Advanced Radiology

by

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A Six Hour Home Study Course

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Course Description

This course begins with a historical summary describing how x-rays were discovered, principles of x-radiation, how x-ray tubes are built and how they work, and the effects and practical aspects of radiation safety. It continues to include common dental imaging terminology, guidelines for prescribing radiographs, intraoral placement techniques, descriptions of various radiographic surveys, and patient management techniques including how to control gagging. The course discusses film processing principles, mounting, infection control, and common errors. It provides information regarding qualities of excellent radiographs and useful techniques that, if mastered, ensure quality x-rays. Shadow casting principles, techniques, and tricks are discussed, and readers are informed how to bisect an angle which overcomes x-ray distortions, and also how to move objects on a radiograph. The Clark Shift and its relation to orthographic surveys is discussed as well as, principles of digital radiographic systems, tomography, CT scanning and finally, cone beam computerized tomography. Legal ramifications of having and using these technologies in the dental office as well as a glossary of radiographic terms are included at the end of the course.

Learning Objectives

- Understand kilovoltage and milliamperage settings.
- Understand effects of and practical aspects of radiation safety.
- Understand guidelines for prescribing and film placement techniques of radiographic surveys.
- List qualities of excellent x-rays
- List common errors and infection control methods.
- Understand shadow casting principles and tricks.
- Understand the Clark Shift.
- Understand CT and cone beam technology.

Martin S. Spiller, DMD

Martin Spiller graduated in 1978 from Tufts School of Dental Medicine. He is licensed in the state of Massachusetts and has been practicing general dentistry in Townsend, MA since 1984. Upon graduation from dental school, Dr. Spiller spent four years as a U.S. Army officer. During this time, he attended a dental, general practice residency in which he received training in numerous dental specialties including oral surgery, endodontics, pedodontics, and orofacial surgical techniques and facial trauma. In 2000, he began work on a general dentistry website (www.doctorspiller.com). The intention at first was to educate the general public about dental procedures and the concepts behind them. Eventually, the website became popular with dental professional students. The website content began reflecting this
Introduction: The History of X-Rays

Wilhelm Conrad Roentgen, a Bavarian physicist, discovered x-rays. He was working with sealed glass vacuum tubes, each containing a cathode and anode. During his experiments, he applied voltage to these tubes and noticed a screen near the tubes was glowing. He blocked the path of the rays to see if this would prevent the screen from glowing. When he placed his own hand between the tube and screen, he could see the outline of his bones on the screen. This historic discovery, on November 8, 1895, dramatically changed diagnostic procedures in medicine and dentistry. Roentgen received the first Nobel Prize in physics in 1901 for his discovery of x-rays.

Roentgen’s Hand

The X-Ray Tube

Dental x-ray tubes are vacuum sealed glass enclosures surrounded by lead shielding. The shielding has one opening in it which allows x-rays to escape. A tungsten filament cathode with a focusing cup and an anode containing tungsten, molybdenum, palladium, or other metal embedded in copper are housed in the glass enclosure. Heat dissipates via oil which circulates through the copper.

The heated tungsten wire in the cathode emits electrons. The focusing cup focuses negatively charged electrons generated by the cathode and directs them across a gap between the cathode and anode to a small spot on the positively charged anode. The point where the electrons are focused is called the focal point.
Two types of energy are generated at the focal spot—heat and x-rays. X-rays escape the housing through an aluminum filter at the tube head opening (collimator). The collimator restricts the x-ray beam to less than 2 ¼ at the patient’s skin surface. A lead lined cone collimates the beam further.

**Bremsstrahlung Radiation**

X-rays are part of the electromagnetic spectrum and are a form of light. X-ray photons travel at the speed of light, and they can produce a latent image on film. Unlike visible light, x-rays can penetrate most opaque matter, make some materials fluoresce, and ionize some materials.

Bremsstrahlung radiation results when an electron passes near an atom’s nucleus causing the electron to change its course. When this happens, the electron loses much energy. In the world of quantum particles, energy is exchanged as photons. As the electron is deflected by the heavy nuclei in the anode target, its energy loss produces x-rays. The dental x-ray tube produces Bremsstrahlung radiation.

**Kilovoltage and Milliamperage**

Electricity flows through wires like water flows through pipes. If water is under low pressure, it flows slowly. If it is under high pressure, water flows faster and more water flows through the pipe per second. In terms of electricity, the pressure in the wire is measured in volts or kilovolts. The amount of electricity (current) flowing through wire each second is measured in amperes or milliamperes.

High voltage electricity flows so fast, it can jump across gaps. Think of water flowing through a fireman’s hose. The hose nozzle constricts water flow and makes it shoot out further. Constriction can be thought of as resistance. Wires are manufactured to various degrees of resistance depending on composition and diameter.

- When current flows through a high-resistance wire, the wire heats up just like a light bulb filament.
- When high voltage pushes electrical current across a low resistance gap, electrons jump the gap. Both these principles operate within an x-ray tube.

X-ray machines use energy from an electrical source and convert it into two, separate voltage streams.
- One stream is a low voltage source which can be varied so different amounts of current can flow through the high resistance wire that composes the cathode filament. The current that flows through the filament is measured in milliamperes.
- The second stream is very high voltage and is measured in kilovolts. The voltage is applied across the gap between anode and cathode.

**How Kilovolts and Milliamperes Come Together in an X-Ray Tube**

The low voltage stream flows through the high resistance wire in the cathode heating element pictured on the left side of the diagram above. The heating element resides in a metal covering called a filament focusing cup. When the metal heats, electrons become excited and boil off the metal's surface. Higher metal temperatures result in more electron loss. As electrons boil off the filament, the filament becomes positively charged. Because a high voltage stream is applied, the negatively charged electrons do not simply fall back into the filament.

A high voltage stream (70,000 volts) is applied across the anode and cathode causing the negatively charged electrons to be attracted to the positively charged anode. In an x-ray tube, the high voltage supplies pressure to the electron stream generated by the filament and causes electrons to speed across the gap with tremendous velocity. The focusing cup is negatively charged and repels the electrons. The electrons are pushed to the center of the cup and are focused into a tight beam.

The electrons hit the tungsten target so hard, they explode into a shower of high energy photons. These photons are x-rays. X-ray photons are like light photons except they contain so much energy, they penetrate opaque objects. But even with their great energy, objects of varying densities can block some x-rays, casting shadows on whatever screen is there. In the case of medical x-rays, the screen is an x-ray film or digital sensor.

- X-ray energy is controlled by voltage. When voltage is increased, x-ray photons have shorter wavelengths, higher energy, and pack a greater punch.
- Number of x-ray photons produced depends on current which is controlled by heating element temperature. The amount of current flowing through the filament is controlled by the milliamperage setting.
Kilovoltage and Milliamperage Settings

In dental x-ray units, kilovoltage and milliamperage are set by manufacturers and are rarely changed by operators. The only variable that is normally operator adjusted is the amount of time that voltage is applied across an x-ray tube. Modern tubes use $1/10^\text{th}$ and $1/100^\text{th}$ of a second as a standard time measurements.

Older machines use pulses. Each pulse is $1/60^\text{th}$ of a second. Many of these machines are still in use, so if you see a unit with a dial labeled in whole numbers, it is probably measuring time in pulses. To figure the actual time, multiply the number on the dial by $1/60^\text{th}$ of a second. Six pulses equal $1/10^\text{th}$ second.

Common settings for dental x-ray units is $70\text{kVp}$ (kilovoltage peak) or $90\text{kVp}$. A 15% increase doubles the radiograph density, so operators must decrease x-ray exposure time by half to maintain the same radiograph density. Kilovoltage is responsible for x-ray beam quality. Milliamperage controls the quantity of x-rays produced. Within dental practice, 7-15 mA is a normal range. The lowest possible kVp should be used, but it should not drop below $60\text{kVp}$. Filtration equivalent to 2.5 mm aluminum should be used when operating at $70\text{kVp}$ or more. Units operating below $70\text{kVp}$ should have the equivalent of 1.5 mm aluminum filtration.

According to federal guidelines, a chart with time settings (in seconds or pulses), kVp, and mA for techniques most commonly used must be posted near the control panel of every x-ray unit in the dental office.

Filtering

Photons produced by x-ray tubes contain a range of energy. It is desirable to limit the x-ray tube’s output to only the most energetic photons. Low energy photons are easily absorbed by soft tissues, do not reach the film, and represent the absorbed dose of radiation to patients. Since aluminum is transparent to high energy x-rays, but opaque to low energy x-rays photons, low energy x-rays can be filtered out by placing a flat aluminum disk in the radiation beam’s path. Most modern machines are factory set to produce $70\text{kVp}$ radiation, so most x-ray tubes come with a 2.5 mm thick aluminum filter.

Controlling X-Rays

X-ray radiation wavelengths and penetration characteristics are controlled by three variables:

1. **Filament Temperature.** High filament temperatures release more electrons. Increasing mA increases amount of electrons emitted from the cathode which increases amount of x-rays produced.

2. **Kilovoltage.** The voltage between the negatively charged cathode and the positively charged anode is expressed in peak kilovolts. Increasing kVp increases the speed of electrons that strike the target. High kVp settings produce shorter wavelength (high energy) x-rays. Shorter wave x-rays penetrate objects more than do longer wave x-rays.

3. **Time.** A timer on the x-ray tube controls the number of seconds electrons are produced by the cathode. This influences number of x-rays produced.
Penetration and X-Ray Images

When x-ray beams enter an object, they have a uniform distribution of high energy wavelengths. The degree to which x-rays are absorbed depends on the tissue type encountered before they strike film. Patients’ tissues form a pattern of x-ray radiation (called differential attenuation).

Effects of Radiation

There are three ways x-rays interact with organic matter.

1. **Classical scattering.** When a photon does not have enough energy to displace an electron from an atom, it gives its energy to the electron. The electron produces another photon with the same energy as the other and sends it off in a different direction. This is called classical scattering.

![Classical scattering diagram](image)

2. **Photoelectric Effect.** If photons have enough energy, they displace electrons from their orbit around atoms. Electrons, called recoil electrons, are lost from atoms. Atoms absorb the photon energy, but are missing electrons. These atoms are positively charged and are called ions. This is called the photoelectric effect.

![Photoelectric effect diagram](image)

3. **Compton Effect.** If a photon collides with an atom or electron and has enough energy to displace it but does not transfer all its energy to the atom or electron, it will continue on, weaker, as scattered radiation. This is the Compton Effect.

![Compton effect diagram](image)
These three reactions are not life threatening. However, molecular interactions involving altered atoms may break molecules into smaller pieces, disrupt molecular bonds, and may form new bonds within or between molecules. Radiation may also interact with cellular water and oxygen disturbing cellular balance and damaging DNA molecules.

High radiation doses to the entire body may cause acute effects. Long term or chronic effects result from repeated exposure to radiation. The body attempts to repair damage, but cannot keep up if radiation exposure is regular and strong.

X-ray device operators should regularly monitor their radiation exposure by using a film badge. Film badges are worn at work and sent to a company to be evaluated for exposure. Operators should step behind a lead barrier when exposing films. If no barrier is available, operators should stand at least six feet away and between 90–135 degrees to the primary beam. Operators should never hold film for a patient during exposure.

Radiographs should not be taken unless benefits for the patient outweigh risks. Lead aprons must be used on all patients, and a thyroid collar should be used while taking intraoral films. A patient would have to undergo 25 complete mouth series in a short time to significantly increase their risk of skin cancer. The benefit of detecting disease outweighs the risk of radiation in small doses used for dental radiography.

Radiation exposure varies according to technique, collimation, film speed, and kilovoltage. The paralleling technique using a long cone results in the least amount of radiation and the best quality radiograph. Rectangular collimation reduces the area of tissue exposed to x-ray beams by 60-70%.

**Practical Aspects of Radiation Safety**

Some people do not want to take diagnostic x-rays, because they have heard radiation is dangerous. Dental x-rays pose very little danger. It is important dental professionals know various terms used when speaking with patients about diagnostic x-ray effects on the body. There are five units used in measuring radiation: the Roentgen, Gray, rad, REM, and Sievert.

1. **Roentgen.** Roentgen is the international unit of x-radiation or gamma radiation equal to the amount of radiation that produces in one cubic centimeter of dry air at 0°C and standard atmospheric pressure ionization of either sign equal to one electrostatic unit of charge.
2. **Gray.** Gray is the SI unit of absorbed radiation dose of ionizing radiation (for example, x-rays), and is defined as the absorption of one joule of ionizing radiation by one kilogram of matter (usually human tissue).

3. **rad.** The rad is a unit of absorbed radiation dose as the dose causing 0.01 joule of energy to be absorbed per kilogram of matter.

4. **REM.** A REM or Roentgen equivalent man is a unit of radiation dose equivalent.

5. **Sievert.** The Sievert (Sv) is the International System of Units (SI) unit dose equivalent radiation. It attempts to quantitatively evaluate the biological effects of ionizing radiation as opposed to just the absorbed dose of radiation energy, which is measured in Grays.

Effective dose is a useful term allowing comparisons to be made between sources of radiation exposure which expose only portions of the body, such as radiographic techniques, and whole-body exposure including those resulting from natural or background radiation.

The effective dose is the sum of the weighted equivalent doses for all irradiated tissues or organs. The tissue weighting factor takes into account the relative detriment to each organ and tissue including different mortality and morbidity risks from cancers, the risk of severe hereditary effects for all generations, and the length of life lost due to these effects.

Effective dosing units are used to compare radiation doses on different body parts on an equivalent basis, because radiation does not affect different body parts in the same way. The units of effective does are the same as used for equivalent dose. They are the Sievert and REM. The REM and Sievert are large units, so exposure to medical radiation is measured in milliREMs (mREM) and milliSieverts (mSv). 1 mSv=100 mREM.

The average dental x-ray taken with film delivers between .75 and .95 mREM effective dose per exposure depending on angulation. This estimate is based on average exposure, because different speed films (D, E, and F) require different exposure settings on x-ray machines, and because dental x-rays taken at one angle may expose different parts of the body to radiation than others taken at different angles.

The average dental, intraoral radiograph exposes patients to about 1 mREM. A digital, dental x-ray delivers a third to half this amount (.3-.5 mREM). Based on this estimate, a full mouth series of dental x-rays delivers approximately 18 mREM. A panorex film delivers 2 mREM to the body.

By comparison, the average person in the U.S. is exposed to approximately 300 mREM per year from naturally occurring background sources. By this measure, it would take approximately 17 series of dental radiographs or 150 panoramic x-rays to equal the background radiation average citizens are exposed to on a yearly basis. Note that most dentists take a new, full series and/or panoramic series every three to five years on average.

Background radiation comes from outer space, the earth, natural materials (including natural foods), and even other people. For example, flying cross country exposes a person to approximately 5 mREM over and above the normal radiation received from
space while walking outdoors for the same length of time. Cooking with natural gas exposes us to approximately 10 mREM per year because of naturally occurring radon in cooking gas. Living in a brick building adds an additional 10 mREM per year more than the radiation a person receives living in a wooden home. Indeed, sleeping next to another person exposes each bed partner to an extra 2 mREM per year! The American Nuclear Society has an excellent web page that allows you to calculate your own yearly exposure to ionizing radiation.

The Washington State Department of Health has set maximum, safe, occupational whole body radiation exposure as 5,000 mREM per year. This is the dose considered safe for people who work with ionizing radiation in their professional lives, including x-ray and nuclear technicians. It would take over 278 full mouth series of dental x-rays to equal this same amount of radiation set by the Department of Health. It would take 2,500 panorex films to reach this limit which is equivalent to 5,000 individual x-ray films. The use of digital radiography further reduces exposure to about 1/3rd the amount of mREM exposure. It would take 50 full series x-rays (taken with a digital sensor) or 360 intraoral films to equal the amount of radiation average citizens are exposed to from naturally occurring background sources each year.

The table on the next page, adapted and updated form the American Dental Association website, is helpful when comparing radiation received from dental x-rays to radiation received from medical and natural occurring sources.

<table>
<thead>
<tr>
<th>Dental Radiographs Exposure</th>
<th>mSv</th>
<th>mREM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single, intraoral (film averages)</td>
<td>.0075-.0095</td>
<td>.75-.95</td>
</tr>
<tr>
<td>Single, intraoral (digital averages)</td>
<td>.0025-.0032</td>
<td>.25-.32</td>
</tr>
<tr>
<td>Bitewings (four films, D speed)</td>
<td>.038-.013</td>
<td>3.8-1.3</td>
</tr>
<tr>
<td>Bitewings (four digital radiographs)</td>
<td>0.15-0.05</td>
<td>15-5</td>
</tr>
<tr>
<td>Full mouth series (approximately19 films)</td>
<td>0.019</td>
<td>1.9</td>
</tr>
<tr>
<td>Panorex (panoramic jaw film)</td>
<td>0.019</td>
<td>1.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Medical Radiographs Exposure</th>
<th>mSv</th>
<th>mREM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower GI series</td>
<td>4.06</td>
<td>406</td>
</tr>
<tr>
<td>Upper GI series</td>
<td>2.44</td>
<td>244</td>
</tr>
<tr>
<td>Chest</td>
<td>0.08</td>
<td>8</td>
</tr>
<tr>
<td>Average radiation from space, Denver, CO</td>
<td>0.51</td>
<td>51</td>
</tr>
<tr>
<td>Average radiation in the U.S. from natural sources</td>
<td>3</td>
<td>300</td>
</tr>
</tbody>
</table>
Dangers to X-Ray Technicians

Radiation doses described in the table pertain to patients. Radiation received by technicians comes exclusively from scatter which is most easily understood by thinking about a flashlight aimed at a wall in a completely dark room. The spot on the wall where the flashlight is aimed is the brightest, because it is directly in front of the beam of light.

However, the rest of the room is dimly illuminated by the light that scatters off the wall. Technicians receive scattered radiation. Scattered radiation falls off (in strength) as the square of the distance from target. For example, a person standing six feet from the target receives $\frac{1}{9}$ as much scatter radiation as does a person standing two feet from the target. Six feet is three times as far as two feet. Three squared equals nine.

Contrast, Density, and Related Dental Imaging Terms

To evaluate dental x-ray quality and optimize images, it is helpful to understand some terms. Two measures of dental x-ray quality are density and contrast.

Note: Although the terms density, contrast, and subject contrast have the same meaning when using a digital sensor as when using film, these radiographs are processed electronically, not chemically. Film contrast and processing are relevant to the software and sensors owned by the practice.

Density

Optical density is the degree of film blackening after exposure and processing. Blacker areas indicated higher density. Density is measured by the ability of the silver in the film to stop light from passing through. X-ray films with too little density appear too light, and films with too much density appear too dark. In either case, detail is lost. Detail is washed out on light films and lost in films that are too dark.

| Low Density (underexposed) | Normal Density | High Density (overexposed) |

Two terms used to express common density values are D-min and D-max. D-min corresponds to the lowest possible density a particular film can achieve. D-max corresponds to the highest possible density a film can achieve. D-min values in intraoral films range from 0.2-0.3 and D-max values are 5.0 and greater.

Contrast

Contrast is differences in optical density (film blackening) in a radiograph between areas of interest. Contrast is critical for distinguishing objects. In a dental x-ray image, contrast is influenced by three factors: subject contrast, film contrast, and processing. In the films
pictured below, notice the difference in the appearance of caries on the #2 mesial as images increase in contrast from left to right.

Low Contrast                            Medium Contrast                       High Contrast

Subject Contrast
Subject contrast results from differential attenuation of x-ray beams by the subject being imaged. As x-ray radiation passes through patients’ soft tissue, bone, and teeth, it is absorbed to various degrees depending on the tissue it encounters. Teeth absorb more x-ray radiation than do soft tissues. Fewer x-ray beams pass through teeth and strike the film. The area of film that corresponds to teeth will appear lighter than areas corresponding to soft tissues.

Film Contrast
Film contrast is a characteristic of film itself. If exposed and processed correctly, films are optimized to deliver very dark blacks and very light whites. Films with excellent contrast help dental professionals adjust for other variables during the imaging process.

Processing
If processing temperature is too high, image densities will be too high and detail will wash out. If processing temperature is too low, images will be too light. Chemical solutions must be fresh to work properly. Old chemicals are not as active which results in light images. Cold chemicals produce coarsely grained radiographs. Subject detail may not properly resolve even if time is increased to compensate for density.

Cold Chemicals                           Chemicals at Proper Temperature
Film Speed

A common misconception in dentistry is that slower speed films are always better for dental x-ray imaging than faster film speeds. Early generations of film did require users to trade off between speed and image quality. E or F speed film looks grainier than a D speed film. However, research has proven that faster films do not negatively affect diagnostic efficacy. In recent years, technology has improved even more.

Film speed is a term that refers to how efficiently light sensitive agents in film emulsion react to energy (x-ray or light) exposure. Two film speeds most commonly used in dental imaging are D speed and E speed films. Recently, Kodak introduced a true F speed film. D speed is the slowest film; F speed the fastest.

Faster radiographic films detect the image forming element (light for photographic film, x-rays for intraoral x-ray films) more efficiently than slower films. In dental imaging, faster films reduce radiation exposure while still providing usable images. Kodak’s InSight is an F speed film which reduces radiation exposure up to 60% compared to D speed products.

A big breakthrough in film design was the development of T grain emulsions. The radiation sensitive compound in dental x-ray film is silver halide. Silver halide crystals are pebble shaped. Kodak scientists have discovered a method of manufacturing silver halide crystals in a flatter shape. Flat crystals intercept more light, but the total amount of silver does not increase. This results in an increase in speed with less grain. Kodak incorporated this technology into its E speed film, Ektaspeed Plus. Ektaspeed Plus delivers excellent image quality and reduces patient radiation exposure significantly.

Guidelines for Prescribing Dental Radiographs

Under FDA supervision, an expert dental panel developed guidelines for prescribing radiographs. The panel’s goal was to improve patient safety. Dentists use the guidelines to determine type of radiograph needed and how often and under what conditions radiographs should be taken. Dentists prescribe radiographs on the basis of clinical
observations and patients’ health histories. Patient selection criteria include descriptions of clinical conditions derived from signs, symptoms, and history that identify benefits from x-ray examination. The recommendations below are subject to each dentist's judgment and may not apply to every patient.

**Positive Historical Findings**
- Previous periodontal or endodontic therapy
- History of pain or trauma
- Familial history of dental anomalies
- Postoperative evaluation of healing
- Presence of implants

**Positive Clinical Signs or Symptoms**
- Clinical evidence of periodontal disease
- Large or deep restorations
- Deep carious lesions
- Malposed or clinically impacted teeth
- Swelling

**Evidence of Facial Trauma**
- Mobility of teeth
- Fistula or sinus tract infection
- Clinically suspected sinus pathology
- Growth abnormalities
- Oral involvement in known or suspected systemic disease
- Positive neurological finding 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
High Risk of Carious Lesions Possible

- Failing existing restoration(s)
- Poor oral hygiene
- Inadequate fluoride exposure
- Prolonged nursing (bottle or breast)
- Diet with high sucrose frequency
- Poor family dental health
- Developmental enamel defects
- Developmental disability
- Xerostomia
- Genetic abnormality of teeth
- Many multi surface restorations
- Chemo or radiation therapy

The table on the following page, recommended by the American Academy of Pediatric Dentistry, lists protocols for taking patient radiographs.

<table>
<thead>
<tr>
<th>Patient Category</th>
<th>Child</th>
<th>Adolescent</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Dentition (prior to eruption of first permanent tooth)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Transitional Dentition (following eruption of first permanent tooth)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Permanent Dentition (prior to eruption of third molars)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dentulous</strong></td>
<td></td>
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<tr>
<td><strong>Edentulous</strong></td>
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</table>

**New patient**
All new patients to assess dental diseases and growth and development

- Posterior bitewing examination if proximal surfaces of primary teeth cannot be visualized or probed
- Individualized radiographic examination consisting of periapical/occlusal views and posterior bitewings or panoramic examination and posterior bitewings
- Individualized radiographic examination consisting of posterior bitewings and selected periapicals. A full mouth intraoral radiographic examination is appropriate when the patient presents with clinical evidence of generalized dental disease or a history of extensive dental treatment.
- Full mouth intraoral radiographic examination or panoramic examination

**Recall Patient**
Clinical caries or high risk factors for caries

- Posterior bitewing examination at six month intervals or until no carious lesions are evident
- Posterior bitewing examination at 6 to 12 month intervals or until no carious lesions are evident
- Posterior bitewing examination at 12 to 18 month intervals
- Not applicable
### Intraoral Film Placement Techniques

Intraoral films are taken with film inside the mouth. They include periapical films, bitewing films, and occlusal films.

Periapical radiographs help diagnose issues with teeth, bone, the lamina dura, and periodontal ligament. Films must include at least three to four millimeters beyond the apex of the tooth being x-rayed.

Bitewing radiographs diagnose problems with crowns and interproximal areas. Decay, calculus, overhanging margins, and interproximal bone loss are best detected in bitewing x-rays, because teeth are not overlapped as in some perapical images.

Occlusal films are used to diagnose disorders of the jaw or palate.

Panoramic films, when combined with intraoral bitewing films, are an excellent screening device. A panoramic film can serve as primary film in situations in which resolution is not an overriding factor or if intraoral films are not possible.

### Radiographic Surveys

Three common series of radiographs taken in dental practice are bitewing surveys, full mouth surveys, and panoramic film. Bitewings consist of a premolar and molar view of each side of the mouth taken in occlusion (two or four films). Full mouth surveys consist of an x-ray series that represents every tooth in the patient’s mouth (with three to four millimeters of surrounding bone) and all other tooth bearing areas of the mouth even if
edentulous (no teeth present). Bitewing x-rays are taken to examine premolar and molar contact areas, and periapicals for teeth and edentulous areas.

**The Bitewing Series**

A bitewing series consists of either two or four films taken of the back teeth (although some offices take them on front teeth as well). The patient bites down, so films contain images of both top and bottom teeth. A bitewing series is the minimum set of x-rays most offices take to document the internal structure of the teeth and gums.

With children under 12 years, two films one on either side, are sufficient. On patients over 12 years, it is advisable to take two on either side to account for the increased distal dimension added by second and developing third molars and to adjust for differences in the mesial/distal angulation between molars and premolars. On patients over age 25, it is prudent to take a full x-ray series.

This example of a full mouth series consists of four bitewing films which are taken at a specific angle to look for decay, and 14 periapical films which are taken from other angles to include root tips and supporting bone. Not all full series look exactly like this, but they all include some combination of bitewing and periapical x-rays. New full mouth series are taken at intervals determined by assessment needs.

Note that each tooth is seen in multiple films. Redundancy provides dentists much information not learned from clinical examination alone. X-rays are taken from slightly different angles which reveal different tooth aspects. Shadows may be longer or shorter that objects which cast them depending on the angle of the light source and screen.
upon which they are projected. Different angulation may cause some structures to overlap. Some views may obscure important information.

Start full mouth series x-rays with anterior views, because easy film placement establishes credibility with the patient. The patient will better relax as molar films are placed. The recommended order for taking a full mouth series is:

Maxillary arch
1. Central and lateral incisors
2. Right cuspid
3. Right bicuspid
4. Right molars
5. Left cuspid
6. Left bicuspid
7. Left molars
8. Bitewings

Mandibular arch
1. Central and lateral incisors
2. Right cuspid
3. Right bicuspid
4. Right molars
5. Left cuspid
6. Left bicuspid
7. Left molars
8. Bitewings

Maxillary Central and Lateral Incisors
Begin the full mouth series with the maxillary central incisors. Patients tolerate this film easily. Insert film vertically into the holder. The beam should pass perpendicularly to the film plane and the film should be placed at 90° to the interproximal area of the maxillary central incisors. The film should be placed well into the palatal region up to the second bicuspid. The curve of the palate may prevent parallel placement of the film.

Maxillary Cuspid
To take x-rays of maxillary cuspids, film is placed vertically into the holder. Center the film on the cuspid, and place the film well into the palate. Place the central x-ray beam perpendicularly to the film and at a right angle to the long axis of the tooth. The mesial contact should be open, but often the distal contact is unavoidably overlapped. The next film will display the distal contact area.

Maxillary Bicuspid
For maxillary bicuspsids, film is placed horizontally into the holder. Contact between the first and second premolars center on the film with the central x-ray beam perpendicular to the film. Contacts for the distal of the canine through the distal of the second premolar should be open. Sometimes, a cotton roll will need to be placed between the
bite block and mandibular teeth. This will stabilize the bite and keep the block from rotating.

**Maxillary Molars**

With maxillary molars, film is placed horizontally into the holder. The second molar centers on the film and the central x-ray beam is perpendicular to the film. The contacts of the first, second, and third molars should be open. The third molar region should be included in this film even if the tooth is not present. It may not always be possible to place film parallel to the teeth. If not, refer to the shadow casting section of this course to learn how to split the angle between the tooth and film.

**Mandibular Anteriors**

With mandibular anteriors, film is placed vertically into the holder. The mandibular central incisors are centered on film with the central x-ray beam perpendicular. Contacts between central incisors should be open. Film should be placed as far into the patient’s mouth as possible without causing discomfort (usually to the second premolar). The tongue is moved back and should not be between the film and teeth. Lateral incisors should be visible in this film. Two smaller films may be used if the patient’s mandible is unusually narrow.

**Mandibular Cuspid**

With mandibular cuspids, film is placed vertically into the holder. The mandibular canine is centered on the film with the central x-ray beam perpendicular. The lateral and distal mesial contacts should be present in this film with the mesial and distal contact of the canine open. The tongue should be mildly displaced, so film can be inserted into the floor of the mouth and far enough away from the teeth so the film doesn’t bend.

Canine x-rays are rarely accomplished keeping film parallel to the tooth, because of the shape of the space available. It is more practical to place film at a steep incisal/apical angle and use the split angle technique to aim the beam.

**Mandibular Premolars and Molars**

With mandibular premolars, film is placed horizontally into the holder. The contact between the second premolar and first molar is centered on the film. The central beam should be centered on the film and perpendicular to the long axis of the tooth. Film should contain the distal of the canine through the mesial of the second molar. Premolar contacts should be open and film should be placed as far into the mouth as possible. Mandibular premolar films include a complete view of the mandibular first molar. The trick to taking the premolar shot is to position the film as far anteriorly as the curvature of the mandible will allow.
With mandibular molars, film is placed horizontally into the holder. The second molar is centered on the film with the central beam perpendicular. The contacts between molars should be open, and the distal of the third molar region should be visible even if there is no tooth present. Be careful placing these films, because sharp edges can be uncomfortable to the patient. Instruct the patient to gently close rather than bite the film holder.

**The Tongue**

There are two keys to placing film painlessly in mandibular molar and premolar areas. The first is to explain to the patient that there is enough room if they relax their tongue. Nervous patients raise their tongue causing the mylohyoid muscle to contract and the floor of the mouth to rise. When the patient relaxes their tongue, there is much more room in which to place the film and therefore, less pain.

The second key to placing film is to angle the film to the lingual, medially toward the tongue. This positions the film edge well away from where the mylohyoid muscle attaches on the lingual aspect of the mandible.

Once film is placed, it is easy to push the dorsum of the tongue out of the way in order to bring the film parallel to the tooth. The mylohyoid muscle slopes inferiorly as it approaches midline, and when the inferior film border is placed into position, it is less likely to encounter strong resistance.

Not every patient can be persuaded to relax their tongue, and it is not always possible to extend the inferior border of the film so that it falls below the apices of the teeth. In this case, place the film at a steep angle leaving the inferior film border angled far lingually to the top of the film. Aim the beam from a low angle. This will shift the shadow up, so the apex will appear on the film. Note: this will also foreshorten the tooth image on the film.

**Panoramic Film (Panorex)**

Panoramic film is a large, single x-ray film that shows the entire bony structure of the teeth and face. It images a much wider area than any intraoral film and shows the sinuses, temperomandibular joints, and wisdom teeth as well as any pathological tumors and cysts. Panoramic films are quick and easy to take and cost just a little more than a full series of intraoral films. In addition to medical and dental applications, panoramic films are good for forensic purposes such as identification of victims of crime or disaster.
A disadvantage of panoramic surveys is low resolution. Intraoral films are crisp and sharp whereas panoramic films show slightly fuzzy outlines. Panoramic films are not good for diagnosing caries. However, if a patient has a gagging problem, a panoramic film may prove adequate.

Panoramic films are entirely extraoral. They are considered tomographs. Tomographs are computer assisted and focus x-ray beams on specific tissues. They image that tissue on film as if there were no other structures outside that particular tissue. Panoramic films are advantageous for use with patients with a strong gag reflex, and it takes little radiation to expose these films. The film cassette contains an intensifying screen which fluoresces upon x-ray exposure.

**Patient Management**

Patients often view x-ray procedures with disdain. They may have had bad experiences, and sometimes, children are overwhelmed. Operators displaying confidence and compassion can do wonders for patient compliance.

**Gag Reflex**

The key to control gagging is breathing through the nose, or holding the breath. When the posterior tongue blocks the throat, gagging does not occur. To position the tongue, ask the patient to open his mouth as wide as possible and then hum through the nose. If noise comes through the mouth, ask the patient to block the throat with the back of his tongue and try humming again.

Once the patient is humming through his nose with his mouth wide open, tell him to inhale through his nose with his tongue in this position. With breathing controlled this way, patients are less likely to gag. It sometimes helps to lighten the mood by asking the patient to hum a tune for a few moments while you listen and congratulate him on
his fine singing voice! As long as patients remember to breathe through the nose and open wide while you insert films, the gag reflex is easy to control.

Although gagging is a physical reaction, it has a psychological component as well. With patients who gag, it is best to start the film series with anterior or premolar films. These are placed further forward in the mouth and are less likely to stimulate the gag reflex. This helps the patient realize they can successfully have x-rays taken.

Don’t leave the film in the patient’s mouth any longer than necessary. Set up the machine and complete all necessary tasks before placing film in a patient’s mouth. Instruct the patient to breathe through his nose while placing film, and set the film with confidence. If the patient gags, reassure him that this is common, and that you know what to do to control it.

There are mouth washes and throat lozenges available that anesthetize the mouth. Some practitioners swear by salt on the tongue, while other practitioners ask patients to concentrate on objects or pictures in the room. Tell patients to breathe through the nose. Since the gag reflex is triggered by psychological factors, ask patients to concentrate on something else.

**Concerned Patients**

Patients will sometimes refuse x-rays. Many do not want to be exposed to radiation. Explain that radiation risks in the dental practice are small in comparison to diagnostic benefits. Also explain that every effort is made to expose patients to the least amount of radiation possible. If a patient has recently had x-rays for medical purposes, she may not want to be exposed again. Each case will be different. If a patient still refuses x-rays, have the dentist speak to her. To establish your credibility, every effort should be made on your part to explain the situation to the patient.

Safety issues are best resolved by explaining to patients that the amount of radiation received from dental x-rays is so small, it would take 20 full series surveys (360 films in all) to equal the same amount of radiation received from normal environmental background sources over the course of one year. It may be helpful to have a printed handout available that contains this information.

If a patient is pregnant, or thinks she might be pregnant, it is probably best to consult with the patient's physician before any x-rays are taken, especially if the patient is in her first trimester. If a patient thinks she might be pregnant, it is wise to postpone routine x-rays.

**Informed Consent/Informed Refusals**

Patients should be given information about benefits and risks associated with radiation exposure. Patients must specifically express their permission to have x-rays taken and should sign an informed consent document. Also, patients should sign a document which states they have been informed of the risks involved by not having diagnostic x-rays taken (informed refusal).

**Film Processing**
X-ray film is made of blue tinted plastic covered in an emulsion. The emulsion contains gelatin and silver halide crystals. Silver halide crystals are energized by radiation exposure. When film is exposed to x-rays, energy reacts with silver halide crystals and creates latent images depending on tissues the x-rays have passed through. The image is latent, because it does not appear until the film is developed.

Tooth fillings block out most of an x-ray beam. Conversely, interproximal spaces let most radiation through. When film is developed, crystals in those areas of film are full of stored energy and will precipitate on the film base as black metallic silver particles. The ability of different tissue densities to absorb radiation is called attenuation. Over time, latent images will disappear, so it is best to process x-ray films as soon as possible after exposure. Film should be stored in a refrigerator to slow attenuation if immediate processing is not possible.

When x-ray films are immersed in developer chemicals, the developing chemicals soak into the film gelatin and react with silver halide crystals. Energized crystals form metallic silver and bromide. In metallic form, silver appears black. Silver is deposited onto the film and causes darker areas. Crystals that are not energized wash away by the fixer, and that area of the film remains white.

The developer reacts with energized crystals to make black areas, and the fixer removes unenergized crystals and leaves those areas white. If the film comes out too dark, it is because it is overexposed (too much radiation) or overdeveloped. If the film is too light, it is underexposed, underdeveloped, or over fixed.

**Manual Processing**

Most offices have an automatic processor and tanks for quick processing. At some time in your career, you may be called upon to develop x-rays manually. The chemicals and theory are the same as with an automatic processor.

The most important factors when developing film are the temperature of the chemicals and the amount of time the film is in contact with chemicals. The higher the solution temperature, the less time needed. The ideal time and temperature for manually processing film is 4 1/2 to 5 minutes at 68ºF. Keep a non mercury thermometer and a timer, accurate in minutes and seconds, in the darkroom to check your solution.

After film is submerged in developer for the proper amount of time, it must be rinsed in clean, circulating water for 30 seconds. Then submerge it in fixer for at least ten minutes. Rinse film with clean, running water for at least 20 minutes to remove all chemicals and silver and hang to dry (or a commercial drying machine or product can be used).

Keep chemicals and water in the darkroom with the developer in the first tank, water bath in the center, and fixer in the third tank. The fixer has a strong vinegary smell. Stir solutions so temperature is even throughout before submerging x-rays. Use different instruments to stir the developer and fixer so the two aren't contaminated. Make sure solution levels are adequate to cover films as they are dipped, and add appropriate chemicals if necessary.

Chemicals should be between 65 and 75ºF (18 to 24ºC) when manually processing film. Adjust the temperature of incoming water to regulate temperature. Given time, the
Advanced Radiology

Chemicals will be the same temperature as the water. The patient's name and date of exposure should be secured somewhere on the rack.

Make sure to turn off the overhead white light and use the safe light. Clip the films firmly to the hanger. Use a timer--don't rely on your memory. Rinse film in between solutions. The final wash should last 20 to 30 minutes. If films are in water for more than an hour, the emulsion may begin to wash off. If films are left in water overnight, they will be clear in the morning.

Chemicals should be handled according to manufacturer's directions. Chemicals must be checked daily and replenished as needed. Every day, six ounces of developer should be removed and replaced with six ounces of fresh developer. Stir the solution to mix well. The fixer should be replenished daily by removing three ounces and replacing it with three ounces of fresh solution.

Chemicals must be completely changed according to manufacturer's directions. There are many factors such as number of x-rays developed, exposure of chemicals to air, and amount of water dilution that determine when it is necessary to change out solutions. The daily checker film is a good indicator of when to change solutions.

**Darkroom**

The darkroom should be kept clean. Chemical fumes can affect the film emulsion, so store unused film in another room. There should be plenty of room to work, especially near the processing tanks. The best darkroom temperature is 70 to 80ºF at 70% humidity. The room should be totally dark with no cracks where light might shine in. There should be hot and cold running water (so solution temperature can be regulated) near the tanks. A white light source and safe light should be available at least four feet away from the working surface.

**Automatic Film Processing**

Automatic film processors develop radiographs more quickly than manual processing, and automatic film processors produce consistently good results. Processors use a heating element to keep solutions at a constant temperature, usually between 85 and 105ºF. Higher temperatures shorten developing time. A series of rollers inside the unit guides film through the chemicals. The rollers disperse chemicals evenly over the film. A roller at the end of each tank squeezes off most the chemicals so there is no mixing or dilution of chemicals.

In automatic processors, the most frequent causes of failure are dirty rollers and old chemicals. Chemicals should be replenished at the beginning of the day. After four full mouth surveys or panoramic film series, the chemicals need four to six ounces of new solution. Rollers soaked for 10 to 15 minutes and washed once a week with warm running water. Two large, extraoral films should be run through the machine to clean the rollers.

Depending on the rate of use, solutions should be changed every two to six weeks. Follow guidelines and use solutions recommended by the manufacturer. Empty all chemicals in an orderly manner so they don't mix. Follow manufacturer's recommendations regarding lubrication, maintenance schedules, and general use. The
cover should be kept slightly ajar when the machine is not in use to let fumes disperse and keep moisture from accumulating on the motor. Feed films in at the recommended rate. Feeding too fast can cause films to stick together.

**Film Duplication**

X-ray films may need to be duplicated if the patient moves, is referred to a specialist, must be preauthorized for insurance, or if x-rays need to be sent outside the office. Originals stay in the patient's chart as permanent office records. Operators can use double films (the type with two films in the same packet) for x-rays that must be sent outside the office. Double films yield two films while exposing patients to radiation only once.

Film duplicators can be used when originals have already been taken. Duplicating film is sensitive to light and becomes lighter when exposed. Regular x-ray film becomes darker when exposed to light. The duplicating procedure takes place in the darkroom with safelights on. Radiographs to be copied are mounted in a special mount designed for duplication with the embossed (raised) dot side down for optimal contact with the duplicating film. These radiographs are placed on the duplicator and the duplicating film is placed on top with the emulsion side against the radiograph originals. Expose according to manufacturer's recommendations. The film is processed in the same way as regular x-rays.

**Qualities of Excellent X-Rays**

Diagnostically useful radiographs have specific visual qualities. X-ray images are a combination of black, white, and shades of gray. Contrast shows definition of the structures and tissues x-rayed. The denser an object is, the more it blocks x-ray beams. Dense tissue appears white on x-rays. Degree of contrast depends on the type of film used, how the film is processed, and the film density.

Extraoral films have their own inherent contrast. Incorrect developing can ruin film contrast by lightening or darkening subtle shades of gray. Over developing will make film too dark; under processing will make film too light. A film with good contrast will include the darkness of soft tissue, the lightness of amalgam, and the subtle shades of gray in the nerve canal and trabecular bone. Film contrast is determined by:

- Thickness of the patient's tissues
- Density of his hard tissue
- Anatomic number of the patient’s tissue

The operator should consider these variables and adjust exposure time to compensate for each if possible.

Density is another important x-rays characteristic. Density is dependent on the amount of radiation that penetrates tissues and reaches film, the distance from the x-ray tube head to the patient, the subject tissue thickness, and the way the film is developed.

Dental x-ray units will be set for different kV and mA; time settings for the same film on the same patient may vary from machine to machine.
The higher the amperage (mA) the more intense the x-ray beam, and the darker the film will be.

The higher the voltage peak (kVp) the more energy is produced, the more intense the x-ray beam, and the darker the film will be.

The farther the patient is from the source of the x-ray beam, the less intense the beam, and the lighter the film will be. This varies with the design of the head of the x-ray unit being used.

The longer the film is exposed, the darker the film will be. This is the one variable that the operator can always adjust to compensate for the other three variables.

The detail quality on a radiograph is called resolution. Low resolution films look fuzzy; high resolution films are sharp and crisp. Films can lose resolution if the patient or film moves during exposure. Tube head movement will not cause blurry distortion, because x-rays emerging from a long cone are parallel, and the tube head swings or drops in such a way that the beam angle does not change. As long as the beam angle remains the same, parallel x-rays do not cast a moving shadow.

A good radiograph will contain the following characteristics:

**Periapical Radiographs**

- The correct anatomic area should be represented.
- Three to four millimeters (1/4 inch) of alveolar bone should be visible beyond the apex.
- Images should not be elongated or foreshortened.
- Radiographs should have acceptable density.
- Radiographs should be free of film handling or processing errors.
- Interproximal contacts should not overlap.
- There should be no cone cuts.
- The embossed (raised) dot should appear at the incisal or the occlusal edge.
- In a complete mouth radiograph series, the apex of each tooth should be visible at least once, preferably twice.

**Bitewing Radiographs**

- Interproximal contacts should not be overlapped from the distal surface of the canine to the mesial surface of the third molar.
- Crowns of the maxillary and mandibular teeth should be centered in the image from top to bottom.
- The crest of alveolar bone should be visible with no superimposition of the crowns of the adjacent teeth.
- The occlusal plane should be as horizontal as possible.

**Common Errors**
Operator Errors

Operator errors with film placement and tube head angulation often result in undiagnostic x-rays. Undiagnostic x-rays must be retaken. Every effort should be taken to minimize errors, because each retake exposes patients to more radiation.

Film Placement

Correct film placement is critical for success with x-rays. If the correct technique is followed every time, positioning errors will be minimized.

- In all premolar views, the distal of the cuspid is visible.
- All molar views should contain the third molar region even if the tooth is not present in the mouth.
- When focusing on a specific tooth, it should be centered on the film.
- Film must be placed high enough in the palate or low enough in the floor of the mouth to clearly show the apex of the tooth in question and three to four mm of bone.
- If possible, films should not be bent, but if the patient is uncomfortable with the edge, try gently reshaping the edge and repositioning the film in the mouth. Ask the patient to gently close. This often decreases discomfort, especially in the floor of the mouth.
- Before placing a film in a patient's mouth, check to make sure it is not backward. The lead foil will leave an artifact on the exposed x-ray, and it will be confusing to mount.
- Make sure exposed films are not mixed up with unexposed ones.

Angulation of the Tube Head

Tube head angular errors are common. When using an instrument, make sure the tube head is aligned correctly, parallel with the indicator rod, and aligned with the ring if the operator is using a Rinn apparatus. If not using a Rinn, the beam should be parallel with the bitewing tab, or at an angle that splits the difference between the angulation of the film and the angulation of the tooth.

Film positioning devices are helpful and, when used correctly, produce effective results. When a patient's anatomy makes using a positioning device difficult, it is best to use the bisecting angle technique. For example, if the patient has a shallow palate, and the instrument will not allow the film to be parallel with the long axis of the tooth, compensate for this by using the split angle technique to avoid foreshortening.

Overlapping is another common angulation error. If the cone is not perpendicular to the film, the contacts will overlap. Some offices routinely use a size three film for a bitewing view that contains all teeth from premolar to molar. Due to the curve of the arch, some area is bound to be overlapped. It is better to position two size two films in a premolar view and then molar view so all contacts will be open.

Cone cutting is another common error. This happens from positioning the cone too far to the distal (mesial cone cuts are the most frequent kind). The film will be cone cut
when the tube head is not covering the whole area of the film. The best way to avoid this is by looking at the film in the patient's mouth and aiming the cone head directly toward the film instead of guessing from extraoral landmarks. Ask the patient to grin wide like the Joker (in the movie, Batman) so you can see down the buccal corridor (the area between the buccal surfaces of the teeth and the buccal mucosa). This makes it much easier to aim the cone.

If the patient moves, the film will be affected. Watch the patient as you expose the film to make sure he doesn't move. The patient should be instructed to hold still and not swallow.

Correct film processing procedures were previously discussed in the section on film processing, but the following table summarizes common film processing errors, the results, and possible solutions.

<table>
<thead>
<tr>
<th>ERROR</th>
<th>RESULT</th>
<th>SOLUTION</th>
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</thead>
<tbody>
<tr>
<td>Developer temperature too low</td>
<td>Films too light</td>
<td>Check and adjust temperature</td>
</tr>
<tr>
<td>Developing time not long enough</td>
<td>Films too light</td>
<td>Use a timer</td>
</tr>
<tr>
<td>Developer solution too old or diluted</td>
<td>Films too light</td>
<td>Keep a schedule of chemical maintenance</td>
</tr>
<tr>
<td></td>
<td>Yellow or brown film</td>
<td>Change solutions when this begins to happen consistently</td>
</tr>
<tr>
<td>Developer too warm</td>
<td>Film too dark</td>
<td>Check and adjust temperature</td>
</tr>
<tr>
<td>Developing time too long</td>
<td>Film too dark</td>
<td>Use a timer</td>
</tr>
<tr>
<td>Light leak in processing</td>
<td>Film too dark</td>
<td>Check processor and darkroom</td>
</tr>
<tr>
<td></td>
<td>Foggy film</td>
<td></td>
</tr>
<tr>
<td>Film exposed to light before processing</td>
<td>Film too dark</td>
<td>Don't open film until safety light is turned on and other lights are off</td>
</tr>
<tr>
<td></td>
<td>Foggy film</td>
<td>Check safety light for leaks</td>
</tr>
<tr>
<td>Film exposed to radiation after exposure</td>
<td>Foggy film</td>
<td>Take exposed films out of room when exposing other radiographs</td>
</tr>
<tr>
<td>Fixer too old or contaminated</td>
<td>Yellow or brown film</td>
<td>Check with checking film</td>
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<tr>
<td></td>
<td>Green film</td>
<td>Replenish and maintain on schedule</td>
</tr>
<tr>
<td>Incorrect rinsing between developer and fixer</td>
<td>Streaking</td>
<td>Follow proper protocol for rinsing between chemicals</td>
</tr>
</tbody>
</table>
### Mounting Films

Films must be mounted consistently and correctly. The x-ray mount should include patient’s name, date of exposure, and the operator’s name.

In the standard method of mounting, the raised dot is oriented upward for bitewings and toward the incisal or occlusal edges with all periapicals. This dot is always facing the tube head. If this convention is followed, and if the dot is on the right of the film, the film image will be the patient's right side. If the dot is on the left side of the film, the film will be an image of the patient's left side. By orienting the dot toward the periapical occlusal or incisal edges, it will not interfere with periapical anatomical images.

When radiographs are dry, take them with the mount to a view box. Turn all films so the dots are facing up. Take all maxillary films and group them together. Put the bitewing x-rays to the side. Face all mandibular films (dot still up) with incisal edges and occlusal surfaces up and all maxillary films with incisal edges and occlusal surfaces down. Mount x-rays from the facial aspect (from the outside in) as if you are standing in front of the patient.

The films representing the patient’s left side are mounted on your right. Sort anterior films and mount them. Mount premolars then molar views. Mount bitewing films. Empty frames on the film mount should be blocked with an opaque film blank. Check that the dots are all on the same side and that objects and restorations on the periapicals match the same areas on the bitewings.

Check root curvatures to make sure they are all pointing distally. The curve of occlusal edges should be upturned at the ends, like a smile. The most common orientation is with the dot raised (pimple), but some practitioners prefer to view x-rays with the dot oriented downward (dimple). The correct way to mount x-rays is according to the direction of the dentist who will be using them.

### Infection Control

It is important to review patients’ medical history before taking radiographs. Wear a clean pair of gloves and mask when working with patients. Disinfect the exposure button.
and tube head or cover it with a fresh protective barrier for each patient. Anything touched during the procedure should be disinfected. The instruments must be sterile and stored in a closed container. As soon as film is placed in the patient's mouth, it is contaminated. It should be placed in a cup behind the barrier.

When the series is complete, assemble all contaminated instruments in a container, and transport them to the sterilization area. Remove gloves and wash your hands. Transport film to the darkroom. Use a clean pair of disposable gloves in the darkroom to open packets. Remove film from the packets without touching them (the powder from the gloves will leave an imprint on the final film). Collect contaminated packets on a disposable paper towel. When all films are out of the packets, discard the towel and packets, and remove your gloves. After washing your hands, process films. Film packets can be decontaminated by wiping them with bleach before taking them into the darkroom.

**Barrier Envelopes**

Barrier envelopes are available for intraoral films. Film packets with barrier envelopes are positioned in the patient's mouth and exposed. After removing the exposed x-ray images, tear open the barrier envelope, and drop films into a clean cup without touching them. After films are placed in the cups, gloves can be discarded. This not only prevents any patient fluids from coming into contact with films, it also keeps powder from the gloves from being deposited onto films.

**Direct Digital Radiography (DDR) Sensors**

Effective cross contamination prevention is critical for direct digital radiography, or DDR, sensors, which are not sterilizable. Current manufacturers’ recommendations for standard precautions are limited to plastic barrier sheaths which are commonly known to tear or leak. To minimize patient cross contamination, the Centers for Disease Control and Prevention recommends cleaning and disinfecting the sensor with an EPA registered intermediate level (tuberculocidal) disinfectant after removing the barrier and before use on another patient. Because sensors and associated computer components vary by manufacturer and are expensive, manufacturers should be consulted regarding specific disinfection products and procedures.

**Shadow Casting Principles**
Shadow casting is one of the most important concepts in dental radiography. Once practitioners understand positioning and angulation of various elements in radiography and the way ordinary shadows are cast the entire process of film and source placement becomes easier to understand.

In this section, I will discuss four terms: source, receptor, object, and angulation. I will also draw analogies between dental radiographic techniques and everyday examples of casting shadows.

The radiographic source of light (x-rays) is the focal point in an x-ray tube. The receptor in radiographic technique is film or the CCD of a digital radiographic sensor. The source in our analogy is the sun. The receptor is the ground.

**Principle One**

X-rays should be emitted from the smallest source of radiation possible. Large sources cause fuzzy images. As electrons strike the focal spot in the x-ray tube, x-rays are emitted. The smaller the focal spot, the greater the detail. Manufacturers govern the size of the focal spot; it cannot be changed by operators. However, the focal spot can become enlarged over time due to continuous use. When focal spot enlargement does occur, x-ray images become less sharp. The focal spot must be monitored through a quality assurance program. Resolution test devices will determine any change in focal spot size.

![Diagram of Penumbra and Umbra](image)

Large sources of light emit rays from their entire surface. In the illustration above, a round disk is placed in the path of a large light source and casts a shadow on the blue wall. The disk is seen edge on, while the shadow is shown as if you were looking at the wall directly. A penumbra is the shadow behind an object lit by a light source (in contrast to a point light source). The penumbra doesn't have sharp boundaries. This is because, each point in the boundary area is only partially shadowed. The area in full shadow is the umbra.

**Principle Two**

The x-ray source to object distance should be as long as possible. The use of a long position indicating device (a long cone which is also lined with lead) will enable x-ray photons to emerge in a less divergent beam, therefore producing a more accurate shadow. The term collimation describes how divergent a beam is. Long cones produce better collimated (less divergent) beams. Longer source to object distances reduce
magnification and increase image sharpness. The resulting image will be a more accurate and sharper presentation of the sizes of various radiographic structures.

In the illustration above, the beam is more divergent emitted from the short cone in the top figure than it is in the long cone in the bottom figure. The beam from the short cone casts a larger illuminated circle on the wall than the beam from the long cone. Rays are more divergent with a short source to object distance than they are with a long source to object distance. This characteristic is actually quite useful when taking panoramic radiographs.

Substitute a slide projector for the light source, and stand several feet from a wall. If the projector is located a long distance from you, your shadow will be more of an accurate representation of your height and width. On the other hand, if the projector is closer to you, your shadow is magnified in all directions and is no longer representative of your height and width. (Note: In some machines, especially newer ones, the external cone may appear short, but the point source is located in the back of the housing which extends the cone length internally.)

**Principle Three**

The object to receptor distance should be as short as possible. Placing the object close to the receptor reduces magnification and increases image sharpness. (This translates to placing the film or digital CCD as close as possible to the tooth.) Less sharp edges come from an exaggerated penumbra effect, even for fairly small point sources.

Consider an airplane flying at 10,000 feet on a sunny day. The airplane’s shadow on the ground may look quite sharp to us as we gaze down on it from on high, but to an observer on the ground, the shadow lacks sharp edges and is actually a great deal larger than the actual size of the airplane itself. On the other hand, once the plane lands, the shadow cast from the sun when it is directly overhead and unobstructed is almost the same exact size as the airplane itself, and the plane’s shadow has sharp edges.

**Principle Four**
The receptor and long axis of the tooth should be parallel. As in the paralleling technique, the distortion of the recorded image is decreased. A projector casting our shadow on a perpendicular wall shows a reasonable representation of our shape in the shadow. However, if we stand as the sun sets, our shadow on the ground gets longer and longer. The shadow elongation is greater at the feet than at the head. When the sun is directly overhead, our shadow is extremely foreshortened. This sort of distortion is important to understand when taking periapical films, since often, there is not enough room in the mouth to place film parallel to the teeth.

The image below left shows an extracted tooth lying flat on film with the x-ray beam aimed at 90 degrees to both. It shows the truest representation of tooth size and shape. In the x-ray on the right, the film and the beam are in ideal alignment, with the beam at 90 degrees to the film. However, the crown of the tooth was tilted up and lies at approximately 30 degrees to the film and beam. You can see the tooth in this image is foreshortened.

This image shows what happens when a Rinn apparatus is used to keep film and beam properly aligned while the apparatus itself is placed in the mouth. There is not enough space in the palate or the floor of the mouth to align the apparatus properly. The best (and easiest) method of compensating for this condition is to use a technique which splits the angle between the film and tooth.
The tooth in the image below is at the same angle as the image above. The difference in the images is due to the beam, because it was repositioned so that it split the difference in angle between the film and the tooth itself. Notice that the filling is slightly foreshortened, and the pulp chamber is visible in this image. The roots, on the other hand, are elongated compared to the roots on the image on the right above.

These effects are due to the non-parallel nature of the beam. (Refer to the photo of the man’s shadow with the very long legs on the previous page.) This is a consequence of adjusting the angle of the beam, so that we are shooting from a higher angle.
**Principle Five**

The x-ray beam should be perpendicular to the receptor. When this principle is not followed, the image will shift and cause overlapping of adjacent structures on the film. If the beam is at a lateral angle to the film while trying to take bitewing x-rays, crowns may appear to be overlapped thus obscuring the contacts. The Rinn film keeps the beam perpendicular to the film. Unfortunately, films are often not perfectly parallel with the teeth.

This is especially important when taking bitewing x-rays in which contacts between teeth must be clearly visible. Misangulation of the x-ray beam causes shadows of adjacent teeth to appear on the film which overlaps, obscuring caries and other anatomical structures.

The radiograph on the left was taken with all three elements, the film, teeth, and the beam in optimum alignment. The film is parallel to the teeth, and the beam is perpendicular to both. Notice that the contact areas between the teeth are clear and there is no overlap.

The radiograph on the right was taken with film and teeth parallel, but the beam is angled 20 degrees from the mesial. Notice the overlap of the contacts between the teeth. This overlap tends to obscure caries that may be present. Notice the root caries on #14 which is apparent in the radiograph on the left, but not in the one on the right.

Finally, notice the teeth have shifted to the mesial on the film in the image on the right which was shot from a mesial angle.

Picture a sharp shadow of your hand with fingers spread apart. As long as the hand is perpendicular to the sun or the slide projector, the shadow on the wall gives an accurate representation of the hand with fingers spread. Now imagine slowly twisting your hand so that the palm becomes parallel to the light. Even though you are keeping your fingers spread, the shadow shows the spaces between the fingers getting progressively smaller until the fingers overlap entirely and you can no longer discern separate fingers at all.

**Note:** Even if the beam and film are exactly perpendicular to each other, if the film is not fairly parallel with the mesial distal plane of the teeth, the adjacent teeth may still overlap at the contacts.
In the images above, the hand on the left is in the same configuration as the hand on the right. The position of the light source and the wall against which the images were shot has not changed. They are perpendicular. The only thing that has changed is the angle of the hand itself.

In the image on the right, the hand is no longer parallel to the wall (receptor). Note how the spaces between the fingers are disappearing as the fingers seem to overlap on the shadow. The same thing happens with bitewings when the film is not parallel with the teeth.

Perfect radiographic technique incorporates all five principles of shadow casting. Unfortunately, researchers have not found an ideal technique which meets all requirements for perfectly accurate shadow casting. The next section in this course helps you make use of distortions to your own advantage.

**Shadow Casting Tricks**

Having read the section on shadow casting principles, you can see why many radiographs may not come out the way you expect. The distortions in the finished product are result from incorrect alignment of the three components of radiographic technique:

1. The beam (source)
2. The object (the tooth or teeth)
3. The film/sensor (the receptor)

Almost all intraoral radiographs include some degree of distortion. There are two things that produce the best radiographs possible:

1. Align the three factors to reduce the distortion as much as possible.
2. Use, and even exaggerate distortions to your advantage.

**Bisecting the Angle**

There is an easily learned technique in which operators can overcome length distortions (foreshortening and elongation) caused by the near impossibility of keeping all three
elements (teeth, film, and beam) in ideal relationship when taking periapical films. It's called bisecting the angle, and once mastered, this technique can be used to produce the least distorted images on all periapical radiographs in a full mouth series.

There is a common misconception that the bisecting angle technique requires a short cone. Short cones have an advantage with this technique, because short cones create more divergent beams. This makes cone cutting less of a problem when exposing a film from a distance. Aiming is a bit more difficult with a long cone, but becomes less of a problem with practice.

Bisecting the angle technique works especially well in cases in which a low palate necessitates tilting a periapical film or sensor medially. While apical parts of teeth are slightly foreshortened, the coronal portions are equally elongated producing an overall image that is quite satisfactory. Once mastered, bisecting the angle technique can shorten time needed to expose a full mouth series. The technique also works especially well when taking periapical films for endodontic purposes, because the overall radiographic length of the tooth approximates very closely with the actual occlusal apical length of the tooth itself.

A Rinn apparatus may be used in this procedure; however the x-ray tube is not placed parallel with the ring. The ring and alignment arm may be helpful in visualizing film alignment in the mouth, but in fact, they are not necessary. When using film instead of a digital sensor, it is helpful if operators use disposable Styrofoam Stabe bite blocks. These bite blocks are compressible and keep film aligned with the plane of the teeth.

A helpful analogy is this. You stand upright on a flat tarmac. As the sun descends in the sky, it eventually reaches an angle at which time, your shadow on the ground is exactly as tall as you are. Your shadow is not entirely distortion free, but this is the least distorted shadow that can be achieved when the receptor (the ground) and the object (you) are not parallel to one another. This type image can be produced on x-ray films by splitting the difference between the tooth and film angle.

To accomplish this, use a dual aiming method. Place film in the mouth using a Stabe bite block or film holder from a Rinn apparatus without the ring or metal rod. Position the film as close to parallel to the long axis of the tooth as is possible. Position the x-ray tube perpendicularly to the film and note the angle of the tube. Call this position one. Then, reposition the tube perpendicularly to the tooth itself. Call this position two. Finally, reposition the tube so that it is at an angle that is exactly half way between positions one and two. This is the angle which will produce the least distorted shadow of the tooth being x-rayed.
Note: This technique becomes unnecessary as operators become familiar with bisecting the angle. Once mastered, this technique is faster and more accurate than using the Rinn. This technique always provides the least distorted shadow possible when the elements you can’t control (the angle of the film and the angle of the tooth) can be compensated for by the beam’s angle.

This technique is essential when taking occlusal films on a child. Occlusal films image erupted and unerupted incisors. The child bites on the film as he would bite on a piece of cardboard. The film is placed in the child’s mouth so it is almost perpendicular to the long axes of both the upper and lower incisors.

Aiming the beam perpendicularly to the film surface foreshortens the teeth since they are now parallel to the beam. Aiming the beam perpendicularly to the teeth elongates them, and the apexes are moved off the end of the film/sensor. But bisecting the angle produces a length corrected shadow of the teeth on film.

Rinn’s XCP-system film holders will keep film perpendicular to the x-ray beam which eliminates one source of distortion, but a Rinn system cannot eliminate distortion produced when film cannot be placed parallel to the teeth. With practice, developing a technique utilizing angle splitting procedures produces less distorted intraoral images and saves time.

**Moving an Image Forward, Backward, Up or Down**

Due to a patient's gag reflex, it is often impossible to position film or sensors posteriorly enough to get clear images of maxillary second or third molars. It is also often difficult to get periapicals of first premolars due to the mandible curvature or shape of the palate.

Moving an object up, down, right or left on a radiograph is a fairly easy trick in radiography. Moving an object on film takes advantage that films or sensors are generally three to four millimeters palatal or lingual to the teeth. The further you move lingually or tilt the film or sensor, the further you can move the tooth image.
Point your index fingers of both hands up, close your left eye, and hold the index fingers so that they are at about 4 inches apart.

Looking through one eye, line up the fingers so that one completely covers the other. Shift your hands, as a unit, right so that you are looking at the fingers from the left side. Notice as you look from the left, the finger closest to your eye seems to shift in the opposite direction from the right. When you shift the fingers left (so you are looking from the right side), the finger closest to your eye seems to shift in the opposite direction, to the left. The same thing happens when you shift the hands up or down. When you gaze at the fingers from above, the finger closest to you seems to move down. When you gaze at them from below, the finger closest to you moves up.

This is the effect of parallax, and we use it to get that difficult to image third molar, or to move the image on the film so that the root tip is not cut off, and so the crown is entirely on the radiograph. You never have to move the sensor if you have digital equipment. Just shift the tube head so the image shifts in the opposite direction. If you want a third molar to move mesially, shoot from the distal. If you need to drop the root tip of a maxillary molar back onto the film, take the x-ray from a higher angle. Remember, you must reangle the tube head toward the film, so the beam is aimed toward it.
The Clark Shift

The Clark Shift is an old trick used by radiologists to determine whether an impacted tooth, tumor, or other object is located to the buccal or lingual of roots of adjacent teeth. A radiograph is just a shadow, and a shadow is a two dimensional projection of a three dimensional object onto a screen. When you look at a single x-ray, you see two objects superimposed over each other. It is impossible to tell from that single film which of the objects lies to the buccal and which lies to the lingual or palatal.

If you take two images of the same field from two angles, parallax causes the buccal object to move distally and the lingual object to move mesially. This is how computerized tomographs make three dimensional reconstructions of anatomic structures. They take multiple shots from different angles, and using the rules of parallax, the object’s three dimensional structures are mathematically calculated.

The MBD rule: If you shoot from the Mesial, a Buccal object moves Distally. If you are taking two films of an impacted canine, and the canine tooth has shifted distally with respect to the lateral and first premolar roots on the image taken from a mesial angle, then it is located buccally of those roots.

The SLOB rule: Same Lingual, Opposite Buccal: This is a different way of saying the same thing as the MBD rule. If an object (on film) moves in the same direction as the cone, it is located on the lingual. (same lingual) If the object moves in the opposite direction, it is located toward the buccal. (opposite buccal)
This rule is a matter of parallax. When riding in a speeding vehicle and looking out a side window, an object on the horizon seems to be moving with you, while the telephone poles on the side of the road appear to be speeding past you in the opposite direction.

The two images above were taken from two different angles. The one on the left was taken straight on; the one on the right was taken from a mesial angle. Notice the buccal roots have moved distally with respect to the palatal root of the same tooth. When taking x-rays from the mesial, buccal objects move distally.

Digital Radiography

For many dental offices, the latest trend in technology is paperless technology. There are many benefits to having a paperless office. Files can be accessed and saved even after unforeseen events occur such as fires. The digital trend is making clinicians aware of the drawbacks of traditional films. One such drawback is the time it takes to handle or retrieve a patient’s film, and the time it takes to duplicate it for insurance companies or for patients.

Darkrooms cost more, and they require maintenance. Film requires an interconnected system in which there is room for processing errors to occur. This can mean increased radiation exposure for the patient due to retakes. Moreover, traditional film is not eco-friendly.

In the mid 1980s, Francis Mouyen at the University of Toulouse developed digital x-rays. At first images could not be stored. Software companies remedied the problem. Digital x-rays became recognized and first used in the United States after FDA (Food
Digital radiography is widely used and quickly becoming the preferred method for many dental professionals. Digital images can be transmitted via modem within seconds. Images can be inserted into a word processing document (such as treatment plans) and printed. Patient radiographs can easily be transmitted from one dentist to another without losing quality. Additionally, images can be manipulated to optimize brightness and contrast enabling dentists to enhance and view areas of concern.

Some say digital images are more graphic and detailed and therefore ideal to use for patient education. Digital radiographs can be magnified and displayed for patients. Patients can be shown caries, and periodontal bone loss can be measured. This is especially useful in endodontic procedures. Intensity, contrast, and brightness can be enhanced to make diagnosis more accurate. A great deal of time can be saved not waiting for records to be received through the mail.

It is more cost effective to use digital radiography. Clinical errors are eliminated, because mislabeling patient computer records does not occur. However, the most beneficial aspect of using digital radiography over traditional x-rays is less radiation exposure to patients! Offices using digital radiography should still follow FDA/ADA guidelines.

Critics of digital radiography present some concerns. The size of the digital sensor and holder is bulkier and more rigid than conventional x-ray film, and they are less comfortable for patients. Additionally, when using a digital system, a cord hangs out of the patient’s mouth causing further discomfort. However, there are many digital sensor aids that help with patient comfort and act as barriers to infection.

Infection control is an important concern. Specifically, infection control involves using barriers between patients and machines, because hardware is sensitive to common disinfectant chemical sprays. All dental practitioners should learn and practice manufacturers’ guidelines when disinfecting equipment.

Though digital radiography has many advantages there are concerns about the exclusive use of digital imagery. There are differences in size between digital and regular films. For example, digital detectors housed in the sensor are smaller than #2 films, and structures being filmed may not always be captured on one image. Sometimes more than one image must be taken to get the same structures that could have been seen on one #2 x-ray film.

Although digital imaging saves money and time, initial equipment costs are substantial. Solid state sensors are expensive, ranging between $8,000 and $10,000. There are yearly insurance fees. PSP plates used in the Phosphor Plate System method cost $30.00 each. They are fragile and tend to accumulate scratches with misuse.

There has been concern surrounding security of patient records stored on computer systems and the ability to tamper with stored records. However, it takes complex processes, knowledge, and equipment to breach security. When an image is saved and stored, it contains a creation date. Each digital image is connected to the patient’s file. There is no way to alter patient names. It is vital that the correct patient file is open on the computer before digital images are taken. This will guarantee images directly attached to a patient’s file are not misfiled.
Computers also track when images are accessed and altered. However, no matter what alterations are made, the image time stamp cannot be altered. Only limited changes can be made to images. Digital software companies use watermarks on altered images, so that both insurance companies and practitioners will know if an image has been changed. Images cannot be accidentally confused with another patient's records; x-rays coming out of a processor cannot be submitted to the wrong patient chart or insurance carrier.

**Digital Radiology Systems**

Indirect systems can utilize preexisting equipment. This means substantially lower costs than with other systems. Indirect digital radiology uses a traditionally exposed film and flatbed or slide scanner to copy images into a JPG or TIFF file that is stored in the computer. Clinicians can take pictures of traditional films with a digital camera and transfer images into digital format. Software from Televere Systems called TigerView copies images using a scanner and automatically arranges them in proper orientation and order. These images can be manipulated, rotated, and enhanced. Zoom, contrast, brightness, and orientation are also variables that can be manipulated. TigerView software is reasonable in cost but not as popular as Direct System software.

The semi direct system of digital radiology uses methods from both the direct and indirect systems. The semi direct system is similar to the indirect system in that stored images are scanned into the computer. The semi direct method uses a photo stimulable phosphor (PSP) also known as a storage phosphor plate. Phosphor plates temporarily store images until they are transferred into a computer. Special packets are used to hold phosphor plates. These look similar to traditional films.

Semi direct systems are more comfortable for patients than digital sensors used in the direct technique, because they are thinner. The phosphor is placed in the patient's mouth in the same way as standard x-ray films. Plates are covered with phosphor crystals which temporarily store x-ray proton energy. Crystals form latent images, similar to the ones formed on x-ray films. The plates are placed in a scanner that reads the image using a laser beam.

The scanner transfers images into patients’ computerized charts. Phosphor plates must be transferred to the scanner in darkness or the plates will be erased by ambient room light. To reuse plates, they are laid out in bright light which erases stored images. The direct system is much faster than the semi-direct or indirect system, and the images are marginally better.

The direct system works with a solid state sensor. The word direct refers to the digital image that is produced directly, without extra steps involved in having to manually develop a phosphor plate, or scan x-ray films into a digital file. There exist two types of sensors used in a solid state or direct system. The most widely used is the charge coupled device (CCD). CCDs are used in digital cameras as well as digital radiography.

A second system recently developed is called the CMOS sensor system, which works differently than CCDs but delivers similar results. A CCD is a semiconductor chip with a rectangular grid of millions of light sensitive elements used to convert light images into electrical signals. When images are taken, radiation energy stimulates sensors and creates images. There is a scintillation layer atop the electronic chip that turns x-ray photons into light photons.
Each of the millions of light sensitive elements in the CCD underlying the scintillation layer converts light photons into analog electrical impulses. Impulses are converted into numbers between 0 and 65536 (with the newest generation of sensors). The numbers transmitted correspond to the intensity of light transmitted to each tiny element in the rectangular array by the scintillating layer. In this way, images are converted to millions of pixels which are reassembled by the computer into a coherent image. CCDs used in dental imaging are the same as the CCDs used in digital cameras.

Digital radiographs are composed of many shades of gray spanning from black to white known as continuous tone images. This means shades of gray blend together with no noticeable interruptions. To convert data from the sensor into digital form, each image element is converted into a bit of information by an analog to digital converter. This information describes the light intensity (brightness) and its location in relation to the picture as a whole. Each small piece of information is called a pixel (short for picture element).

The computer reassembles the pixels in the correct order and brightness to build a digital image. Image processor manufacturers use standard 12 bit or 4,096 levels of gray for images. The latest image processors use a 16 bit or 65,536 levels of gray. Increasing number of bits expands the gray scale so digital images more closely resemble original images. The higher number of pixels used to define the image and the more closely they are packed, the closer the digital image resembles the original image.

This means that a digital image is identical to images presented on x-ray films. The more pixels and bits of information involved in the picture, the more memory the computer requires for processing and storing the image. A typical imaging system is composed of an image receptor like a camera or a CCD, a frame grabber with A/D and D/A converters, a host computer with hard disk storage, image processing software or hardware, and a video monitor. Once the image is stored in the computer, it can be manipulated, enhanced, enlarged, filtered, and compared to other images. The technique used to capture images must be able to reproduce images of the same area taken at different times so they can be compared.

Another sensor is the metal oxide semiconductor (or CMOS) based chip. The primary difference with the CMOS sensor is that the electronic components are integrated inside the electronic chip instead of having a scintillation layer like the CCD sensor. Although it saves time and money to produce CMOS sensors with internal mechanisms, the charge coupled device is used more often probably, because the CCD was on the market first. There seems to be no difference in image quality.

Techniques used for digital radiography still use sensor holding devices similar to those used with x-rays. When a digital system is installed in an office, the sensor generally comes with Rinn sensor positioning devices. Software and computer maintenance guidelines are provided and should be followed. Computer screens should be ergonomically placed and appropriate for clinicians and patients. Aprons are still needed, and each office should follow FDA/ADA guidelines.

**Tomography and 3-D X-Rays**

Most dental professionals are familiar with panorex machines, know something about CAT scans and cone beams, but do not understand their operational principles or how images are assembled using this technology.
Panoramic X-Rays-Tomography

*Tomos* is the Greek word for cut or section, and tomography is a technique for digitally cutting a specimen open using x-rays to reveal interior details. Panoramic x-rays are examples of tomography. X-rays are the simplest form of tomogram in medicine, because they do not include volumetric or 3-D information. X-rays produce a two dimensional image of a single slice along the mandibular arch.

The x-ray beam is fan shaped, with the fan unfolded in the vertical dimension. The beam projects through a vertical slit close to the patient as the machine slowly revolves around his or her head. The beam and the x-ray revolve around the patient's head in the same direction (clockwise when viewed from the top), while the cassette moves in the opposite direction. The images produced show the bony structures closest to the film cassette.

You might wonder how only the bony structures closest to the cassette are recorded, since x-ray beams have to pass through bony structures on the opposite (contra lateral) side of the skull before encountering structures closest to the cassette. Why doesn't the panoramic image show those structures as well? The panorex makes use of distortions, which in ordinary intraoral radiographs would produce very poor images.

Unlike the beam of a normal long cone, dental x-ray machine, the panorex fan shaped beam is quite divergent (like an expanded fan). Divergent beams magnify objects closer to the source than those closer to the receptor (film or sensor). Since the contralateral side of the skull (which is furthest from the cassette) is closer to the x-ray source, any shadow cast on the receptor by structures on that side of the skull are greatly magnified. This not only blurs edges of contralateral shadows, but since the image is disbursed over a larger expanse, the intensity of the shadow cast will be much dimmer than the shadow cast by objects close to the cassette (the ipsilateral side).

The contralateral structures are closer to the focal spot, and the fan shaped beam is highly divergent; only a small wedge of the contralateral structures is illuminated allowing fewer recognizable structures to leave disbursed shadows. The cassette moves in the direction opposite than the x-ray head. The cassette velocity is controlled to equal the velocity of the projection of the anatomic features which are closest to the film. This means the shadows cast by objects on the ipsilateral side will spend more time on the receptor than objects further away from the cassette. Longer exposure creates a darker shadow than those cast by objects on the contralateral side. Since the cassette is moving opposite the direction of the x-ray beams, it is moving more slowly with respect to the structures closer to the cassette than it is for structures further away. Since the contralateral structures shadows move so quickly across the receptor, they will appear much more blurred than structures which are closer and moving slowly.
So, the reasons the contralateral structures show faintly or not at all on film are:

- They appear very enlarged, blurry and dim.
- They are made dimmer, because shadows these objects cast spend less time falling on the receptor.
- Shadows of the contralateral objects are blurred by their greater velocity.

**CT Scans**

The term CAT scan means Computerized Axial Tomography. The basic principle behind computed tomography is to acquire multiple views of an object over a range of angular orientations. These views are manipulated by a computer program to form a coherent image. CT images are typically called slices, as they are similar to a slice of a loaf of bread.

Early CT scanners provided one slice per scan. As technology improved, the number of slices per scan increased making it possible to stack up slices just like a loaf of thinly sliced raisin bread. A single slice shows a two dimensional section through the bread, looking at the face of the slice. This view reveals size, position, and shape of each raisin
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in that slice. When you begin to stack up slices, the three dimensional position and shape of the raisins are revealed. Three dimensional image analysis has been expanded to 64 slices in some modern machines. We are used to speaking in terms of pixels (meaning picture elements) when discussing digital imaging. However, the term used when discussing three dimensional picture elements is voxels.

A CT scanner consists of:

X-Ray Source
Unlike x-ray tubes used for taking intraoral radiographs, CT scanners emit a continuous stream of x-rays (instead of a simple pulse) and produce a thin, divergent, fan shaped beam.

CT scanners must have a small focal point in order to avoid the penumbra effect. Small focal points produce high resolution. (When we speak of resolution, we are referring to the fuzziness of the final image.)

The beam's energy spectrum defines how well x-rays penetrate the subject, as well as their expected relative attenuation as they pass through materials of different density. High energy x-rays penetrate more effectively than low energy x-rays but are less sensitive to changes in material density and composition. Low energy x-rays are more prone to attenuation by soft tissue, and since soft tissue is often the specific target of CT scans, the beam contains a lot of low frequency x-ray photons.

Series of Detectors
A series of detectors measure x-ray signal attenuation by the object being imaged. Detectors are similar to the CCDs used in dental radiology, except that they are arranged in a one dimensional line or arc instead of in a two dimensional array.

Rotating Gantry
A CT scanner has a rotating gantry upon which both the x-ray source and the detectors are mounted. The source and the detector array are mounted on opposite sides of the
gantry and maintain a fixed positional relationship. The center around which the gantry rotates is called the axis of rotation.

**Subject**

A subject sits midway between the x-ray source and the one dimensional detector array. The subject is situated so the slice desired is centered on the gantry’s axis of rotation. The only part of the subject that is directly exposed to the beam is the portion immediately surrounding the slice to be imaged.

**How CT Scanners See a Slice**

The x-ray source projects a thin, fan shaped beam through the slice the clinician wants to image. The line detector is situated opposite the detector on the other side of the subject. The x-ray source and the detector are mounted on the gantry opposite one another as they both revolve around the subject. The subject is seated so the axis around which the source and detector revolve is aligned with the center of the desired slice.

The detector begins to capture images. As the gantry rotates around the subject, the detector captures images from slightly different angles. Each image is called a view. Views look like gray lines with varying degrees of darkness along their length. The pixel intensity depends on how much the x-ray beam is attenuated by structures encountered. (Attenuation is a general term that refers to reduction in signal strength.)

Going back to our sliced raisin bread analogy, one beam might encounter two raisins in its path, another beam three raisins, and a third, none. Beams encountering more raisins in their path are more attenuated, and resulting pixels are lighter than other pixels which might be darker (because the beam encountered fewer or no raisins).

A linear view may not be exciting, and may not inform much about the structure of the slice, but as the source and detector continue on their trajectory around the axis of rotation, a computer program compares different views taken from different angles, and adds them up to construct a complex two dimensional image which includes the position of each raisin in the slice and the shape and density of each raisin. In order to compose a complete image, the source and sensor need to complete only a half revolution around the subject.

**Algorithms and the Magic of Perspective**

Computer programs build two dimensional slices using mathematical principles which are versions of shadow casting principles. A single, intraoral x-ray image gives us a two dimensional picture of objects perpendicular to the beam of the x-ray machine. By itself, a single image gives us no information about the third dimension, which is parallel to the beam.

However, when two films of the same area are taken from two different angles, perspective enables us to determine relative buccal lingual positions of objects on film. Using the Clark Shift technique, we are able to deduce relative positions of objects in the plane of the x-ray beam.
The Clark Shift

The two images above were taken from two different angles. The one on the left was taken straight on; the one on the right was taken from a mesial angle. Notice the two buccal roots have each moved distally with respect to the palatal root of the same tooth. When we shoot from the mesial, the buccal roots appear to move distally, and palatal roots move mesially relative to buccal roots.

This is how the computer compares all views of objects in the scan beam. Each tiny detector in the linear array records the density of the sum of all objects that attenuate the beam. The detector stores information in the computer's memory. It does this again and again for each of the hundreds of views it sees as the scanner moves around its trajectory.

After one complete revolution of the CT scanner, the computer uses a mathematical algorithm to compare each linear view with other views in the series. An algorithm is simply a process, or group of actions that repeats over and over. Each repetition is called an iteration, and after numerous algorithmic iterations, images are created.

For example, if instead of shooting just two films as in the x-rays pictured above, we were to shoot hundreds, increasing the angle of the beam slightly more mesially for each shot, and then used these images to make a motion picture, the result would be a three dimensional tour around the teeth. In effect, we are using a mechanical algorithm. Each image is an iteration. In the process of watching the film, we build a picture of the three dimensional structure of the teeth and surrounding bone using only information garnered from a series of two dimensional images. We do this using our innate understanding of the laws of perspective.

How the Computer Draws a Slice

CT scanner computers have programs with complex algorithms which use repetitive mathematical processes to create perspective. Algorithms convert series of linear views into images of slices of the subject in the plane of the x-ray beam.

The first step in creating a CT scan involves creating a series of two dimensional images, one from each view, composed of straight lines drawn perpendicularly from each tiny detector in the linear array. The intensity of each line represents the intensity of x-ray beams reaching corresponding detectors. The angle of the lines is
perpendicular to the sensor at that point in its trajectory around the subject. The intensity of each line depends upon accumulated density of all objects the beam encounters. The algorithm reads each line’s intensity as a probability that one or more objects lies along that path of the x-ray beam.

After all images are drawn, they are superimposed over each other. Lines intersect with lines from other views, because each view is taken from a different angle. At each point where lines intersect, probabilities are summed and averaged to assign each pixel on the beam’s plane an intensity corresponding to the probable density the beam encountered at that point. The more views from different angles incorporated into analysis, the higher probability the intensity (shade) of that point on the image corresponds to the density of the material at that point in the plane of the beam.

As a simple example, let’s look at a loaf of raisin bread we want to slice using a very simple CT scanner that sees only black and white with no shades of gray. In our example, there are only two raisins in this slice, so it looks like this when we actually cut the loaf at that point.

We'll start by examining two of the CT scanner's internal views. The ones we'll look at first are at right angles to each other. The only thing the computer summarizes is that there is a 100% probability there are objects in the slice where the colored lines are located, and 0% probability in areas where there are no lines.

The next step in the algorithm is to combine the two views and mathematically calculate the probability of finding an object where the lines intersect.
Note the lines intersect in 4 places. We know there are only two raisins in the slice, but the computer does not. It knows only that there is a high probability that dense objects lie at these four points in the plane of the beam, and 0% probability elsewhere. Two of the black rectangles represent the real raisins, and the other two are ghost images. But which two are real? We solve the mystery with a third view from another angle.

Now the computer knows that there is a 100 % probability that dense objects lie someplace along the two yellow lines, and also there is a 0% chance that any dense objects lie in areas not covered by the yellow lines. We compare this image with the combined image above, and come up with the image to the left below.

Dense objects can exist only where all three color lines intersect, and this happens in only two areas. The superposition of all three images rules out ghost images and makes the position of the real raisins definite. But it does something else as well. When we draw in the exact shape of the overlap of the lines, the rectangular shape of the images begins to soften and we see the oblong, rounded shape of the raisins. This results from only three views from three different angles (perspectives) using pixels that are only
white or black. The CT scanner takes hundreds of views, from virtually all angles, and uses detectors that can discriminate black, white and 65,534 shades of gray.

**Dosing Considerations**

CT scans are most frequently taken to image soft tissues. In order to image these tissues, the beam must contain a high concentration of low frequency, low energy photons. Because of this, the patient absorbs many more x-rays than would be the case with high energy beams like the ones in imaging devices built primarily to image hard tissue. In addition to the dose delivered directly to the tissues of interest, there is quite a bit of scatter from low energy x-ray photons which increases the effective dose to remote tissues.

The effective dose delivered by modern CT scanners is quite high, about 1.5 mSv for a CT scan of the head. Compare that with the 0.050 mSv delivered by a full series of intra oral films (19 films). Some health facilities advertise full body scans as a preventive measure; however, the radiation exposure from a full body scan is the same as if a person were standing 2.4 km away from the atomic bombs dropped on Hiroshima and Nagasaki. In 2000/2001 a comprehensive survey in the United Kingdom found that CT scans constituted 7% of all radiologic examinations but contributed 47% of the total collective dose from medical x-ray examinations.

**Cone Beams**

![Cone Beam Technology](image)

**Three Dimensional Radiography**

The newest innovation in dental radiography is three dimensional radiography. This technology is called Cone Beam Computerized Tomography (CBCT). The innovation making this technology possible was improvements in x-ray and sensors, faster, cheaper computers with enormous memory capacity, and innovative graphics programming.

Today it takes only minutes for a computer to create three dimensional images. In comparison, in 1972, the first CT scanner took two and a half hours to produce a single two dimensional slice using the fastest computer available at that time.
Cone beam technology offers clinicians late generational computational power that can image bone and soft tissue in high resolution, see normal and pathological anatomy, and even measure structures accurately for procedures such as implants, root canals and reconstructive surgery.

The principles used in three dimensional radiography are the same as used in CT scanning. Like linear array CT scanners, cone beam images are made on a machine with a rotating gantry, a continuously operating x-ray source, and a detector array. Unlike the fan shaped beam used in a CT scan however, CBCT uses a cone or pyramid shaped beam and a two dimensional array similar to a very large version of the CCDs used in intraoral digital radiography.

The patient is seated, and the area of interest (mandible or maxilla) is centered in the beam. The axis of rotation is centered in the area of interest. The x-ray source and the detector revolve around the patient in unison as is done in a CT scan. During the rotation of the device, between 150 and 600 images are captured by detectors. The images are simple two dimensional pixel arrays, and each one resembles an ordinary AP or Lat (anterior posterior or lateral) view. A single rotation is all that is required to capture a three dimensional image of the structures in the field.

A three dimensional image needs different terminology to describe its individual picture elements. We are used to speaking in terms of pixels (meaning picture elements) when
dealing with ordinary digital images. However the term used when dealing with three dimensional picture elements is voxels. A voxel has height, width, and depth.

**Algorithms**

Each view represents a coherent two dimensional image recognizable by the human eye; it is easy to visualize the motion picture analogy used when discussing the Clark Shift. Just as important is that each individual pixel on any given view represents the total density of all objects that the x-ray beam had to pass through in its journey between the x-ray source and the detector. One algorithm used to create a final image involves steps similar to those used in CT scans. Another algorithm used to manipulate data is a complex mathematical version of a simpler, mechanical algorithm a draftsman uses to draw three dimensional views of an object.

The orthographic drawings in the left image are two dimensional views of a widget. These simple drawings represent simplified versions of two dimensional views captured by cone beam detectors. The letters stand for the lengths of each vertical and horizontal line in the drawing. In order to get from two dimensional drawings on the left to the three dimensional drawing on the right, the draftsman uses a T-square and a 30 degree triangle.
The triangle allows the draftsman to draw lines at right angles to the T-square, as well as lines at 30 degrees in either direction. He begins by using a set of axes at 30 degrees, like the one on the left. The draftsman measures along the three axes using the same measurements taken from the orthographic drawings. He draws all horizontal lines along the 30 degree axes, and the vertical lines remain at ninety degrees to the T-square.

Finally, the draftsman adds missing vertical and horizontal lines and ends up with a three dimensional drawing.

The mathematical transformations used in CBCT, while immensely complex, go about their business in nearly the same manner as the draftsman. The cone beam image is more complex with many layers of internal structure, but the principles are the same. Instead of three images of the object viewed from three different angles, the cone beam uses hundreds of images taken from hundreds of angles, as well as the depth slice images created using the first algorithm described in the CT scan section of this course. The computer can rapidly rotate the image to any angle, slice any part of the image at any angle, and allow the practitioner to take virtually any measurement he wants. It also
allows the practitioner to cut virtual windows through exterior layers to reveal hidden interior anatomical structures in three dimensions.

**Dosing Considerations**

Cone beam technology exposes patients to much less radiation than conventional CT scanners. Older CT scans expose patients to effective doses of up to 2000 mSV. Cone beam scans confined to the maxilofacial region reduce this dose by up to 98.5%. CBCT x-ray sources are tuned to image hard tissues which mean cone beams are low intensity, high energy beams. Fewer x-ray photons are needed per image, and there is less absorption in soft tissues and less scatter.

The sensors are sensitive and need fewer photons to illuminate them. The collimation can be operator controlled to allow the beam to illuminate only the portion of the body under consideration. The scan is quite rapid, which not only reduces patient exposure to ionizing radiation but also reduces distortion due to patient movement.

**Resolution**

Resolution is defined as image fuzziness. Cone beam sensors have a wide range of spatial definition, from 0.4 mm to as low as 0.076 mm. A machine with 0.4 mm resolution would present images with fuzzier edges than one with 0.076 mm resolution. Sensors are so sensitive, the highest resolution images are degraded due to noise and contrast artifacts caused by scatter radiation. There is a practical limit on the need for high resolution machines in normal clinical practice.

**Other Advantages with Cone Beam Technology**

Viewing hidden structures in three dimensions offers clinicians the ability to see spatial relationships at a glance. Even without advanced software modules, the ability to view bony structures and rotate images makes diagnosis and treatment planning easier and more accurate. This includes assessment of bony and dental pathologies, recognition of structural maxillofacial deformities and fractures, preoperative assessment of impacted teeth, TMJ imaging, orthodontic evaluations, and assessment for the adequacy of bone available for implant placement.

Advanced software rendering techniques are limited only by the imagination of the software developer. On screen objects are neither distorted nor magnified. Clinicians can make accurate on screen measurements of dental and bony structures using various techniques and can record them on separate layers which may be overlaid onto the original image. Clinicians are able to slice the image in virtually any plane--axial, sagittal or coronal--which creates images similar to those produced by a CT scanner. Clinicians can magnify and zoom into specific areas of interest, cut virtual windows through superficial structures, and add annotations including drawings and alphanumeric information to layers which are overlaid on top of the original image.

**Legal Ramifications**

With improved technologies comes increased responsibility. A dentist might use his cone beam imaging technology for reasons specific to his specialty, such as assessment for adequacy of bone for implant placement. However, if the practitioner
does not recognize abnormal anatomical structures, he can be held legally responsible if the patient suffers future injuries relating to missed observations. For example, if an adenocarcinoma has caused visible distortion or disintegration of any bony structure seen in the scan, the dentist is responsible for notifying the patient and referring the patient to an appropriate specialist.

This also means that if an image includes the entire sinus region, the dentist is responsible for recognizing abnormalities in the sinus, even though this lies outside of his area of expertise. For this reason, it may be unwise to use cone beam technology unless the clinician has training to recognize head and neck abnormalities. Even if a scan is done by referral to another office, it remains the dentist’s responsibility to recognize pathology when he sees it.

Conclusion

This review, while seemingly quite technical in nature, barely scratches the surface of radiography. This course is intended as a review for the dentist and an introduction for any staff interested in learning more technical information regarding radiology. Understanding general shadow casting principles, the Clark Shift, and principles of parallax helps practitioners take expert, diagnostic x-rays and will save patients from unnecessary radiation exposure. Once dental technicians learn these techniques and others such as bisecting the angle they will consistently take quality radiographs. Since many dental offices are becoming paperless, understanding digital radiographic systems is advantageous and useful knowledge for practitioners and in many offices may be a requirement.
Glossary

**Actual Focal Spot:** The area of the anode which electrons strike.

**Aluminum Filter:** Various thicknesses of aluminum used as filtration in x-ray beams.

**Ampere:** The unit of intensity of an electric current produced by 1 volt acting through a resistance of 1 ohm.

**Angulation:** The direction of the primary radiation beam in relation to an object and film.

**Anode:** The positive terminal of an x-ray tube; a tungsten block embedded in a copper stem and set at an angle to the cathode.

**Background Density:** The density of a processed film owing to factors other than the radiation exposure received through the recorded objects or structures.

**Backscatter:** Radiation deflected by scattering processes at angles greater than 90 degrees to the original direction of the x-ray beam.

**Beam:** An emission of electromagnetic radiation or particles.

**Beam Guiding Instrument:** Instrument used during radiography to facilitate correct alignment of the central ray.

**Binding Energy:** Energy needed to eject an electron from the atom.

**Bisecting Angle Technique:** A radiographic technique used with intraoral films.

**Bremsstrahlung Radiation:** A spectral distribution of x rays ranging from very low energy photons to those produced by the peak kilovoltage applied across an x-ray tube.

**Cassette:** A light tight container in which x-ray films are placed for exposure to x-ray radiation; usually backed with lead to reduce the effect of backscatter radiation.

**Cathode:** A negative electrode from which electrons are emitted.

**Cathode Ray:** A stream of electrons passing from the hot cathode filament to the target or anode in an x-ray tube.

**Cathode Ray Tube:** A tube cathode containing a spirally wound filament that becomes incandescent, producing electrons when a low voltage electric current passes through.

**Central Ray:** The theoretical center of the x-ray beam.

**Characteristic (Discrete) Radiation:** Electromagnetic radiation produced by electron transitions from higher energy orbitals to replace ejected electrons of inner electron orbitals. The energy of the electromagnetic radiation emitted is unique or characteristic of the emitting atom.

**Collimation:** Any device used for the elimination of the peripheral divergent portion of the useful x-ray beam, such as metal tubes, cones, or diaphragms interposed in the path of the beam.

**Collimator:** A lead disc with an aperture of various sizes and shapes. The diaphragm limits the size of the primary beam to the area of interest, thereby minimizing patient exposure to the primary beam.
Cone: A device on a dental x-ray machine that is designed to indicate the direction of the central ray and to serve as a guide in establishing a desired source to film distance.

Cone Cutting: Failure to expose the entire area of a radiograph with the useful beam thereby only partially exposing the film.

Cone Distance: The distance between the focal spot and end of the cone.

Constant Potential Kilovoltage: The potential formed by a constant voltage generator expressed as constant potential kilovolts (kVcp).

Contrast: The difference in image density appearing on a radiograph, representing various degrees of beam attenuation.

Critical Tissues (Organs): Those tissues that react unfavorably to radiation or, by their nature, attract and absorb specific radiochemicals.

Daylight System: A method of loading, unloading, and feeding films into the processor in normal room light. This system entails the use of special equipment, with no need for a darkroom.

Density (Photographic or Film): The degree of darkening of exposed and processed photographic or x-ray film.

Developer: A chemical (potassium bromide) used to check the development of unexposed silver bromide and to control the working speed of exposed silver bromide.

Direct-Exposure Film: Film that is highly sensitive to the direct action of x rays but that has low sensitivity to screen fluorescence.

Directly Ionizing Particles: Charged particles having sufficient kinetic energy to produce ionization by collision.

Dose Equivalent: The product of absorbed dose and modifying factors. The traditional unit of dose equivalence is the REM.

Effective Focal Spot: That apparent size and shape of the focal spot when viewed from a position in the useful beam.

Ektaspeed Film: Direct exposure film with a speed of approximately 25 R -1.

Electrode: Either of the two terminals of an electric source—an anode or a cathode.

Electromagnetic Radiation: The forms of energy propagated by wave motion as photons or discrete quanta which include radio waves, infrared waves, visible light, ultraviolet radiation, x rays, gamma rays, and cosmic radiation.

Electromagnetic Wave: A wave produced by mutual induction of electric and magnetic fields.

Electron Stream: Electrons moving from the cathode to the anode across a potential difference in a low pressure gas tube or a vacuum tube.

Electron Volt: The kinetic energy gained by an electron falling through a potential difference of 1 volt.

Exposure: A measure of the ionization produced in air by x radiation or gamma radiation. It is the sum of the electrical charges on all of the ions of one sign produced in...
air when all of the electrons liberated by the photons in a volume element of air are completely stopped in air divided by the mass of air in the volume element.

**Exposure Factors**: Radiographic kilovoltage, exposure time, milliamperage, and source to film distance: The primary radiographic factors considered when taking radiographs.

**Factor**: The linear energy transfer dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) a quantity that expresses the effect of the absorbed dose on a common scale for all ionizing radiations.

**Film Base**: The thin, transparent sheet of cellulose acetate or similar material that carries the radiation and light sensitive emulsion of x-ray films.

**Film Contrast**: A characteristic inherent in the type of film used.

**Film Speed**: Speed in radiography refers to the relative amount of darkening produced on a film (with reference to film or screen characteristics) from a given amount of radiation.

**Filter**: The material (usually aluminum) placed in the useful, primary beam of x-rays.

**Fixer**: The solution in which the manifest image is fixed and hardened.

**Focal Spot**: That part of the target on the anode of an x-ray tube that is bombarded by the focused electron stream when the tube is energized.

**Focusing Cup**: Along with the filament, the focusing cup determines the size and shape of the target (focal) spot.

**Gamma Radiation**: Short wavelength electromagnetic radiation of nuclear origin, within a range of wavelengths from about 8 to 11 cm.

**Gray**: A unit of radiation measurement established in 1974 by the International commission on Radiation Units and Measurements. One gray (Gy) = 1 joule/Kg= 100 rad. The Gray is a unit of absorbed dose and replaces the rad.

**Grid**: A device used to prevent as much scattered radiation as possible from reaching an x-ray film during the exposure of a radiograph.

**H and D Curve**: A characteristic curve of a photographic emulsion obtained by plotting film density against the logarithm of the exposure.

**Halides**: Compounds of metals with halogen elements; bromide, chlorine, and iodine.

**Hard Radiation**: A slang term for x rays of short wavelengths and high penetrating power.

**Impulse**: The burst of radiation generated during a half cycle of alternating current.

**Indirectly Ionizing Particles**: Uncharged particles, which can liberate directly ionizing particles or initiate a nuclear transformation.

**Inherent (Film) Density**: The density of a processed film owing to such intrinsic factors as film base density and emulsion gelatin.

**Intraoral Radiograph**: Radiograph produced on a film placed intraorally to the teeth.
Ion: An atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

Ionization: The process or the result of a process by which a neutral atom or molecule acquires either a positive or a negative charge.

Ionizing Radiation: Electromagnetic radiation or particulate radiation capable of ionizing air directly or indirectly.

K Electron: an electron having an orbit in the K shell, which is the first shell of electrons surrounding the atom's nucleus.

keV: The symbol for 1000 electron volts.

Kilovoltage: The potential difference between the anode and the cathode of an x-ray tube.

Kilovoltage Peak (kVp): The crest value (in kilovolts) of the potential difference of a pulsating-potential generator.

Latent Period: The period between the time of exposure of tissue to an injurious agent and the clinical manifestation of a particular response.

Line Focus: A principle employed in the design of x-ray tubes by which the effective focal spot is sharply reduced relative to the actual focal spot.

Localization: Taking a radiograph to identify a site in relation to surrounding tissues.

Long Cone: A cylindrical or rectangular cone with an anode to skin distance 27 to 36 cm.

Long Scale Contrast: An increased range of grays between blacks and whites on a radiograph. Higher kilovoltages increase this range.

Magnification Distortion: Proportional enlargement of a radiographic image.

Maximum Permissible Dose (MPD): For radiation workers, 50 mSv per year is permissible. The MPD is the maximum dose of radiation that, in view of present knowledge, would not be expected to produce significant radiation effects.

Milliampere (mA): Electrically, the milliampere is 1/1000 of an ampere.

Milliampere Seconds (mAs): The product of the x-ray tube operating amperage and exposure time, in seconds.

Millirad (mrad): One-thousandth of a rad.

Millirem (mREM): One-thousandth of a REM.

Milliroentgen (mR): One-thousandth of a Roentgen.

Object (Tissue) Density: The resistance of an object to passage of x rays.

Osteoradionecrosis: Damage and death of normal bone, which may result from a curative dose of radiation used in the treatment of malignant or nonmalignant disease.

Oxidation: A chemical reaction in which an electron is removed from an atom.

Paralleling (Right-Angle) Technique: An intraoral radiographic exposure where the plane of the film packet is made parallel to the long axis of the tooth being
radiographed. The central beam axis or central ray of the x-ray beam is directed at right angles to both.

**Penetrability**: The ability of an x-ray beam to pass through matter; kilovoltage and filtration determine the degree of penetrability.

**Penumbra**: The secondary shadow that surrounds the periphery of the primary shadow; the term pertains to the shadow proper. A penumbra is the ill-defined margin or shadow produced by light.

**Photoelectric Effect**: The ejection of bound electrons by an incident photon such that the whole energy of the photon is absorbed and transitional or characteristic x-ray emissions are produced.

**Photoelectron**: An electron emitted from a substance under a stimulus or other radiation of appropriate wavelength.

**Position Indicating Device (PID)**: A device usually composed of a plastic ring through which a metal rod can be placed to assist in properly aligning the cone and film.

**Projection**: A term for the position of a part of the patient with relation to the x-ray film and the x-ray beam.

**rad (Radiation Absorbed Dose; Roentgen Absorbed Dose)**: A unit of measurement for the absorbed dose of any type of ionizing radiation in any medium. One rad is the energy absorption of 100 ergs (Gray).

**Radiation Dermatitis**: Inflammation of the skin resulting from high radiation doses. The reaction varies with the quality and quantity of radiation used and is usually transitory.

**Radiolucency**: The appearance of dark images on film owing to greater amounts of radiation that penetrate structures and reaches the film.

**Radiographic Magnification**: The enlargement or distortion of a radiographic image recorded on film emulsion, minimized by reducing the object-to-film distance, and increasing the focus film distance.

**Radiolucent**: Permitting x rays passage with relatively little attenuation.

**Radiopacity**: The appearance of light images on film owing to the lesser amount of radiation that penetrates structures and reaches the film.

**Radiopaque**: A structure that strongly inhibits the passage of x rays.

**Radiosensitivity**: Relative susceptibility of cells, tissues, organs, organisms, or any substance to the injurious action of radiation.

**RBE (Relative Biological Effectiveness)**: A factor used to compare the biologic effects of absorbed dosages of differing types of ionizing radiation in a particular organism or tissue. The standard of comparison is medium voltage x rays delivered at about 10 rad/min. The unit of RBE is the REM.

**REM (Roentgen-Equivalent-Man)**: A unit of dose of any radiation to body tissue, expressed in terms of its estimated biologic effects relative to an exposure of 1 Roentgen of gamma or x-radiation.

**Resolution (Image)**: The discernible separation of closely adjacent image details.
**Reticulation**: A network of corrugations in the emulsion of a radiograph as a result of too great a difference in temperature between any two of the three darkroom solutions.

**Roentgen (R)**: An international unit of exposure based on the ability of radiation to ionize air, ions carrying 1 electrostatic unit of quantity of either positive or negative electricity. (2.083 billion ion pairs).

**Scattered Radiation**: Radiation that during passage through a substance has deviated in direction. It may also have been modified by an increase in wavelengths. It is one form of secondary radiation.

**Secondary Ionization**: Particles, usually electrons, ejected by recoil when a primary ionizing particle passes through matter.

**Secondary Radiation**: Particles or photons produced by the interaction of primary radiation with matter.

**Screen Film**: A film that is sensitive to the fluorescent light of intensifying screens but not as sensitive to the direct action of x rays.

**Short Cone**: A conical or cylindrical cone with an anode to skin distance of up to 18 cm.

**Short Scale Contrast**: A reduced range of grays between the blacks and whites on a radiograph. Lower kilovoltages decrease this range.

**Spatial Resolution**: The smallest distance between two points in an object that can be distinguished as separate detail in the image; generally indicated as a number of black and white line-pairs per millimeter.

**Speed of x rays**: X rays travel at the speed of light, 186,000 miles/sec, or at 3 X 10^8 meters per second in a vacuum.

**Source**: The point of emanation of gamma or x rays when used as an origin of radiation.

**Static Marks**: marks on a radiograph resembling small streaks of lightening; they result from static electricity that occurs when the film is removed from the wrapper paper or when films are separated after being piled on top of one another.

**Stop Bath**: a solution of water and acetic acid used between the developer and the fixer that stops the development of the film.

**Subject Contrast**: Relative differences in density and thickness of components of radiographed subjects.

**Target**: The area on the anode subject to electron bombardment, usually consisting of a tungsten insert on the end face of a solid copper anode.

**Target Film Distance (TFD)**: This is the same as focal film distance (FFD) in that it is the distance from the focal spot of the x-ray tube to the x-ray film.

**Thermionic Emission**: The release of electrons from the cathode filament by heating.

**Umbra**: A complete shadow produced by light, with sharply demarcated margins. In radiography, a sharply delineated image detail.
**Vertical Distortion:** Disproportional change in size, either elongation or foreshortening owing to incorrect vertical angulation or improper film placement.

**Volt:** The unit of electrical pressure or electromotive force necessary to produce a current of 1 ohm.

**Wetting Agent:** A solution used in film processing, it follows the washing process to accelerate the flow of water from both film surfaces and to hasten the drying of radiographs.

**X ray:** A type of electromagnetic radiation characterized by wavelengths of 100 angstroms or less.

**X-ray Spectrum:** A portion of the electromagnetic spectrum with photon energies greater than 100 eV.