The Fundamentals of X-Ray

Radiology is common topic tested on the INBDE. You can be certain that you will encounter several questions on this topic on your exam. Fortunately, our team has created these notes to help you efficiently prepare for everything that can show up on the INBDE. These notes will review radiology principles, radiology dosages, film and digital imaging, types of imaging, and interpreting radiographs.

1 Ionizing Radiation

Before learning about X-rays, we first need understand the concept of ionizing radiation. **Ionizing radiation** - form of energy created by the movement of electrons in atoms and molecules of air, water and living tissue. The result is the formation of ions.

Types of Ionizing Radiation

There are two types of ionizing radiation:

1. **Electromagnetic radiation** - created by a combination of electric and magnetic fields.
    - Electromagnetic waves described by **wavelength -** distance between crests of the wave
        - shorter wavelength = higher energy
    - waves travel at the speed of light.
    - Energy organized on an **electromagnetic spectrum** into different classifications
        - Radio < microwave < infrared < visible (violet to red) < UV (ultraviolet) < X-ray < Gamma
        - **Ionizing radiation** ranges from gamma waves to high energy UV
            - ✦This is enough energy to ionize biological molecules
        - **Non-ionizing radiation** does not contain enough energy to ionize molecules
    - **X-rays** lie between UV and gamma radiation on the electromagnetic spectrum
    - All rays on the electromagnetic spectrum are packed into **photons** (high energy waves)

INBDE Pro Tip: Electromagnetic is about WAVES. Particulate is about PARTICLES

2. **Particulate radiation** - atomic nuclei or subatomic particles rapidly moving. Examples of these particles include...
    - Protons and neutrons
    - Alpha (α) & beta (β) particles
        - α-**particles** are helium nuclei
            - ✦can be stopped by a thin sheet of paper
        - β-**particles** (aka positrons)
            - ✦can be stopped by a thin sheet of aluminum
    - For comparison, gamma (γ) rays need a dense material to be stopped, such as lead or concrete

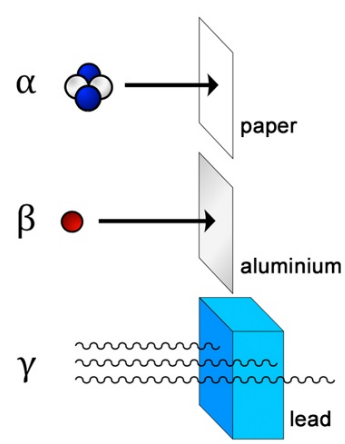


Figure 1.01 Particulate radiation

2 The X-Ray Machine

The exterior of an X-ray is made up of:
X-ray tube - generates x-rays
Position indicating device - orients X-ray unit to correct location and distance from patient's mouth

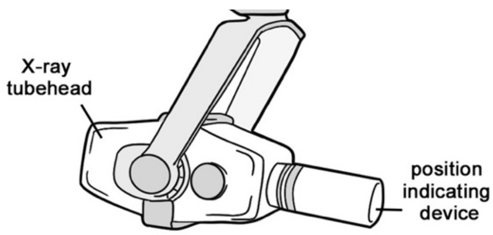


Figure 1.02 X-Ray machine

X-Ray Tube

The inside an X-ray tube is where X-ray photons are created and is made up of the following parts:

Cathode (-) - **tungsten filament** creates electrons when heated

- **Molybdenum focusing cup** - focuses electron beam onto a focal point on the tungsten target

Anode (+) - **tungsten target** converts electrons into X-ray photons

- Connected to a **cooper rod**
- Electron conversion is 99% heat and 1% photons. Therefore, cooper is a good choice because it ...
  - has a high melting point
  - conducts electricity
  - has good heat dissipation

Glass encloses the tube. It has a high melting point, insulates electricity, acts a vacuum and helps transmit X-rays.

Aluminum filters the X-rays

Lead aids in absorption of scattered X-rays. It surrounds the tube except at the tube window. This results in maintenance of a single X-ray beam in a process called **collimation**

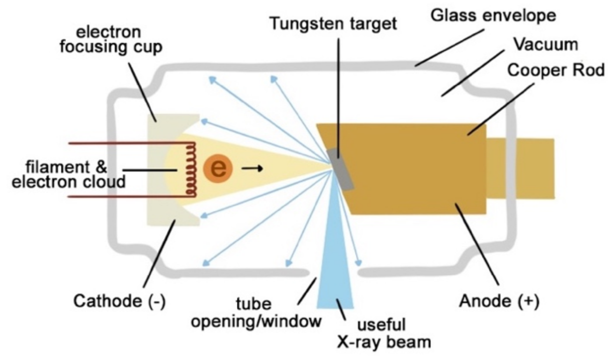


Figure 1.03 X-ray tube

Note that in an X-ray tube, the anode is positive and the cathode is negative. This is the opposite of what you find in a battery.

INBDE Pro Tip: Each part can be described in one word

- Filament = electrons
- Tungsten target = X-rays
- Glass = insulation
- Aluminum = filtration
- Lead = collimation

Attenuation and Receptor

Once the generated X-ray photons exit the X-ray tube, they are absorbed and scattered by human tissue.

- X-ray photons experience **attenuation** (weakening of the X-ray beam as it travels through matter)
- Denser matter results in less photons traveling through to the other side.

Once the photons travel through matter, they will contact a **receptor** to create an image of the tissues.
Examples of receptors on the market:

- Sheets of film processed in chemicals
- Digital sensors that automatically generate a computerized image
- Vinyl filmed packets processed by scanner

INBDE Pro Tip: Know the relative density of dental tissues & materials
Example: enamel > dentin
amalgam > composite

Summary of an X-ray machine

Electricity from high voltage power

- electricity creates heat
- creates electrons
- electrons produce X-rays
- photons attenuate through tissue
- penetrated photons hit the receptor
- receptor processes an X-ray image
- image observed & analyzed

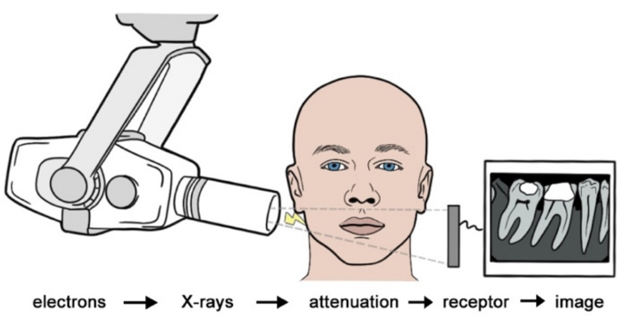


Figure 1.04 X-Ray process

3 Types of X-Ray Production

X-ray production takes place when electrons hit the tungsten target.
There are two types of X-ray production:

1. **Bremsstrahlung** (primary source of X-rays)
   - Electrons attracted to positive nuclei of tungsten
     - electrons strike tungsten target
     - electrons decelerate when contacting tungsten
     - loss of kinetic energy
     - energy lost converted to X-rays as a continuous spectrum of energy

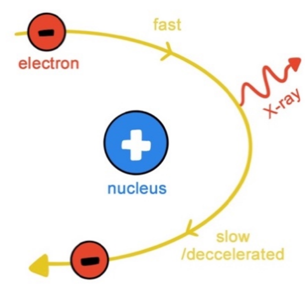


Figure 1.05 Bremsstrahlung radiation

2. **Characteristic** (secondary source of X-rays)
   - Electrons hit tungsten target
     - electrons knock into other electrons
     - electrons drop into lower energy orbitals (usually K-shell)
     - energy drop between shells emitted as X-ray

INBDE Pro Tip: Each photon emitted has a specific energy level since the atom itself has distinct energy levels. The specific electron knocked out will result in a specific energy level emitted in the X-ray. Hence, "characteristic".

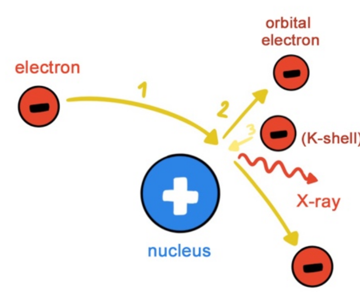


Figure 1.06 Characteristic radiation

4 Factors Influencing Radiographs

Radiographic images are described by density and contrast

Density – opacity of image

- Result of **x-ray intensity** (quantity of electrons and photons)

Contrast – difference among neighboring regions

- Results of **x-ray energy** (quality of electrons and energy of photons)

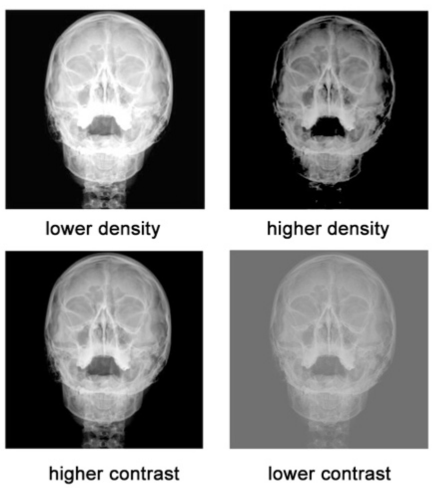


Figure 1.07 Radiographic images

> **INBDE Pro Tip:** Imagine the receptor being completely white, like a blank canvas. As x-ray photons contact the receptor, the image is being generated, like black/grey paint on a canvas.

Density and contrast of a radiograph are influenced by the following factors.

Exposure Time

Exposure time – length of time high voltage is applied to x-ray tube to produce x-rays

- Measured in seconds (s)
- Most frequently changed setting
- **Changes intensity**
- Too long = dark image = overexposed
- Too short = noisy image = underexposed
- Adults and bigger patients need longer exposure time
- Children, smaller patients and edentulous patients need shorter exposure time
- Digital sensors lessen exposure time due to increased efficiency

Tube Current

Tube current – current flow from filament to anode and back to filament

- Measured in milliamps (mA)
- Usually not adjustable
- **Changes intensity**
- Too high = dark image = overexposed
- Too low = noisy image = underexposed

Tube Potential

Tube Potential – maximum voltage of the x-ray beam

- Measured in peak kilovoltage (kVp)
- **Changes intensity and energy**
- Increase kVp increases mean beam energy
- Too high = low contrast/gray image
    - Mostly due to **Compton scattering** (next chapter)
- Too low = high contrast/light image
    - Mostly due to **photoelectric absorption** (next chapter)
- Increased kVp
    - increased number & energy of x-ray photons generated at anode
    - more photons hitting receptor + increased energy of photon beam
    - increased density (at a greater scale than increased tube current or exposure)

Filtration

Filtration – removal of low energy photons from the x-ray beam

- Decreases patient radiation exposure
- Aluminum or Copper filters low energy photons = **decreases intensity**
- Increases mean energy of beam
- Increases image quality
- Similar to **beam hardening** - filtering low energy photons and keeping high energy photons

Collimation

Collimation – reducing size of X-ray beam to decease scattering of radiation

- Collimator is a metallic barrier (usually lead) built into the position indicating device
  - Can be round or rectangular
  - Rectangular collimation works BEST to reduce patient radiation exposure
- Reducing scattering = **better image contrast** = improves image quality

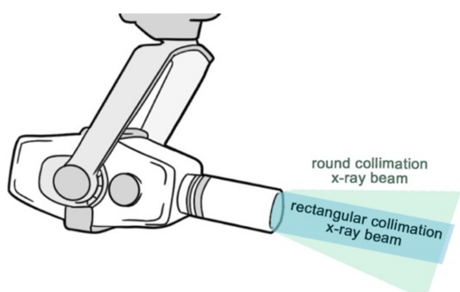


Figure 1.08 Collimation

Distance

There are a few types of distances to factor in radiographic imaging.

Source to Image Distance (SID) – distance from x-ray source to receptor

- Also known as **focal film distance (FFD)**

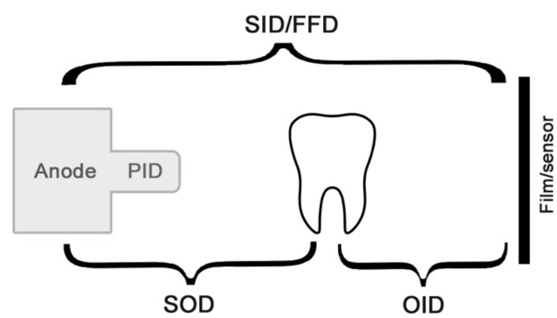
Source to Object Distance (SOD) – distance from x-ray source to tooth

- **Inverse square law** = intensity inversely proportional to the square of distance of source
  - Further from source =less photons per unit area = lighter image
- Increased SOD = decreased intensity
- Increased SOD = sharper image

Object to Image Distance (OID) – distance from tooth to receptor

- Decreased OID = sharper image + less magnification

Best results when minimize OID + maximize SOD



Note: Operator should be at least 6ft away from source

Figure 1.09 Diagram of distances

INBDE Pro Tip: Remember, even though the positing indicating device is up against the patient's mouth, the x-ray is generated at the tube-head.

Geometry

Resolution – ability to differentiate between two points

- Influenced by geometry (distances, sizes etc.)

Umbra – shadow of the image where no light reaches

Penumbra – area around the umbra

- Some light present but not a lot, results in fuzzy border around the umbra
- Controlled by 3 factors
  - Focal spot size (FSS) – light source size
    - Smaller = sharper image
  - SOD
  - OID
- **Blurriness = FSS x OID / SOD**

INBDE Pro Tip: It's helpful to make summary charts of what you've learned as such

	Density	Contrast
↑ Current	↑	
↑ Exp Time	↑	
↑ Potential	↑	↓
↑ Filter	↓	↓
↑ Distance	↓	

Radiation Dosage

1 Forms of Photon Interaction

Coherent Scattering

- Incident photon strikes outer shell electron to become a scattered photon
- ~10% of interactions in dental x-ray beam
- Photons redirected into a different direction from contact with outer electron
- Scattering decreases contrast because photons are not going in the same direction
- No ionization, ion pair formation or energy lost

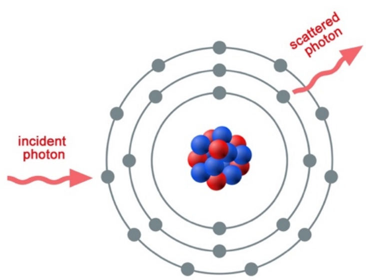


Figure 2.01 Coherent scattering

Photoelectric Absorption

- incident photon strikes an inner shell electron to create an ion pair
- ~30% of interactions in dental x-ray beam
- Low kVp = more photoelectric absorption = increases contrast

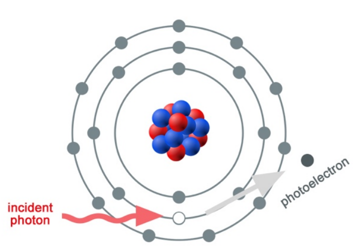


Figure 2.02 Photoelectric absorption

Compton Scattering

- incident photons strikes outer shell electron to create an ion pair
- ~60% of interaction in dental x-ray beam
- Part of incident photon ejects electron to ion pair and other part scatters photons
- Higher kVp = more Compton scattering = decrease contrast

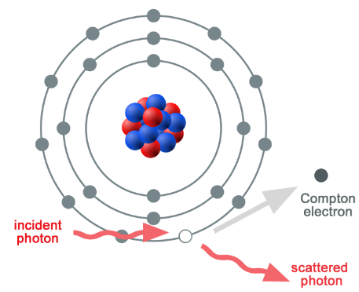


Figure 2.03 Compton scattering

2 Dosimetry

Dosimetry is the quantification and assessment of patient ionizing radiation exposure and dose. There are various measures of dosimetry.

1. **Exposure** – amount of energy produced from x-ray beam
   - Unit of Measure = Roentgens (R)
   - SI Units = 3.88 x 10^3 R = 1C/kg
2. **Absorbed Dose** – amount of energy absorbed in tissue
   - SI Unit = 1 Gray (Gy) = 100 rads = 1J/kg
3. **Equivalent Dose** – amount of energy absorbed in tissue X radiation weighting factor
   - SI Unit = 1 Sievert (Sv) = 100 rems
   - Radiation **Weighting Factor (W_R)** ranges from 1-20 (ex. 1 for x-rays, 20 for α-particles)

4. **Effective Dose** – amount of energy absorbed in tissue X tissue weighting factor (W_T)
    - Different tissues are more sensitive to radiation (ex. lungs > skin)
    - W_T of all body tissues total to 1

3 Effects of Radiation

Deterministic Effects

- Radiation needs to meet or surpass **threshold dose** for effects to occur
    - *Ex. Alopecia, skin damage, cataracts, oral mucositis*
- Higher doses result in more severe effects
    - 0.1 Gy → in-utero birth defects
    - 2.0-3.0 Gy → sterility
- Dental x-rays are very low dose (in the micrograys) = no deterministic effects

Stochastic Effects

- Provides a probability effect will occur
    - *Ex. Cancer and genetic effects*
- **Linear no-threshold model** – a threshold dose does not exist
    - Any exposure of radiation will increase risk
    - Probability proportional to dose
    - Radiation doses below 0.1 Gy were extrapolated and assumed to have a linear effect

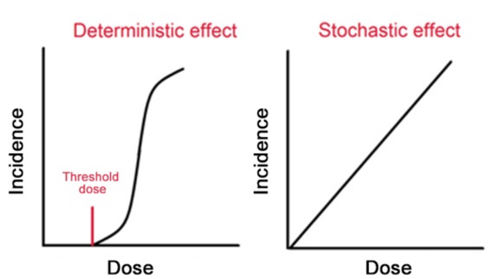


Figure 2.04 Types of radiation effect

4 Radiation Chemistry

Indirect

- Water converted to free radicals via ionizing radiation. Free radicals then alter biologic molecules
- Dominant process in x-rays and gamma rays
- 2/3 of biological effects

Direct

- Directly target biologic molecules (protein, DNA)
    - *Ex. radiation causing breaks in DNA*
- Dominant process of α-particles and neutrons
- 1/3 of biological effects

INBDE Pro Tip: The following are important concepts for the INBDE
- Highly metabolically active and mitotically active cells are more radiosensitive
    - Epithelial, gastrointestinal, sperm cells, hematopoietic etc.
- Less metabolically active and non-dividing cells least likely to be damaged
    - Nerve, muscle etc.

Sources of Radiation Exposure

The annual average radiation exposure for an individual in the US is 6.2 mSv. It comes from two types of radiation exposure.

1. **Background radiation** – radiation from natural resources (3.1 msv)
    - Food, natural deposits, sun rays etc.
    - Primary source = radon (2.28 mSv)

2. **Manmade radiation** – radiation from manmade resources (3.1 msv)
    - Nuclear medicine, building materials, smoke detectors etc.
    - Primary source = medical

Occupational Dose Reduction

Occupational Radiation dose exposure is limited to 50mSv per year. Usually the guiding principle of exposure at work is to gather the most information with the lowest dose. The following acronyms commonly are used in the workplace.

- **ALARA** = As Low As Reasonable Achievable
- **ALADA** = As Low As Diagnostically Acceptable
  - Newer standard, avoids risk of sub-par image from too low of a radiation

Dose reduction can also be achieved in the dental office by the following:

- Digital imaging or E/F speed films
- Rectangular collimation
- Over 18cm SOD

Film & Digital Imaging

1 Film Versus Digital Imaging

Film Imaging

- Film processed in chemicals to produce an image + requires developing time
- Higher resolution = better image quality
- Higher radiation dose than digital

Figure 3.01 Film imaging

- X-ray film has 3 parts
  - **Base** – cellulose acetate (flexible plastic)
  - **Film emulsion** – silver halide (usually Bromide) crystals in gelatin.
    - Crystals can also be iodide or chloride
    - Sensitive to x-rays and visible light to capture the image
    - Some films have double emulsion layers
  - **Intensifying screen** – covered with fluorescent phosphor to convert photon energy to light = reduce exposure needed
    - Used in panoramic and cephalometric films
    - Phosphor disperses light = decreased resolution

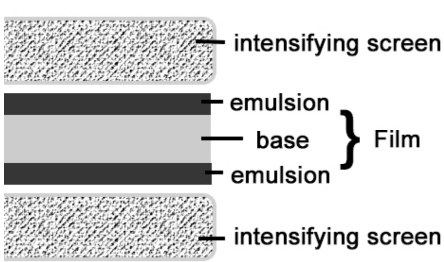


Figure 3.02 X-ray film

About half of dentists use film imaging and the other half use digital. However, the number of digital users is growing.

Film Speed

- Speed setting range from A→F
  - A = slowest, F=fastest
    - D and F most commonly used
- faster speed = less radiation exposure required
- fast speed may also lose some resolution
  - image quality and dose often inversely related
- Speed chosen based on...
  - more emulsion layers = faster
  - bigger crystal = faster
  - radiosensitive dyes in emulsion = faster

Film Imaging

Blank film creates an image when photons strike the film. Think of the film as a blank canvas and the photos as black and gray paint.

- X-ray photons convert silver halide crystals into neutral silver atoms in emulsion to produce a latent image
  - **Latent Image** – invisible image that requires chemical processing to turn visible
- **Radiolucent** – photons travel through tissue to contact film
- **Radiopaque** – photons cannot reach film because they cannot attenuate through tissue

Chemical Processing

Chemical processing of x-ray film takes place in dark room where the invisible silver atoms turn black. The process has 4 main steps

1. **Developing**
    - Transforms exposed crystals into metallic silver grains = invisible image turns visible
    - **Phenidone** – donates electron to silver ions (reduction) that become metallic silver on latent image
    - **Hydroquinone** – replenishes electrons to oxidized phenidone (reduction) into its original active state

2. **Fixing**
    - Removes anything other than silver halide crystals from emulsion
    - **Ammonium thiosulfate** (removal agent) – removes impure silver halide crystals
    - **Aluminum salts** (tanning agent) – protects and solidifies emulsion
    - **Acetic acid** (acidifier) – preserves fixing solution's acidity and stops developer
    - **Water** (solvent) – dissolves other components

3. **Washing**
    - Underdeveloped silver grains and residual chemicals are washed away

4. **Drying**

2 Digital Imaging

Digital
- No chemicals or developing needed
- Image produced instantly
- Images can be adjusted for brightness, contrast etc.
- Smaller radiation dose
- Two types: PSP and CCD/CMOS

PSP (Photostimulable phosphor)
- X-ray energy captured and stored by **barium fluorohalide plates**
- PSP captures image before shown on computer

CCD/CMOS (charge-couple device/ complementary metal oxide semiconductor)
- **Silicon sensor chip** captures x-ray energy
- No scanning step, image rapidly displayed on computer

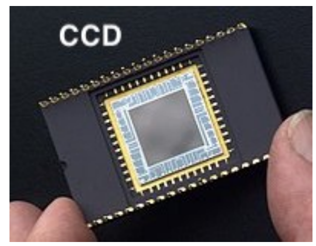


Figure 3.03 CCD/CMOS

Detector Characteristics
Contrast resolution – differentiates shades of gray
- Film > Digital
    - Film is an analogue system (unlimited gray scale)

Spatial resolution – differentiate between two points
- Film > CCD/CMOS > PSP

Latitude – exposure range that allows useful image intensities
- PSP > CCD/CMOS > Film

Sensitivity – dose needed to reach the standard gray level
- F-speed film > CCD/CMOS
    - CCD/CMOS is half F-speed film

3 Image Quality Assurance

Quality Assurance in Radiology

Quality assurance programs should be implemented in any dental office. They ensure optimal and consistent performance of each component of the imaging chain. The following tasks should be implemented.

- Record image errors (daily)
- Review error log (weekly)
  - Phantom can be an object shaped like a human head
- Inspect for scratches on PSP plates, and tears on aprons (monthly)
- Calibrate machines by health physicist, thoroughly examine digital sensors with phantom (yearly)

Troubleshooting

Troubleshooting imaging problems is usually seen with film. Here are some examples

- Overexposed
  - Exposure time too long, overdeveloped film, film exposed to light
- Underexposed
  - Inadequate development, low exposure time, defective chemicals, temperature too low
- Dark line
  - From creases in film
- Black tree-branch lines
  - From static electricity
- Herringbone effect
  - Tire track appearance on image
  - Film placed backwards
    - Lead foil pattern on back of film projected onto emulsion layer

Types of Radiographs

1 Types of Radiographs

The different types of radiographs can be divided into two categories

1. **Direct/Intra-oral radiographs** are used when the receptor is place inside the mouth. X-ray photons then directly interact with the receptor. Direct radiographs include...
    - Periapical
    - Bitewing
    - Occlusal

2. **Indirect/Extra-oral radiographs** place a screen outside the patients mouth that x-ray photons contact before interacting with film. Indirect radiographs include...
    - Panoramic
    - Cephalometric
    - Cone Beam Computed Tomography

2 Direct/Intra-oral Radiographs

Periapical (PA)
- Exposes root apices
- Used for anterior teeth caries detection
- Positioned vertical for anteriors, horizontal for posteriors

Bitewing (BW)
- Root apices not illustrated
- Good to analyze bone levels
- Focuses more on crowns and bone height
- Usually exposed horizontally, but can be vertical too

Occlusal
- Receptor lies flat on occlusal plane
- Shows teeth from canine to canine
- Good for analyzing trauma, supernumerary teeth, impacted teeth
- Easier to pediatric patients due to less discomfort and pinching on lips

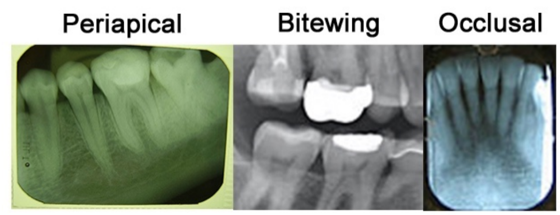


Figure 4.01 Direct/Intra-oral radiograph

3 Indirect/Extra-oral Radiographs

Panoramic (Pan)/ Orthopantomogram (OPG)
- X-ray spins around patient's head
- Shows all teeth and jaws
- For screening, jaw pathology, 3rd molars

Figure 4.02 Panoramic

INBDE Pro Tip: It's easier to examine radiographs globally before examining locally
- Ex. start from condyle → articular eminence → lateral wall → medial wall → nasal cavity → then counting teeth, crowns, bone levels and roots
- Ex. start from gonial angle →inferior border of mandible → gonial angle on opposite side → then counting teeth, crowns, bone levels and roots

Cephalometric
- Gathers information about the head
- **Lateral**
  - Most commonly used type
  - Shows side profile
  - Can superimpose two lateral radiographs on top of each other to see before and after treatment results
- **Posterior-Anterior (PA)**
  - Front-back view of head
  - Can used to see transverse asymmetry
  - Not commonly used (cone beam usually used instead)

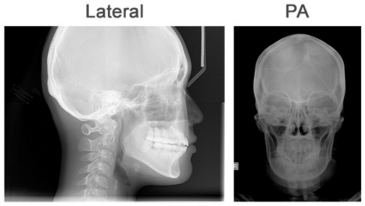


Figure 4.03 Cephalometric

Cone Beam Computed Tomography
- Provides several different views
  - Axial = top-bottom view
  - Sagittal = side view
  - Coronal = front-back view
  - Volume render = 3D view, can zoom in/out and rotate at different angles

CBCT is helpful for various uses
- Endodontics
  - Fracture, resorption, canal anatomy
- Implants
  - Assess bone quality and quantity, anatomy of nerves and arteries, anatomy to make implant templates
- TMJ hard tissue visualization
  - Condylar head, fossa, articular eminence
  - Soft tissue needs an MRI
- Orthodontics
  - Impacted teeth and tooth orientation
- Pathology
  - See pathology not seen in 2D imaging

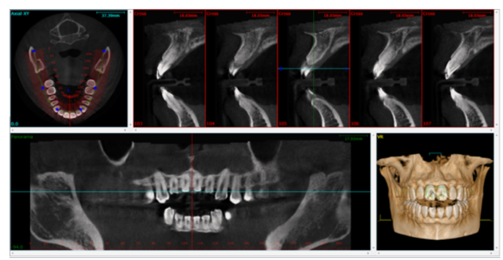


Figure 4.04 CBCT

4 Specialized X-ray Views

Water's View
- 45° angle from orbital-medial line
- Patient faces film, x-ray source come from behind the head
- Used to identify anterior view of paranasal sinuses, mid-face and orbits

Towne's View
- Angle PA cephalometric radiographs
- Film behind head, x-rays from the front
- Used to identify condyles and neck of mandible
  - Avoid superposition and zygoma and mastoid muscles over the condyles

Submentovertex View

- Projection of the base of the skull
- Film above the head, x-ray under the chin
- Used to identify basilar skull and zygomatic fractures

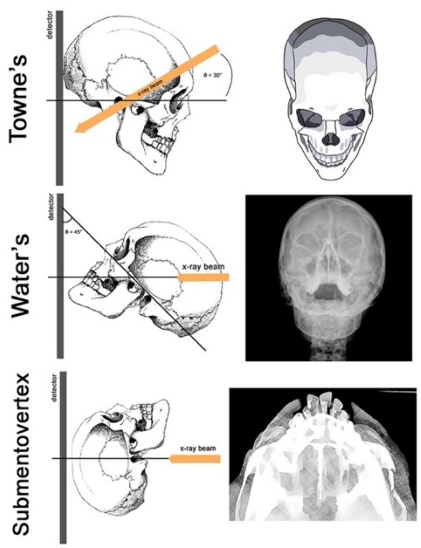


Figure 4.05 Specialized X-ray views

5 Intra-oral Imaging Techniques

Bisecting Angle Technique

- X-ray beam perpendicular to imaginary bisector between long axis of tooth and long axis of receptor
- In theory, image on film equal to the length of the tooth
- Image may be distorted
  - Due to angulation and possible stretching/distortion

Paralleling Technique

- X-ray beam perpendicular to long axis of tooth and receptor
- Receptor parallel to long axis of tooth
- Less distortion than bisecting angle
- OID increased because palatal vault of mouth is in the way
  - Image more magnified

- **Extension cone paralleling device**
  - Positions film/digital sensor
  - Must be used to ensure position indicating device is pointing in the right direction

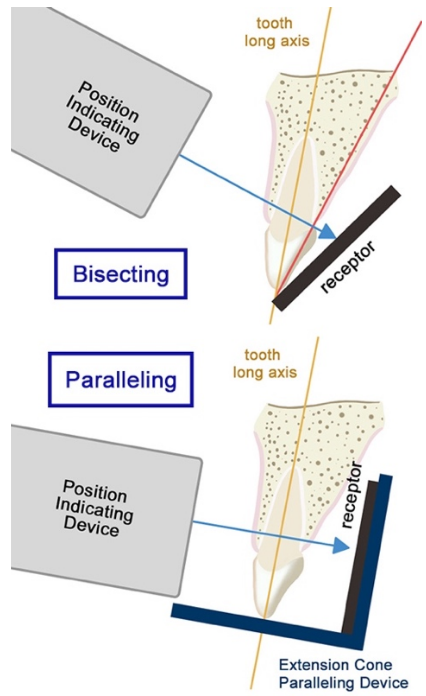


Figure 4.06 Intra-oral Imaging Techniques

6 Common Errors

1. Elongation of teeth (most frequent)
   - Due to angulation or bent receptor
2. Cone Cut
   - X-ray beam and receptor not lined up
3. Underexposed
   - Image too light and grainy
4. Overexposed
   - Image too dark
5. Double Exposure
   - New image placed on PSP plate that was not cleared of previous image → two images exposed on same PSP plate

6. Motion
    - From patient moving, swallowing etc.
        - irregular lines in otherwise well-defined places
7. Chin Down → Smile
    - Chin too far down → excessive upward curve of occlusal plane
8. Chip Up → Frown
    - Chin too far up → flat or downward curve of occlusal plane

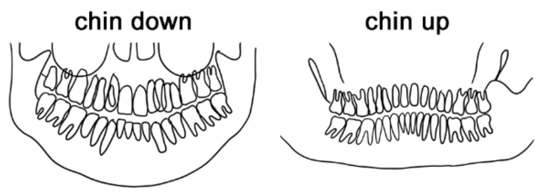


Figure 4.07 Errors by chin movement

9. Ghosting
    - Radiopaque artifact (jewelry, glasses, metal dentures etc.) projected to other side of radiograph
    - Represents an image detection lag

Interpreting Radiographs

When reading radiographs, there are a few general guiding principles to follow

1. Know what normal should look like
2. Compare each side (look for symmetry)
3. Classify the finding, abnormality or disease
4. Begin broad, and narrow it down (start with big structures/landmarks, then go to smaller ones)

Radiolucent Lesions

1 Radiographic Lesions

1. **Non-corticated Unilocular**
   - One radiolucent compartment with no clear border, edges are diffuse or hard to trace
2. **Corticated Unilocular**
   - One radiolucent compartment with a radiopaque border
3. **Multilocular**
   - Multiple radiolucent lesions normally separated by septations
   - One central part/point of origin
4. **Multifocal Confluent**
   - Multiple radiolucent lesions that have multiple points of origin
   - Lesions are starting to converge together
5. **Moth-Eaten**
   - Irregular and ragged edges
   - Generalized (large region of mouth) local effect

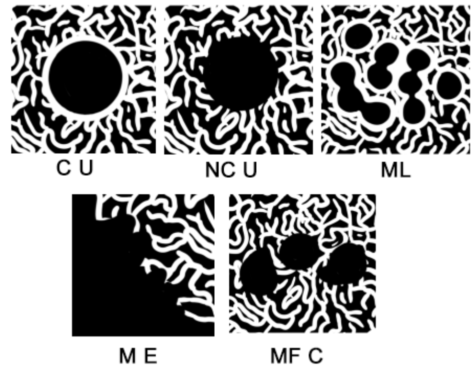


Figure 5.01 Radiolucent lesions

Radiopaque Lesions

1. **Focal Opacity**
   - Single radiopaque site
   - Can be homogenous (same density) or heterogeneous (varying density)
2. **Target Lesion**
   - Radiopaque center with radiolucent band around it
   - Corticated border around the radiolucent band
3. **Multifocal Confluent**
   - Multiple radiopaque sites with multiple points of origin
   - Sites are started to converge together
4. **Irregular**
   - Irregular edges
   - **Osteosarcoma** = classic irregular radiopacity
5. **Ground Glass**
   - Fine granular appearance
     - Resembles an orange peel
6. **Mixed Density**
   - Mixed radiopaque and radiolucent (heterogeneous)
   - May be corticated
   - Sometimes seen in maxillary sinus, zygoma or crown of unerupted tooth

7. Soft Tissue Opacity
- Calcifications within soft tissue
- Not in hard tissue on jaw bone

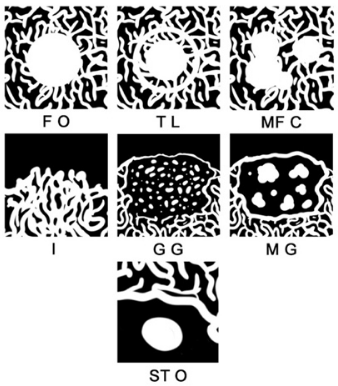


Figure 5.02 Radiopaque lesions

Panoramic Radiopacities

1. **Phlebolith** – calcified blood clot
   - Usually located in pterygoid plexus by the sigmoid notch or pterygomaxillary fissure
2. **Calcified lymph nodes**
   - Have cauliflower-like appearance
   - Often seen at angle of the mandible
3. **Tonsilloliths –** hard bits of bacteria and debris on tonsils
   - Most common calcification
   - Common cause of halitosis
   - Often superimposed at the ramus
4. **Calcified atheromatous plaque –** calcified plaque in arteries
   - Often seen below angle of the mandible at the level of the hyoid bone (level C3-C4 of vertebrae)
5. **Antrolith** – calcified mass in maxillary sinus
6. **Ossified stylohyoid ligament**
7. **Sialoliths** – calcified mass in salivary glands
   - Often seen in submandibular gland or Wharton's duct near mandibular incisors
   - Appear flatter if in a duct, round in a gland

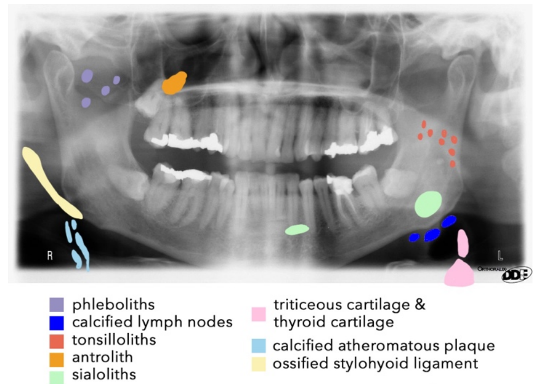


Figure 5.03 Panoramic radiopacities

Benign and Malignant Radiographic Lesions

Benign Lesions

	Effect
Margins	Defined (narrow transition) Smooth, regular, corticated
Shape	Round like, regular
Internal	Tumors – multilocular, likely for resorbed roots Cysts – unilocular, more corticated, hydrostatic
Location	Coronal or above mandibular canal
Cortical Bone	Expanded, thinning, displaced, erosion if aggressive
Max. Sinus	Displacement
Mand. Sinus	Displacement w/ no neurosensory defects
Tooth Position	Displacement May prevent eruption
Tooth Root	Horizontal resorption
PDL Space	N/A
Lamina Dura	N/A

Malignant Lesions

	Effect
Margins	Poorly defined (wide transition zone), moth eaten
Shape	Irregular
Internal	Often radiolucent (exception: osteocarcoma is irregular and opaque)
Location	Ramus Posterior body of mandible
Cortical Bone	Erosive and destructive
Max. Sinus	Erosive and destructive
Mand. Sinus	Invasive and destructive Neurosensory defects
Tooth Position	Floating teeth = bone around tooth eaten, possible tooth resorption
Tooth Root	Vertical resorption = spiked roots, No resorption = floating teeth
PDL Space	Asymmetric widening
Lamina Dura	Loss of lamina dura

2 Caries Detection

A tooth needs 30-40% mineral loss before it can be identified on a radiograph. That is, carious lesions are always smaller on a radiograph than they are clinically. Enamel cavitation and lesion into dentin are more evident on a radiograph, meanwhile a white spot can hardly be seen on a radiograph. The different types of caries can be identified on a radiograph by identifying their different characteristics.

1. **Inter-proximal** – little triangle at or below the meeting point
2. **Occlusal** – small radiolucency below fissure
   - Has diffuse borders that are hard to differentiate where caries stops
   - Relatively centered on crown
3. **Buccal** – Small circle at the level of buccal/ lingual pit in molar
   - Has sharper borders
4. **Recurrent** – Gingival/beneath restoration
   - Bitewing radiographs can hide these
   - PA radiograph tends to show these due to angulation
5. **Root** – hemispherical/semicircular at or below CEJ
   - Root edge seems to disappear, cannot trace root outline
   - Easily confused with cervical burnout since mesial/distal surface of CEJ has low x-ray absorption

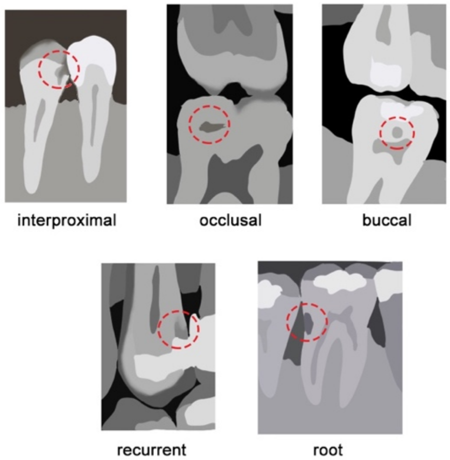


Figure 5.04 Caries detection

3 Detection of Periodontitis

1. **Mild Bone Loss** – at upper 1/3 of root
    - 1-2mm bone loss beyond normal
    - Often seen when alveolar root area is fuzzy
2. **Moderate Bone Loss** – at middle 1/3 of root
    - >2mm bone loss
3. **Severe Bone Loss** – at lower 1/3 of root
    - Commonly in mandibular anterior region
    - Calculus forms there quick + thin bone in that area

Figure 5.05 Bone loss

Buccal Object Rule

A big limitation of 2D x-rays is that there is no sense of depth. One way around this is to compare two x-ray images of the same spot that are at slightly different angles. Then apply the buccal object rule to decipher if an object is more lingual/buccal or mesial/distal.

The Buccal Object Rule follows the acronym **SLOB** (same lingual opposite buccal). To understand the concept, follow these steps.

1. Hold a peace sign with your left hand.
2. Rotate your whole left hand so that the middle finger and index finger of the peace sign are in-line with each other in your line of sight.
3. Move your head slightly to the right. Notice how the middle finger (finger that's farther away) appears to be moving the same direction your head is moving. On the other hand, your index finger (finger closer to you) seems to be moving the opposite direction.

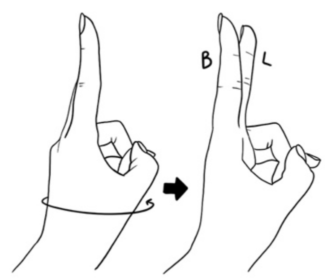


Figure 5.06 Buccal object rule

The Buccal Object Rule demonstrates that as you move the tube-head in one direction, the more lingual object in the image will move in same direction of the tube-head. The buccal object will move in the other direction.

INBDE Pro Tip: For vertical changes in angulation, hold the peace sign horizontally. For horizontal angulation changes, hold the peace sign upright.

Now let's apply this rule to radiographic

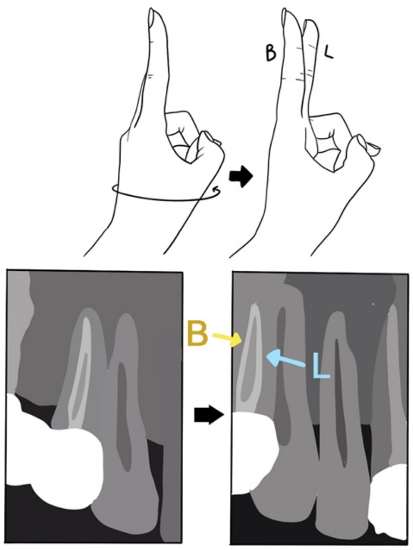


Figure 5.07 Buccal object rule in radiographic image

images

1. In the first radiograph, we see two root canals. However, we cannot tell which one is lingual and which one is buccal.
2. By taking a second radiograph that is slightly more anterior (to the right), we notice that the orientation of the canals has changed.
3. Using the Buccal Object Rule, we know that the canal towards the right followed the direction the x-ray tube-head moved. Therefore, the right canal is lingual and the left canal is buccal.