

Radiation Protection Update



Pennsylvania Dental Association

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Reviewed by the Pennsylvania Department of Environmental Protection

Radiation Protection Update

- Radiation in the Healing Arts is an invaluable tool with many obvious benefits.
- While greatly beneficial, radiation can pose serious health risks to patients and equipment operators if used improperly.
- In addition, Americans face a much higher risk of developing cancer due to overuse of radiation for medical testing.

Radiation Protection Update

- The critical importance of safe and effective radiation use, while reducing risks to patients and equipment operators, has resulted in government oversight, including regulation of dental offices and personnel.
- Oversight by the government is handled by agencies administering and enforcing laws and regulations.

Radiation Protection Update

- In Pennsylvania, the two regulatory agencies are:
 - The Department of State
 - Governing Statute: The Dental Law, 63 P.S. § 120, et seq
 - The Department of Environmental Protection
 - Governing Statute: Radiation Protection Act, 35 P.S. §7110.101, et seq

Radiation Protection Update

- Pennsylvania Department of State (DOS)
 - Administers and enforces The Dental Law, which provides for initial licensure and certification requirements for dental professionals
 - Handled through the Department of State, Bureau of Professional and Occupational Affairs

Radiation Protection Update

- Pennsylvania Department of Environmental Protection (DEP)
 - Administers and enforces the Radiation Protection Act (aka the “X-Ray Law”), which provides for equipment registration and inspections, and ongoing training requirements for personnel operating X-ray equipment
 - Handled through the Department’s Bureau of Radiation Protection

Radiation Protection Update

- DOS and DEP both have regulations to implement their respective statutes.
- Regulations, like statutes, have the force and effect of law.
- Policies, or “Technical Guidance” (the term used by the DEP), also guide agency action and interpretation of law, but do not themselves have force of law.

Radiation Protection Update

- Nearly all regulatory issues concerning X-rays in dental offices are addressed by DEP under the Radiation Protection Act (RPA), which became law in 1984.
- RPA governs “radiation sources” (i.e. X-ray equipment) and “radiation source users” which includes any person who owns or is responsible for a radiation source.
- RPA gives broad regulatory powers to DEP.

Radiation Protection Act

- Regulation of X-rays in dental offices is handled under DEP's regulations entitled "X-RAYS IN THE HEALING ARTS".
- Regulations are found in Pennsylvania's Administrative Code, [25 Pa. Code Chapter 221](#).
- In 1998, additional regulations were promulgated which included an "Appendix A" to address training and competency for individuals who operate X-ray equipment.

Radiation Protection Act

- Chapter 221 requires verification of initial competence and ongoing continuing education.
- Determination of initial competence is based on 11 factors.

Determination of Competence

- Individuals shall be trained and competent in the general operation of the X-ray equipment and in the following subject areas:
 - Basic properties of radiation
 - Units of measurement
 - Sources of radiation exposure
 - Methods of radiation protection
 - Biological effects of radiation exposure
 - X-ray equipment
 - Imaging and processing
 - Patient exposure and positioning
 - Procedures
 - Quality assurance program
 - Regulations

Initial Competency Verification

- Any individual who satisfies the requirement of the DOS Professional and Occupational Standards to practice in their discipline is deemed by DEP to have met the initial competency requirement.
- DEP recognizes that the DOS determines initial competency requirements not only for physicians/dentists, but “auxiliary personnel” as well.

Continuing Education

In addition to the initial determination of competence, the regulations further state that “there shall be continuing education in radiation safety, biological effects of radiation, quality assurance and quality control.”

I. Radiation Safety

- Written safety procedures and rules shall be available at all facilities, including descriptions of the operating technique required for the safe operation of the particular X –ray system.
- The operator shall be familiar with the rules.

I. Radiation Safety

- Review medical history and physical condition prior to taking X-rays
- Accommodate needs of the patient
- Verify non-pregnancy of female patients prior to taking x-rays; postpone elective x-rays until pregnancy is over
- Inquire about any past radiation therapy
- If a patient has been exposed to large doses of radiation over the last two years, elective radiographs should be minimized

I. Radiation Safety

- All ionizing radiation is harmful. To protect the patient and the operator from excess exposure, radiation exposure guidelines have been established.
- The amount of radiation that reaches the body of the operator can be measured through use of a monitoring device known as a film badge.

I. Radiation Safety

- Radiation is measured in units called sievert or gray (formerly known as rem or rad).
- Maximum permissible dose (MPD) recommendations specify the dose limits for exposure to the ionizing radiation without tissue damage.
- MPD for those who work with radiation is 0.05 sievert/year (System International – SI Units) or 5.0 rems/year.
- For the public, it is 0.001 Sv/year or 0.1 rem/year.
- MPD for x-ray operators who are pregnant is 0.001 Sv/year or 0.1 rem/year, for the entire pregnancy.

I. Radiation Safety

- Effective Dose (Sv)

The effective dose is used to estimate risk in humans. It allows the risk from exposure to one region of the body to be compared with the risk from exposure to another region. It also considers the radio sensitivities of different tissues for cancer formation or heritable effect.

Summary of Radiation Quantities and Units

**Data from The NIST reference on Constants, Units and Uncertainty

Quantity	SI Unit	Conventional Unit	Conversion
Exposure	Coulomb/ kilogram	Roentgen (R)	1C/kg= 3876 R
Absorbed dose	Gray (Gy)	rad	1Gy= 100rad
Equivalent dose	Sievert (Sv)	rem	1 Sv= 100 rem
Effective dose	Sievert (Sv)	---	---

I. Radiation Safety

Kilovoltage

- A kilovolt is a measure of electrical current equal to 1000 Volts.
- The higher the voltage, the more energetic (thus a higher penetrating potential) the X-ray will be.
- Lower energy X-rays are absorbed by the body and objects through which they pass.
- X-rays that are absorbed do not make it to the film to create an image.

I. Radiation Safety

Kilovoltage

- Kilovoltage peak (kVp) is the maximum amount of voltage used in an X-ray machine.
- Some machines can be adjusted from 50 to 100 kVp; other machines are preset to 70 kVp.
- Settings below 60 and above 85 kVp are rarely used in dentistry.

I. Radiation Safety

Kilovoltage

- Every 15% increase in kVp will cause a doubling in the exposure or radiographic density.
- Going from 70 to 80 kVp doubles the exposure. To compensate, exposure time would have to be decreased by half.
- Going from 70 to 60 kVp decreases the exposure by half. To compensate, exposure time would need to be doubled.

I. Radiation Safety

Milliamperage

- A milliampere (mA) is measure of electrical current and is equal to 1/1000A.
- The higher the amperage, the higher quantity of X-rays there will be.
- Some machines can be adjusted from 10 to 15 mA; some machines are preset to 6 or 7 mA.

I. Radiation Safety

- Utilization of proper equipment aids in limiting the amount of radiation dental patients receive.
- The dental X-ray tubehead must be equipped with appropriate aluminum filters, lead collimator, and position-indicating device.
- State and federal laws regulate the required thickness of the aluminum filters. Machines that operate below 70 kVp require a minimum of 1.5mm aluminum thickness if manufactured after December 1, 1980.

I. Radiation Safety

- Machines manufactured prior to December 1, 1980 will require a minimum of 0.3mm (operating below 51 kVp) or a minimum of 1.2mm (operating between 51 kVp – 70 kVp)
- All machines operating above 70 kVp require a minimum of 2.1mm aluminum thickness.
- Collimation is used to restrict the size and shape of the X-ray beam. It is a lead plate with a hole in the middle and is fitted over the opening of the machine housing where the X-ray beam exits the tubehead.

I. Radiation Safety

- The position-indicating device (PID) appears as an extension of the X-ray tube and is used to direct the X-ray beam.
- There are three types of PIDs:
 - Conical (no longer used in dentistry)
 - Rectangular
 - Round

I. Radiation Safety

- Rectangular and round PIDs are available in varying lengths from short (8") to long (16"); the long PID is preferred.
- The rectangular type is the most effective in reducing patient exposure and can reduce patient dose by up to 60 %.
- Thyroid collars, lead aprons, fast film, and film-holding devices all reduce radiation received by the patient.

I. Radiation Safety

- Lead thyroid collars protect the thyroid gland from scatter radiation.
- Lead prevents radiation from reaching the highly radiosensitive tissues of the thyroid.
- May be separate or connected to the lead apron
- Thyroid collars are recommended for all intraoral films, but not for extraoral films because it obscures information on the film (ex. panorex).

I. Radiation Safety

- Intensifying Screens and Film
 - Extraoral films are typically screen films and require the use of intensifying screens and a cassette for exposure.
 - The two most common extraoral films include panoramic and cephalometric films.
 - Rare earth intensifying screens are recommended combined with high speed film of 400 or greater. (ADA 2006)
 - Rare earth screens decrease patient exposure by as much as 55% in panoramic and cephalometric radiology.

I. Radiation Safety

- Source to Skin Distance

Use of a long source-to-skin distance of 40cm, rather than shorter distances of 20cm, decreases exposure by 10 to 25%. Distances between 20cm and 40cm are appropriate, but the longer distances are optimal. (ADA 2006)

I. Radiation Safety

- Fast film is the most effective method of reducing a patient's radiation exposure.
- Fast film is available for intraoral and extraoral radiography.
- F-speed is the fastest intraoral film currently available; it offers a 60% reduction over D-speed film.
- Do not use film slower than D-speed.
- Current digital sensors offer greater or equal dose savings.

I. Radiation Safety

- Dentist must prescribe X-rays based on individual needs
- Dentist must use professional judgment to determine the number, type, and frequency of dental radiographs
- ADA, in conjunction with the Food and Drug Administration, has adopted guidelines for prescribing X-rays.

I. Radiation Safety

- There are three guiding principles in radiation protection:
 - 1) Principle of Justification
 - 2) Principle of Optimization
 - 3) Principle of Dose Limitation

I. Radiation Safety

Principle of Justification

- Obligates the dentist to do more good than harm
- Dentist should identify situations where the benefit to the patient from diagnostic exposure exceeds the low risk of harm

I. Radiation Safety

Principle of Optimization

- Holds that dentists should use every means to reduce unnecessary exposure to both their patients and themselves
- This philosophy of protection is known as the principle of ALARA (As Low As Reasonably Achievable)

I. Radiation Safety

Principle of Dose Limitation

- Dose limits are used for occupational and public exposures to ensure that individuals are not exposed to unacceptably high doses.

I. Radiation Safety

Minimizing Radiation

- Use fastest film possible
- Expose as few films as possible
- Use correct exposure values
- Use film aiming devices
- Process films correctly
- Use appropriate filters
- Consult doctor if film is flawed or has artifact

I. Radiation Safety Operator

- Dental radiographer must use proper protection measures to avoid occupational exposure
- Proper procedures include:
 - Avoid the primary beam
 - Stand at least 6 feet away from the X-ray tubehead
 - Stand in the safe zone which is 90-135 degrees from the direction of the primary beam
 - Never hold a film in place during exposure
 - Never hold the tubehead during exposure

II. Biological Effects of Radiation

- All ionizing radiation can produce biological changes in living tissues and must be used judiciously.
- Although the amount of radiation used in dentistry is very small, biological damage can still occur.

II. Biological Effects of Radiation

- Not all X-rays pass through the patient to reach the X-ray film.
- Some X-rays are absorbed by the patient's tissues.
- Chemical changes can occur that result in biological damage.

II. Biological Effects of Radiation

There are two types of radiation injury that can occur:

- 1) Ionization
- 2) Free Radical Formation

II. Biological Effects of Radiation

Ionization

- May occur when X-rays strike a patient's tissues
- Causes formation of a positive atom and a dislodged negative electron
- The excited electron can cause a chemical change in the cell that results in biological damage
- Ionization has little effect if the chemical changes do not alter sensitive molecules
- Can cause substantial changes in DNA

II. Biological Effects of Radiation

Free Radical Formation

- Radiation may cause the formation of free radicals, which are the primary cause of cell damage
- Highly reactive and unstable atom
- May recombine with other free radicals to cause cell damage
- May combine with ordinary molecules to form a toxin

II. Biological Effects of Radiation

Short Term Effects – large amounts of radiation delivered in minutes, days, or weeks. Not applicable to dentistry.

Long Term Effects – small amounts of radiation absorbed repeatedly over a long period of time.

II. Biological Effects of Radiation

Patient Exposure and Dose

- Patient dose from dental radiography is usually reported as the amount of radiation received by a target organ. Although actual exposures vary considerably, dental exposures are a small fraction of the annual average background exposure.
- The most radiosensitive target organs commonly studied include bone marrow, thyroid gland, brain, and salivary glands.

II. Biological Effects of Radiation

Sources of Ionizing Radiation

- 1) Natural (background)
- 2) Technologically induced

II. Biological Effects of Radiation

Annual Estimated Average Effective Dose Equivalent Received by a Member of the Population of the US

<u>Source</u>	<u>Average Annual Effective Dose Equivalent</u>	
	(Sv)	(mrem)
Inhaled (Radon and Decay Products)	2000	200
Other Internally Deposited Radionuclides	390	39
Terrestrial Radiation	280	28
Cosmic Radiation	270	27
Cosmogenic Radioactivity	10	1
Rounded Total from Natural Sources	3000	300
Rounded Total from Artificial Sources	600	60
Total	3600	360

*Source: University of Michigan¹¹

II. Biological Effects of Radiation

As shown in the table on the previous slide, 82% of the total average annual effective dose is from natural sources of radiation, and of that, most is from radon. Of the other 18%, the majority is from medical diagnosis and treatments, with less than one percent from nuclear power and fallout.

II. Biological Effects of Radiation

Effective Dose From Diagnostic X-Ray Examinations

<u>Dental Examinations</u>	<u>Effective dose (mSv)</u>
-Rectangular collimation	
Posterior bitewings: PSP or F-speed film	.005
FMX: PSP or F-speed film	.035
-Round collimation	
FMX: PSP or F-speed film	.171
FMX: D-speed film	.388
-Panoramic	.009 - .026
-Cephalometric	.003 - .006
-Cone-beam Imaging	.058 - .206

**occupational dose limit – 50 mSv per year

**non-occupational (public) dose limit -1 mSv per year

*Source: White and Pharoah⁴

II. Biological Effects of Radiation

Effective Dose From Diagnostic X-Ray Examinations

<u>Medical Examinations</u>	<u>Effective dose (mSv)</u>
Chest (2 views)	0.1
Cervical spine	0.20
Thoracic spine	1.0
Mammography	0.4
Extremity	0.001
Upper GI	6.0
Barium enema	8.0
CT scan – head	2.0
CT scan – chest	7.0

*Source: Mettler and Upton²

II. Biological Effects of Radiation

Somatic effects:

- Are seen in the person irradiated
- Are not transferred to future generations
- Radiation injuries can produce changes in somatic cells and result in poor health
- Somatic cells include all cells except reproductive

II. Biological Effects of Radiation

Genetic effects:

- Are not seen in the person irradiated
- Are passed on to future generations
- Radiation injuries can produce changes in reproductive cells
- Genetic damage cannot be repaired

III. Digital Radiography

Digital Imaging is emerging as the dominant technology as computers have become integral to practice management

III. Digital Radiography

Advantages:

- Eliminates poor diagnostic quality due to inadequate film processing
- Eliminates chemical processing and hazardous wastes
- Quality images are immediately available and can be electronically stored and transferred
- Digital intraoral receptors require less radiation than film

III. Digital Radiography

Disadvantages:

- Initial expense of equipment and setup
- High replacement costs of certain components
- Constantly changing software and manufacturers
- Imaging quality no better than lower cost film

III. Digital Radiography

Digital Imaging

- Requires analog- to-digital conversion (ADC)
- Two methods of ADC are: solid- state technology and photostimulable phosphor technology (PSP)
- Solid-state technology is known in medicine as digital radiography, and in dentistry as intraoral “sensors”
- PSP technology is known in medicine as computed radiology or sometimes “image plates”

III. Digital Radiography

Digital Imaging: Solid-state technology

- Charge –Coupled Devices (CCD): introduced to dentistry in 1987; uses a thin wafer of silicon to record images; more sensitive to light than to x-ray, increasing x-ray absorption efficiency
- Complementary Metal Oxide Semiconductors (CMOS): less expensive than CCD and used for intraoral imaging
- Flat Panel Detectors: commonly used in medical imaging; more expensive and typically limited to specialized imaging tasks such as cone-beam imaging

III. Digital Radiography

Digital Imaging: Photostimulable Phosphor (PSP)

- Uses PSP plates similar in size to panoramic and cephalometric imaging
- Plates must first be erased by light exposure
- Images must be processed quickly and in semi dark conditions (not red light) to avoid data loss
- After exposure, the plates are read by a laser scanning device, and the image appears on a computer monitor

III. Digital Radiography

- Digital radiographic sensors and phosphor plates contact mucous membranes and must be covered with FDA approved hygienic barriers.
- Holders for digital radiographic sensors and phosphor plates must be disposable or autoclavable.

III. Digital Radiography

- The following general principles apply to radiographic sensors:
 - Digital Radiographic Sensors:
 - Cover sensor and any cords which contact mucosa or contaminated hands or gloves.
 - Prior to disinfecting:
 - Remove barrier sheaths
 - Clean organic matter from sheath and cord
 - Disinfect the sensor with a germicidal wipe or EPA registered anti-tubercular disinfectant. **Do not** use chlorine bleach as it is corrosive.

III. Digital Radiography

- The following general principles apply to phosphor plates:
 - Phosphor Plates:
 - Cover with protective sheath
 - Disinfect with intermediate-level disinfectant (can use 10% bleach)
 - Do not soak overnight
 - Avoid contact with:
 - Isopropyl alcohol
 - Hydrogen peroxide
 - Citrus-based cleaners
 - Hand lotions or alcohol gel sanitizers

III. Digital Radiology

Each manufacturer of digital radiographic sensors also has specific guidelines for disinfecting their sensors. Contact specific suppliers for their recommended disinfection procedures. In addition, each manufacturer has specific guidelines for sterilizing their digital sensor holders.

III. Digital Radiology

Cone-Beam Computed Tomography

- First introduced in 1982; initially used for maxillofacial imaging
- Uses a cone-shaped source of ionizing radiation and 2-dimensional area detector to produce 3-dimensional computer images
- Less radiation exposure and less expensive than traditional CT

III. Digital Radiology

Cone-Beam Computed Tomography

- CBCT exposure is higher than other routine radiographic procedures
- The ALARA principle must be applied: diagnostic benefits must outweigh detriments of patient radiation exposure
- CBCT commonly used for assessment of pathological conditions, structural maxillofacial deformity, impacted teeth, and availability of bone for implant placement

III. Digital Radiology

Intraoral Radiography

- Patient exposure for intraoral radiography can vary depending on the KvP, ma and length of exposure for each radiograph. Typically for film at 70KvP and 7mas, an exposure of 0.2-0.3 pulses is used. For phosphor plates, a setting of 0.08-0.14 pulses is used.
- Digital radiographs would require 40-60% less exposure compared to conventional radiography.

III. Digital Radiography

Comparing Cone Beam CT with Medical CT

<u>Type of Examination</u>	<u>Effective Dose (Sv)</u>
Intraoral Film (per exposure)	< 8.3
Dental Panoramic	9-26
Dental Cephalometric	3-6
Cone Beam CT- Dental- Alveolar (focus field view)	5-38.3
Full Mouth Series	35-388
Cone Beam CT- Craniofacial	65-599
Medical CB Maxilla and Mandible	2,000

*Source: White and Pharoah⁴

IV. Quality Assurance

- Quality Assurance procedures are used to assure high quality diagnostic radiographs.
- A Quality Assurance program includes both quality control tests and quality assurance procedures.
- Quality of radiographic procedures is fundamental to the proper diagnosis and treatment of patients.

IV. Quality Assurance

An effective Quality Assurance program helps to ensure that radiation exposure to patients and equipment operators is as low as reasonably achievable (ALARA) while providing efficient, consistent, high quality diagnostic results.

IV. Maintenance and Modification of the Quality Assurance Program

- DEP regulations require that Quality Assurance program records be maintained for three years.
- Records should be sufficiently detailed for the DEP to reconstruct Quality Assurance activities.
- Review your Quality Assurance program annually and modify as needed.
- At a minimum, periodically check the X-ray beam collimation and positioning stability.
- Perform equipment maintenance as recommended by the manufacturer.

IV. Elements of a QA Program

- Documentation to demonstrate compliance. There should be a written description of the program (i.e. manual).
 - Manuals should contain checklists of QA activities and results of tests
 - Manuals should contain standards to assess quality
 - Manuals should show how patient safety is assured

IV. Elements of a QA Program

Important considerations

- 1) Quality of images (clinical value)
- 2) Patient safety

IV. Elements of a QA Program

Quality of Images

- Contrast - the difference in degrees of blackness
- Density - the overall darkness or blackness of a radiograph
- Fog - film that has expired, been improperly stored, or has been exposed to radiation appears fogged. Fresh film appears clear with a slight blue tint.
- Artifacts - unwanted images that appear in film due to improper handling or patient preparation
- Coverage of clinical area - proper alignment of the X-ray beam will be centered over the film. Misalignment can result in cone-cut.

IV. Elements of a QA Program

Patient Safety

- Establish and adhere to optimum exposure technique settings.
- If settings no longer yield quality images, the cause must be promptly investigated.

IV. Quality Assurance

Quality Control Tests

- X-ray machines – should be tested for minor malfunctions, output variations, collimation problems, tubehead drift, and milliamperage readings (DEP generally performs)
- X-ray film – fresh film test can be used to determine whether film is properly stored and protected
- Screens and cassettes – examine periodically for adequate closure, light leaks and warping
- Darkroom lighting – use a light leak test to check for light leaks in the darkroom
- Safelight test – used to check for proper safelight conditions

IV. Quality Assurance

Quality Control Tests

- Processing equipment – manual and automatic processing equipment should be carefully maintained and monitored according to the manufacturer's instructions.
- Processing solutions – developer strength can be monitored by a reference radiograph; fixer can be checked by a clearing test; follow a consistent processing protocol.

IV. Quality Assurance

Repeat Rate

- Establish a system to record the occurrence of repeat X-rays and the reasons why the X-ray had to be retaken.
- A repeat exposure record may help to identify equipment, operator or technique problems.

IV. Quality Assurance

QA Manual Sample

Quality Assurance Manuals should include at least:

- Certificates from DANB “X-Ray” test for operators to show evidence of initial competency
- Certificates from any completed continuing education courses
- Sample DEP QA program with modifications
- Sample DEP written safety program with modifications
- Repeat exposure log
- General maintenance log
- DEP inspection log

Sample Quality Assurance Documents can found on the PDA website at:
www.padental.org/radiology

Note: These documents are samples and should be modified to meet the needs of your office.

Instructions for Obtaining Continuing Education Credit for this Online Course

For reviewing the “Radiation Protection Update” PowerPoint, you are eligible to receive two continuing education (CE) credits towards the radiology CE requirement. In order to receive a certificate of completion, you must pass a short quiz based on the content in this PowerPoint. If you are not able to pass the quiz, you will not receive credit for the course. To access the quiz, please use the quiz link located at www.padental.org/radiology , under the “Radiology PowerPoint” header.

Please enter your preferred email and mailing address into the fields provided on the last slide the quiz and then hit the “submit” button. Upon successful completion of the quiz, a certificate will be mailed to you. If you do not pass the quiz, an email will be sent to the provided email address within 1-2 weeks notifying you that you did not pass and that you will have to try again. You will only receive an email in the event that you do not pass the quiz.

If you have any further questions regarding radiology continuing education, please refer to the “[Radiology Continuing Education Questions and Answers](#)” page, located on the PDA website, or contact the PDA Central Office at (717) 234-5941.

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