DPH-08-015

Medical and Dental X-ray Quality Assurance

Reference list

1. National Council on Radiation Protection Report Number 99, Quality Assurance for Diagnostic Imaging, pages 47 & 50. Available at: http://www.ncrppublications.org/index.cfm?fm=Product.AddToCart&pid=9871570695.

2. Journal of the American Dental Association, *The Use of Dental Radiographs, Update and Recommendations*. 2006;137:1304-12. Available at: http://jada.ada.org/cgi/reprint/137/9/1304.

3. Conference of Radiation Control Program Directors, Inc. Publication E-03-2, Patient Exposure and Dose Guide – 2003, page 21. Table A-1, Technique/Exposure Guides for the Dental Bitewing Projection. Available at: http://www.crcpd.org/Pubs/ESERePublishedApr03.pdf.

REFERENCE 1

National Council on Radiation Protection Report Number 99,
Quality Assurance for Diagnostic Imaging,
Pages 47 & 50.

NCRP REPORT No. 99

Quality Assurance for Diagnostic Imaging

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National Council on Radiation Protection and Measurements

NCRP REPORT No. 99

Quality Assurance for Diagnostic Imaging

Recommendations of the
NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS

Issued 30 December 1988
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National Council on Radiation Protection and Measurements
7910 WOODMONT AVENUE / BETHESDA, MD 20814

white light should be eliminated, and indicator lights on processors, timers, etc. should be checked to ensure that they don't cause film fogging.

The test for fogging should use the fastest film normally handled in the darkroom. If more than one type of film (*e.g.*,blue sensitive, green sensitive, double emulsion, single emulsion, etc.) is used, then the fastest film of each type should be tested. A *visible light* exposure should be made on the film with a step wedge or sensitometer so that a complete range of densities is obtained. ("Visible light" means exposure to any light source which results primarily in a light, not x-ray, exposure. It is appropriate to make a radiograph of an aluminum step wedge using a screen-film system.)

Exposure of test film for one minute in the darkroom with safelight on should produce less than a 0.05 increase in the mid-density portion of the film (*i.e.*, at a density of about 1.20). Ideally, less than a 0.05 increase should also be obtained with the two minute exposure to the darkroom lights. A more detailed discussion of the test for darkroom fog is available (Gray *et al.*, 1983).

Testing for fog by placing an unexposed sheet of film on the counter top in the darkroom and covering part of it with an opaque object will not properly indicate the fogging conditions (Gray, 1975). Since photographic materials have a threshold, the unexposed portion of the film will be less sensitive to fog than a portion already exposed.

Darkrooms should be checked for fog at least every six months, any time that fog or increased film speed may be suspected, any time light bulbs or filters are changed in the darkroom safelights, or any time maintenance is done on the processor or in the darkroom.

6.1.4 *Manual Processing*

Facilities at which the daily volumes of film are low or where films may be processed a few days a week should probably use manual film processing. Most small dental practices would probably obtain more consistent film quality at a lower cost with proper manual processing.

Processing time must be selected based on the temperature of the developer solution (manufacturers provide time-temperature charts for the particular film-developer combination being used). *"Sight" development should never be used to compensate for poor radiographic technique.* An accurate timer should be used for all processing, and the development time should be that specified by the manufacturer for the developer temperature being used. The accuracy of the timer and thermometer should be checked monthly. Solutions should be processor, it will be necessary to monitor that processor with each type of film, meaning that more than one sensitometric control strip will be needed.

It needs to be reemphasized that the control strips should be exposed with a sensitometer, and processed within two hours of exposure (ANSI, 1982; Gray *et al.*, 1983), and that the type of film used for the control strips should be the same as that normally processed in a particular machine, even if this means processing more than one control strip for each machine.

6.2.3 *Photographic Processor Control Charts, Operating Levels, and Control Limits*

Control charts are the key to the photographic quality control program, since they allow for the perception of trends, both slow and rapid changes, in the areas being monitored. For detailed discussions of control charts see Gray, 1977; Gray *et al.*, 1976; 1977; 1983; Western Electric, 1983.

Most processor quality control programs monitor three quantities: base-plus-fog density; mid-density (usually around 1.0 above the base-plus-fog level); a density difference (usually measured between 0.25 and 2.00 above the base-plus-fog level). These levels are based on the American National Standards Institute (ANSI) standard for measuring radiographic film speed and contrast (ANSI, 1981) and are also suitable for other applications, *e.g.*, nuclear medicine, those handling mostly films from hard-copy video cameras, or those processing mostly single emulsion or duplicating films. It has also been suggested that it is only necessary to monitor a mid-density level for a basic processor quality control program (Goldman *et al.*, 1977).

Since the photographic manufacturers do not provide standards, establishing the operating levels presents a problem but detailed guidance is available (Gray *et al.*, 1983). The upper and lower control limits can be readily set. For radiographic materials and films of similar contrast the upper control limit (UCL) and lower control limit (LCL) for the mid-density and density difference should be set at ± 0.10 (in density) and the UCL for the base-plus-fog level should be set at + 0.05. It has been suggested (Lawrence, 1973) that the control limits for the mid-density and the density difference should be broader (± 0.15), especially for the mid-density level. However, it may be worthwhile to set the limits at this broader range upon initiation of the processor control program and then decrease them to ± 0.10 after a month or two of experience. For lower contrast

REFERENCE 2

Journal of the American Dental Association
The use of dental radiographs, Update and Recommendations
2006;137:1304-12.

THE JOURNAL OF THE AMERICAN DENTAL ASSOCIATION

JADA

The use of dental radiographs: Update and recommendations

American Dental Association Council on Scientific Affairs

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The use of dental radiographs

Update and recommendations

American Dental Association Council on Scientific Affairs

ABSTRACT

ADA CONTINUING EDUCATION CE ARTICLE 4

Background and Overview. The National Council on Radiation Protection & Measurements updated its recommendations on radiation protection in dentistry in 2003, the Centers for Disease Control and Prevention published its Guidelines for Infection Control in Dental Health-Care Settings in 2003, and the U.S. Food and Drug Administration updated its selection criteria for dental radiographs in 2004. This report summarizes the recommendations presented in these documents and addresses additional topics such as patient selection criteria, film selection for conventional radiographs, collimation, beam filtration, patient protective equipment, film holders, operator protection, film exposure and processing, infection control, quality assurance, image viewing, direct digital radiography and continuing education of dental health care workers who expose radiographs.

Conclusions. This report discusses implementation of proper radiographic practices. In addition to these guidelines, dentists should be aware of, and comply with, applicable federal and state regulations.

Clinical Implications. Dentists should weigh the benefits of dental radiographs against the consequences of increasing a patient's exposure to radiation and implement appropriate radiation control procedures.

Key Words. Radiographs; X-ray; radiographic examination; radiation exposure; digital radiography; quality assurance.

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Dental radiographs are a useful and necessary tool in the diagnosis and treatment of oral diseases such as caries, periodontal diseases and oral pathologies. Although radiation doses in dental radiography are low,[1,2] exposure to radiation should be minimized where practicable. Dentists should weigh the benefits of dental radiographs against the consequences of increasing a patient's exposure to radiation, the effects of which accumulate from multiple sources over time. The "as low as reasonably achievable" (ALARA) principle should be followed to minimize exposure to radiation.

This report discusses implementation of proper radiographic practices. It addresses topics such as patient selection criteria, film selection for conventional radiographs, collimation, beam filtration, patient protective equipment, film holders, operator protection, film exposure and processing, infection control, quality assurance, image viewing, direct digital radiography and continuing education of dental health care workers who expose radiographs. This report also summarizes the updated recommendations of the National Council on Radiation Protection & Measurements (NCRP) on radiation protection in dentistry[3] (available for purchase on the Web at "www.ncrppublications.org/index.cfm?fm=Product.AddToCart&pid=1845765544" or by phone at 1-800-229-2652), the Centers for Disease Control and Prevention's Guidelines for Infection Control in Dental Health-Care Settings[4] ("www.cdc.gov/OralHealth/infectioncontrol/guidelines/index.htm") and the U.S. Food and Drug Administration (FDA) selection criteria for dental radiographs ("www.ada.org/prof/resources/topics/radiography.asp").[5]

In addition to these guidelines, dentists should be aware of, and comply with, applicable federal and state regulations. (The Web site of the Conference of Radiation Control Program Directors at "www.crcpd.org/Map/map.asp" provides contact information for state radiation control and protection programs.)

PATIENT SELECTION CRITERIA

There is little evidence to support radiographic exposure of all dentulous areas of the oral cavity in search of occult pathoses in the asymptomatic patient.[3,6-8] Studies have shown 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 without a clinically consequential increase in the rate of undiagnosed disease.[9,10]

In collaboration with the ADA, the FDA has updated its guidelines for the selection of patients for dental radiographic examination (Table 1).[5] These guidelines provide recommendations for radiographs with consideration given to a patient's caries risk, periodontal status, stage of growth and development, and other specific circumstances. The guidelines recommend that radiographs be limited to the areas required for adequate diagnosis and treatment on the basis of the sound exercise of professional judgment.[3,5-8,11] Dentists should not prescribe routine dental radiographs at preset intervals for all patients.[3] Instead, they should prescribe radiographs after an evaluation of the patient's needs that includes a health history review, a clinical dental history assessment, a clinical examination and an evaluation of susceptibility to dental diseases.[3] For new or referred patients, clinicians should obtain recent dental radiographs from the patient's previous dental health care provider.[3] They also should review early radiographs, if available, for comparative purposes.

Dental radiographs may be prescribed for pregnant patients with careful adherence to the FDA selection criteria guidelines.[3,5] Dental disease left untreated during pregnancy can lead to problems for both the mother and the fetus, and dental radiographs may be required for proper diagnosis and management.[12]

No special considerations apply to dental radiographs for patients undergoing radiation therapy to the head and neck. These patients are at a high risk of developing dental diseases, and the radiation exposure from dental radiographs is negligible when compared with the therapeutic exposure they already are receiving in their treatment.[13,14]

Panoramic radiographs may reveal calcifications of the carotid artery through examination of the region 1.5 to 2.5 centimeters posterior and inferior to the angle of the mandible.[15-19] It is not recommended that the clinician take dental panoramic radiographs specifically to evaluate for carotid artery calcification, but rather that he or she evaluate radiographs taken for dental purposes for this condition as well. If the dentist suspects this condition, he or she should refer the patient to a physician for evaluation.

FILM SELECTION FOR CONVENTIONAL RADIOGRAPHS

The American National Standards Institute and the International Organization for Standardization have established standards for film speed.[20,21] 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. The use of faster film speed can result in up to a 50 percent decrease in exposure to the patient without compromising diagnostic quality.[3,22] Film of a speed slower than E-speed should not be used for dental radiographs.[3,22,23]

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

TABLE 1

U.S. Food and Drug Administration guidelines for prescribing dental radiographs.*

The recommendations in this table 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. Because every precaution should be taken to minimize radiation exposure, protective thyroid collars and aprons should be used whenever possible. This practice is strongly recommended for children, women of childbearing age and pregnant women.

TYPE OF ENCOUNTER	PATIENT AGE AND DENTAL DEVELOPMENTAL STAGE				
	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 or Partially Edentulous	Adult, Edentulous
New Patient† Being Evaluated for Dental Diseases and Dental Development	Individualized radiographic examination 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 examination at this time	Individualized radiographic examination consisting of posterior bitewings with panoramic examination or posterior bitewings and selected periapical images	Individualized radiographic examination consisting of posterior bitewings with panoramic examination or posterior bitewings and selected periapical images; a full-mouth intraoral radiographic examination is preferred when the patient has clinical evidence of generalized dental disease or a history of extensive dental treatment		Individualized radiographic examination, based on clinical signs and symptoms
Recall Patient† With Clinical Caries or at Increased Risk of Developing Caries‡	Posterior bitewing examination at six- to 12-month intervals if proximal surfaces cannot be examined visually or with a probe			Posterior bitewing examination at six- to 18-month intervals	Not applicable
Recall Patient* With No Clinical Caries and Not at Increased Risk of Developing Caries‡	Posterior bitewing examination at 12- to 24-month intervals if proximal surfaces cannot be examined visually or with a probe		Posterior bitewing examination at 18- to 36-month intervals	Posterior bitewing examination at 24- to 36-month intervals	Not applicable
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 in which periodontal disease (other than nonspecific gingivitis) can be demonstrated clinically				Not applicable
Patient for Monitoring of Growth and Development	Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development		Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development; panoramic or periapical examination to assess developing third molars	Usually not indicated	
Patient With Other Circumstances Including, but not Limited to, Proposed or Existing Implants, Pathology, 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				

* Reprinted from U.S. Department of Health and Human Services, Public Health Service, Food and Drug Administration; and American Dental Association, Council on Dental Benefit Programs, Council on Scientific Affairs.[5]

† Clinical situations for which radiographs may be indicated include, but are not limited to, the following. **Positive historical findings:** Previous periodontal or endodontic treatment, history of pain or trauma, familial history of dental anomalies, postoperative evaluation of healing, remineralization monitoring, presence of implants or evaluation for implant placement. **Positive clinical signs/symptoms:** clinical evidence of periodontal disease, large or deep restorations, deep carious lesions, malposed or clinically impacted teeth, swelling, evidence of dental/facial trauma, mobility of teeth, sinus tract ("fistula"), clinically suspected sinus pathology, growth abnormalities, oral involvement in known or suspected systemic disease, positive neurologic findings in the head and neck, evidence of foreign objects, pain and/or dysfunction of the temporomandibular joint, facial asymmetry, abutment teeth for fixed or removable partial prosthesis, unexplained bleeding, unexplained sensitivity of teeth, unusual eruption, spacing or migration of teeth, unusual tooth morphology, calcification or color, missing teeth with unknown reason, clinical erosion.

‡ Factors increasing risk for caries may include, but are not limited to, the following: high level of caries experience or demineralization, history of recurrent caries, high titers of cariogenic bacteria, existing restoration of poor quality, poor oral hygiene, inadequate fluoride exposure, prolonged nursing (bottle or breast), diet with high sucrose frequency, poor family dental health, developmental or acquired enamel defects, developmental or acquired disability, xerostomia, genetic abnormality of teeth, many multisurface restorations, chemotherapy/radiation therapy, eating disorders, drug/alcohol abuse, irregular dental care.

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.[3,24,25] Rare-earth film systems, combined with a high-speed film of 400 or greater, can be used for conventional panoramic radiographs.[3] Older panoramic equipment can be retrofitted to reduce the radiation exposure to accommodate the use of rare-earth high-speed systems.

COLLIMATION

Collimation limits the amount of radiation, both primary and scattered, to which the patient is exposed. 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.[3] Since a rectangular collimator decreases the radiation dose by up to fivefold as compared with a circular one,[1,3,26] radiographic equipment should provide rectangular collimation for exposure of periapical and bitewing radiographs.[3] The position-indicating device (PID) should be open-ended and have a metallic lining to restrict the primary beam and reduce the tissue volume exposed to radiation.[3,27] Use of long source-to-skin distances of 40 cm, rather than short distances of 20 cm, decreases exposure by 10 to 25 percent.[2,3] Distances between 20 cm and 40 cm are appropriate, but the longer distances are optimal.[3]

BEAM FILTRATION

The operating potential of dental X-ray machines 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 kilovoltage.

The operating potential of dental X-ray machines must range between 50 and 100 kilovolt peak but should range between 60 and 80 kVp.[3] Manufacturers of low-kVp (less than 60) dental radiographic equipment are required to install internal aluminum beam filters so that the mean beam energy will approach 60 kVp.[28]

PATIENT PROTECTIVE EQUIPMENT

Leaded aprons and thyroid shields that contain lead or other materials are patient-protective equipment that minimize exposure to scattered radiation. If all of the NCRP recommendations are followed rigorously, the use of a leaded apron on patients is not required.[3] However, if any of the recommendations is not implemented, then a leaded apron should be used.

Thyroid shielding with a leaded thyroid shield or collar is strongly recommended for children and pregnant women, as these patients may be especially susceptible to radiation effects.[3,5,29] Thyroid shielding also is recommended for adults when it will not interfere with the exposure.[3] To prevent cracks from occurring in the leaded shield, practitioners should ensure that leaded aprons and collars are hung and not folded.

FILM HOLDERS

Film holders that align the film precisely with the collimated beam are recommended for periapical and bitewing radiographs. Heat-sterilizable or disposable intraoral radiograph film-holding devices are recommended for optimal infection control.[4] Dental professionals should not hold the film holder during exposure.[3] Under extraordinary circumstances in which members of the patient's family (or other caregiver) must provide restraint or hold a film holder in place during exposure, such a person should have appropriate shielding.[3]

OPERATOR PROTECTION

Although dental professionals receive less exposure to X-radiation than do other health care workers,[3,30-32] operator protection measures are essential to minimize occupational exposure to ionizing radiation. Operator protection measures include education, the implementation of a radiation protection program, annual and lifetime limits of exposure to ionizing radiation, recommendations for personal dosimeters and the use of barrier shielding.[3]

The maximum permissible annual dose of ionizing radiation for health care workers is 50 millisieverts and the maximum permissible lifetime dose is 10 mSv multiplied by a person's age in years.[3,33] Personal dosimeters should be used by workers who may receive an annual dose greater than 1 mSv to monitor their exposure levels. Dental personnel who expose radiographs and are pregnant also should use personal dosimeters, regardless of anticipated exposure levels.[3]

Operators of radiographic equipment should use barrier protection when possible, and barriers should contain a leaded glass window to enable the operator to view the patient during exposure.[3] 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.[3] The NCRP report "Radiation Protection in Dentistry" offers detailed information on shielding and office design (in its Appendix F).[3]

FILM EXPOSURE AND PROCESSING

Exposure settings and film processing procedures can affect the quality of the radiographic image. The operator should set the amperage and time settings for exposure of dental radiographs of optimal quality. Radiographs should not be overexposed and then underdeveloped, because this practice results in greater exposure to the patient and dental health care worker and can produce images of poor diagnostic quality. Dental radiographs should not be processed by sight, and manufacturers' instructions regarding time, temperature and chemistry should be followed.[3]

Darkrooms should have adequate ventilation, and dental personnel should use protective procedures to avoid contact with the development chemicals.[34] A darkroom is preferable to daylight-loading processors, as the latter makes infection control procedures difficult to follow.[34] The length of time for which a film can be exposed to the safelight should be determined for the specific safelight/film combination used.[34]

State regulations may provide instructions regarding disposal of film-processing solutions and lead foil from the film packet. Fixer solutions may be considered hazardous waste because of their silver content and should be placed in containers and transported for recycling or to disposal sites.[35,36] The EPA recommends that lead foil be disposed of in accordance with local regulations.[35,36]

INFECTION CONTROL

Each dental health care facility should use standard precautions when exposing dental radiographs.[4] The personnel exposing the films should set out all necessary supplies and adjust the patient chair and head position before beginning the procedure. They should wear gloves when exposing the film and handling contaminated items, and they should always wash their hands before and after wearing gloves.[3,4,11] They should wear additional personal protective equipment, such as eyewear and a mask or face shield, when exposure to body fluids is anticipated.[4,37,38]

Heat-sterilizable or disposable intraoral radiograph film-holding devices are recommended, and barrier-protected film should be used whenever possible to prevent contamination and to minimize infection control procedures.[4] Digital intraoral film receptors that cannot be heat-sterilized should be covered with FDA-cleared protective barriers.[4] Because contamination of daylight-loading film processors is difficult to avoid, barrier-protected film also is recommended for use with these.

The film packet should be dried after a film is exposed.[4,34,37] If a protective film barrier is used, it should be removed carefully to avoid contamination of the film packet.[4] The uncontaminated contents then can be handled without gloves or other precautions. If the barrier is not used, gloves should be worn when the contaminated film packet is opened and the film allowed to fall out of the packet.[4,34,37] After all of the films have been removed in this manner, the gloves are removed and hands washed.[4,34,37] Once his or her hands are clean, the operator now can place the films in the processor as well as mount the processed radiographs.

All extraoral devices that will be contacted during the procedure should be either disinfected between patients or protected by a barrier and changed between patients.[3,4,37,38] An EPA-registered hospital-level disinfectant with low-to-intermediate activity should be used to treat any surfaces that become contaminated.[3,4,38]

QUALITY ASSURANCE

Quality assurance protocols for the X-ray machine, imaging receptor, film processing, dark room, and leaded aprons and thyroid collars should be developed and implemented for each dental health care setting.[3] All quality assurance procedures, including date, procedure, results and corrective action, should be logged for documentation purposes.[3]

A qualified expert should survey all X-ray machines on their placement and should resurvey the equipment every four years or if there are any changes made to it during this interval.[3] 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.[3] Leaded aprons and thyroid collars should be inspected visually for damage on a monthly basis and examined fluoroscopically on an annual basis.[3] Leaded aprons and collars in poor condition should be disposed of using a recycler licensed to handle lead waste.[39] Table 2 lists specific methods of quality assurance procedures, covering not only inspection of the X-ray machine itself but also of the film processor, the image receptor devices, the darkroom and leaded aprons and collars[40,41] (Figure, page 1311).

IMAGE VIEWING

The dentist should view radiographs under appropriate conditions for analysis and diagnosis. An illuminated viewer, preferably with variable intensity to allow for optimization of high- and low-density areas, should be used. Minimum room light will reduce reflections, and an opaque film holder will help to prevent glare and loss of visual acuity.[42] Magnification should be used as needed.

DIGITAL RADIOGRAPHY

A high-quality image can be obtained through the use of direct digital radiography while minimizing exposure to both patient and health care provider. Advantages of digital radiography include a decrease in radiation exposure for intraoral radiographs, speed in obtaining the image, ease of digital storage and electronic transmission of the image, and discontinued need for darkroom equipment.[3,42-45] A digital radiographic image can be adjusted for optimal diagnostic quality, including alterations in contrast, density, magnification and color.[3,44,45] Radiographic images can be printed on photo-quality paper or transparent sheets using any of a number of standard printers.

Widely available forms of direct digital radiography include photostimulable storage phosphor (PSP) sensors (also known simply as "storage phosphor sensors"), solid-state electronic sensors such as charged-coupled devices (CCD) and complementary metal-oxide semiconductor active pixel sensors (CMOS-APS). The image receptor used by the PSP format is similar in size, shape and flexibility to that of a conventional radiographic film. On exposure, the image is converted into stored energy on the image receptor.[46] The exposed image receptors are placed in a processor and scanned by a laser.[3] The image is converted into a digital format in one to two minutes. The image receptor can be reused after proper infection control procedures are carried out, and after erasure of the residual image by exposure to a strong light source for one minute. Because of the time required to obtain an image in this processing format, a PSP system is suited for instances in which an immediately available image is not essential.

The CCD and CMOS-ASP formats use a reusable intraoral image receptor that is sensitive to X-rays and visible light and is connected by a cable directly to a computer. The receptor is the size of intraoral films, but the image's active area may be smaller than this size. Upon exposure, the image is immediately converted to a digital format. The speed of obtaining an image makes these systems desirable when instant images are essential (such as oral surgery procedures, endodontics and implant placement).

Although technological advances in direct digital radiography have made the diagnostic quality of digital images comparable to that of conventional films,[3,47-49] there are some concerns about direct digital radiographs. These include the small receptor area that may require multiple exposures per area, the thickness and rigidity of some receptors that may make positioning difficult, and decreased resolution. FDA-cleared protective barriers are necessary for adequate infection control due to the lack of heat-tolerant intraoral equipment.[3] Finally, proprietary formats for image-viewing may limit electronic transfer and accessibility of the digital image.

The Digital Imaging and Communications in Medicine (DICOM) standard, developed by the American College of Radiology and the National Electrical Manufacturers Association, aims to facilitate a common method of transmission for medical radiographic images.[50] The ADA supports the use of DICOM. To further adapt the DICOM standards for the exchange of digital radiographic images used in dentistry, the ADA Standards Committee on Dental Informatics (SCDI) developed a report, Technical Report (TR) No 1023: Implementation Requirements for DICOM in Dentistry.[51] The DICOM requirements presented in the Technical Report enable exchange of digital

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 leaded apron and thyroid collar are adapted from the National Council for Radiation Protection & Measurements report, "Radiation Protection in Dentistry."[3] 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 state regulations)
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: Stepwedge (See Figure)** An aluminum stepwedge may be purchased or fabricated to resemble stairs, with each step of the aluminum stepwedge at 1 millimeter thick and 3 to 4 mm wide, with at least six steps A film is exposed through the stepwedge with the same machine settings, film placement and stepwedge placement used for each daily exposure The processed film is compared visually with a reference film A change in density of one or more steps indicates a problem with either the development time, temperature or the developer solutions *Advantage* Cost effectiveness *Disadvantage* Less precision
	On installation Daily	**Method 3: 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* Least sensitivity
Image Receptor Devices		
Film	Monthly With each new batch of film	Method 1: Sensitometry and Densitometry (as described above) Method 3: Reference Film (as described above)
Intensifying Screen and Extraoral Cassettes	Every six months	Visual inspection of cassette integrity Examination of intensifying screen for 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 a 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 the film Detection of the object indicates a problem with the safelight or light leaks in the darkroom
Leaded Apron and Collar	Monthly (visual) Annual (fluoroscopic)	Visual: inspection of the apron and collar for obvious tears, rips, cuts, etc. Fluoroscopic: performed by a qualified professional†

* There are three options for evaluating a film processor.
† As indicated in Lambert and McKeon[40] and Michel and Zorn.[41]

radiographic images between dental providers regardless of operating systems. Dental digital imaging system vendors that follow the requirements should certify that they are in compliance with ADA SCDI TR 1023.

TRAINING AND EDUCATION

Where permitted by law, auxiliary dental personnel can perform intraoral and extraoral film exposure.[3,52,53] Personnel certified to expose dental radiographs should receive appropriate education.[3,52,53] They also should receive training in infection control procedures because radiographic operators are subjected to occupational exposure to bloodborne pathogens.[3,4,38] 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. The ADA's Web site provides access to a continuing education course list in topics of dental radiographs, radiation safety and infection control ("www.ada.org/prof/ed/ce/index.asp").

CONCLUSION

Dentists should consider developing and implementing 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. ■

This report makes recommendations to dentists on implementation of radiographic practices. It is not intended to establish a legal standard of care for the practice of dentistry. In reviewing these recommendations and in making treatment decisions, the dentist's own professional judgment must remain paramount. In addition, the recommendations set forth here are general. Practitioners must consult their state laws for specific requirements. State law may address who may perform radiographic exposures, the level of supervision and training required, equipment inspection and maintenance, waste disposal, operator protections and other issues.

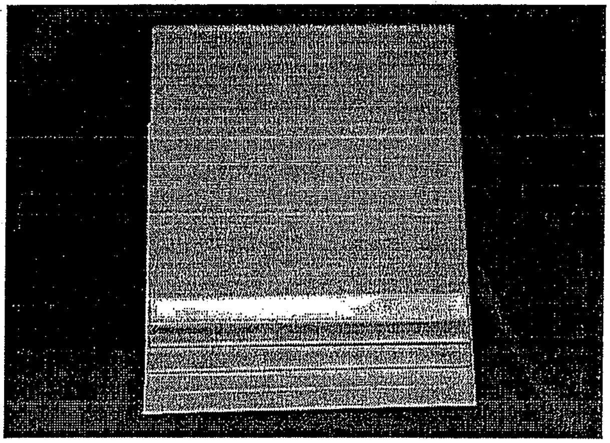

Figure. An aluminum stepwedge, which may be purchased or fabricated, can aid in the quality assessment of a radiographic film processor.

1. Freeman JP, Brand JW. Radiation doses of commonly used dental radiographic surveys. Oral Surg Oral Med Oral Pathol 1994;77(3):285-9.
2. Gibbs SJ, Pujol A Jr, Chen TS, James A Jr. Patient risk from intraoral dental radiography. Dentomaxillofac Radiol 1988;17(1):15-23.
3. National Council for Radiation Protection & Measurements. Radiation protection in dentistry. Bethesda, Md.: National Council for Radiation Protection & Measurements; 2003.
4. Center for Disease Control and Prevention. Guidelines for Infection Control in Dental Health-Care Settings—2003. Available at: "www.cdc.gov/mmwr/preview/mmwrhtml/rr5217a1.htm". Accessed July 27, 2006.
5. U.S. Department of Health and Human Services, Public Health Service, Food and Drug Administration; and American Dental Association, Council on Dental Benefit Programs, Council on Scientific Affairs. The selection of patients for dental radiographic examinations. Rev. ed. 2004. Available at: "www.ada.org/prof/resources/topics/radiography.asp". Accessed May 26, 2005.
6. Brooks SL. A study of selection criteria for intraoral dental radiography. Oral Surg Oral Med Oral Pathol 1986;62(2):234-9.
7. Brooks SL, Cho SY. Validation of a specific selection criterion for dental periapical radiography. Oral Surg Oral Med Oral Pathol 1993;75(3):383-6.
8. Matteson SR, Morrison WS, Stanek EJ 3rd, Phillips C. A survey of radiographs obtained at the initial dental examination and patient selection criteria for bitewings at recall. JADA 1983;107(4):586-90.
9. Atchison KA, White SC, Flack VF, Hewlett ER, Kinder SA. Efficacy of the FDA selection criteria for radiographic assessment of the periodontium. J Dent Res 1995;74(7):1424-32.
10. Atchison KA, White SC, Flack VF, Hewlett ER. Assessing the FDA guidelines for ordering dental radiographs. JADA 1995;126(10):1372-83.
11. Recommendations in radiographic practices: an update, 1988. Council on Dental Materials, Instruments, and Equipment. JADA 1989;118(1):115-7.
12. Little JW, Falace DA, Miller CS, Rhodus NL. Dental management of the medically compromised patient. 6th ed. St. Louis: Mosby; 2002:306.
13. Matteson SR, Joseph LP, Bottomley W, et al. The report of the panel to develop radiographic selection criteria for dental patients. Gen Dent 1991;39(4):264-70.
14. Gibbs SJ. Biological effects of radiation from dental radiography. Council on Dental Materials, Instruments, and Equipment. JADA 1982;105(2):275-81.
15. Ravon NA, Hollender LG, McDonald V, Persson GR. Signs of carotid calcification from dental panoramic radiographs are in agreement with Doppler sonography results. J Clin Periodontol 2003;30(12):1084-90.
16. Friedlander AH, Freymiller EG. Detection of radiation-accelerated atherosclerosis of the carotid artery by panoramic radiography: a new opportunity for dentists. JADA 2003;134(10):1361-5.
17. Ohba T, Takata Y, Ansai T, et al. Evaluation of calcified carotid artery atheromas detected by panoramic radiograph among 80-year-olds. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96(5):647-50.
18. Almog DM, Horev T, Illig KA, Green RM, Carter LC. Correlating carotid artery stenosis detected by panoramic radiography with clinically relevant carotid artery stenosis determined by duplex ultrasound. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;94(6):768-73.
19. Friedlander AH, Altman L. Carotid artery atheromas in postmenopausal women. Their prevalence on panoramic radiographs and their relationship to atherogenic risk factors. JADA 2001;132(8):1130-6.
20. American National Standards Institute. Photography—intra-oral dental radiographic film—specification. New York: American National Standards Institute; 1997. ANSI/ISO 3665:1996, ANSI/NAPM IT2.49-1997.
21. American National Standards Institute. Photography—direct-exposing medical and dental radiographic film/process systems—determination of ISO speed and ISO average gradient. New York: American

National Standards Institute; 1983. ISO 5799:1991. ANSI PH2.50-1983.

22. U.S. Food and Drug Administration, Center for Devices and Radiological Health. Dental radiography: Doses and film speed. Available at: "www.fda.gov/cdrh/radhlth/dentalradio.html". Accessed July 16, 2006.

23. Svenson B, Welander U, Shi XQ, Stamatakis H, Tronje G. A sensitometric comparison of four dental X-ray films and their diagnostic accuracy. Dentomaxillofac Radiol 1997;26(4):230-5.

24. Gratt BM, White SC, Packard FL, Petersson AR. An evaluation of rare-earth imaging systems in panoramic radiography. Oral Surg Oral Med Oral Pathol 1984;58(4):475-82.

25. Kaugars GE, Fatouros P. Clinical comparison of conventional and rare earth screen-film systems for cephalometric radiographs. Oral Surg Oral Med Oral Pathol 1982;53(3):322-5.

26. Gibbs SJ. Effective dose equivalent and effective dose: comparison for common projections in oral and maxillofacial radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;90(4):538-45.

27. van Aken J, van der Linden LW. The integral absorbed dose in conventional and panoramic complete-mouth examinations. Oral Surg Oral Med Oral Pathol 1966;22(5):603-16.

28. U.S. Department of Health and Human Services, Food and Drug Administration. Performance standards for ionizing radiation emitting products. 21CFR1020. Rockville, Md.: U.S. Food and Drug Administration; 1995.

29. Hujoel PP, Bollen AM, Noonan CJ, del Aguila MA. Antepartum dental radiography and infant low birth weight. JAMA 2004;291(16):1987-93.

30. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. Vol. I: Sources. UNSCEAR 2000 Report to the General Assembly, with References. New York: United Nations Scientific Committee on the Effects of Atomic Radiation; 2000.

31. Health & Safety Executive. Occupational exposure to ionising radiation 1990-1996: Analysis of doses reported to the Health and Safety Executive's Central Index of Dose Information. Norwich, United Kingdom: Health & Safety Executive; 1998.

32. Kumazawa S, Nelson DR, Richardson AC. Occupational exposures to ionizing radiation in the United States: A comprehensive review for the year 1980 and a summary of trends for the years 1960-1985. Washington: U.S. Environmental Protection Agency; 1984. EPA 520/1-84/005.

33. National Council on Radiation Protection and Measurements. Limitation of exposure to ionizing radiation: recommendations of the National Council on Radiation Protection & Measurements. Bethesda, Md.: National Council on Radiation Protection & Measurements; 1993. NCRP report 116.

34. American Academy of Oral and Maxillofacial Radiology infection control guidelines for dental radiographic procedures. Oral Surg Oral Med Oral Pathol 1992;73(2):248-9.

35. Environmental Protection Agency. CFR Title 40: Protection of the environment. Subchapter 1—Solid wastes. Washington: U.S. Environmental Protection Agency; 1994.

36. ADA Council on Scientific Affairs. Managing silver and lead waste in dental offices. JADA 2003;134(8):1095-6.

37. ADA Council on Scientific Affairs and ADA Council on Dental Practice. Infection control recommendations for the dental office and the dental laboratory. JADA 1996;127(5):672-80.

38. U.S. Department of Labor, Occupational Safety and Health Administration. Occupational exposure to bloodborne pathogens, needlestick and other sharps injuries, final rule. Fed Reg 2001;66:5317-25.

39. Burrell KH. Fluorides. In: Ciancio SG, ed. ADA guide to dental therapeutics. 3rd ed. Chicago: American Dental Association; 2003:237-43.

40. Lambert K, McKeon T. Inspection of lead aprons: criteria for rejection. Health Phys 2001;80(5 supplement):S67-S69.

41. Michel R, Zorn MJ. Implementation of an X-ray radiation protective equipment inspection program. Health Phys 2002;82(2 supplement):S51-S53.

42. ADA Council on Scientific Affairs. An update on radiographic practices: information and recommendations. JADA 2001;132(2):234-8.

43. Wenzel A. Digital radiography and caries diagnosis. Dentomaxillofac Radiol 1998;27(1):3-11.

44. Wenzel A, Grondahl HG. Direct digital radiography in the dental office. Int Dent J 1995;45(1):27-34.

45. Dunn SM, Kantor ML. Digital radiology: facts and fictions. JADA 1993;124(12):38-47.

46. Parks ET, Williamson GF. Digital radiography: an overview. J Contemp Dent Pract 2002;3(4):23-39.

47. Molander B, Grondahl HG, Ekestubbe A. Quality of film-based and digital panoramic radiography. Dentomaxillofac Radiol 2004;33(1):32-6.

48. White SC, Yoon DC. Comparative performance of digital and conventional images for detecting proximal surface caries. Dentomaxillofac Radiol 1997;26(1):32-8.

49. Syriopoulos K, Sanderink GC, Velders XL, van der Stelt PF. Radiographic detection of approximal caries: a comparison of dental films and digital imaging systems. Dentomaxillofac Radiol 2000;29(5):312-8.

50. Digital Imaging and Communications in Medicine Standards Committee. Digital Imaging and Communications in Medicine (DICOM); Supplement 92: Media application profile for digital radiographic images in dentistry. June 15, 2004. Available at: "ftp://medical.nema.org/medical/dicom/final/sup92_ft.pdf". Accessed Aug. 1, 2006.

51. American Dental Association Standards Committee on Dental Informatics. Technical report no. 1023-2005: Implementation requirements for DICOM in dentistry. Chicago: American Dental Association; 2005.

52. National Council on Radiation Protection and Measurements. Operational radiation safety program. Bethesda, Md.: National Council on Radiation Protection and Measurements; 1998. NCRP report 127.

53. National Council on Radiation Protection & Measurements. Operational radiation safety training: Recommendations of the National Council on Radiation Protection & Measurements. Bethesda, Md.: National Council on Radiation Protection & Measurements; 2000.

REFERENCE 3

Conference of Radiation Control Program Directors, Inc.
Publication E-03-2,
Patient Exposure and Dose Guide – 2003, page 21
Table A-1, Technique/Exposure Guides for the Dental
Bitewing Projection.

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APPENDIX

Table A-1. Technique/Exposure Guides for the Dental Bitewing Projection

kVp	D-Speed film ESE (mR)	E-Speed film ESE (mR)
50	425-575	220-320
55	350-500	190-270
60	310-440	165-230
65	270-400	140-200
70	240-350	120-170
75	170-260	100-140
80	150-230	90-120
85	130-200	80-105
90	120-180	70-90
95	110-160	60-80
100	100-140	50-70

Notes:

- Source: HHS Publication No. (FDA) 85-8245, August 1985.
- Values may be converted to entrance air kerma (mGy) by multiplying by 0.00876 mGy/mR.
- Exposures are specified as free-in-air exposures without backscatter.
- The bitewing guides represent the range of exposures (under the indicated conditions) that will produce, in the judgment of a panel of experienced dental radiologists, acceptable quality radiographs. The radiographs of a 3M™ dental phantom were produced under well-controlled conditions (in terms of both exposure and processing). The radiographs were taken at 10 mA at the indicated kVp's using a GE 90 II x-ray machine. In the 50-70 kVp range, 1.5 mm Al of filtration was used and in the 75 – 100 kVp range the filtration was 2.5 mm Al.
- Note that the indicated kVp can be significantly different from the actual kVp. If the actual kVp can be determined, use this value when referring to the table, rather than the indicated kVp.