evidence of generalized oral disease or a history of extensive dental treatment.

Adult (Edentulous)

The clinical and radiographic examinations of edentulous patients generally occur during an assessment of the need for prostheses. The most common pathological conditions detected are impacted teeth and retained roots with and without associated disease.[51] Other less common conditions also may be detected: bony spicules along the alveolar ridge, residual cysts or infections, developmental abnormalities of the jaws, intraosseous tumors, and systemic conditions affecting bone metabolism.

The original recommendations for this group called for a full-mouth intraoral radiographic examination or a panoramic examination for the new, edentulous adult patient. Firstly, this recommendation was made because examinations of edentulous patients generally occur during an assessment of the need for prostheses. Secondly, the original recommendation considered edentulous patients to be at increased risk for oral disease.

Studies have found that from 30 to 50 percent of edentulous patients exhibited abnormalities in panoramic radiographs.[51-55] In addition, the radiographic examination revealed anatomic considerations that could influence prosthetic treatment, such as the location of the mandibular canal, the position of the mental foramen and maxillary sinus, and relative thickness of the soft tissue covering the edentulous ridge.[51,53,55] However, in studies that considered treatment outcomes, there was little evidence to support screening radiography for new edentulous patients. For example, one study reported that less than 4 percent of such findings resulted in treatment modification before denture fabrication, and another showed no difference in post-denture delivery complaints in patients who did not receive screening pretreatment radiographs.[54,56]

This panel concluded that prescription of radiographs is appropriate as part of the initial assessment of edentulous areas for possible prosthetic treatment. A full mouth series of periapical radiographs or a combination of panoramic, occlusal or other extraoral radiographs may be used to achieve diagnostic and therapeutic goals. Particularly with the option of dental implant therapy for edentulous patients,[57] radiographs can be an important aid in diagnosis, prognosis, and the determination of treatment complexity.

Therefore, an individualized radiographic examination, based on clinical signs, symptoms, and treatment plan is recommended.

Recall Patient with Clinical Caries or Increased Risk for Caries

Child (Primary and Transitional Dentition) and Adolescent (Permanent Dentition)

Clinically detectable dental caries may suggest the presence of proximal carious lesions that can only be detected with a radiographic examination. In addition, patients who are at increased risk for developing dental caries because of such factors as poor oral hygiene, high frequency of exposure to sucrose-containing foods, and deficient fluoride intake (see caries risk assessment forms, 0 – 6 years of age and over 6 years of age) are more likely to have proximal carious lesions.

The bitewing examination is the most efficient method for detecting proximal lesions.[16,18,58] The frequency of radiographic recall should be determined on the basis of caries risk assessment.[15,59,60] It should be noted that a patient's caries risk status may change over time and that an individual's radiographic recall interval may need to be changed accordingly.[61]

Therefore, a posterior bitewing examination is recommended at 6 to 12 month intervals if proximal surfaces cannot be examined visually or with a probe.

Adult (Dentate and Partially Edentulous)

Adults who exhibit clinical dental caries or who have other increased risk factors should be monitored carefully for any new or recurrent lesions that are detectable only by radiographic examination. The frequency of radiographic recall should be determined on the basis of caries risk assessment.[15,59,60] It should be noted that a patient's risk status can change over time and that an individual's radiographic recall interval may need to be changed accordingly.[61]

Therefore, a posterior bitewing examination is recommended at 6 to 18 month intervals.

Recall Patient (Edentulous Adult)

A study that assessed radiographs of edentulous recall patients showed that previously detected incidental findings did not progress and that no intervention was indicated.[62] The data suggest that patients who receive continuous dental care do not exhibit new findings that require treatment.

An examination for occult disease in this group cannot be justified on the basis of prevalence, morbidity, mortality, radiation dose, and cost.[53-55]

Therefore, no radiographic examination is recommended without evidence of disease.

Recall Patient with No Clinical Caries and No Increased Risk for Caries

Child (Primary and Transitional Dentition)

Despite the general decline in dental caries activity, recent data show that subgroups of children have a higher caries experience than the overall population.[63,64] The identification of

patients in these subgroups may be difficult on an individual basis. For children who present for recall examination without evidence of clinical caries and who are not considered at increased risk for the development of caries, it remains important to evaluate proximal surfaces by radiographic examination. In primary teeth the caries process can take approximately one year to progress through the outer half of the enamel and about another year through the inner half.[20,65-68] Considering this rate of progression of carious lesions through primary teeth, a time-based interval of radiographic examinations from one to two years for this group appears appropriate. The prevalence of carious lesions has been shown to increase during the stage of transitional dentition.[25,69] Children under routine professional care would be expected to be at a lower risk for caries. Nevertheless, newly erupted teeth are at risk for the development of dental caries.

Therefore, a radiographic examination consisting of posterior bitewings is recommended at intervals of 12 to 24 months if proximal surfaces cannot be examined visually or with a probe.

Adolescent (Permanent Dentition)
Adolescents with permanent dentition, who are free of clinical dental caries and factors that would place them at increased risk for developing dental caries, should be monitored carefully for development of proximal carious lesions, which may only be detected by radiographic examination. The caries process, on average, takes more than three years to progress through the enamel.[20,65-68] However, evidence suggests that the enamel of permanent teeth undergoes posteruptive maturation and that young permanent teeth are susceptible to faster progression of carious lesions.[70-73]

Therefore, a radiographic examination consisting of posterior bitewings is recommended at intervals of 18 to 36 months.

Adult (Dentate and Partially Edentulous)
Adult dentate patients, who receive regularly scheduled professional care and are free of signs and symptoms of oral disease, are at a low risk for dental caries. Nevertheless, consideration should be given to the fact that caries risk can vary over time as risk factors change. Advancing age and changes in diet, medical history and periodontal status may increase the risk for dental caries.

Therefore, a radiographic examination consisting of posterior bitewings is recommended at intervals of 24 to 36 months.

<u>Recall Patient with Periodontal Disease</u>

Child (Primary and Transitional Dentition), Adolescent (Permanent Dentition), and Adult (Dentate and Partially Edentulous)
The decision to obtain radiographs for patients who have clinical evidence or a history of periodontal disease/treatment should be determined on the basis of the anticipation that important diagnostic and prognostic information will result. Structures or conditions to be assessed should include the level of supporting alveolar bone, condition of the interproximal bony crest, length and shape of roots, bone loss in furcations, and calculus deposits. The

frequency and type of radiographic examinations for these patients should be determined on the basis of a clinical examination of the periodontium and documented signs and symptoms of periodontal disease. The procedure for prescribing radiographs for the follow-up/recall periodontal patient would be to use selected intraoral radiographs to verify clinical findings on a patient-by-patient basis.[28,74]

Therefore, it is recommended that clinical judgment be used in determining the need for, and type of radiographic images necessary for, evaluation of periodontal disease. Imaging may consist of, but is not limited to, selected bitewing and/or periapical images of areas where periodontal disease (other than nonspecific gingivitis) can be identified clinically.

Patient (New and Recall) for Monitoring of Dentofacial Growth and Development, and/or Assessment of Dental/Skeletal Relationships

Child (Primary and Transitional Dentition)
For children with primary dentition, before the eruption of the first permanent tooth, radiographic examination to assess growth and development in the absence of clinical signs or symptoms is unlikely to yield productive information. Any abnormality of growth and development suggested by clinical findings should be evaluated radiographically on an individual basis. After eruption of the first permanent tooth, the child may have a radiographic examination to assess growth and development. This examination need not be repeated unless dictated by clinical signs or symptoms. Cephalometric radiographs may be useful for assessing growth, and/or dental and skeletal relationships.

Therefore, it is recommended that clinical judgment be used in determining the need for, and type of radiographic images necessary for, evaluation and/or monitoring of dentofacial growth and development, or assessment of dental and skeletal relationships.

Adolescent (Permanent Dentition)
During adolescence there is often a need to assess the growth status and/or the dental and skeletal relationships of patients in order to diagnose and treat their malocclusion. Appropriate radiographic assessment of the malocclusion should be determined on an individual basis.

An additional concern relating to growth and development for patients in this age group is to determine the presence, position and development of third molars. This determination can best be made by the use of selected periapical images or a panoramic examination, once the patient is in late adolescence (16 to 19 years of age).

Therefore, it is recommended that clinical judgment be used in determining the need for, and type of radiographic images necessary for, evaluation and/or monitoring of dentofacial growth and development, or assessment of dental and skeletal relationships. Panoramic or periapical examination may be used to assess developing third molars.

Adult (Dentate, Partially Edentulous and Edentulous)
In the absence of any clinical signs or symptoms suggesting abnormalities of growth and development in adults, no radiographic examinations are indicated for this purpose.

Therefore, in the absence of clinical signs and symptoms, no radiographic examination is recommended.

Patients with Other Circumstances
(including, but not limited to, proposed or existing implants, other dental and craniofacial pathoses, restorative/endodontic needs, treated periodontal disease and caries remineralization)

All Patient Categories
The use of imaging, as a diagnostic and evaluative tool, has progressed beyond the longstanding need to diagnose caries and evaluate the status of periodontal disease. The expanded technology in imaging is now used to diagnose other orofacial clinical conditions and evaluate treatment options. A few examples of other clinical circumstances are the use of imaging for dental implant treatment planning, placement, or evaluation; the monitoring of dental caries and remineralization; the assessment of restorative and endodontic needs; and the diagnosis of soft and hard tissue pathoses.

Therefore it is recommended that clinical judgment be used in determining the need for, and type of radiographic images necessary for, evaluation and/or monitoring in these circumstances.

LIMITING RADIATION EXPOSURE

Dental radiographs account for approximately 2.5 percent of the effective dose received from medical radiographs and fluoroscopies.[75] Even though radiation exposure from dental radiographs is low, once a decision to obtain radiographs is made it is the dentist's responsibility to follow the ALARA Principle (As Low as Reasonably Achievable) to minimize the patient's exposure. Examples of good radiologic practice include

- use of the fastest image receptor compatible with the diagnostic task (F-speed film or digital);
- collimation of the beam to the size of the receptor whenever feasible;
- proper film exposure and processing techniques;
- use of protective aprons and thyroid collars, when appropriate; and
- limiting the number of images obtained to the minimum necessary to obtain essential diagnostic information.

RECEPTOR SELECTION

The American National Standards Institute and the International Organization for Standardization have established standards for film speed.[76,77] Film speeds available for dental radiography are D-speed, E-speed and F-speed, with D-speed being the slowest and F-speed the fastest. According to the U.S. Food and Drug Administration, switching from D to E speed can produce a 30 to 40 percent reduction in radiation exposure.[78] The use of F-speed film can reduce exposure 20 to 50 percent compared to use of E-speed film, without compromising diagnostic quality.[79-85]

Exposure of extraoral films such as panoramic radiographs requires intensifying screens to minimize radiation exposure to patients. The intensifying screen consists of layers of phosphor crystals that fluoresce when exposed to radiation. In addition to the radiation incident on the film, the film is exposed primarily to the light emitted from the intensifying screen. Previous generations of intensifying screens were composed of phosphors such as calcium tungstate. However, rare-earth intensifying screens are recommended because they reduce a patient's radiation exposure by 50 percent compared with calcium tungstate-intensifying screens.[86-89] Rare-earth film systems, combined with a high-speed film of 400 or greater, can be used for panoramic radiographs.[86] Older panoramic equipment can be retrofitted to reduce the radiation exposure to accommodate the use of rare-earth, high-speed systems.

Digital imaging provides an opportunity to further reduce the radiation dose by 40 to 60 percent.[90-93] In digital radiography, there are three types of receptors that take the place of conventional film: charge-coupled device (CCD), complementary-metal-oxide-semiconductor (CMOS), and photo-stimulable phosphor (PSP) plates. Systems that use CCD and CMOS-based, solid-state detectors are called "direct." When these sensors receive energy from the x-ray beam, the CCD or CMOS chip sends a signal to the computer and an image appears on the monitor within seconds. Systems that use PSP plates are called "indirect." When these plates are irradiated, a latent image is stored on them. The plate is then scanned and the scanner transmits the image to the computer.

RECEPTOR HOLDERS

Holders that align the receptor precisely with the collimated beam are recommended for periapical and bitewing radiographs. Heat-sterilizable or disposable intraoral radiograph receptor-holding devices are recommended for optimal infection control.[94] Dental professionals should not hold the receptor holder during exposure.[86] Under extraordinary circumstances in which members of the patient's family (or other caregiver) must provide restraint or hold a receptor holder in place during exposure, such a person should wear appropriate shielding.[86]

COLLIMATION

Collimation limits the amount of radiation, both primary and scattered, to which the patient is exposed. An added benefit of rectangular collimation is an improvement in contrast as a result of a reduction in fogging caused by secondary and scattered radiation.[89] The x-ray beam should not exceed the minimum coverage necessary, and each dimension of the beam should be collimated so that the beam does not exceed the receptor by more than 2 percent of the source-to-image receptor distance.[86] Since a rectangular collimator decreases the radiation dose by up to fivefold as compared with a circular one, [86,95,96] radiographic equipment should provide rectangular collimation for exposure of periapical and bitewing radiographs.[86] Use of a receptor-holding device minimizes the risk of cone-cutting (non-exposure of part of the image receptor due to malalignment of the x-ray beam). The position-indicating device should be open ended and have a metallic lining to restrict the primary beam and reduce the tissue volume exposed to radiation.[86] Use of long source-to-skin distances of 40 cm, rather than short distances of 20 cm, decreases exposure by 10 to 25 percent.[86,97] Distances between 20 cm and 40 cm are appropriate, but the longer distances are optimal.[86]

OPERATING POTENTIAL AND EXPOSURE TIME

The operating potential of dental x-ray units affects the radiation dose and backscatter radiation. Lower voltages produce higher-contrast images and higher entrance skin doses, and lower deep-tissue doses and levels of backscatter radiation. However, higher voltages produce lower contrast images that enable better separation of objects with differing densities. Thus, the diagnostic purposes of the radiograph should be used to determine the selection of kilovolt setting. A setting above 90 kV(p) will increase the patient dose and should not be used.[89] The optimal operating potential of dental x-ray units is between 60 and 70 kVp.[86,89]

Filmless technology is much more forgiving to overexposure often resulting in unnecessary radiation exposure. Facilities should strive to set the x-ray unit exposure timer to the lowest setting providing an image of diagnostic quality. If available, the operator should always confirm that the dose delivered falls within the manufacturer's exposure index. Imaging plates should be evaluated at least monthly and cleaned as necessary.

PATIENT SHIELDING AND POSITIONING

The amount of scattered radiation striking the patient's abdomen during a properly conducted radiographic examination is negligible.[98] The thyroid gland is more susceptible to radiation exposure during dental radiographic exams given its anatomic position, particularly in children.[93,99,100] Protective thyroid collars and collimation substantially reduce radiation exposure to the thyroid during dental radiographic procedures.[101,102] Because every precaution should be taken to minimize radiation exposure, protective thyroid collars should be used whenever possible. If all the recommendations for limiting radiation exposure are put into practice, the gonadal radiation dose will not be significantly affected by use of abdominal shielding.[86] Therefore, use of abdominal shielding may not be necessary.

Protective aprons and thyroid shields should be hung or laid flat and never folded, and manufacturer's instructions should be followed. All protective shields should be evaluated for damage (e.g. tears, folds, and cracks) monthly using visual and manual inspection.

Proper education and training in patient positioning is necessary to ensure that panoramic radiographs are of diagnostic quality.

OPERATOR PROTECTION

Although dental professionals receive less exposure to ionizing radiation than do other occupationally exposed health care workers,[75,86] operator protection measures are essential to minimize exposure. Operator protection measures include education, the implementation of a radiation protection program, occupational radiation exposure limits, recommendations for personal dosimeters and the use of barrier shielding.[103] The maximum permissible annual dose of ionizing radiation for health care workers is 50 millisieverts (mSv) and the maximum permissible lifetime dose is 10 mSv multiplied by a person's age in years.[86] Personal dosimeters should be used by workers who may receive an annual dose greater than 1 mSv to monitor their exposure levels. Pregnant dental personnel operating x-ray equipment should use personal dosimeters, regardless of anticipated exposure levels.[86]

Operators of radiographic equipment should use barrier protection when possible, and barriers should ideally contain a leaded glass window to enable the operator to view the patient during exposure.[86] When shielding is not possible, the operator should stand at least two meters from the tube head and out of the path of the primary beam.[103] The National Council on Radiation Protection & Measurements report "Radiation Protection in Dentistry" offers detailed information on shielding and office design.[86] State radiation control agencies can help assess whether barriers meet minimum standards.

HAND-HELD X-RAY UNITS

Hand-held, battery-powered x-ray systems are available for intra-oral radiographic imaging. The hand-held exposure device is activated by a trigger on the handle of the device. However, dosimetry studies indicate that these hand-held devices present no greater radiation risk than standard dental radiographic units to the patient or the operator. No additional radiation protection precautions are needed when the device is used according to the manufacturer's instructions. These include: 1. holding the device at mid-torso height, 2. orienting the shielding ring properly with respect to the operator, and 3. keeping the cone as close to the patient's face as practical. If the hand-held device is operated without the ring shield in place, it is recommended that the operator wear a lead apron.

All operators of hand-held units should be instructed on their proper storage. Due to the portable nature of these devices, they should be secured properly when not in use to prevent accidental damage, theft, or operation by an unauthorized user. Hand-held units should be stored in locked cabinets, locked storage rooms, or locked work areas when not under the direct supervision of an individual authorized to use them. Units with user-removable batteries should be stored with the batteries removed. Records listing the names of approved individuals who are granted access and use privileges should be prepared and kept current.

FILM EXPOSURE AND PROCESSING

All film should be processed following the film and processer manufacturer recommendations. Once this is achieved, the x-ray operator can adjust the tube current and time and establish a technique that will provide consistent dental radiographs of diagnostic quality. Poor processing technique, including sight-developing, most often results in underdeveloped films, forcing the x-ray operator to increase the dose to compensate, resulting in patient and personnel being exposed to unnecessary radiation.

A safelight does not provide completely safe exposure for an indefinite period of time. Extraoral film is much more sensitive to fogging. The length of time for which a film can be exposed to the safelight should be determined for the specific safelight/film combination in use.

QUALITY ASSURANCE

Quality assurance protocols for the x-ray unit, imaging receptor, film processing, dark room, and patient shielding should be developed and implemented for each dental health care setting.[86] All quality assurance procedures, including date, procedure, results, and corrective action, should be logged for documentation purposes. A qualified expert should survey all x-ray units on their placement and should resurvey the equipment every four years or after any

changes that may affect the radiation exposure of the operator and others.[86] Surveys typically are performed by state agencies, and individual state regulations should be consulted regarding specific survey intervals. The film processor should be evaluated at its initial installation and on a monthly basis afterward. The processing chemistry should be evaluated daily, and each type of film should be evaluated monthly or when a new box or batch of film is opened.[86] Abdominal shielding and thyroid collars should be inspected visually for creases or clumping that may indicate voids in their integrity on a monthly basis.[86] Damaged abdominal shielding and collars should be replaced. Table 2 lists specific methods of quality assurance procedures, covering not only inspection of the x-ray unit itself but also of the film processor, the image receptor devices, the darkroom and abdominal shielding and collars.[103,104]

It is imperative that the operator's manual for all imaging acquisition hardware is readily available to the user, and that the equipment is operated and maintained following the manufacturer's instructions, including any appropriate adjustments for optimizing dose and image quality.

TECHNIQUE CHARTS/PROTOCOLS

Size-based technique charts/protocols with suggested parameter settings are important for ensuring that radiation exposure is optimized for all patients. Technique charts should be used for all systems with adjustable settings, such as tube potential, tube current, and time or pulses. The purpose of using the charts is to control the amount of radiation to the patient and receptor. Technique charts are tables that indicate appropriate settings on the x-ray unit for a specific anatomical area and will ensure the least amount of radiation exposure to produce a consistently good-quality radiograph.

Technique charts for intraoral and extraoral radiography should list the type of exam, the patient size (small, medium, large) for adults and a pediatric setting. The speed of film used, or use of a digital receptor, should also be listed on the technique chart. The chart should be posted near the control panel where the technique is adjusted for each x-ray unit. A technique chart that is regularly updated should be developed for each x-ray unit. The charts will also need to be updated when a different film or sensor, new unit, or new screens are used.

RADIATION RISK COMMUNICATION

Dentists should be prepared to discuss with their patients the benefits and risks of the x-ray exam.[105] To help answer patient and parent questions about dental radiology radiation safety, the American Academy of Oral and Maxillofacial Radiology and the Alliance for Radiation Safety in Pediatric Imaging partnered to create a brochure targeted at parents and patients.[106]

Table 2.

Quality Assurance Procedures for Assessment of Radiographic Equipment		
The following procedures for periodic assessment of the performance of radiographic equipment, film processing, equipment, image receptor devices, dark room integrity, and abdominal and thyroid shielding are adapted from the National Council for Radiation Protection and Measurements report, "Radiation Protection in Dentistry."[86] Please refer to state guidelines for specific regulations.		
Equipment	**Frequency**	**Method**
X-ray Machine	On installation At regular intervals as recommended by state regulations Whenever there are any changes in installation workload or operating conditions	Inspection by qualified expert (as specified by government regulations and manufacturers recommendations).
Film Processor	On installation Daily	**Method 1: Sensitometry and Densitometry** A sensitometer is used to expose a film, followed by standard processing of the film. The processed film will have a defined pattern of optical densities. The densities are measured with a densitometer. The densitometer measurements are compared to the densities of films exposed and processed under ideal conditions. A change in densitometer values indicates a problem with either the development time, temperature or the developer solutions. *Advantages* Accuracy Speed *Disadvantage* Expense of additional equipment **Method 2: Reference Film** A film exposed and processed under ideal conditions is attached to the corner of a view box as a reference film. Subsequent films are compared with the reference film. *Advantage* Cost effectiveness *Disadvantage* Less sensitive
Image Receptor Devices Intensifying Screen and	Monthly With each new batch of film Every six months	**Method 1: Sensitometry and Densitometry** (as described above) **Method 2: Reference Image** (as described above) Visual inspection of cassette integrity Examination of intensifying screen for

Extraoral Cassettes		scratches Development of an unexposed film that has been in the cassette exposed to normal lighting for one hour or more
Darkroom Integrity	On installation Monthly After a change in the lighting filter or lamp	While in a darkroom with the safelight on, place metal object (such as a coin) on unwrapped film for a period that is equivalent to the time required for a typical darkroom procedure Develop film Detection of the object indicates a problem with the safelight or light leaks in the darkroom
Abdominal and Thyroid Shielding	Monthly (visual and manual inspection)	All protective shields should be evaluated for damage (e.g., tears, folds, and cracks) monthly using visual and manual inspection. If a defect in the attenuating material is suspected, radiographic or fluoroscopic inspection may be performed as an alternative to immediately removing the item from service. Consideration should be given to minimizing the radiation exposure of inspectors by minimizing unnecessary fluoroscopy.

TRAINING AND EDUCATION

Where permitted by law, auxiliary dental personnel can perform intraoral and extraoral imaging.[103] Personnel certified to take dental radiographs should receive appropriate education. Practitioners should remain informed about safety updates and the availability of new equipment, supplies and techniques that could further improve the diagnostic quality of radiographs and decrease radiation exposure. Free training materials are available for limiting radiation exposure in dental imaging through the International Atomic Energy Agency.[107]

CONCLUSION

Dentists should conduct a clinical examination, consider the patient's oral and medical histories, as well as consider the patient's vulnerability to environmental factors that may affect oral health before conducting a radiographic examination. This information should guide the dentist in the determination of the type of imaging to be used, the frequency of its use, and the number of images to obtain. Radiographs should be taken only when there is an expectation that the diagnostic yield will affect patient care.

Dentists should develop and implement a radiation protection program in their offices. In addition, practitioners should remain informed on safety updates and the availability of new equipment, supplies, and techniques that could further improve the diagnostic ability of radiographs and decrease exposure.

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