L.1-2

Radiation Physics

By

Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.

Oral Radiology Teacher, Anbar University

Introduction

Radiology is the science that deals with diagnosis, therapeutic and researches application of high energy radiation.

Dental radiography is a process of image production for an object through the use of x– radiation.

Radiologic examination is an integral component of the diagnostic procedure. Dentists often make radiographic images of patients to obtain additional information beyond that available from a clinical examination or their patient's history. Information from these images is combined with the clinical examination and history to make a diagnosis and formulate an appropriate treatment plan.

Atomic theory: An Atom is a small part of element that takes part in chemical reactions. It is made up of three subatomic structures called Protons, Neutrons, and Electrons.

Radiology is the science that deals with diagnosis, therapeutic and researches application of high energy radiation.

Dental radiography is a process of image production for an object through the use of x – radiation.

Radiologic examination is an integral component of the diagnostic procedure. Dentists often make radiographic images of patients to obtain additional information beyond that available from a clinical examination or their patient's history. Information from these images is combined with the clinical examination and history to make a diagnosis and formulate an appropriate treatment plan.

Atomic Structure:

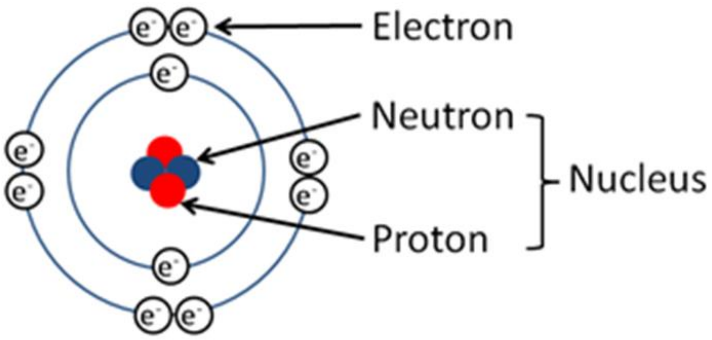
The nucleus, in the center of an atom, consist of protons and neutrons. Orbiting around the nucleus are the electrons. Each unique element has an Atomic Number equal to the number of protons it contains.

There are 94 naturally occurring elements (1-94) and others which have been artificially created (95+...). Each element has an Atomic Weight for the most commonly found isotope.

In a stable uncharged atom the number of electrons will equal the number of protons. If the number of electrons is changed the atom will become ionized and gain either a positive (fewer electrons) or negative (greater electrons) charge.

Different materials (for example, gold and lead) will have different numbers of protons/electrons in their atoms. However, all the atoms in a given material will have the same number of electrons and protons.

Neutrons act as binding agents within the nucleus, they counteract the repulsive forces between the protons.



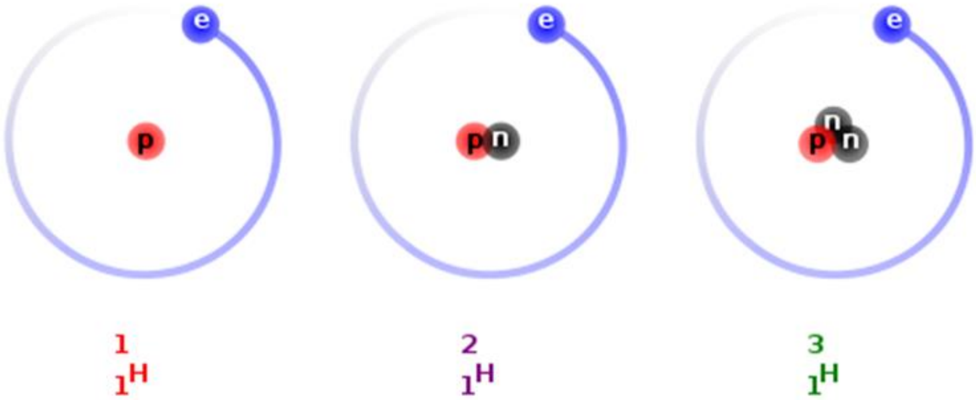
Atomic Number (Z): Number of protons in the nucleus of an atom.

Neutron Number (N): Number of neutrons in the nucleus of an atom.

Atomic Mass number (A): Sum of the number of protons and neutrons in an atom.

Isotopes:

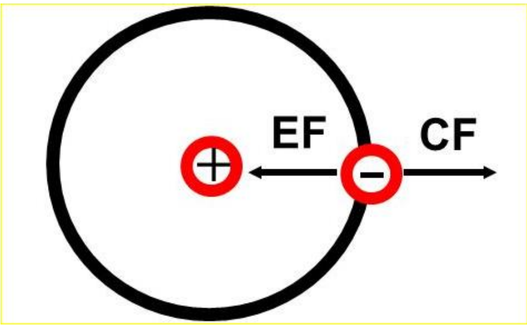
The same element can exist in different forms, each form having the same atomic number (Z), but different Atomic Mass Number (A) and hence different number of neutrons. These forms are called isotopes. Isotopes that cannot decay during a defined period are called stable isotopes. And isotopes that can decay during a defined period are called unstable (or radioactive) isotopes.



Nucleons: Protons and Neutrons together are referred to as nucleons.

Electrostatic force is the attraction between the negative electrons and the positive protons. This attraction causes the electrons to be pulled toward the protons in the nucleus.

In order to keep the electrons from dropping into the nucleus, **the centrifugal force,** pulls the electrons away. The balance between these two forces keeps the electrons in orbit around the nucleus.



- Electrostatic force is the attraction between the positive protons and negative electrons.
  - Electrons in the orbit closest to the nucleus (the K-shell) will have a greater electrostatic force than will electrons in orbits further from the nucleus.
- Binding energy: is the amount of energy required to overcome the electrostatic force to remove an electron from its orbit. For our purposes, electrostatic force and binding energy are the same.
  - The higher the atomic number of an atom (more protons), the higher the electrostatic force will be for ALL electrons in that atom.

Ionization potential: It is the minimum amount of energy that must be transferred to the least tightly bound orbital electron in order to remove it completely from the atom.

Radioactivity: Unstable atoms or elements whose nuclei undergo spontaneous disintegration or decay in an effort to reach a more balanced nuclear state**.**

Radiation: It is the emission and propagation of energy in space or substance in the form of waves or particles**.**

Particulate Radiation:

They are tiny particles of matter that possess mass and travel in straight lines at high speeds.

	Charge	Origin
Beta particles	-1	Nucleus
Cathode rays	-1	X-ray tube
Neutrons	0	Nucleus
Protons	+1	Nucleus
Alpha particles	+2	Nucleus

(2 protons and 2 neutrons)

***Electromagnetic Radiation*:**

- It is the emission and propagation of energy through space or substance as a combination of electric and magnetic fields oscillating perpendicular to one another and to the path of travel. They travel through space in wave form.
- Examples of electromagnetic radiation are: x-rays, radiowaves, tv waves, visible light, microwaves and gamma rays.
- Electromagnetic radiation travel at the speed of light (186,000 miles/s or $3x10^8$ m/s).

<u>Particle concept:</u>

It characterizes electromagnetic radiation as discrete bundles of energy called photons or quanta with no mass or charge, travelling in space at the speed of light in straight lines.

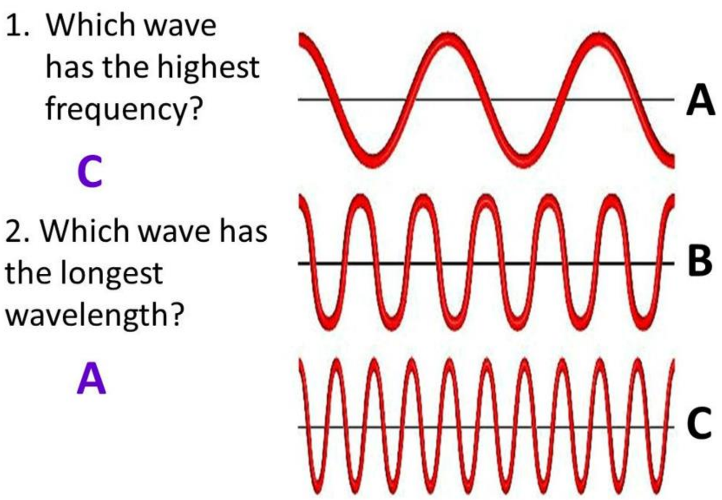
Wave concept:

It characterizes electromagnetic radiation as waves and focuses on the properties of waves (velocity, wavelength and frequency).

X – Ray photons travel with a wave motion called (sine – wave) and the distance between the crests of these waves called (wave – length) which measured by a unit (A°). The X – ray photons wave length used in diagnostic radiography is ranged between 0.1 – 0.5 A°, and the amount of energy contained in each photon called (photon energy) which depend on Wave length and Frequency of x – ray.

Properties of electromagnetic radiation waves:

1. Velocity is the speed of the wave.
2. Wavelength (W) is the distance from the crest of one wave to the crest of the next wave.
3. Frequency (F) is the number of waves in a given time.
    - If the distance between waves decreases (W becomes shorter), the frequency will increase.
4. The C wave has a shorter wavelength and a higher frequency than the waves above it.



Particulate Radiation:

1. Has mass.
2. Has charge (except Neutrons).

3. Travel at high speed.
4. Travel as tiny particles in a straight line.

***Electromagnetic Radiation*:**

1. No mass.
2. No charge.
3. Travel at speed of light ($3x10^8$ m/s).
4. Travel as photons in a wave form in a straight line.
5. Has frequency and wavelength.

X-ray Energy:

X – Ray was discovered by (Roentgen) in 1895, it travels in a form of pure energy and the basic unit is x – ray photon or (quantum).

- The energy of a wave of electromagnetic radiation represents the ability to penetrate an object.
- The higher the energy, the more easily the wave will pass through the object.
- The shorter the wavelength, the greater the energy will be & the higher the frequency, the greater the energy will be.
- X-rays and Gamma rays are the same type of radiations, the only difference between the two is their source. Gamma rays are emitted from nuclei of certain radioactive elements in the process of nuclear decay whereas X-rays are produced as a result of rapid deceleration of high speed electrons.

X-ray Characteristics:

1. Differentially absorbed by the materials they pass through.
2. Cause certain materials to fluoresce (We use this property with intensifying screens used in extraoral radiography).
3. Harmful to living tissue.
4. High energy waves with very short wavelengths
5. No mass.

6. Electrically neutral (cannot be accelerated or made to change direction by a magnet or electric field).
7. Travel at speed of light.
8. Invisible.
9. Travel in straight lines.
10. Cannot be focused to a point.
11. Diverges (spreads out) as it travels toward and through the patient.
12. Forms a polyenergetic or heterogeneous beam.
13. Cause chemical changes in radiographic and photographic film.
14. No medium is required for propagation.

Comparison between x – ray and light:

1. Both belong to the same electro – magnetic radiation family.

2. Both travel in straight lines at the same speed which is 186,000 miles per seconds.

3. Both affected the photographic films and made them black.

4. Both not affected by magnetic fields.

5. X-ray and light cast the shadows of the objects in the same manner.

6. X-ray has the ability to penetrate objects that the light cannot pass through.

7. X-ray has the ability to ionize atoms.

8. X-ray has the ability to produce light (blue light) when it hits some objects and this phenomena called (fluorescence).

9. X-ray is invisible.

Parts and components of the dental x-ray machine:

X-ray machines produce x-rays that pass through a patient's tissues and strike a digital receptor or film to make a radiographic image.

General. The standard structural parts of the dental x-ray machine include a **control panel** (usually mounted behind a protective shield); a **tube head**, which houses the *dental x-ray tube* *and its power supply*; and a **flexible extension arm** from which the tube head is suspended.

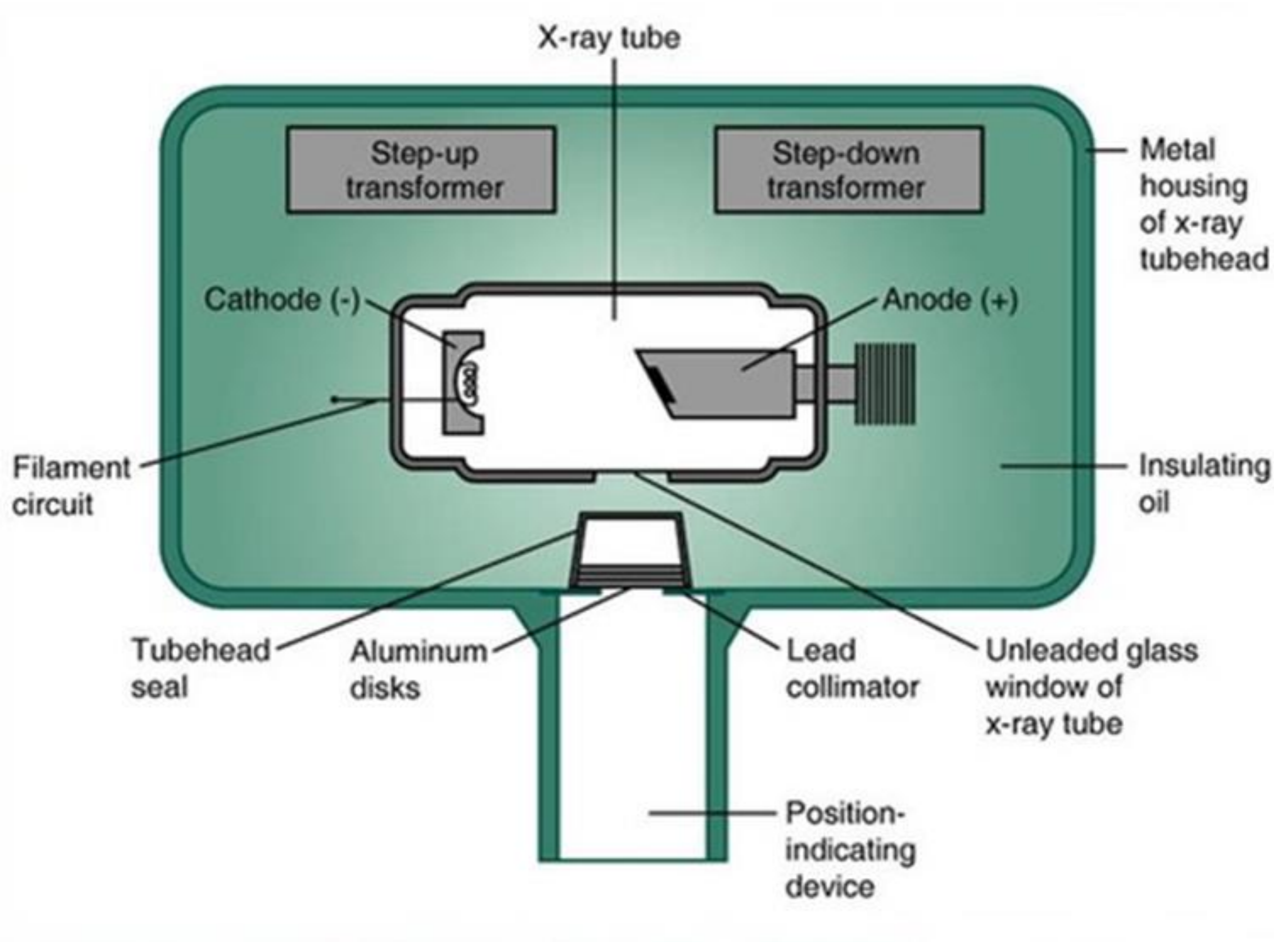
1.The Control Panel. The components of the **control panel** are switches, dials, gauges, and lights. Basically, each control panel has the same function, the arrangement and location of these components will differ, depending upon the make, model, and year of construction of the dental x-ray unit. An operator's manual is issued with each unit. The operator should study it until he is familiar with its operational capability. The control panel allows the operator to adjust the duration of the exposure, and often the energy and exposure rate of the x-ray beam.

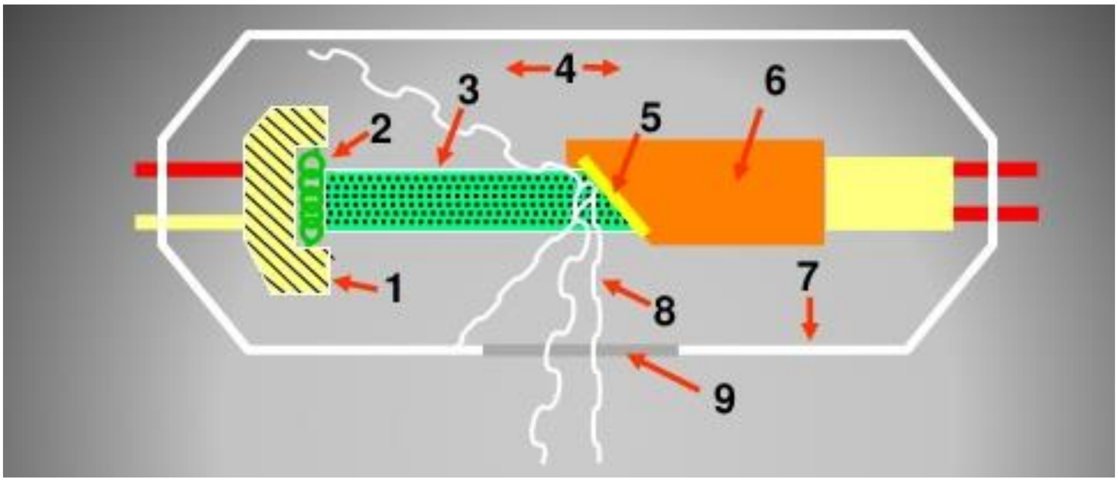
2. The Extension Arm. The tube head is attached to the metal **extension arm** by means of a yoke that can revolve 360 degrees horizontally where it is connected. The construction of the yoke also provides vertical movement as well.

3. The Tube Head. Inside the metal tube housing is the x-ray tube. This tube emits radiation in the form of photons or x-rays. X-ray photons expose the film. In addition to exposing the film, it also exposes the patient to radiation. Unless certain protective measures are taken, the x-ray technician may also be exposed. An electrical insulating material, usually oil, surrounds the tube and transformers. It grounds the high voltage component and protects the X-ray tube. The primary function of the oil is to insulate the electrical components. It also helps to cool the anode and, as we will discuss later, it helps infiltration of the x-ray beam. The Tube head seal prevents the oil from leaking out of the tubehead but still allows most x-rays to pass through. Often, the tube is recessed within the tube head to increase the source-to-object distance and minimize distortion.

Examples of modern dental X-ray generating equipment. A Wall-mounted Prostyle Intra® manufactured by Planmeca. B Mobile Kodak 2200. C Hand-held Nomad ™ manufactured by Aribex.

Positioning-indicating device (PID): Aims and shapes the x-ray beam also, referred to as the cone.





<u>X-ray Tube Components:</u>

1. Focusing cup.
2. Filament.
3. *Electron stream.*
4. Vacuum.
5. Target.
6. Copper stem.

7. Leaded glass.
8. X-ray.
9. Unleaded glass window.

X–ray tube is composed of a cathode and an anode situated within an evacuated glass envelope or tube.

1. Focusing cup: focuses electrons on target, electrons cross from filament to target during length of exposure. It is made of Molybdenum.

2. Filament: releases electrons when heated.

3. Vacuum: no air or gases inside x-ray tube that might interact with electrons crossing tube.

- The x-ray tube is evacuated to prevent collision of the fast-moving electrons with gas molecules, which would significantly reduce their speed. So the vacuum will increase velocity of the electrons and prevent ionization of the gas molecules during electron bombardment of the target.

- The vacuum also prevents oxidation, or "burnout," of the tungsten filament.

4. Target: x-rays produced when electrons strike target.

5. Copper stem: helps remove heat from target.

6. Leaded glass: Keeps x-rays from exiting tube in wrong direction, X-rays produced in target are emitted in all directions.

7. Unleaded Glass Window: It allows x-rays to pass through. The PID would be located directly in line with this window.

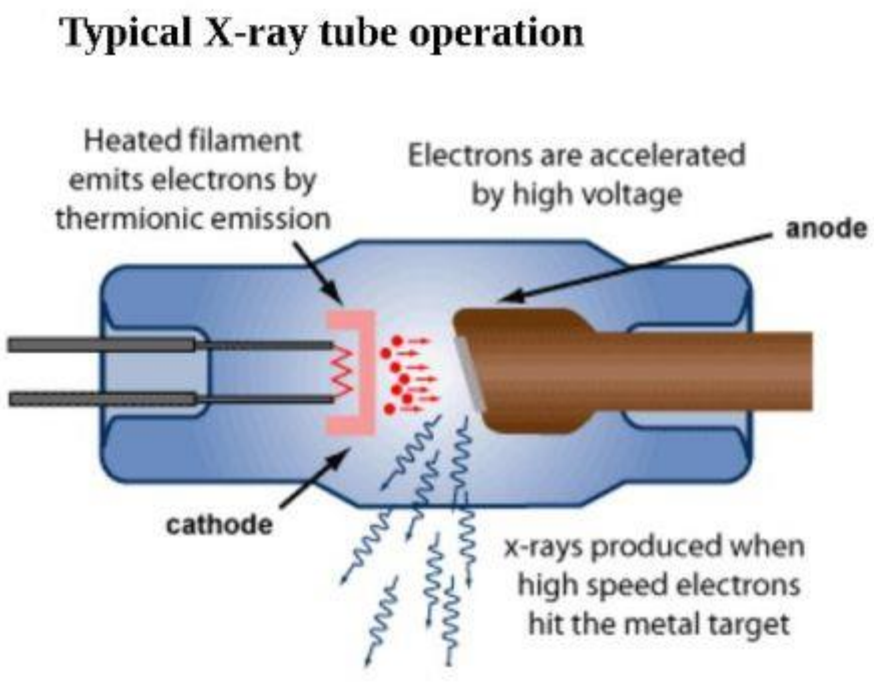
The cathode is composed of a tungsten filament which is centered in a focusing cup. The filament is a coil of tungsten wire approximately 2 mm in diameter and 1 cm or less in length, and typically contains approximately 1% thorium, which greatly increases the release of electrons from the heated wire. The filament is heated by a low-voltage source and emits electrons at a rate proportional to the temperature of the filament. The focusing cup is made of concave molybdenum bowl. Electrons are produced by the filament (the source of electrons) by thermionic emission and are focused on the target of the anode where the x-rays are produced. The focusing cup has a negative charge, like the electrons, and this helps direct the electrons to the target ("focuses" them; electrons can be focused, x-rays cannot).

Thermionic Emission:

It is the release of electrons from the Tungsten filament when electric current passes through it and heats it up. The hotter the filament gets, the greater the number of electrons that are released.

The anode in the x-ray tube is composed of a tungsten target, an element that has several characteristics of an ideal target material, embedded in a copper stem. Copper has a high thermal capacity and good conduction properties. The large block of copper which functions as a thermal conductor helps to take some of the heat away from the target so that it doesn't get too hot, reducing the risk of the target melting. The electrons emitted by the filament into a narrow beam directed at a small rectangular area on the anode called the focal spot. Focal spot is the area of the target to which the focusing cup directs the electrons from the filament. When electrons from the filament hit the target and generate x-rays, a lot of heat is produced. The purpose of the target in an x-ray tube is to convert the kinetic energy of the colliding electrons into x-ray photons.

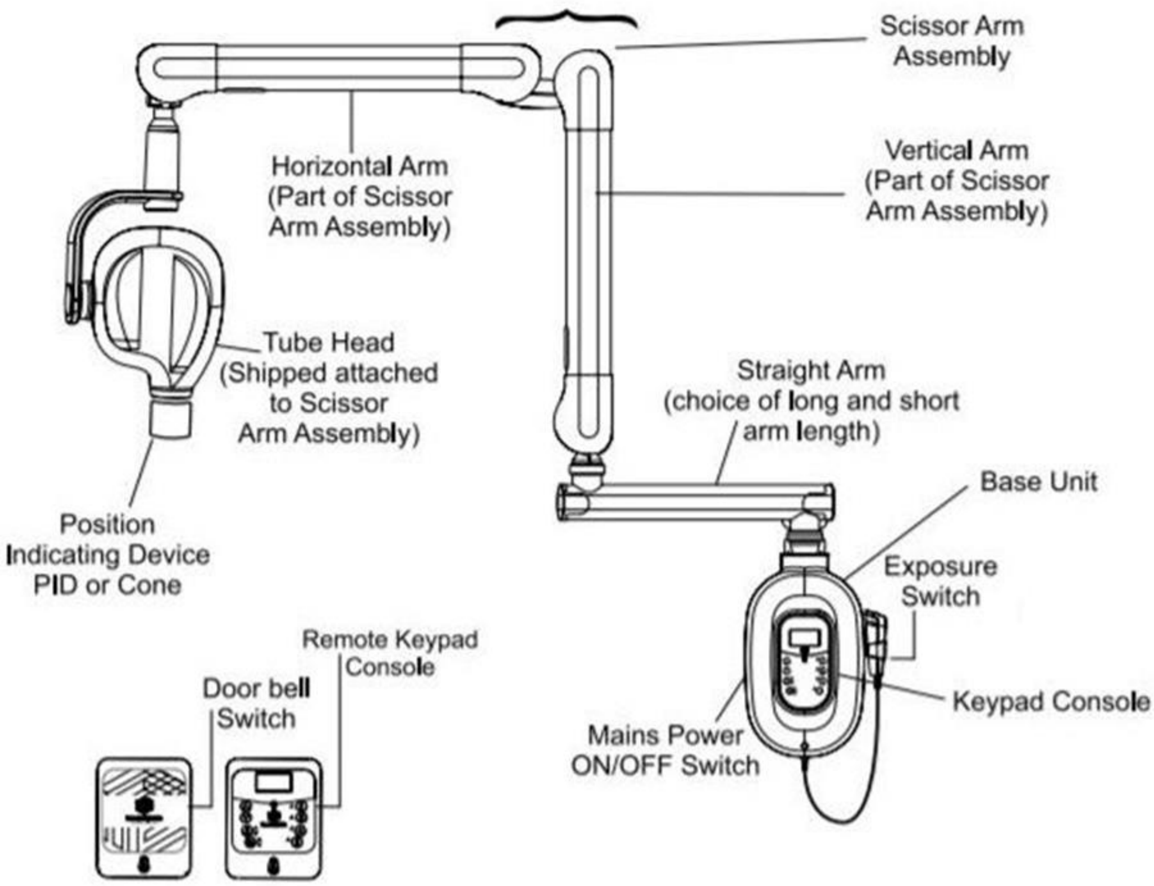
To produce x-rays, electrons stream from the filament in the cathode to the target in the anode, where the energy from some of the electrons is converted into x-rays.



Tungsten: ***(Filament and Target)***

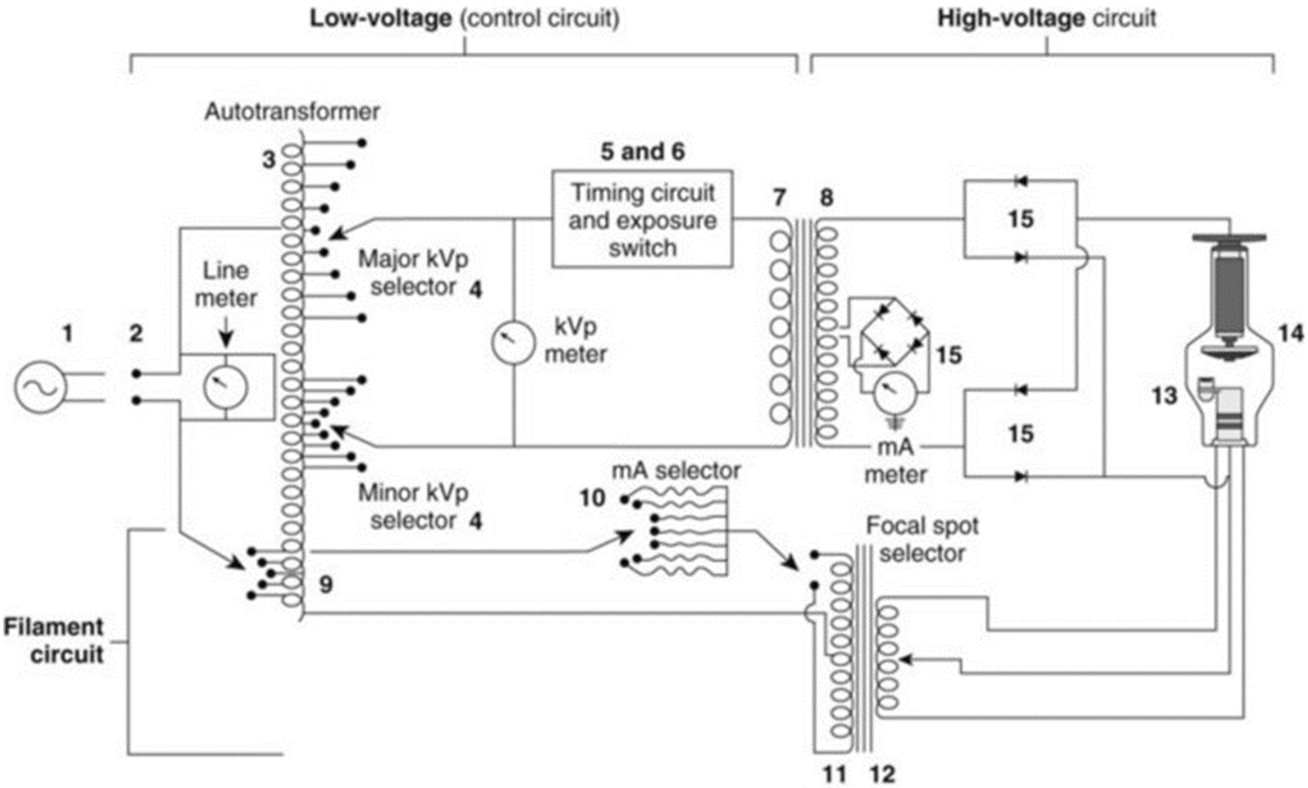
1. High atomic number (Z=74), allows for efficient x-ray production.
2. High thermal conductivity (173 W m−1 K−1), transfers heat readily, to dissipate the heat produced away from the target.
3. High melting point (3422°C), to withstand heat produced during x-ray production.
4. Can be drawn into fine wire.
5. Low vapor pressure at the working temperatures of an x-ray tube, to help maintain vacuum in the tube at high operating temperatures.

X-ray Machine Components:



Wall Mounted Intraskan DC

***Electrical circuits*:**



Simplified diagram of an x-ray circuit. Electric circuit going into the x-ray room is at far left (1) and circuit ends at x-ray tube far right (14).

The x-ray machine is plugged into the electrical outlet (110 volts usually). The length of the exposure is selected with the timer. The current flows into the x-ray tubehead. This activates the low-voltage circuit which heats the filament.

When the exposure button is depressed, the high-voltage circuit is activated to pull the electrons from the filament to the target, producing x-rays. The x-rays pass through the filter and collimator before exiting through the PID.

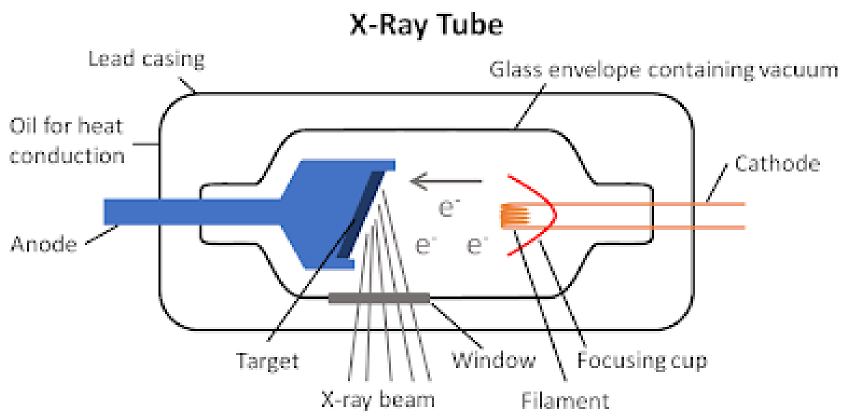
***X-ray Exposure*:**

1. Low-voltage circuit heats the filament.

2. High-voltage circuit pulls electrons across tube.

3. Electrons cross tube, strike target and produce x-rays.

4. X-ray production stops when exposure time ends. Release exposure button.



Exposure Button:

The timer determines the length of the exposure, not how long you hold down the exposure button; you cannot overexpose by holding the exposure button down for an extended period. However, you can underexpose by releasing the exposure button too soon; the exposure terminates as soon as you release the button.

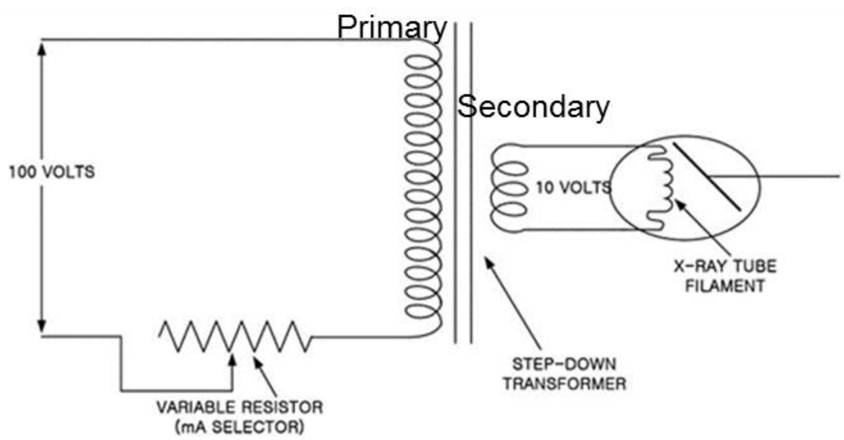
The milliAmpere (mA) selector:

The mA setting determines the amount of current that will flow through the filament in the cathode. This filament is very thin; it doesn't take much current (voltage) to make it very hot.

The higher the mA setting, the higher the filament temperature and the greater the number of electrons that are produced.

Step-Down Transformer:

The fewer turns in the coil on the secondary side, the lower the output voltage will be.



If the voltage flowing through the filament is too high, the filament will burn up. In order to reduce the voltage, the current flows through a step-down transformer before reaching the filament.

The voltage reaching the step-down transformer is determined by the mA setting.

The step-down transformer reduces the incoming voltage to about 10 volts, which results in a current of 4-5 amps flowing through the filament.

KiloVolt peak (kVp) control:

The kVp control regulates the voltage across the x-ray tube. (A kilovolt represents 1000 volts; 70 kV equals 70,000 volts. A 70 kVp setting means the peak, or maximum voltage, is 70,000 volts).

The higher the voltage, the faster the electrons will travel from the filament to the target. The kVp control knob regulates the autotransformer.

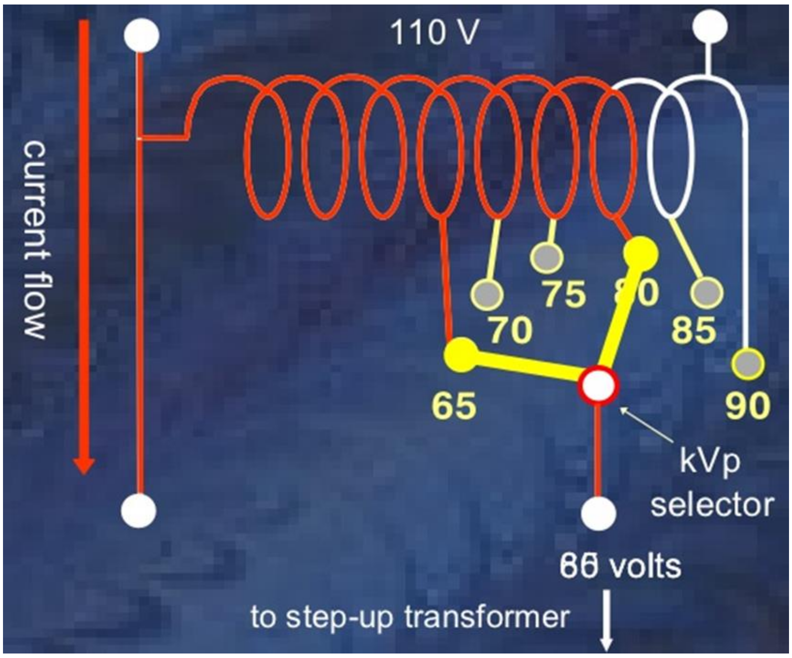
Examples of modern dental X-ray equipment control panels. A Focus® manufactured by Instrumentarium Imaging. B Prostyle Intra® manufactured by Planmeca. C

Heliodent® DS manufactured by Sirona. They are all anatomical timers suitable for film and digital imaging.

Autotransformer: the initial setting is 65; 65 volts leave the autotransformer. If the setting is changed to 80, 80 volts leave the autotransformer. The autotransformer determines how much voltage will go to the step-up transformer.

The more turns of the coil that are selected (using the kVp control knob), the higher the voltage across the x-ray tube will be.

The incoming line voltage will be 110 volts. The exiting voltage will be 65 volts if the kVp control is set at 65. The exiting voltage will be 80 volts if the kVp setting is 80.

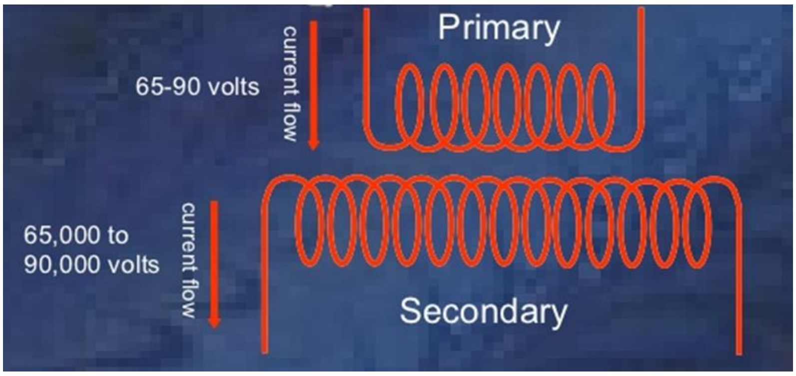


Step-Up Transformer:

The voltage coming from the autotransformer next passes through the step-up transformer, where it is dramatically increased.

The ultimate voltage coming from the step-up transformer is roughly a thousand times more than the entering voltage. For example, if you set the kVp control knob to 65, 65 volts will exit the autotransformer. This 65 volts is increased to 65,000 volts by the step-up transformer. (The "k" in kVp stands for one thousand; 65 kV is 65,000 volts).

The more turns in the coil on the secondary side, the higher the output voltage will be. The secondary coil in the step-up transformer has 1000 times as many turns as the p*rim*ary coil.



Line Focus Principle:

The smaller the focal spot (target), the sharper the image of the teeth will be.

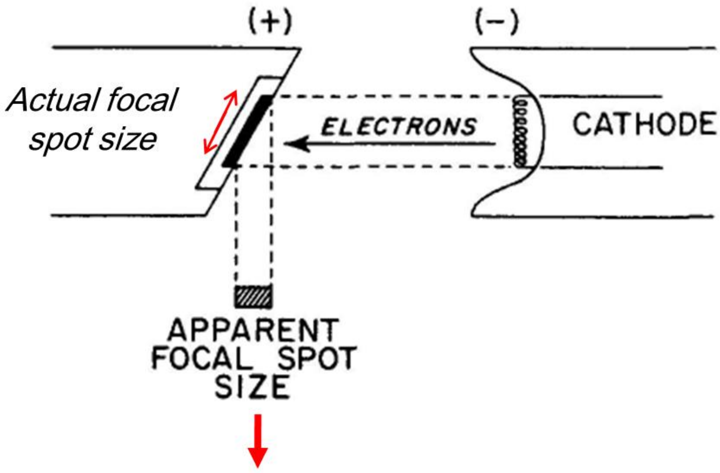
The larger the focal spot (target), the higher the work load capacity

During x-ray production, a lot of heat is generated. If the target is too small, it will overheat and burn up. In order to get a small focal spot, while maintaining an adequately large target, the line focus principle is used.

The target is at an angle (not perpendicular) to the electron beam from the filament.

Because of this angle, the x-rays that exit through the PID "appear" to come from a smaller focal spot.

Even though the actual focal spot (target) size is larger (to withstand heat buildup), the smaller size of the apparent focal spot provides the sharper image needed for a proper diagnosis.



Actual focal spot size refers to the size of the area on the anode target that is exposed to bombarding electrons from the cathode.

Effective focal spot size refers to focal spot size as measured directly under the anode target.

X-ray Production:

The conversion of the kinetic energy of the electrons into x-ray photons is an inefficient process. Only 1% of the interactions between the high-speed electrons and the target atoms result in x-rays photons with more than 99% of the electron kinetic energy converted to heat.

Interactions:

At the anode, electrons can interact with the atoms of the anode in several ways to produce x-ray photons.

1. **Outer shell interaction** (Heat producing interactions): low energy electromagnetic radiation released and quickly converted into heat energy.

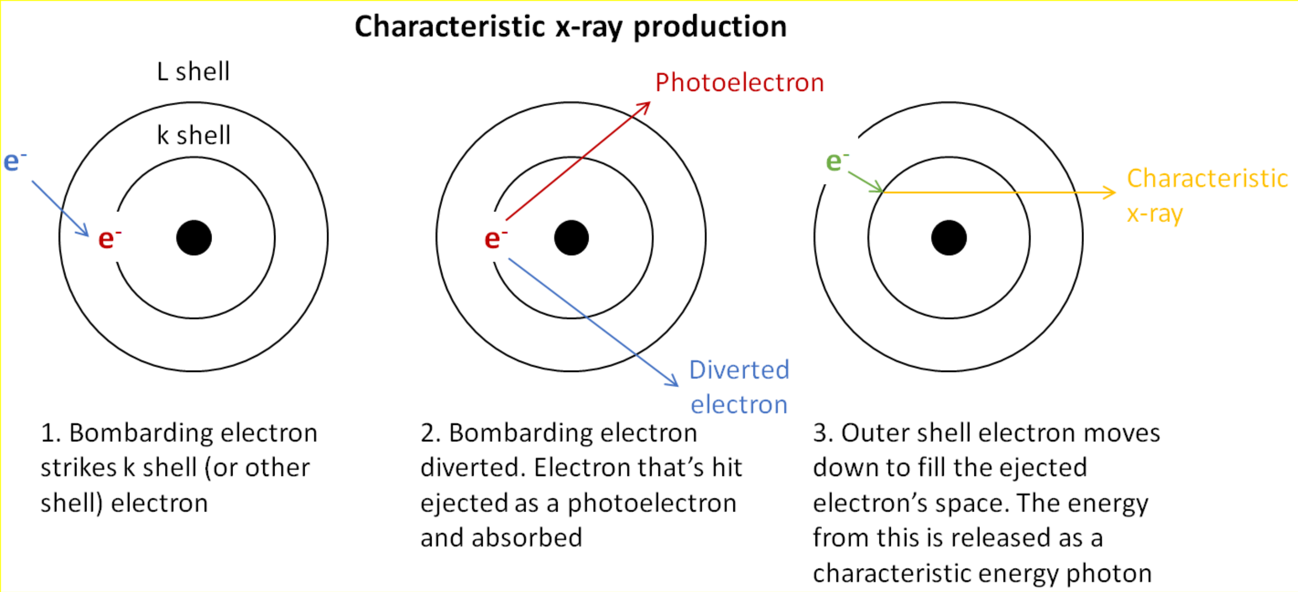
There are two types of x-rays produced in the target of the x-ray tube. The majority are called Bremmstrahlung radiation and the others are called Characteristic radiation.

2. **Inner shell interaction**: produces characteristic radiation via interaction with inner shell electrons.

Characteristic x-rays have energies “characteristic” of the target material.

The energy will equal the difference between the binding energies of the target electrons involved. For example, if a K-shell electron is ejected and an L-shell electron drops into the space, the energy of the x-ray will be equal to the difference in binding energies between the K- and L-shells.

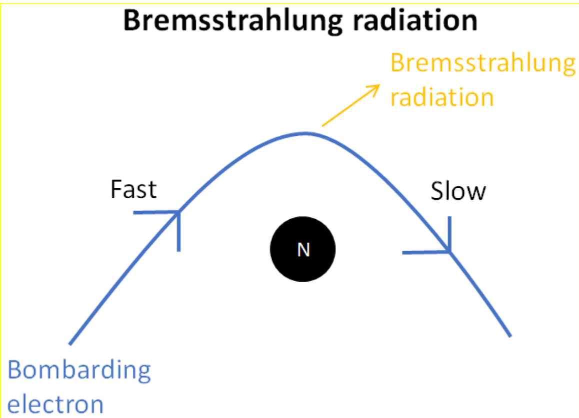
The binding energies are different for each type of material; it is dependent on the number of protons in the nucleus (the atomic number).



3. **Nucleus field interaction:** Bremsstrahlung radiation. (Braking radiation Or General radiation Or Continuous Radiation)

80% of x-rays are emitted via Bremsstrahlung. Bremmstrahlung x-rays are produced when high-speed electrons from the filament are slowed down as they pass close to, or strike, the nuclei of the target atoms. The closer the electrons are to the nucleus, the more they will be slowed down. Rarely, the electron is stopped completely and gives up all its energy as a photon.

The higher the speed of the electrons crossing the target, the higher the average energy of the x-rays produced. The electrons may interact with several target atoms before losing all of their energy. More commonly, a series of interactions happen in which the electron loses energy through several steps. Bremsstrahlung causes a spectrum of photon energies to be released.



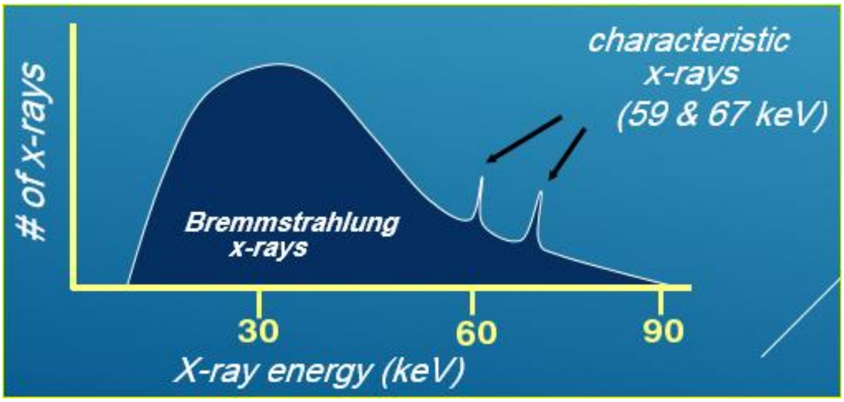
Characteristic Radiation	Bremsstrahlung

Only accounts for small percentage of x-ray photons produced	Accounts for 80% of photons in x-ray beam
Bombarding electron interacts with inner shell electron	Bombarding electron interacts with whole atom, does not penetrate atom
Radiation released due to electron dropping down into lower energy state	Radiation released due to diversion of bombarding electron as a result of the atomic pull
Radiation released is of a specific energy	Radiation released is of a large range of energies
X-ray beam energy depends on element of target atoms not tube voltage	X-ray beam energy depends on tube voltage

X-ray Spectrum:

An x-ray beam will have a wide range of x-ray energies; this is called an x-ray spectrum. The maximum energy is determined by the kVp setting. As shown below, characteristic x-rays contribute a very small number of x-rays to the spectrum (could be as much as 30%).

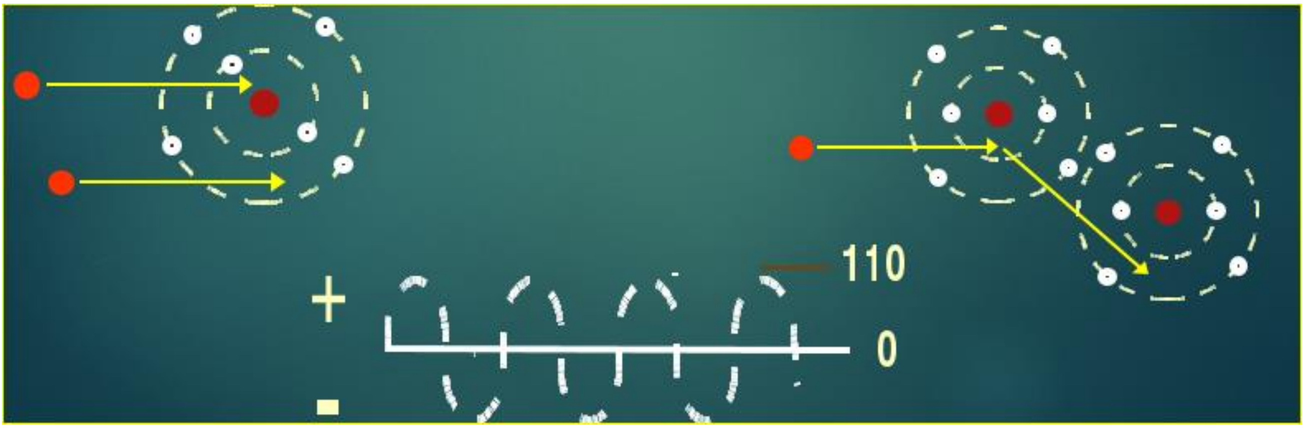
Below 70 kVp (with a tungsten target), 100% of the X-ray beam consists of Bremsstrahlung interactions. Above 70 kVp, approximately 85% of the beam consists of Bremsstrahlung interactions 70 kVp is referred to as the critical voltage. Dental X ray equipment usually operate between 50 kVp and 90 kVp.



X-ray Spectrum results from three factors:

- The varying distances between the high-speed electrons and the nucleus of the target atoms.
- Multiple electron interactions. The high-speed electrons keep going until all energy is lost.

- Varying voltage. With an alternating current, the speed of the electrons will change as the voltage changes. The higher the voltage, the faster the electrons will travel.



Heat Dissipation:

The excess heat is controlled by the high melting point of the tungsten target, the conductive properties of the copper sleeve and the cooling from the oil surrounding the x-ray tube.

If the target gets too hot, electrons will "boil off" and accelerate from the target to the filament during the reverse half of the alternating cycle when the target is negative and the filament is positive. Undesired radiation will be produced and the filament will be damaged by the electron bombardment.

Heat capacity or Tube rating:

5 minutes are required after a single continuous exposure of 17 seconds at 90 kVp and 15 mA for adequate heat dissipation before another exposure is made.

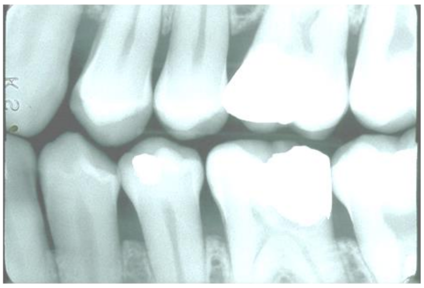
Duty cycle:

The permissible continuous exposure within a given time period

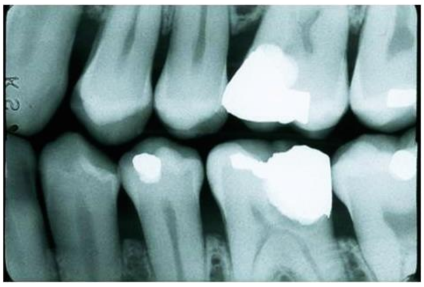
- One 4-second exposure each minute.
- Or 4 one-second exposures each minute.
- Or 8 half-second exposure each minute.

Exposure Factors:

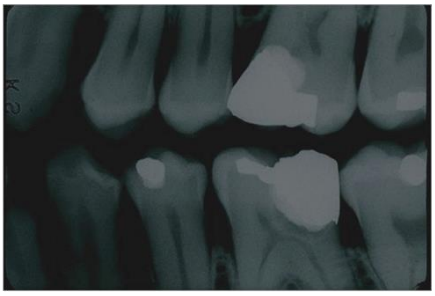
The energy of the x-ray beam and the number of x-rays are primarily regulated by the kVp control, the mA setting and the exposure time.



Exposure factors too low (too light)

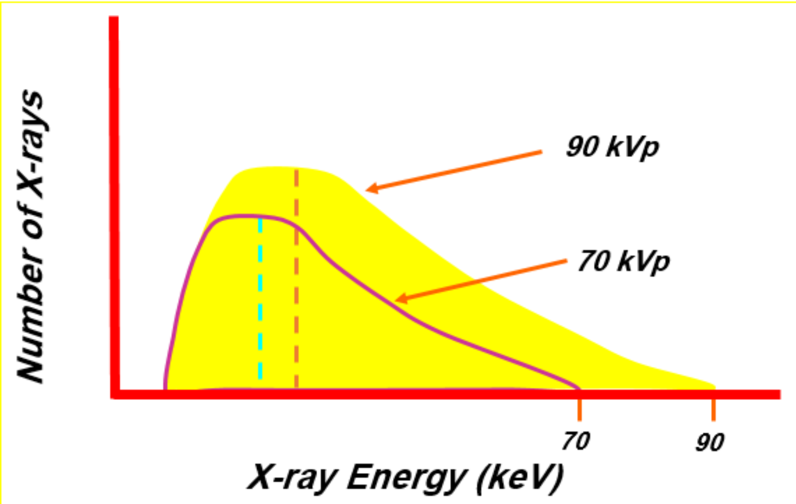


Correct exposure factors



Exposure factors too high (too dark)

kVp (kiloVolt peak):



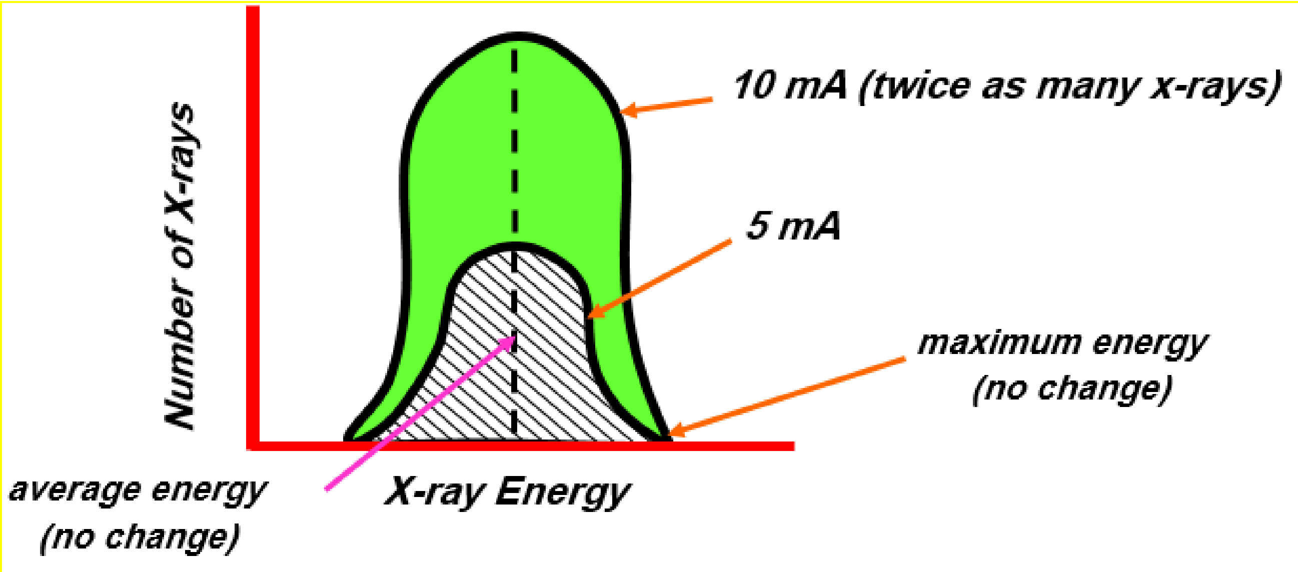
In switching from 70 kVp to 90 kVp, the average energy increases, the maximum energy increases (from 70 keV to 90 keV) and the number of X-rays increases.

The kVp primarily controls the energy or penetrating quality of the x-ray beam. The higher the kVp, the higher the maximum energy and the higher the average energy of the beam and the higher its penetrating ability.

A higher kVp will also result in the production of more x-rays. Because of this, an increase in kVp will allow for a decrease in exposure time, which may be helpful in children or in adults with uncontrolled head movement.

Dental X ray machines generate x rays in the range of 50,000 to 100,000 volt.

mA (milliampere):



The mA setting determines the heating of the filament. The hotter the filament, the more electrons that are emitted; the more electrons crossing the x-ray tube, the greater the number of x-rays that result. There is no change in the average energy or maximum energy of the x-ray beam. Doubling the mA setting results in twice as many x-rays.

An increase in exposure time will result in an increase in the number of x-rays. Doubling the exposure time doubles the number of x-rays produced. Exposure time has no effect on the average or maximum energy of the x-ray beam.

mAs or mAi:

mAs = milliamperes (mA) x seconds (s)

mAi = milliamperes (mA) x impulses (i)

All x-ray machines have an mA setting and an exposure time setting for each radiograph taken.

The product of the mA setting times the exposure time equals mAs or mAi, depending on whether the exposure time is in seconds or impulses.

As long as the mAs remains constant for a given patient size, the x-ray output will remain the same.

For example, if the mA setting is 5 and the exposure time is 0.5 sec, the mAs would be 2.5 (5 times 0.5). If we change the mA setting to 10 and decrease the exposure time to

0.25 sec, the mAs is still 2.5 (10 times 0.25). There will be no change in the number of x-rays. If an x-ray machine has variable mA settings, increasing the mA will allow for a decrease in exposure time; this will be advantageous in most cases.

Filtration:

X –ray used in dentistry must be able to penetrate dental hard tissues (teeth and bone). Low-energy x-rays (often referred to as soft x-rays) do not contribute to the formation of an x-ray image and are not useful in diagnostic radiology; all they do is expose the body to radiation. Therefore, we need to get rid of them by passing the beam through a filter made from Aluminum which absorb most of long wave length photons (soft X–ray), the resulting X–ray beam will consist mainly of X – ray photons with short wave length, high energy photons and high penetrating power that's why they named (hard X – ray beam). The process of removing these low-energy x-rays from the x-ray beam is known as filtration. Filtration increases the average energy (quality) of the x-ray beam.

Types of filtration:

Inherent filtration, results from the materials present in the x-ray machine that the x-rays have to pass through. These include the unleaded glass window of the x-ray tube, the oil in the tubehead and the tubehead seal. This removes very weak x-rays. The inherent filtration is determined by the manufacturer and the dentist has no control over it. The inherent filtration tends to increase with age because some of tungsten metal of both target and filament is vaporized and deposited on the inside of the tube window.

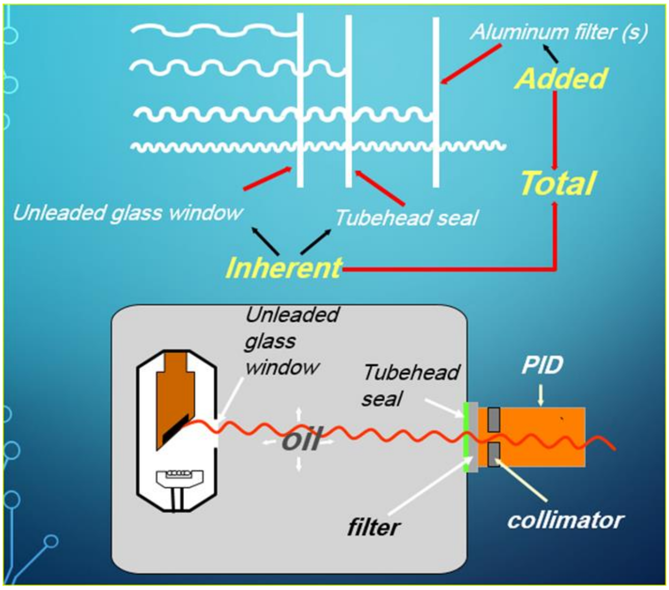
Added filtration: done by using aluminum sheet as extra filter. Added filtration removes the x-rays that had enough energy to get through the inherent filtration but are still not energetic enough to contribute to image formation.

Total filtration is the combined inherent and added filtration for the x-ray machine.

Federal regulations require that an x-ray machine capable of operating at or above 70 kVp must have total filtration of 2.5 mm aluminum equivalent.

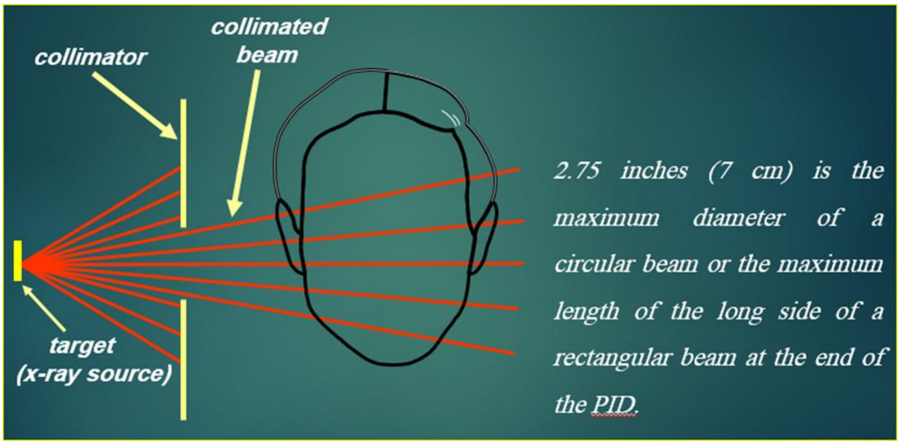
X-ray machines operating below 70 kVp need to have a total filtration of 1.5 mm aluminum equivalent.

Although adding additional filters to the machine removes a greater percent of lower energy (less penetrating) radiation and a lesser percent of higher energy (more penetrating) radiation, the total quantity of radiation in the primary beam is reduced and a compensation must be made for this reduction e.g. exposure time must be increased. The filter is usually located in the end of the PID which attaches to the tubehead.



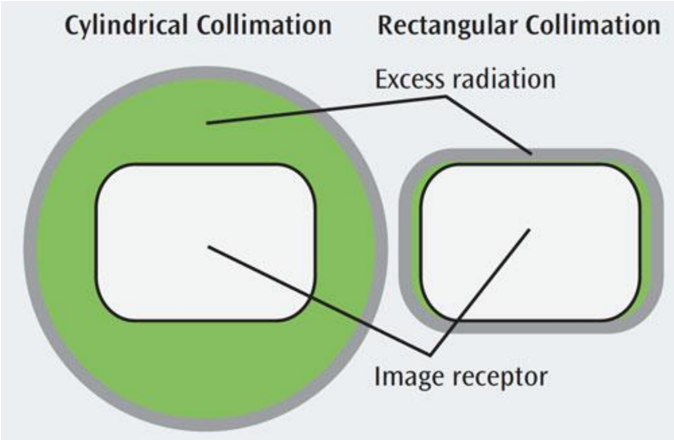
Collimation:

Collimation controls the size & the shape of the X-ray beam. It is used to restrict the area of the head that the x-rays will contact. We want to cover the entire film with the x-ray beam, but don't want to overexpose the patient.



In dental radiography its essential to get the diameter of **circular X – ray beam** at patients skin surface is not great than 2.75 inches, while for **rectangular X – ray beam** the dimensions at the skin should be approximately 1½ × 2 inches.

The diagram below demonstrates the difference in the size of the radiated area when using a round collimator versus a rectangular collimator.



Also, when x-rays from the tubehead interact with the tissues of the face, scatter radiation is produced. This scatter radiation creates additional exposure of the patient and also decreases the quality of the x-ray image. So collimation decreases the total number of available photons and decreases the amount of scattered radiation.

Types of collimators:

1. Diaphragms (round or rectangular shape).

Diaphragm Consists of a metal plate or disk made from lead with a hole in the center of the disk located in the end of the PID where it attaches to the tubehead which allow the beam to pass through it only. The shape and size of X – ray beam determine by the shape and size of the diaphragm hole such diaphragm is placed over the opening in the head of X – ray machine (at the end of the PID). Rectangular collimation results in the patient receiving 55 % less radiation when compared to what they would receive with a round collimation.

2. Metal cylinders, cones and rectangular tubes.

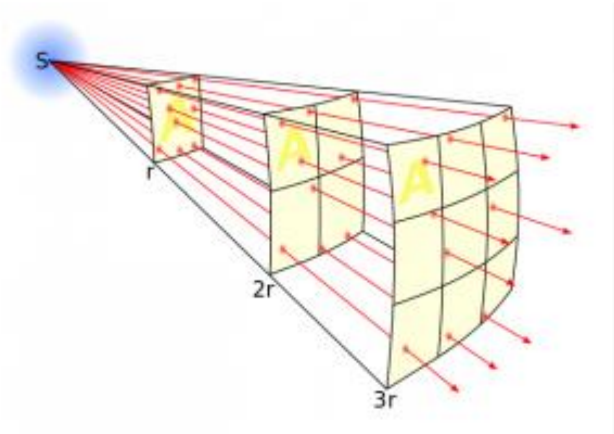
PID’s come in varying lengths; longer PID’s have a smaller opening in the collimator.

Inverse Square Law:

The radiation Intensity is inversely proportional to the square of the distance. Notice in the diagram that as the distance doubles, the area quadruples and thus, the initial radiation amount is spread over that entire area and is therefore reduced, proportionately.

Imagine we are trying to expose a piece of x-ray film (radiograph) and we move the x-ray source twice as far away on each shot, will the film be more or less exposed ? Therefore, while the inverse square law pertains to radiation safety, it also helps us to determine source to film distances (SFD), time of x-ray exposure, and the intensity (KV) of our x-ray tube.

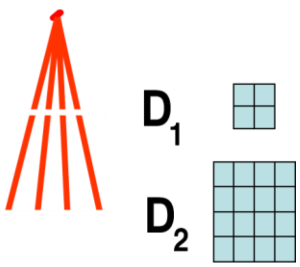
$$\frac{I_1}{I_2} = \frac{D_2^2}{D_1^2}$$



I_1 = Intensity with a distance measured as (R/hr or mR/hr), D_1 = Distance with an intensity (usually measured in feet), I_2 = Intensity without a Distance, D_2 = Distance without Intensity.

The farther you get from the target, the less the number of x-ray photons per unit area will be. The inverse square law is a formula used to identify the quantity of x-ray photons in a given x-ray beam at a given distance from the target.

In the diagram below, the distance D2 is 2 times the distance of D1. The x-ray beam covers 4 squares at D1 and 16 squares at D2, or four times as many; the quantity is ¼ as much because the beam is spread out over four times as many squares. The change in distance is two times; the square of 2 is 4 and the inverse of 4 is ¼. If the change in distance is 3 times as much, calculate as follows:



The square of 3 is 9, and the inverse is 1/9. The quantity at three times the distance would be 1/9 what it was at the initial distance.

Half – value layer:

It's a method of monitoring the penetration quality of the X – ray beam. Determination of half –value layer is done by placing thin filtering material such as aluminum filter in front of the beam so we continue increase the thickness of filtering material until we have a thickness that reduce the number of X – ray photons in the beam passing through it to one half, reduce the intensity of the beam energy by 50%, this will representing a half – value layer for such beam of radiation. High half value layer the high penetrating ability of the beam. Indicates the quality (energy) of the x-ray beam. HVL can be used as an indirect measure of the total filtration in the path of the X-ray beam.

In oral diagnosis the acceptable value is approximately 2 mm of aluminum (2.5 mm aluminum when the machine working on ≥ 70 kVp and 1.5 mm aluminum when the machine working on < 70 kVp.

Definition of terms used in X – ray interaction:-

Scattering: - change in direction of photon with or without a loss of energy.

Absorption: - deposition of energy i.e. removal of energy from the beam.

Attenuation: - reduction in the intensity of X – ray beam caused by absorption and scattering attenuation = absorption + scattering.

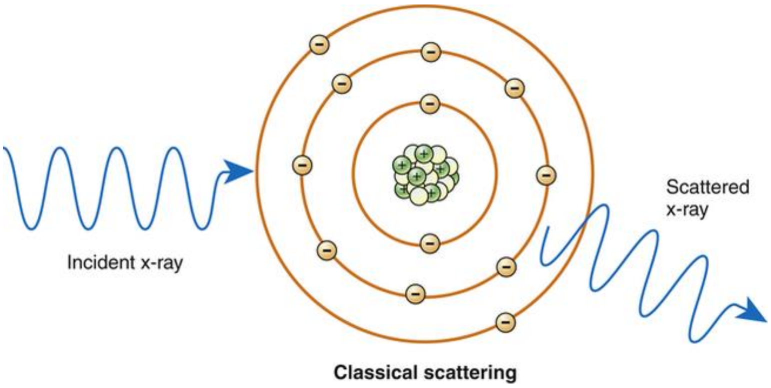
Ionization: - removal of an electron from neutral atom.

X-ray interaction with matter (Absorption of X – ray):

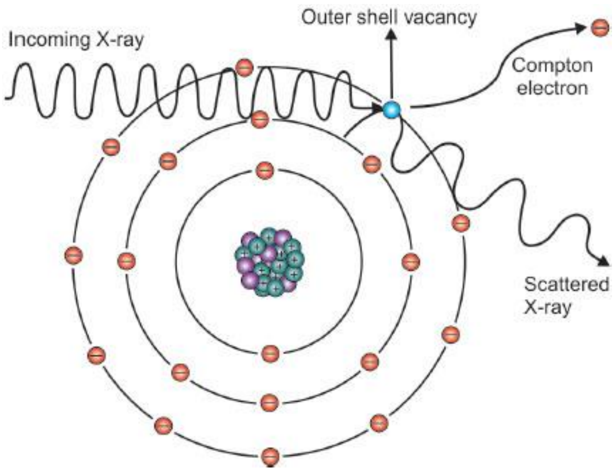
X – Ray absorbed by any form of matter (solid, liquid, and gas) when photons reach an atom, different types of interaction may occur depends on photon energy:

1. (No interaction=transmission): X – Ray photons can pass through the atom without any change occurred to both of them.

2. Coherent or Unmodified scatter (8%) sometimes called classical scattering or Thompson scattering occur by interaction of low energy x-ray photon and atom, there is no loss of photon energy only changes in direction (photon of scattered radiation).

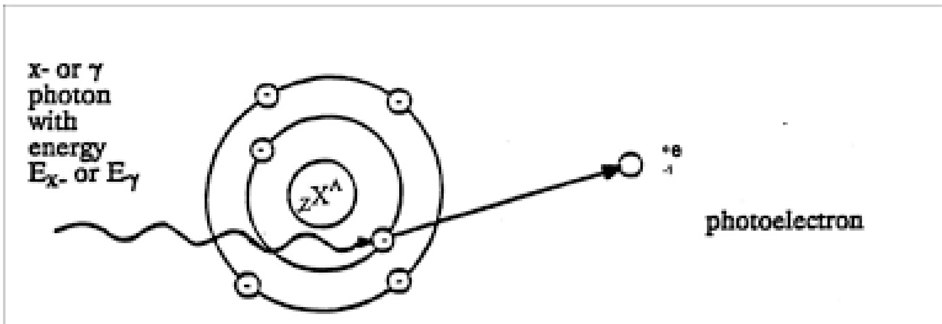


3. Compton Effect (62%): occur between moderate energy x-ray photon and free or loosely bound outer shell electron of atom. It result in ionization of atom (ejection of Compton recoil electron), reduction of photon energy (there is some absorption of photon energy by ejected electron which undergoes further ionization interaction within the tissue), and change in x-ray direction (scattered radiation).



4. Photoelectric effect (30%): occur by X – Ray photon interaction with inner – shell electron of the tissue atom (ex. From k shell), the X – ray photon disappears and deposits all its energy this process is pure absorption. Now the inner – shell electron is ejected with considerable energy (now called a photo – electron) into the tissue for further interaction with other electrons of other tissue atoms. So this high – energy ejected photo electron behaves like the original high energy X – ray photons interact and eject other electrons as it passes through the tissues, these ejected electrons are

responsible for the majority of ionization interactions within the tissue and the possible resulting damage attributable to the X – rays.



When k electron removed out of its orbital, an electron from L shell falls into k shell and release energy in the form of x-ray photon. This photon has definite wavelength of a particular element, this phenomena is used to identify elements and the radiation is called characteristic radiation.

There are two other types of interaction Pair production (between high energy x-ray photon and nuclear force field) and photodisintegration (between high energy photon and nucleus) but both of them not occur in diagnostic radiology.

The areas that absorb incoming X-ray photons (photoelectric effect) create the white or clear areas (low density) on the radiographic image. The incoming X-ray photons that are transmitted create the black areas (high density) on the radiographic image.

Photoelectric absorption occurs with inner shell electrons, while Compton and Coherent scatter occur with outer shell electrons.

Types of radiation:

Primary Radiation (Primary beam or Useful beam):

The penetrating X-ray beam that is produced at the target of the anode and exits the tubehead in form of collimated useful X – ray beam.

Central ray: is X– ray photons that traveling in very center of the cone of radiation (radiation beam), and it's commonly used to fix and locate the position of X – ray beam.

Bremsstrahlung radiation: radiation produced when projectile electron is slowed by the electric field of target atom nucleus.

Characteristic radiation: radiation produced when an outer shell electron fills an inner shell void (empty orbital).

Leakage Radiation: Any X-rays, other than the primary beam, that escape through the protective housing and result in unnecessary exposure of the patient and radiologic technologist and have no value in diagnostic radiology.

Secondary Radiation (Exit Radiation):

X-radiation that is created when the primary beam interacts with matter. Secondary radiation is less penetrating than primary radiation.

Scatter Radiation:

X-radiation that has been deflected from its path by the interaction with matter. It is a form of secondary radiation. It does not contribute any useful information about the area of interest. It creates unwanted density on the image called fog. It must be controlled during radiographic imaging.

X-ray measuring units:

1. Traditional Units

Roentgen (R) is the basic unit of radiation exposure for the amount of X-radiation or gamma radiation which will produced in one cc of air ions carrying one electrostatic unit of either sign.

rad (roentgens absorbed dose) is a measure of the amount of energy absorbed by an organ or tissue.

rem (roentgens equivalent man) is a measure of the degree of damage caused to different organs or tissues.

Curie (Ci): is the unit of quantity of radioactive material and not the radiation emitted by that material.

RBE: is a relative biological effectiveness dose.

2. International system of units SI Units

Coulomb per kilogram (C\kg): 1 C\kg = 3876 R

Gray (Gy): 1 Gy = 100 rad

Sievert (Sv): 1 Sv = 100 rem

Becquerel (Bq): 1 Bq=2.7 x 10*11 Ci

L.3

Image Receptors

By

Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.

Oral Radiology Teacher, Anbar University

The advancements in technology have made dental practice more comfortable, effective and time saving for the patients. Radiography does play a very essential role in the practice of dentistry by helping in ***the diagnosis, evaluation, management, and treatment planning*** of various dental conditions/diseases.

Regular cleanings and exams are part of caring for patients' oral health. However, dental radiographs are also commonly used to catch problems before they arise and to diagnose existing problems. There are many different types of dental X-ray films a dentist can provide. If we want to be better prepared our patients for their next dental radiographs, we should understand the different types of dental X-ray films and when or if we may need them.

What is X-ray Film?

- X-ray film is photographic film, ***with some adaptations***, consisting of photographically active or radiation sensitive emulsion coated on a thin sheet like material.
- It is responsible to record the physical impression of an object by which we can get detail about the object by exposing the object and the film to X-ray.

Radiograph: A photographic image of an object which produced on dental X-ray film when it is exposed to x-rays that have passed through teeth and adjacent tissues.

Many modern dental offices don't use film anymore. Instead, they use a sensor, this makes the process a little faster because they don't have to develop the film. An intraoral sensor is a small device comprising a sensor used in to take radiographic images of the mouth. The sensor records images and sends electrical signals via leads to a computer where they are converted to digital images that can be displayed on a monitor.

Figure (1): Intraoral digital X-ray imaging system.

Dental Image Receptors:

Types according to film position:

Intra-oral film

Extra-oral film

Types of dental films according to use of intensifying screen:

Direct Action Film (Non Screen Film)	***Indirect Action Film (Screen Film)***
Sensitive primarily to x-ray photons	Sensitive primarily to light photons
Used intra-orally	Used extra-orally
Periapical Bitewing Occlusal	Lateral Oblique Skull Radiographs Panoramic Tomographs All routine medical radiography

Types of intraoral films according to the use (examination type):

Periapical	Bitewing	Occlusal
Bisecting angle technique		1. Topographic
Parallel technique		2. Lateral
		3. Cross sectional

American National Standards Institute (ANSI) classification of intraoral film types and sizes:

2 digits numbers separated by a decimal point:

Left digit; the type of film	Right digit; the size of the film
Periapical 1	0 ,1 , 2 , 3 or 4
Bitewing 2	
Occlusal 3	

Types and sizes of intraoral film:

Classified on numerical basis into:

A- Type I

It called **periapical film** and used to examine the apical area of the tooth and the surrounding structures (record the crowns, roots, and surrounding bone). Film packs come in three sizes:

Size 0; (22×35 mm), used for small children for both periapical and bitewing films.

Size 1; (24×40 mm), which is relatively narrow and used for views of the adult anterior teeth with the paralleling technique.

Size 2; (31×41 mm), the standard film size used for adults. Used for adult posterior periapicals and bitewings and also used in adult anterior periapicals taken with bisecting-angle technique. Also used for children with larger mouths and may be used for occlusal films in children.

So the available sizes are (1.**0**, 1.**1** and 1.**2**).

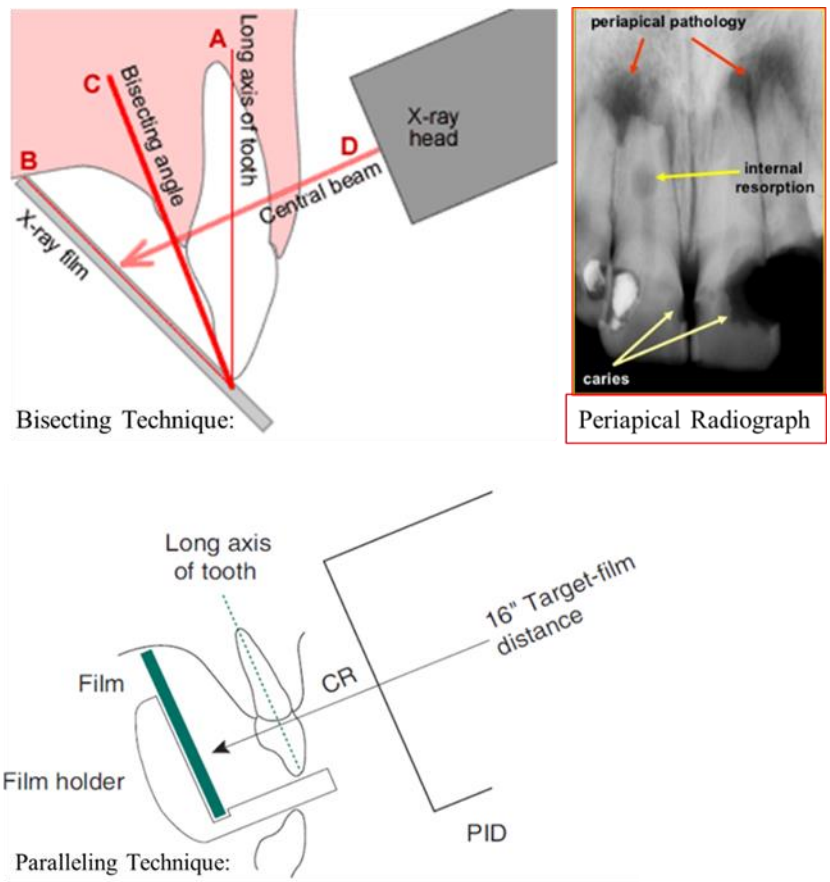


Figure (2): Top left, intraoral bisecting technique. Top right, intraoral periapical radiograph. Bottom, intraoral paralleling technique.

Figure (3): Types and sizes of intraoral X-ray films.

Figure (4): Dental x-ray film is commonly supplied in various sizes. Top Left, size 0 for child-size film. Top Middle, size 1 for adult anterior film. Top right, size 2 for adult posterior film. Bottom left, extra-long bitewing film. Bottom right, occlusal film.

B– Type II

It called **bitewing film** (incredibly common) and commonly used to detect the interproximal caries, evaluate the height of alveolar bone between two adjacent teeth, locate the source of tooth discomfort and also to detect any overhang filling.

Bite wing films may be purchased from the manufacturer with attached tabs. These X-rays are called bitewing because the paper or plastic tab attached to the film that you bite down on allows the film or digital sensor to hover between your bite in a similar fashion to an airplane wing. These tabs, which surround both traditional film and a digital sensor, are connected to the center of these objects, and are referred to as bite-wing loops.

The alveolar is the region of bone in the jaw that holds the teeth intact. Four films are generally required to obtain an adequate view, and these films capture images of the teeth from the molar furthest back in your mouth, forward to the canine teeth.

Should deeper views be deemed necessary to capture more of the root in addition to the crown, the bitewing loops can be turned 180° from their typical position so they are longer from north to south, than east to west. This enables them to capture more of the alveolar and overall jawbone structure. Other options include periapical X-rays, which captures a view of the entire tooth, or a panoramic X-ray, which captures a 360° view of the entire skull.

The smaller **size 1** is preferred in children. In small children, **size 0** may be used. **Size 2** film is normally used in adults. A relatively **long size 3** **(27×54 mm)** is also available and used for extra-long bitewing films; one film covers all teeth on one side of the mouth.

So the available sizes include (2.**0**, 2.**1**, 2.**2** and 2.**3**).

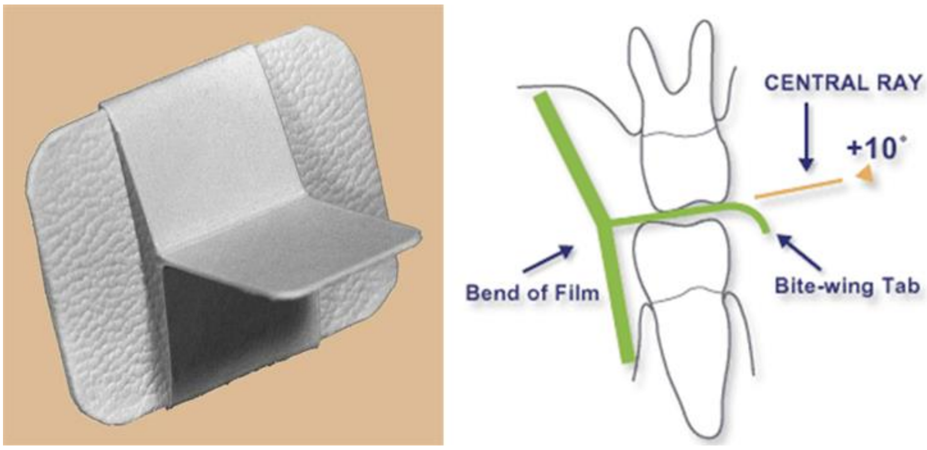


Figure (4): Left, paper loop placed around a size 2 adult film to support the film when the patient bites on the tab for a bitewing projection. Right, bitewing technique.

C– Type III

It called **occlusal film** and used to demonstrate area larger in dimension than area appearing in periapical film. It used to show the roof or floor of the mouth and are used to find extra teeth (supernumerary teeth), teeth that have not yet broken through the gums, jaw fractures, a cleft palate, cysts, abscesses or growths. These films also are used to obtain right-angle views to the usual periapical view.

The film usually is held in position by having the patient bite lightly on it to support it between the occlusal surfaces of the teeth.

Occlusal film, size **4**, is more than three times larger than size 2 film and used primarily for adults. Known as 3.**4** film (57x76 mm).

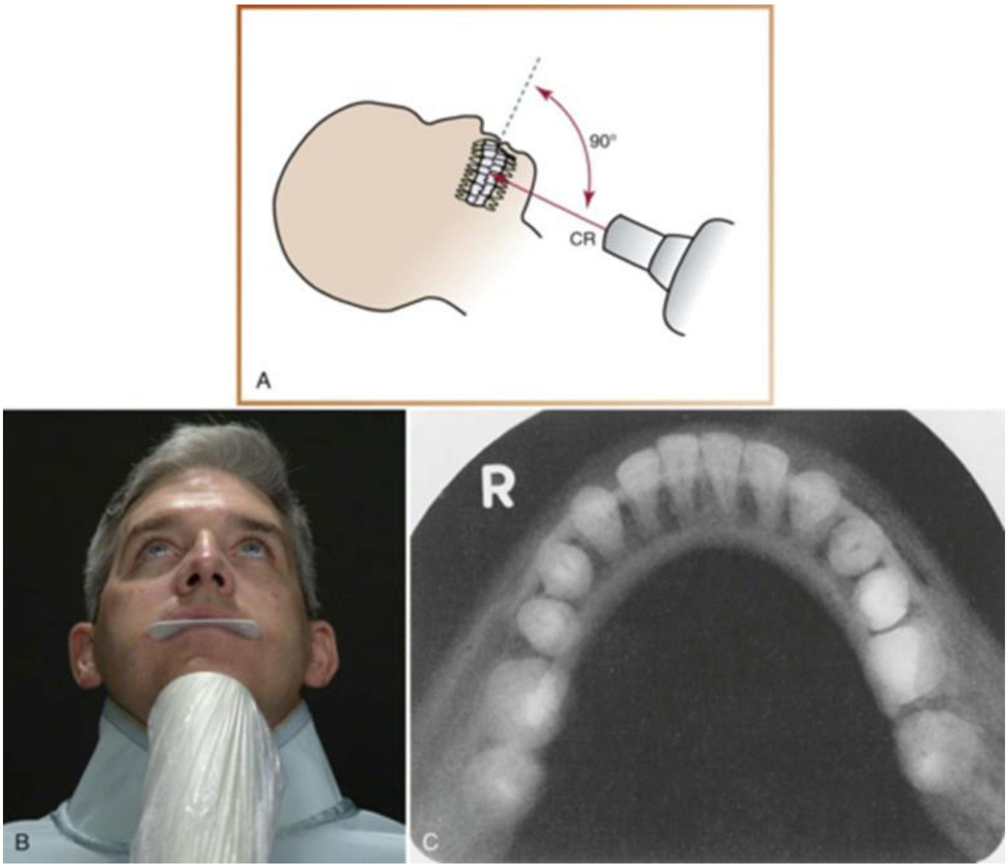


Figure (5): Mandibular cross-sectional occlusal projection

<u>Dental X-Ray Film Construction/Composition.</u>

All contemporary intraoral x-ray film is direct-exposure film. Direct exposure means that the incoming x rays striking the dental, x-ray film surface interact directly with the materials coated on the film to create a latent image.

Dental X-ray film packet components:

The film is packaged in moisture and light proof wrappers. The Paper or plastic wrapper protects the film from light and moisture.

Lead Foil:

The dental X-ray film "sandwich" is wrapped in black paper. A single piece of lead foil is placed on one side of black paper, between the film and the plastic outer packaging.

The thin sheet of lead foil is usually placed behind the film *to <u>(1)</u>* ***prevent most of secondary radiation*** that originated in the tissue of the patient behind the film from reaching it. Therefore this lead foil ***reduces secondary radiation (back scatter***

radiation) and minimizes film fog. In addition the lead foil (2) absorbs X-ray that have passed through the object and the film so it ***reduces the exposure of the tissue behind the film*** (reduces patient exposure)**.** This foil has a design of (herring bone pattern) ***to*** (3) ***identify reversed film error***.

The dental X-ray film is clearly marked on one side **"opposite side toward tube."** This is to ensure that the lead foil, placed to reduce the numbers of X-rays exiting the film and thus exposure to the patient, is not between the film and the X-ray source. If the film is so placed, that is, backwards, then the resultant image will be too light and the image information obscured by the pattern on the lead foil.

The exterior, sensitive side of the film packet also reveals a raised or embossed **"dot".** This dot also helps the radiographer to orient the sensitive side of the film toward the anode (source) and can be placed in the **"slot"** of the biteblock when exposing periapical radiographs, to assist with film orientation and to keep it from being superimposed over region of interest, like an apex.

A

B

Figure (6): A, The raised film dot (arrow) indicates the tube side of the film and identifies the patient's right and left sides. B, The location of this dot is clearly marked with a black circle on the outside of every film packet. (Courtesy of Carestream Dental, a division of Carestream Health, Inc.)

Black Paper:

The intraoral film is wrapped by opaque material (black paper) to prevent light from reaching the film because light photons can activate the silver halides crystals ***(black paper protects the film from light, moisture, lead foil and fingers).***

Film (raw film)

- Single or double film.
- Embossed dot at one corner.

Figure (7): Moisture-proof and lightproof packets, paper on the left and vinyl on right, contain an opening tab on the side opposite the tube. Inside is an interleaf paper wrapper that is folded around the film as well as a sheet of lead foil. Film is packaged with one or two sheets of film. The foil is positioned between the back side of the packet and the paper wrapper. In this position, it absorbs radiation that has passed through the film and prevents scatter radiation from blurring the image. If the film packet is inadvertently placed backward in the patient's mouth, the mottled image of the foil shows on the resultant image. (Courtesy of Carestream Dental, a division of Carestream Health, Inc.)

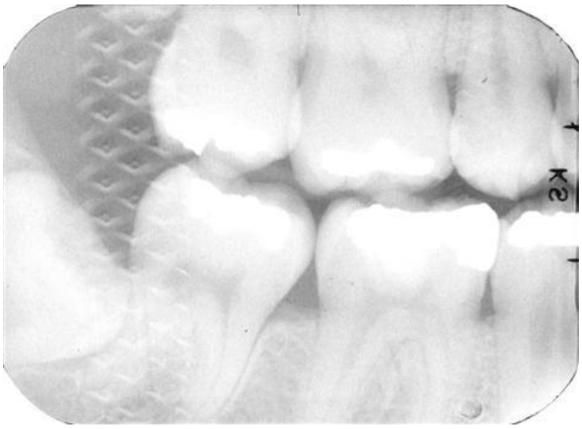


Figure (8): Placing a film backward in the patient's mouth when the exposure was made results in a radiograph that is too light and shows the characteristic markings caused by exposure through the lead foil in the film packaging. In such an image, the left and right sides of the patient are reversed when using the dot as the orientation guide.

Chemical composition of intraoral X-ray film:

It consists of a sensitized emulsion present on both sides of transparent base (backbone). **The base** is the foundation of the radiographic film, made from cellulose acetate. Its primary purpose is to provide support and rigid structure onto which the emulsion can be coated. It's flexible and fracture resistant to allow easy handling but rigid enough to be placed on the viewer (0.2 mm thick). Blue tinted to enhance its optical properties.

The emulsion is the heart of the X-ray film, it's the material with which the x-ray or light photons interact and forming the image. It consists of homogenous mixture of silver halides crystals mainly silver bromides and few silver iodide (iodide has larger diameter crystals) suspended in gelatin on both sides of the base. The silver halides crystals are sensitive to light, X-ray photons, pressure, chemicals, heat and age. Its size determines film speed, image sharpness and resolution.

Gelatin:

1. Soluble in water at high temperature.
2. Insoluble in water at processing temperature.
3. Absorbs water and swell which facilitates processing solutions penetration to emulsion.
4. Upon Drying it hardens and shrinks.
5. No volumetric changes during water absorption and drying (no image distortion).

6. Chemically inert.
7. Good optical properties.
8. Inexpensive and available.

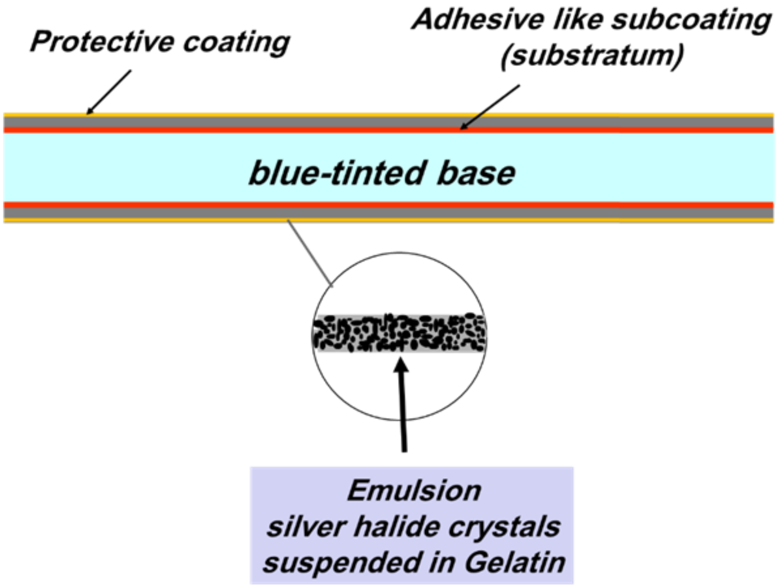


Figure (9): Diagram showing the cross-sectional structure of radiographic film.

Intra-oral films according to Emulsion coating:

- Single coated (Gelatin on both sides, but AgBR crystals on one side only) ex. duplicating film.
- Double coated (shows lower sharpness than single coated films).

Intra-oral films according to number of films per packet:

- Single film.
- Double film (for research and insurance).

Intra-oral films according to lead foil in the back of film packet:

- With lead foil.
- Without lead foil (injectable films).

Intraoral film speed:

Speed means the sensitivity of X-ray film silver bromide crystals (AgBr) to X-ray photons. There is direct relation between the speed of the film and the size of the crystals, the larger crystal size the faster film speed. The faster mean it need less amount of radiation to produce radiographic image so less radiation dose absorbed by patient.

The classification of film speed based on alphabetical basis so from A to F, film speed A is the slowest while speed F is the faster one. Only films with a D or faster speed rating are appropriate for intraoral radiography. E/F-speed film is preferred because it requires approximately half the exposure time and thus half the radiation dose of D-speed film. In the United States the most widely used films are ULTRA-speed (D-speed) and INSIGHT (E/F speed).

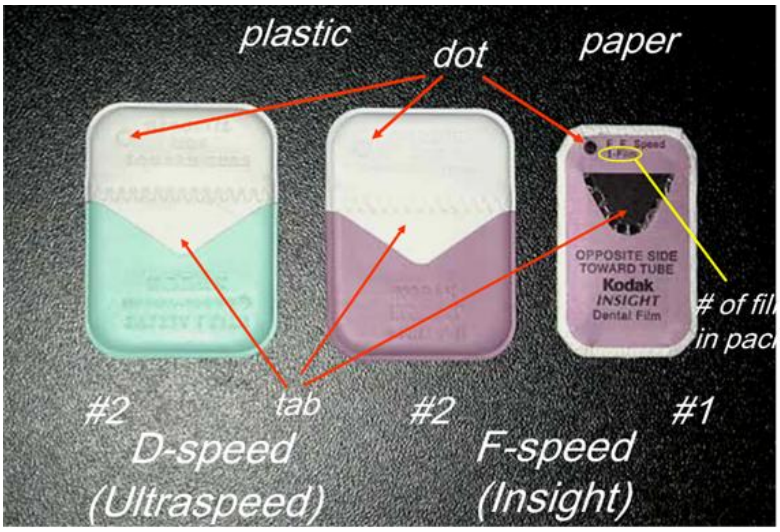


Figure (10): Intraoral film speed (# 1 and # 2).

***Extraoral Films*:**

Extraoral Film is placed outside of the mouth during x- ray exposure. The purpose of using such film is to make a radiographic image able to examine a large area in and around the jaw that can't be seen by intraoral film, such as panoramic, cephalometric and other skull radiographs.

We have 2 types of extaoral film:

1. Non screen film.

2. Screen film.

Non screen film:

Is an extraoral film that does not require the use of screen for exposure .The non-screen film is exposed directly to x-rays than to the light, because the emulsion is sensitive to direct x- ray exposure rather than fluorescent light.

Non screen film either have one emulsion layer or may have a double emulsion like intraoral film, but with greater thickness than intraoral film. Increasing the emulsion size and thickness, make the film fast (need less exposure time and increasing the processing time by 50%). The non-screen film requires more exposure time than screen film so is not recommended for use in dental radiography.

The film placed in a card board holder or envelope which has a definitive exposure side. A sheet of an x-ray absorbing material is placed in the back of the film to absorb X-ray after they have passed through the film. The size of the film used in dentistry include; **5×7 and 8×10 inches**.

Screen film:

The majority of extraoral films are screen films. A screen film is a film that requires the use of screen for exposure. The emulsion of the film is sensitive to visible light and ***more specifically to blue light of visible light spectrum***. The screen film placed between 2 florescent screen in a rigid holder or cassette .These screens are made of (tiny calcium tungstate crystals) bound together in a uniform layer on a film base. When the cassette is exposed to X-ray, the screen convert the X-ray energy into light, which in turn exposes the screen film to produce the image.

Films used in a screen film combination are sensitive to specific colors of fluorescent light. ***Some screen films are sensitive to blue light, whereas others are sensitive to green light.*** Blue light sensitive film must be paired with screen that produce blue light, and green-sensitive film must be paired with screen that produce green light.

The screen film must be in intimate contact with fluorescent screen and any space between them will result in unsharp image in the radiograph. Intimate film screen contact is obtained through the use of spring or clamps. The sizes of screen film include **5 x7, 8x10 and 10x12 inches.**

No orientation dot embossed on the film i.e. it needs some form of additional identification.

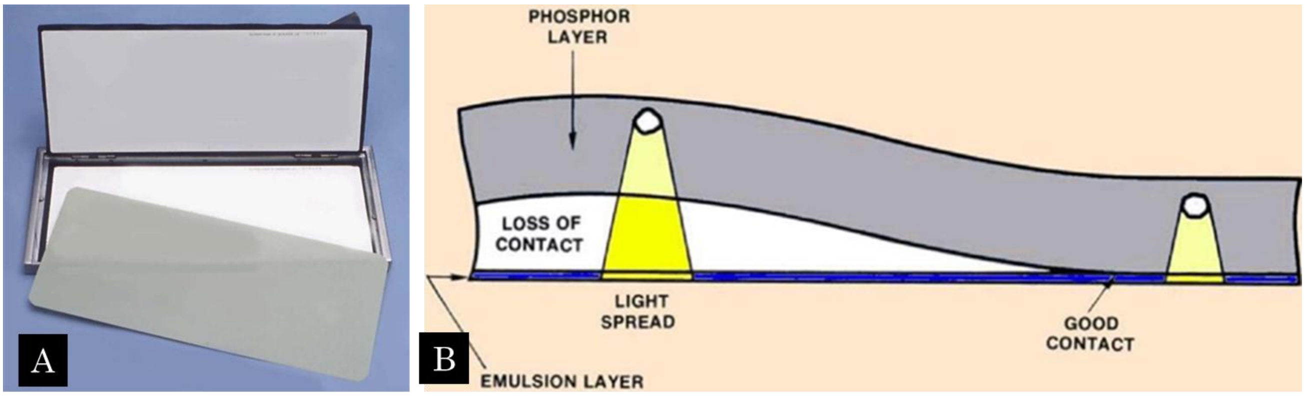


Figure (11): A, Cassette for 8 inch × 10 inch film along with a sheet of screen film. When the cassette is closed, the film is supported in close contact between the two white intensifying screens seen on the inside of the cassette. These intensifying screens absorb most of the incident x-ray beam and then fluoresce and expose the film. B, Poor and good film screen contact.

Extraoral films according to sensitivity to light spectrum:

- Blue light sensitive.
- Green light sensitive.
- Ultraviolet light sensitive.

Extraoral films according to emulsion coating:

- Single coated.
- Double coated.

Cassettes:

- Hold the intensifying screens in tight contact with film.
- Any loss of film/screen contact will degrade the image.
- Different sizes.
- Rigid or Flexible.
- Light tight.

Two screens are used, one in front of the film and the other at the back. The front screen absorbs the low energy X-ray photons and the back screen absorbs the high energy photons, together they are efficient at stopping the transmitted X-ray beam.

Indirect film (screen film) emulsion:

Emulsion is sensitive primarily to light rather than X-rays.

Standard Silver Halide emulsion sensitive to Blue light.

Modified Silver Halide emulsion sensitive to UV light.

Orthochromatic emulsion sensitive to Green light.

Panchromatic emulsion sensitive to Red light.

The film and the intensifying screen must match each other.

Intensifying Screen:

Early in the history of radiography, scientists discovered that various inorganic salts or phosphors fluoresce (emit visible light) when exposed to an X-ray beam. The intensity of this fluorescence is proportional to the X-ray energy absorbed. These phosphors are incorporated into intensifying screens for use with screen film. The sum of the effects of the X-rays and the visible light emitted by the screen phosphors exposes the film in an intensifying cassette.

One of the properties of X-rays is that they cause certain materials to **fluoresce (emit light);** the phosphor crystals found in intensifying screens are one of these materials. The light emission is usually **green or blue**, depending on the type of phosphor crystal used. The composition of the films used with these screens is adjusted by the manufacturer to be sensitive to either blue light or green light, *the X-ray film used, should be compatible with light emitted from the fluorescent screen (blue-sensitive film with blue light-emitting screen, etc.),* .

The presence of intensifying screens creates an image receptor system that is **10 to 60** times more sensitive to X-rays than the film alone. Consequently, use of intensifying screens substantially reduces the dose of x-radiation to the patient. The intensifying screens absorb about 60% of the X-ray photons that reach the cassette after passing through the patient (**about 30-60** times less radiation than that required by direct exposure film).

Intensifying screens are used with films for virtually all extraoral radiography, including panoramic, cephalometric, and skull projections. Intensifying screens are not used intraorally with periapical or occlusal films because their use would reduce the resolution of the resulting image below that necessary for diagnosis of much dental disease.

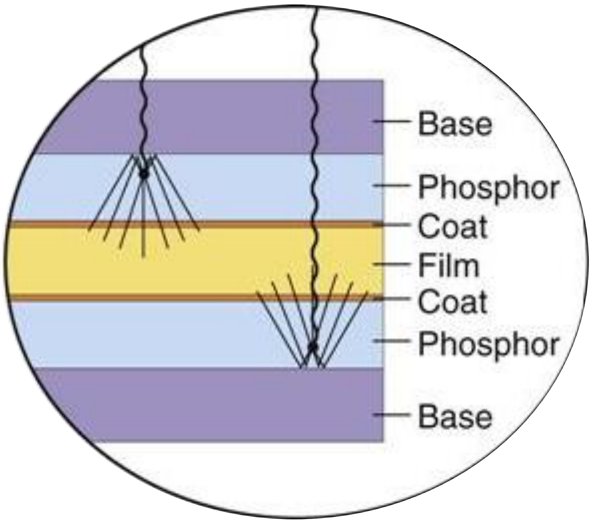


Figure (12): X-ray photons entering at the top, traveling through the base, and striking phosphors in the base. The phosphors emit visible light, exposing the film. Some visible light photons may reflect off the reflecting layer of the base.

Intensifying Screen Function:

- Consists of fluorescent phosphors.
- Converts x-ray energy into light energy (fluorescence) by the photoelectric effect; light then exposes the film.
- Screen/film combination uses less radiation than direct exposure film.
- Sharpness decreases because of light cross over.

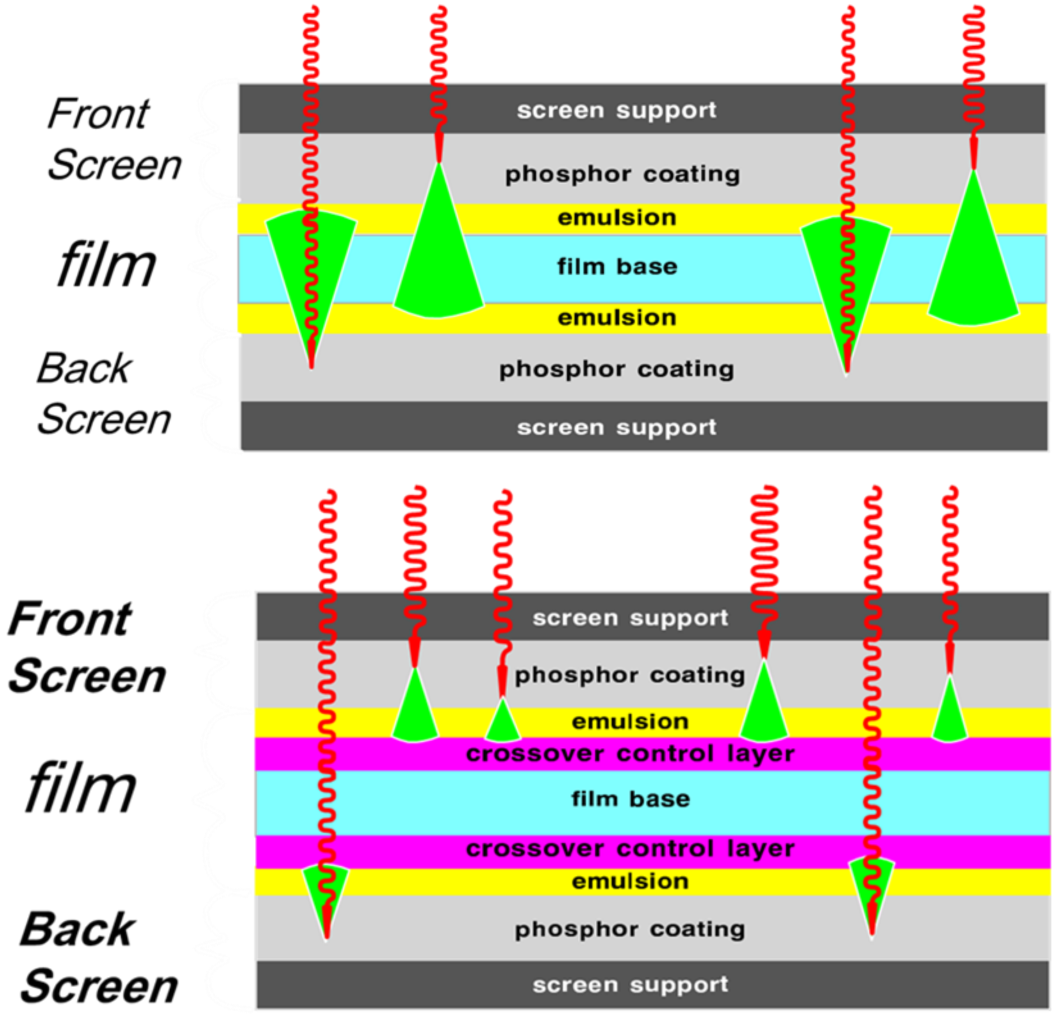


Figure (13): Top, light crossover. Bottom, anti-crossover by light absorbing dye.

Ideal Properties of Phosphor Layer:

1. High atomic number (to absorb X-rays).
2. Emits large amounts of light per x-ray absorption (high conversion efficiency).
3. Light emitted must be of proper wavelength to match the film sensitivity spectrum.
4. Minimal afterglow.
5. Not affected by heat or humidity.

Fluorescent materials of Phosphor Layer:

Calcium tungstate: Emits blue light.

Many rare earth screens emit light in the green spectrum.

Terbium activated Gadolinium oxysulfide: emits green light.

Thulium activated Lanthanum oxybromide: emits blue light.

Yttrium: Emits UV light with narrower light diffusion.

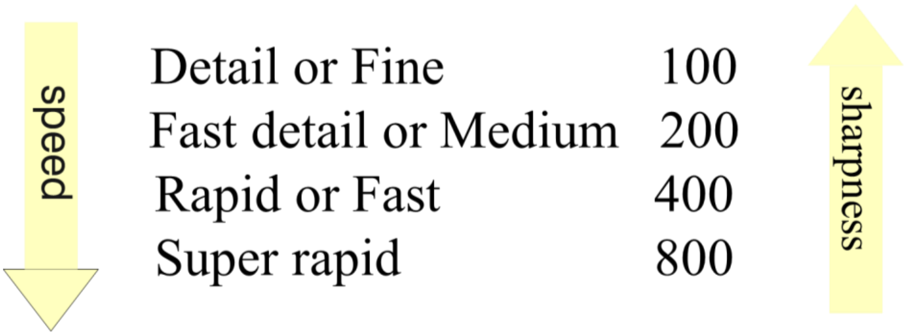
Rare earth and Yttrium screens are five times faster than calcium tungstate screens which reduces the radiation dose to the patient. Calcium tungstate screens are no longer recommended.

Screen speed: Time taken for the screen to emit light after exposure to X-rays, the higher the speed the less the radiation dose.

Screen speed depends on:

1. Thickness of phosphor layer; the thicker the screen, the higher the speed.
2. Size of Phosphor crystals; the larger the crystal, the higher the speed.
3. Conversion-efficiency of phosphor (Rare earth screens have higher conversion efficiency than Calcium Tungstate screens); the higher the conversion efficiency, the higher the speed.
4. Presence or absence of light absorbing dyes within the screen; presence of light absorbing dye decreases screen speed.
5. The faster the screen, the lower the radiation dose to the patient, the lower the image detail.

Screen Speed:



Screen maintenance:

1. Regular cleaning (Any debris between the screen and film will result in a white spot on the film).
2. Careful handling.
3. Checking film screen contact. So an intimate or complete contact with screen is a must, otherwise, unsharp and blurred images will be the result.

Any material that is in the cassette between the intensifying screen and the film will block the light exposure of the film. This includes hair, straw, stains on the screen surface, Etc. The shape and pattern of the material will show as a sharp white image on all studies made with that cassette. The screens should be routinely checked for debris and cleaned.

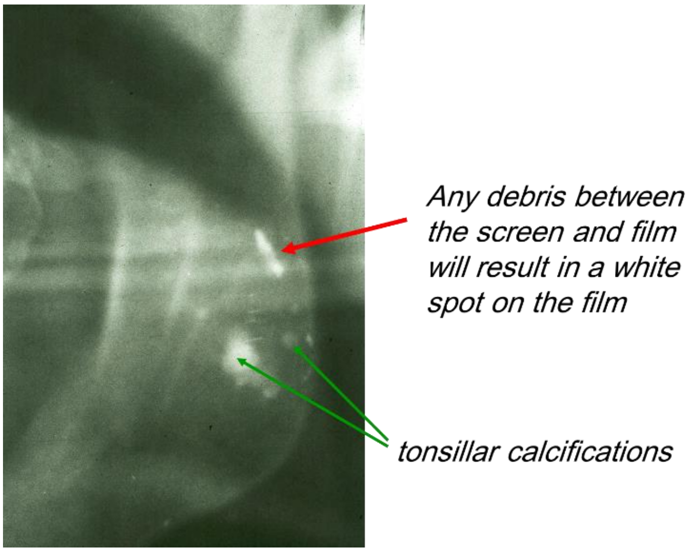


Figure (14): Debris within the film cassette.

L.4 # Intraoral Examination Techniques

By

Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.

Oral Radiology Teacher, Anbar University

Intraoral radiographic techniques:

There are three main types of intraoral radiographs:

1. **Periapical radiograph**
2. **Bitewing radiograph**
3. **Occlusal radiograph**

The anatomic area of interest and type of pathology suspected helps the clinician to decide the type of radiograph to be taken.

Periapical radiograph:

The name periapical is derived from the Greek peri, which means "around," and apical, which means "tip“. The Periapical radiograph is the basic investigation that gives graphic information about the alveolar bone, periodontal areas and the hard tissues of the tooth. Each image usually shows 2-4 teeth. It shows the apex of the tooth and surrounding bone as well as the entire crown.

Indications:

The main clinical indications for periapical radiography include:

1. Detection of apical infection/inflammation.
2. Assessment of the periodontal status.
3. After trauma to the teeth and associated alveolar bone.
4. Assessment of the presence and position of unerupted teeth.
5. Assessment of root morphology before extractions.
6. During endodontics.
7. Preoperative assessment and postoperative appraisal of apical surgery.
8. Detailed evaluation of apical cysts and other lesions within the alveolar bone.
9. Bone evaluation in presurgical implant insertion and evaluation of implants postoperatively.

Ideal positioning requirements for periapical radiographic examination:

The ideal requirements for the position of the image receptor and the X-ray beam, relative to a tooth, are shown in Fig. 1. ***They include:***

1. The tooth under investigation and the image receptor should be **in contact or**, if not feasible, **as close together as possible**.
2. The tooth and the image receptor should be **parallel to** one another.
3. The image receptor should be positioned with its long axis **vertically** for incisors and canines, and **horizontally** for premolars and molars with sufficient receptor beyond the apices to record the apical tissues.
4. The X-ray tubehead should be positioned so that the beam meets the tooth and the image receptor at **right angles** in both the vertical and the horizontal planes.
5. The positioning should be **reproducible**.

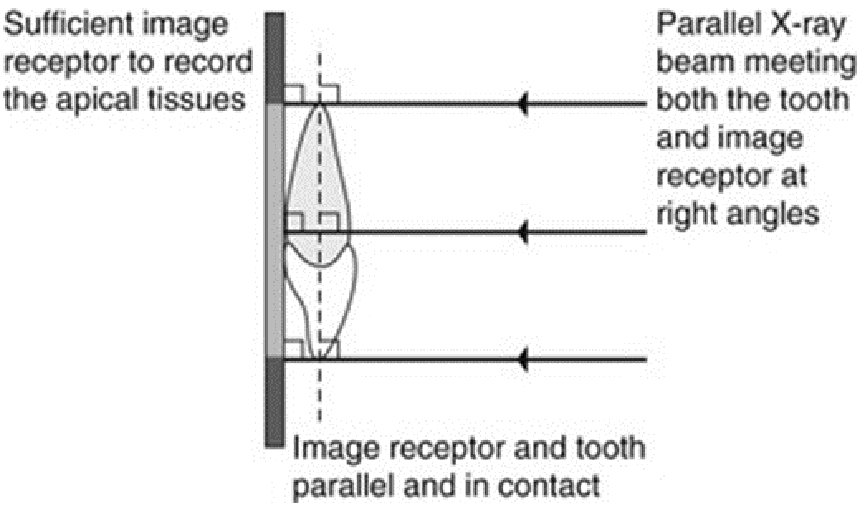


Figure 1: Diagram illustrating the ideal geometrical relationship between image receptor, tooth and X-ray beam.

Radiographic techniques:

The anatomy of the oral cavity does not always allow all these ideal positioning requirements to be satisfied. In an attempt to **overcome the problems**, **two techniques for periapical radiography have been developed:**

1. **The paralleling technique:**
2. **The bisecting angle technique:**

Paralleling Technique; (extension cone paralleling, right angle, long cone technique):

Patient Preparation:

1. Infection control procedures.
2. Explain procedure.
3. Seat the patient.
4. Position the patient upright in the chair.
5. Adjust headrest.
6. Place lead apron, thyroid collar.
7. Remove all objects from the mouth.

Theory of parallel technique:

It called so because film and the tooth must be parallel to each other. ***The requirements of this technique are:-***

1. The image receptor is placed in a holder and positioned in the mouth **parallel** to the long axis of the tooth under investigation.
2. The X-ray tubehead is then aimed at **right angles** (vertically and horizontally) to both the tooth and the image receptor.
3. By using a film or sensor holder with fixed image receptor and X-ray tubehead positions, the technique is **reproducible**.

This positioning has the potential to satisfy four of the five ideal requirements mentioned earlier (page 2). However, the anatomy of the palate and the shape of the arches mean that the tooth and the image receptor cannot be both **parallel** and **in contact**. As shown in Fig. 2, the tooth and image receptor to be parallel they have to be positioned some distance apart.

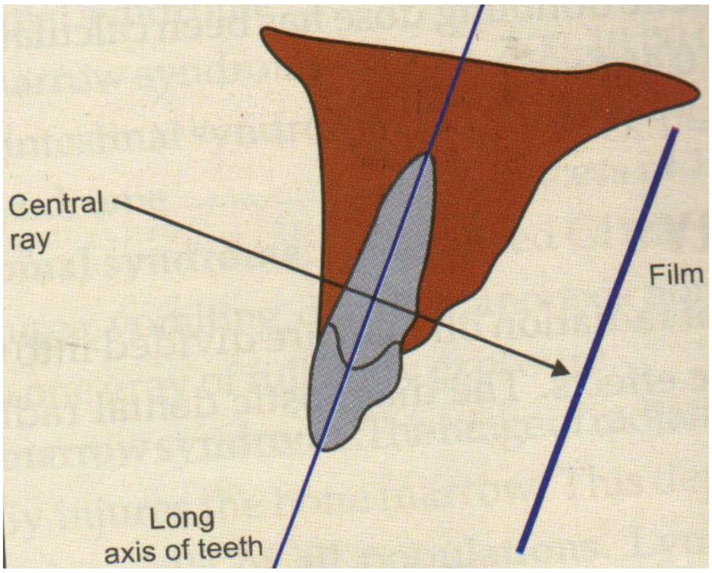


Figure 2: Diagram showing the position the image receptor has to occupy in the mouth to be parallel to the long axis of the tooth, because of the slope of the palate.

To prevent the magnification of the image that this separation would cause Fig. 3 (A), a parallel, non-diverging, X-ray beam is required. This is achieved usually by having a long focal spot to skin distance (fsd) Fig. 3 (B), ideally using long cone of 16 inches with paralleling technique.

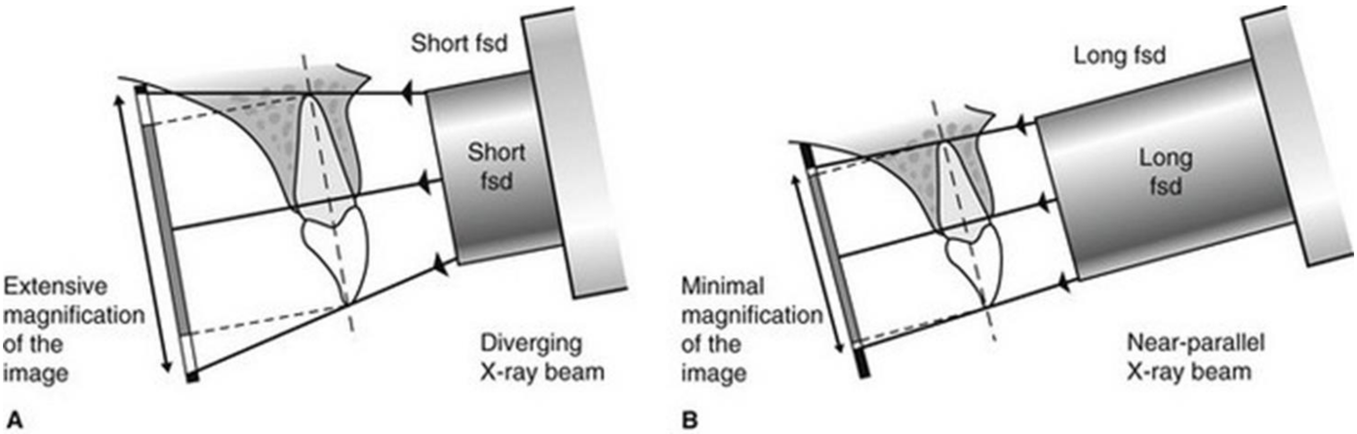


Figure 3: Diagrams showing the magnification of the image that results from using: **(A)** a short focal spot to skin distance and a diverging X-ray beam and **(B)** a long focal spot to skin distance and a near-parallel X-ray beam.

The ideal geometrical relationship between image receptor, tooth and X-ray beam in parallel technique:

1. When placing a film in a patient's mouth, the radiographer must keep in mind that **the long axes of the teeth do not parallel the midsagittal plane**. Most maxillary teeth flare out slightly, tipping the root apices toward the center of the palate. The

mandibular anterior teeth often have a similar inclination, with the root apices tipped toward the floor of the mouth. Mandibular premolars are more upright, and the mandibular molar crowns may be lingually inclined, placing the roots in a slightly buccal position. The relative positions of the teeth in the jaws must be kept in mind during film placement.

2. In order to **achieve parallelism** between the long axes of the teeth and the film, the film must be placed away from the teeth, toward the midline of the oral cavity. If the film is placed too close to the teeth, parallelism is very difficult to achieve.
3. Additionally, **films that are placed too close to the teeth may not record enough tissue in the area of the root apices.** The alveolar process just lingual to the teeth prevent a film from reaching the depth of the palate or floor of the mouth. **To ensure adequate coverage and parallel placement,** films must be positioned away from the teeth, with the patient biting near the anterior edge of the bite block.
4. An **increased film-to-object distance** results in some magnification and geometric unsharpness in an image if the short target-object distance were employed Fig. 3 (A); the proper placement of the film in the paralleling technique creates such a distance between the film and the objects being imaged. To compensate, a long (16- inch) x-ray source-to-film distance is used to help minimize the magnification and unsharpness generated by the distance between the film and the teeth Fig. 3 (B). The paralleling technique is sometimes referred to as the **"long-cone"** technique because of the length of the position-indicating device (PID) that is required.
5. In order for **the film to remain parallel to the long axes of the teeth**, **a film holder must be used;** the patient cannot hold the film and keep it in its proper position. There are many types of film holders available commercially. Several have some sort of an indicator in addition to the film holder to help with beam alignment. Proper infection control dictates that film holders should be autoclavable or disposable.

Film packet/sensor holders:

A variety of holders has been developed for this technique. The choice of holder is a [1]matter of personal preference and [2]dependent on the type of image receptor–film packet or digital sensor (solid-state or phosphor plate)–being used. The different holders vary in cost and design, as shown in Fig. 4 but essentially consist of ***three basic components:***

1. A mechanism for holding the image receptor parallel to the teeth that also prevents bending of the receptor.
2. A bite block or platform.
3. An X-ray beam-aiming device. This may or may not provide additional collimation of the beam.

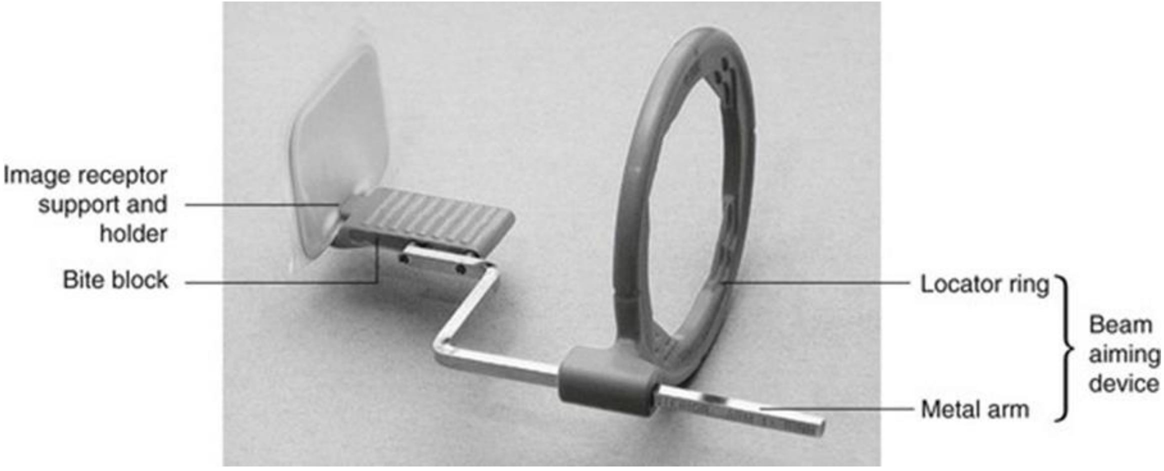


Figure 4: Posterior Rinn XCP image receptor holder showing the three basic components common to most holders.

A variety of holders has been developed for this technique could be Rinn XC**P** instrument (X-extended, C-cone, and **P-paralleling**).

The different components of the various holders usually need to be ~~**assembled**~~ together before the holder can be used clinically. **The holder design used depends upon whether the tooth under investigation is:**

1. Anterior or posterior.
2. In the mandible or maxilla.
3. On the right- or the left-hand side of the jaw.

These variables mean that ~~**assembling**~~ the holder can be confusing, but it must be done correctly. To facilitate this ~~**assembly**~~ some manufacturers now **color-code** the various components. Once ~~**assembled**~~ correctly the entire image receptor should be visible when viewed through the beam-aiming device, as shown in Fig. 5, A (~~assembled~~ correctly) and Fig. 5, B (~~assembled~~ incorrectly). A selection of different holders is shown in Fig. 6.

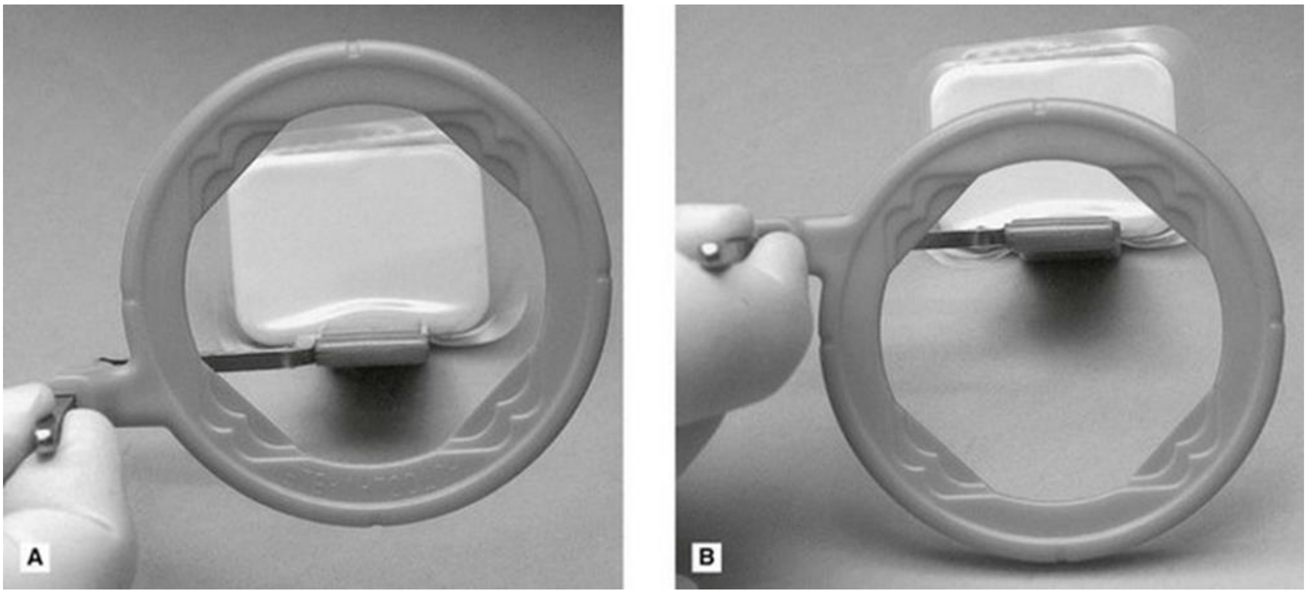


Figure 5: **(A)** The appearance of the film packet when viewed through the locator ring of a correctly assembled Rinn XCP holder. **(B)** The appearance when the image receptor holder has been assembled incorrectly.

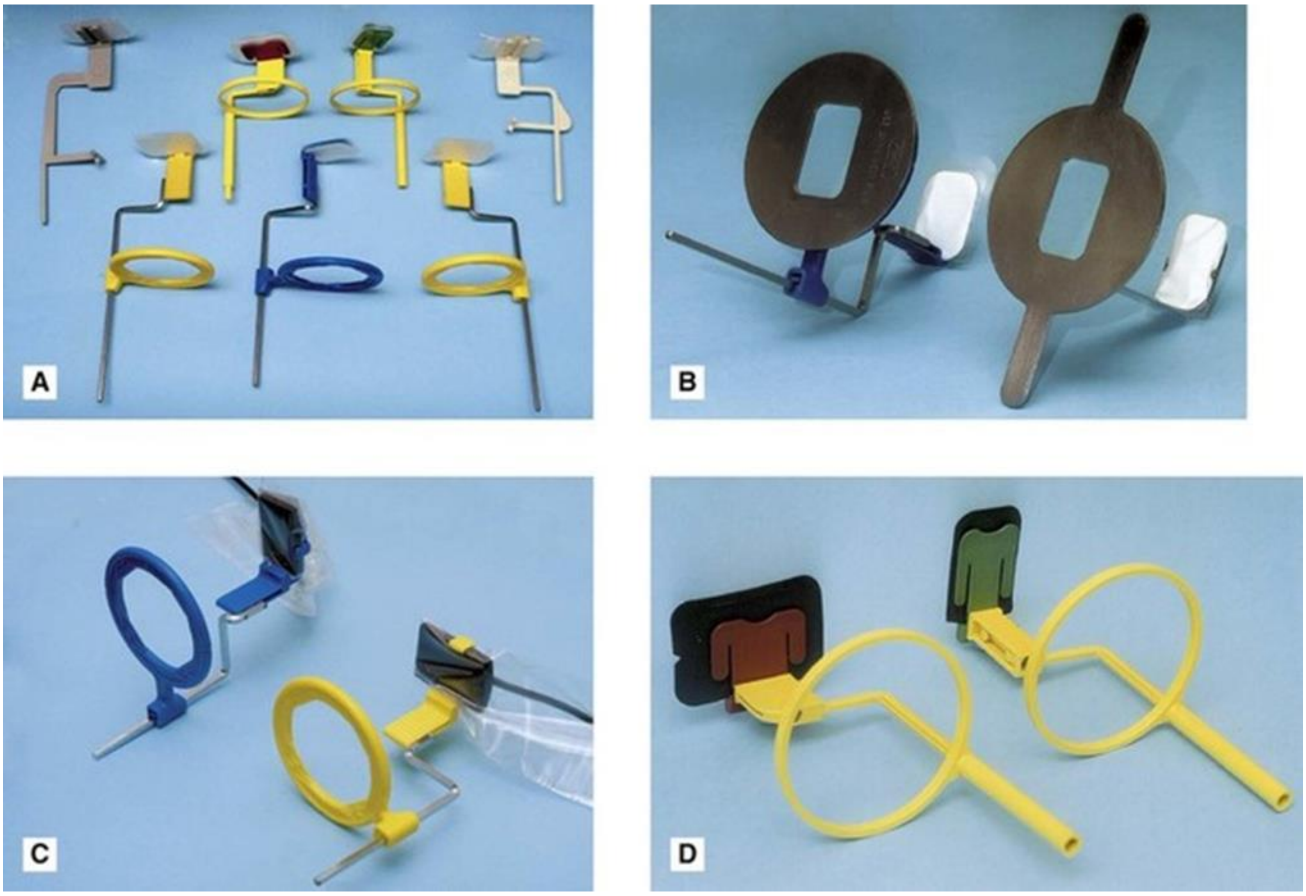


Figure 6: (A) a selection of film packet and digital phosphor plate holders designed for the paralleling technique. Note how some manufacturers use colour coding to identify holders for different parts of the mouth. (B) Holders incorporating additional rectangular collimation – the Masel Precision all-in-one metal holder and the Rinn XCP holder with the metal collimator attached to the locator ring. (C) Blue anterior and yellow posterior Rinn XCP-**DS** solid-state **digital sensor** holders. (D) Green/yellow anterior and red/yellow posterior **Hawe–Neos holders** suitable for film packets and digital phosphor plates.

Typically, the same anterior holder can be used for right and left maxillary and mandibular incisors and canines utilizing a small image receptor (22×35 mm)[#0] with its long axis vertical. Four images in the maxilla and three images in the mandible are usually required to cover the right and left incisors and canines, as shown in Fig. 7.

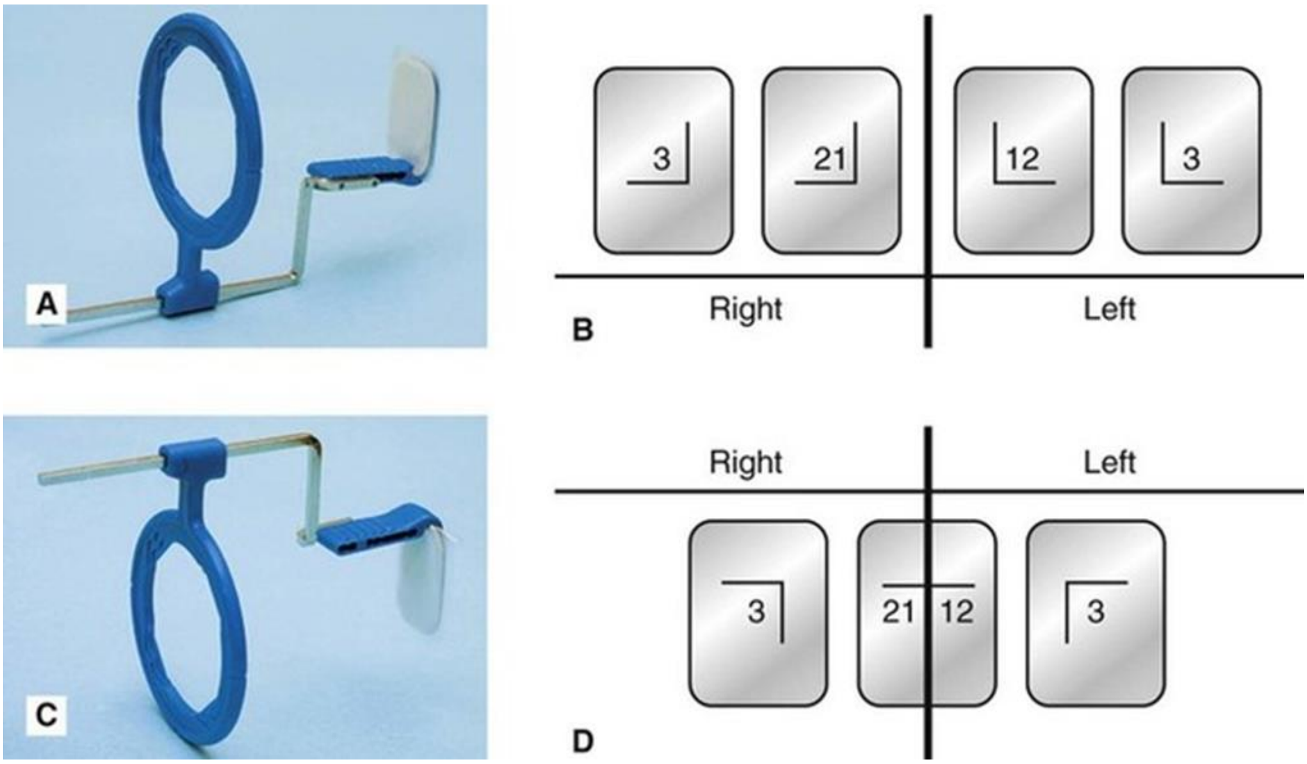


Figure 7: (A) The anterior Rinn XCP holder suitable for imaging the maxillary incisors and canines. (B) Diagram showing the four small image receptors required to image the right and left maxillary incisors and canines. (C) The same anterior Rinn XCP holder suitable for imaging the mandibular incisors and canines. (D) Diagram showing the three small image receptors required to image the right and left mandibular incisors and canines.

Typically different holders are required for the right and left premolar and molar maxillary and mandibular posterior teeth. The different designs allow the holders to hook around the cheek and corner of the mouth. A large image receptor (31×41 mm)[#2] is ideally utilized with its long axis horizontal. Two images are usually required to cover the premolar and molar teeth in each quadrant, as shown is Fig. 8.

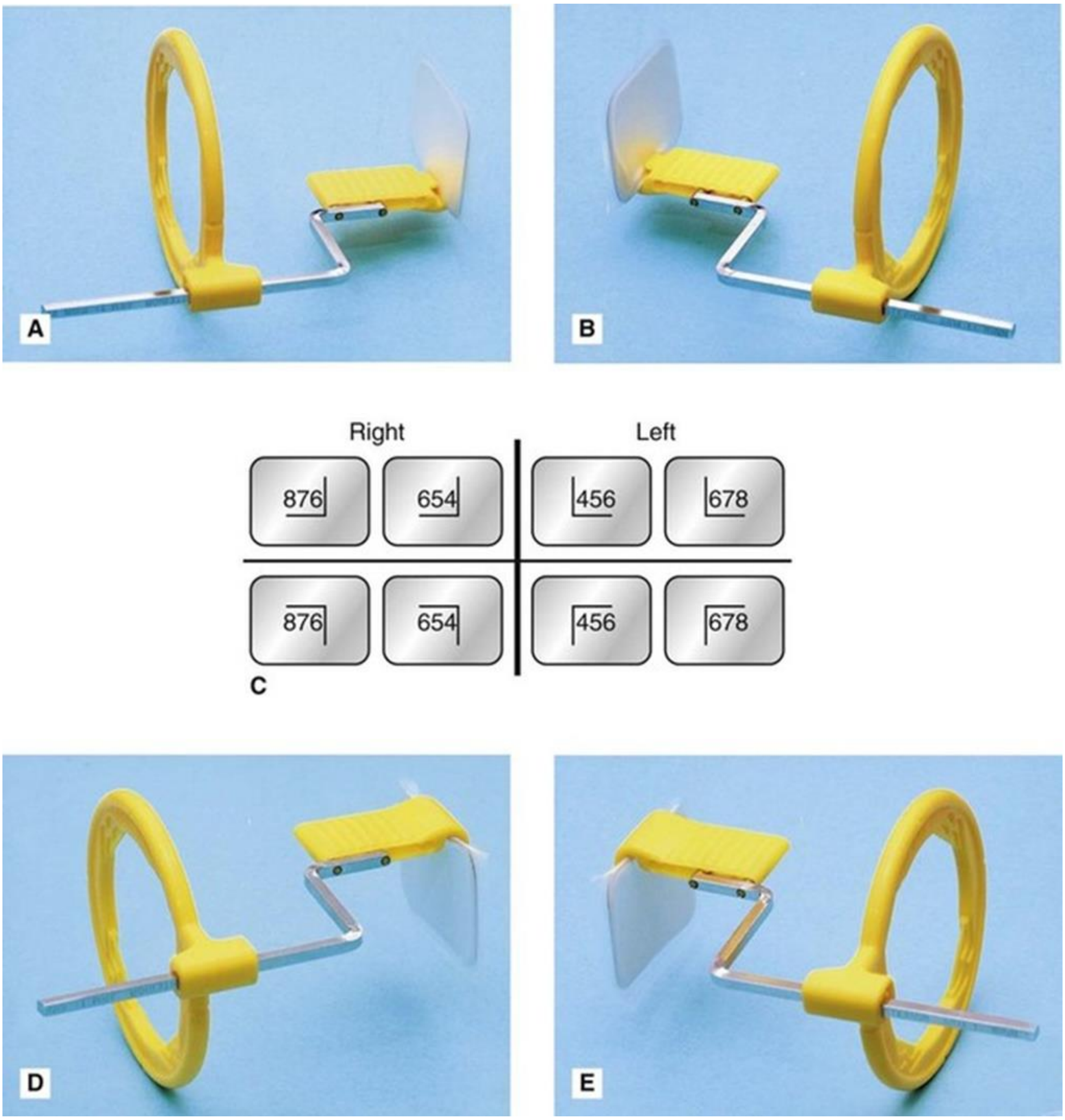


Figure 8: (A) The posterior Rinn XCP holder assembled for imaging the RIGHT maxillary premolars and molars. (B) The posterior Rinn XCP holder assembled for imaging the LEFT maxillary premolars and molars. (C) Diagram showing the two large image receptors required to image the right and left premolars and molars in each quadrant. (D) The posterior Rinn XCP holder assembled for imaging the RIGHT mandibular premolars and molars. (E) The posterior Rinn XCP holder assembled for imaging the LEFT mandibular premolars and molars.

Positioning techniques in parallel technique:

The radiographic techniques for the permanent dentition can be summarized as follows:

1. The patient is positioned with the head supported and with the occlusal plane horizontal.
2. The holder and image receptor are placed in the mouth as follows:
   a) Maxillary incisors and canines; the image receptor is positioned sufficiently posteriorly to enable its height to be accommodated in the vault of the palate.
   b) Mandibular incisors and canines; the image receptor is positioned in the floor of the mouth, approximately in line with the lower canines or first premolars.
   c) Maxillary premolars and molars; the image receptor is placed in the midline of the palate, again to accommodate its height in the vault of the palate.
   d) Mandibular premolars and molars; the image receptor is placed in the lingual sulcus next to the appropriate teeth.
3. The holder is rotated so that the teeth under investigation are touching the bite block.
4. A cotton wool roll is placed on the reverse side of the bite block. This often helps to keep the tooth and image receptor parallel and may make the holder less uncomfortable.
5. The patient is requested to bite gently together, to stabilize the holder in position.
6. The locator ring is moved down the indicator rod until it is just in contact with the patient's face. This ensures the correct focal spot to film distance.
7. The spacer cone is aligned with the locator ring. This automatically sets the vertical and horizontal angles and centers the X-ray beam on the image receptor.
8. The exposure is made.

Positioning clinically using film packets and digital phosphor plates is shown in Figs 9–16 for the following different areas of the mouth:

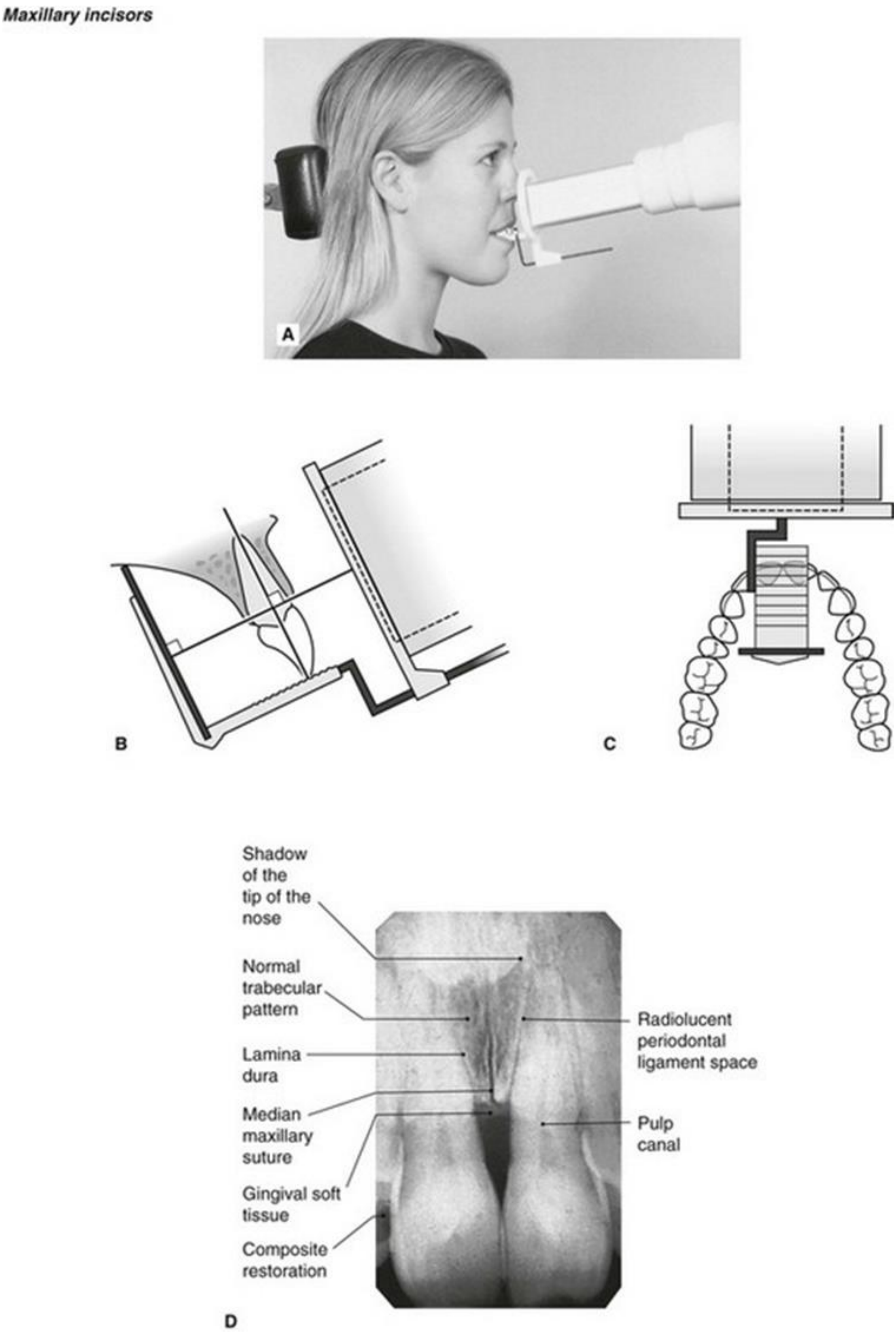


Figure 9: (A) Patient positioning (maxillary central incisor). (B) Diagram of the positioning. (C) Plan view of the positioning. (D) Resultant radiograph with the main anatomical features indicated.

Maxillary canine

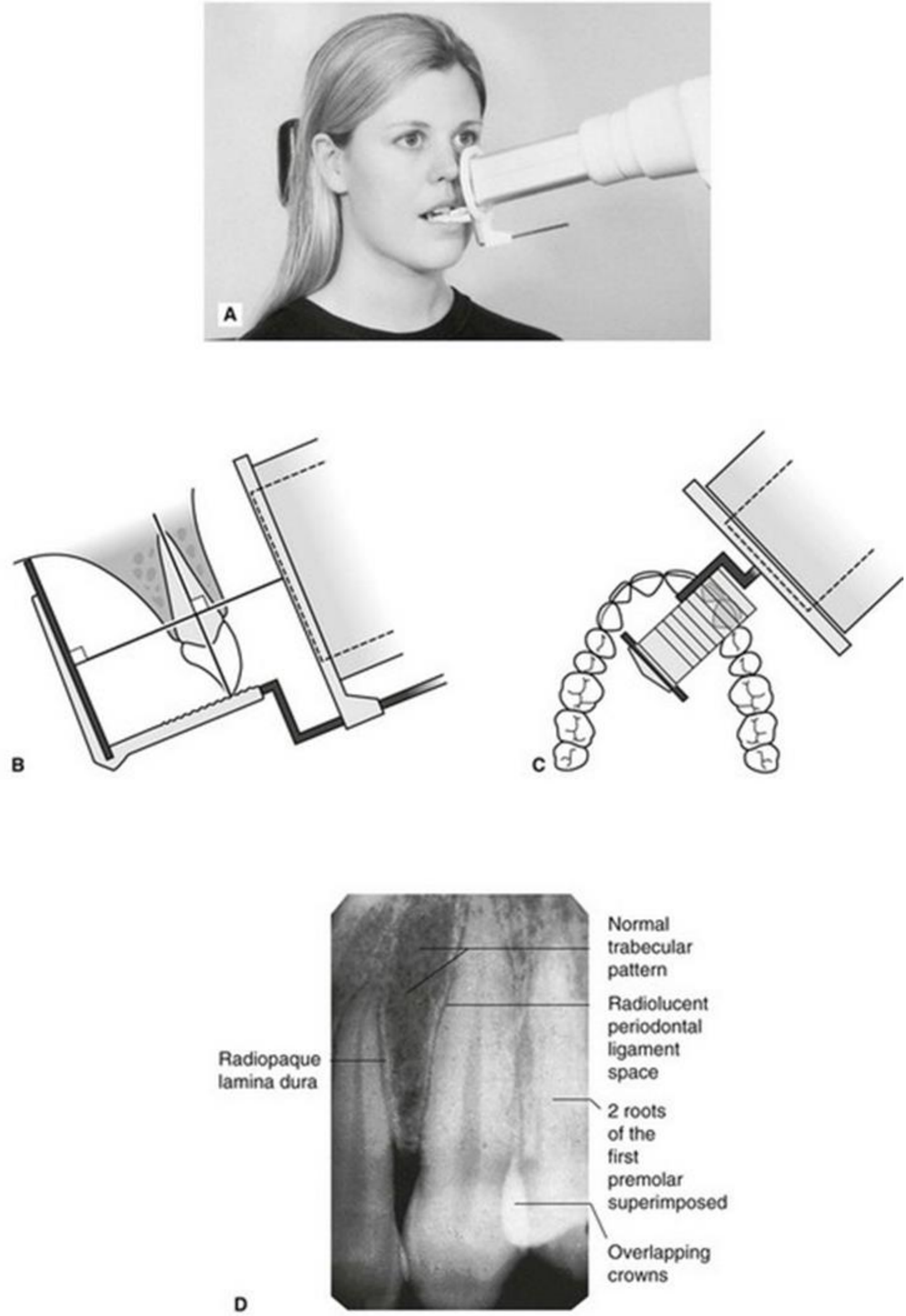


Figure 10: (A) Patient positioning (maxillary canine). (B) Diagram of the positioning. (C) Plan view of the positioning. (D) Resultant radiograph with the main anatomical features indicated.

Maxillary premolars

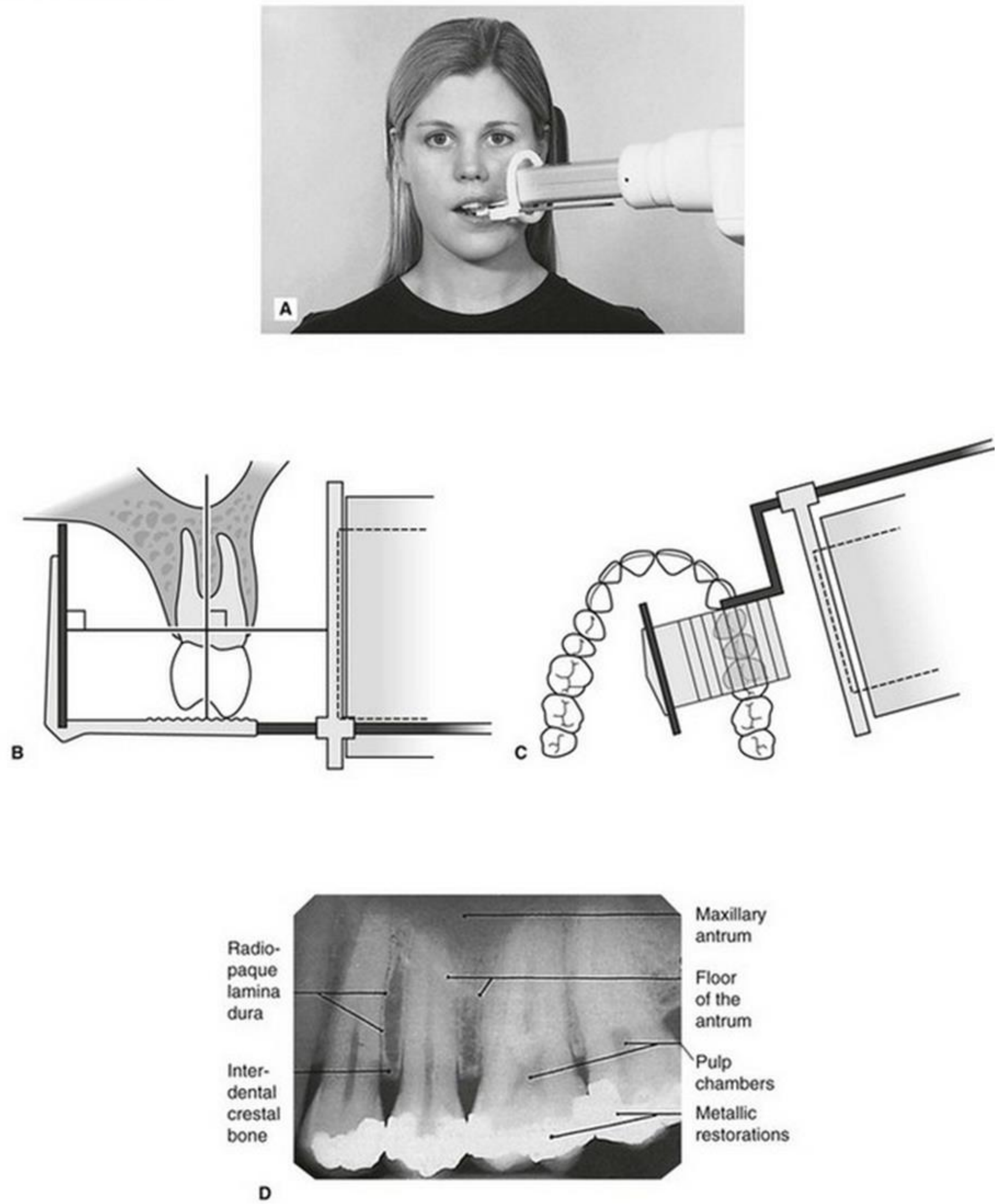


Figure 11: (A) Patient positioning (maxillary premolars). (B) Diagram of the positioning. (C) Plan view of the positioning. (D) Resultant radiograph with the main anatomical features indicated.

Maxillary molars

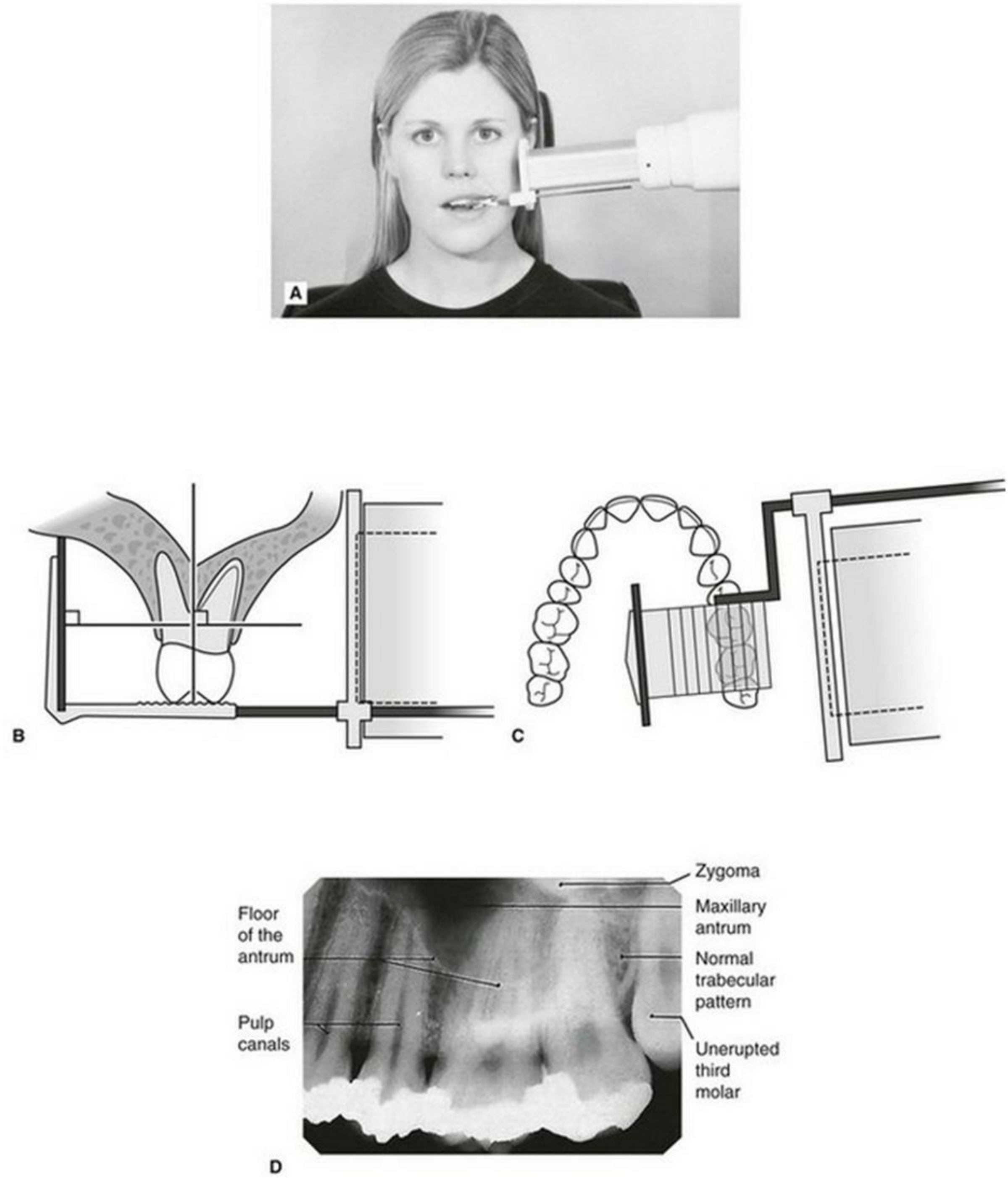


Figure 12: (A) Patient positioning (maxillary molars). (B) Diagram of the positioning. (C) Plan view of the positioning. (D) Resultant radiograph with the main anatomical features indicated.

Mandibular incisors

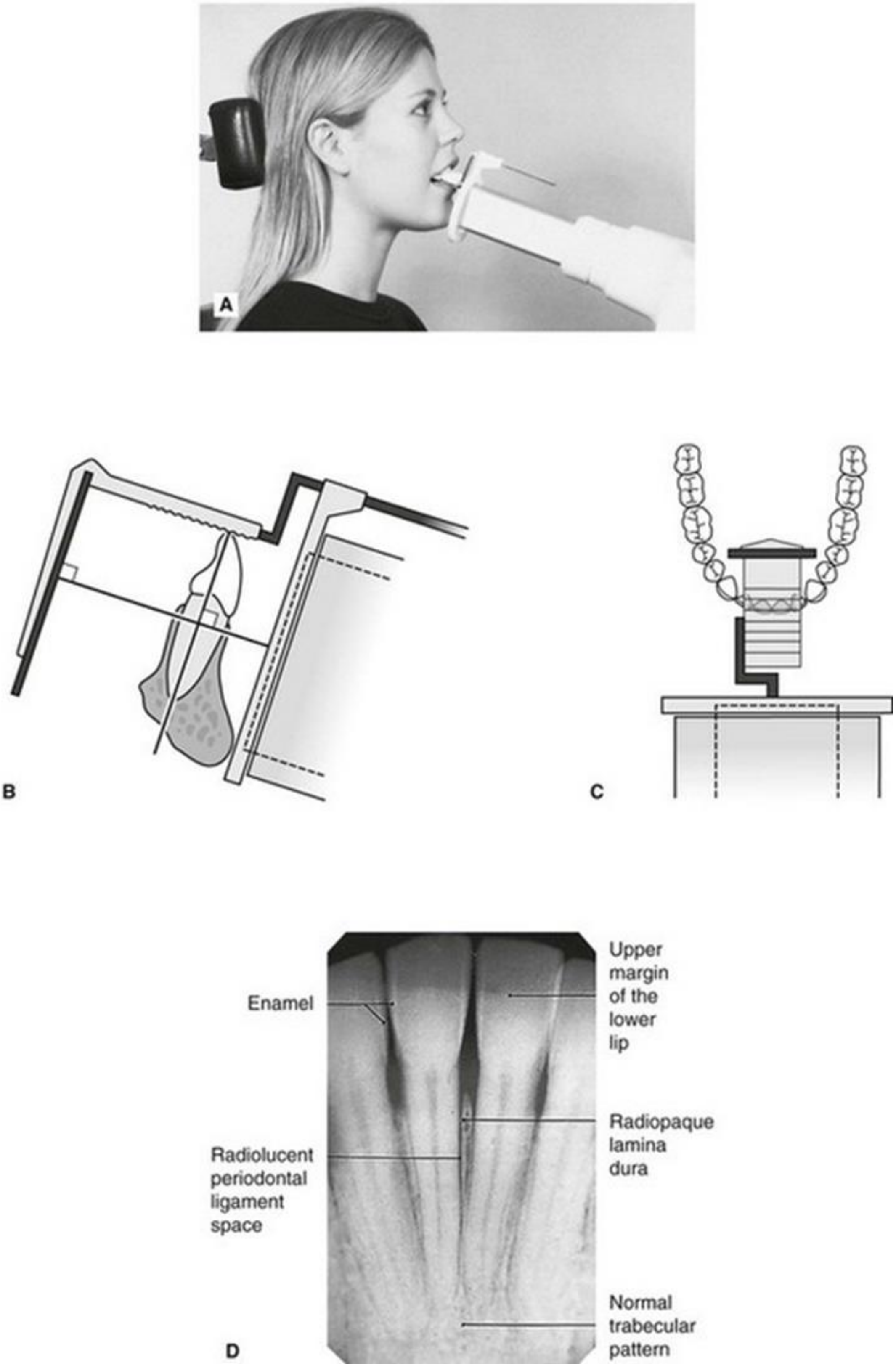


Figure 13: (A) Patient positioning (mandibular incisors). (B) Diagram of the positioning. (C) Plan view of the positioning. (D) Resultant radiograph with the main anatomical features indicated.

Mandibular canine

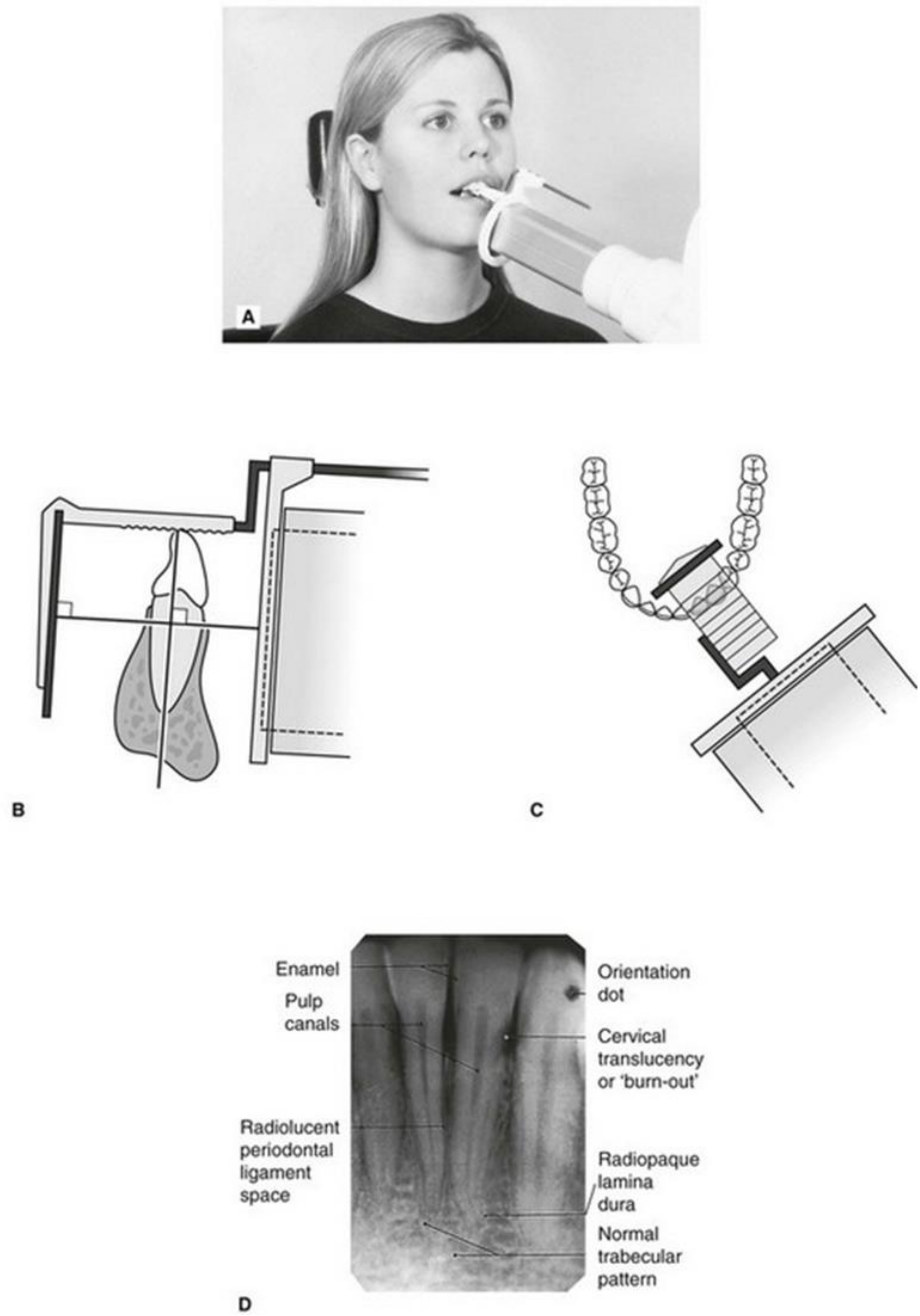


Figure 14: (A) Patient positioning (mandibular lateral and canine). (B) Diagram of the positioning. (C) Plan view of the positioning. (D) Resultant radiograph with the main anatomical features indicated.

Mandibular premolars

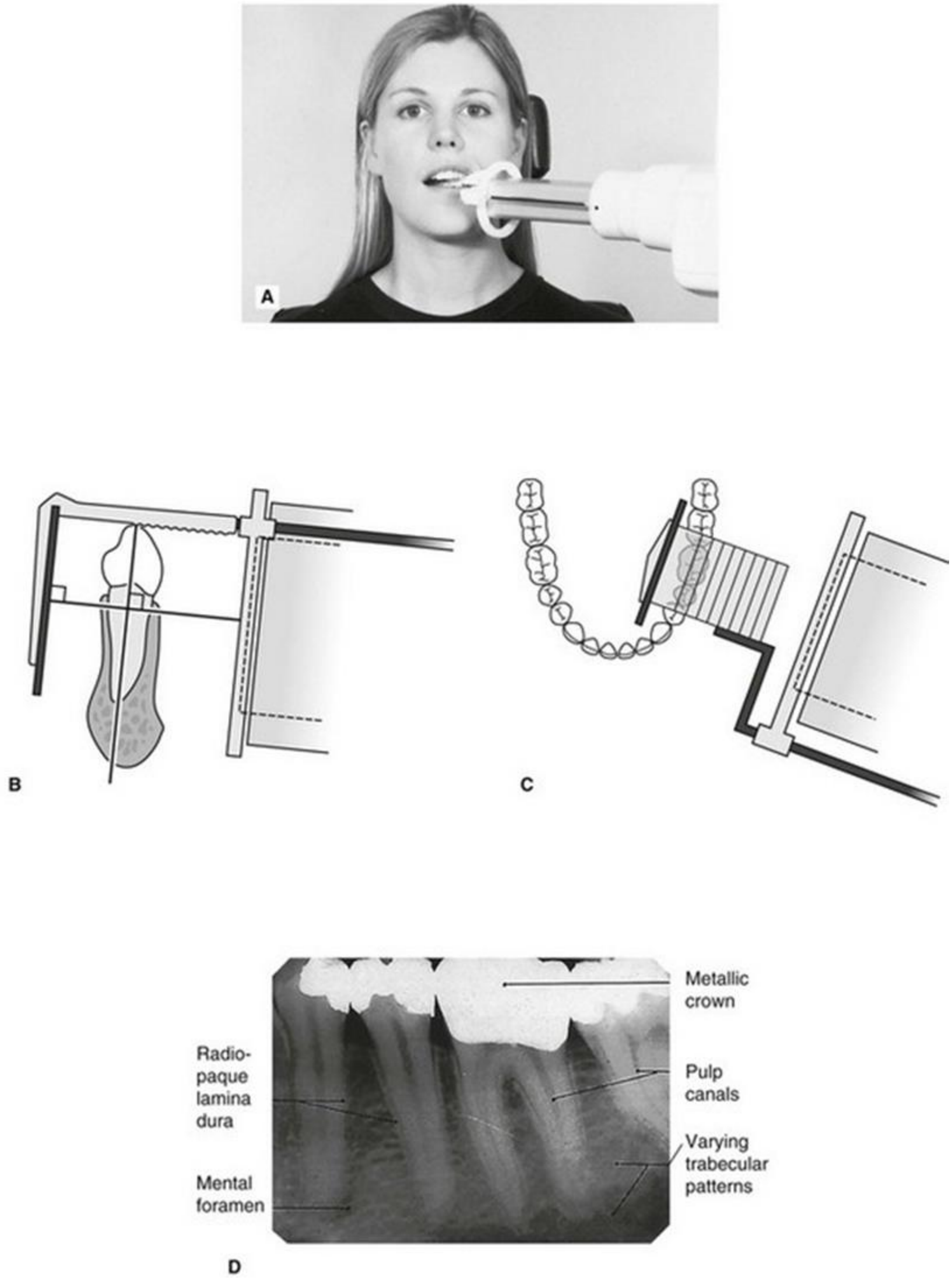


Figure 15: (A) Patient positioning (mandibular premolars). (B) Diagram of the positioning. (C) Plan view of the positioning. (D) Resultant radiograph with the main anatomical features indicated.

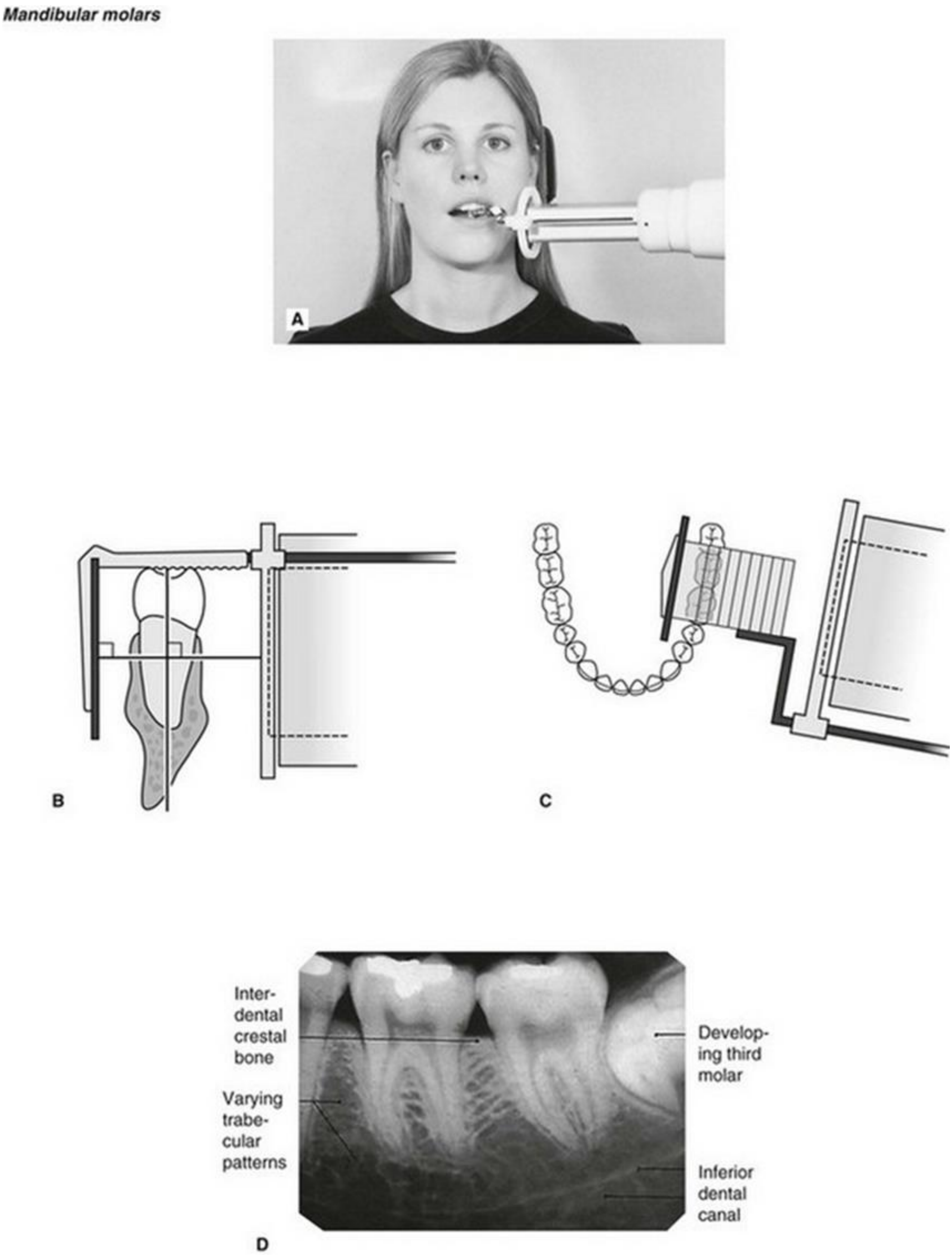


Figure 16: (A) Patient positioning (mandibular molars). (B) Diagram of the positioning. (C) Plan view of the positioning. (D) Resultant radiograph with the main anatomical features indicated.

Note:

1. Full mouth survey is the terminology used to describe the full collection of **15** periapical radiographs (seven anterior and eight posterior) showing the full dentition.

2. When using film packets and digital phosphor plates **the end of the receptor with the orientation dot** should be placed opposite the crowns of the teeth to avoid subsequent superimposition of the dot over an apex.

Exposure Sequence:

When exposing radiographs, establish an exposure sequence, or definite order for periapical film placement. Without an exposure sequence, there is a good chance that you will omit an area or expose the same area twice.

When exposing periapical films with the paralleling technique, always **start with the anterior teeth** (canines and incisors) because:

1. The **size 1** film used for anterior teeth is small, less uncomfortable, and easier for the patient to tolerate.
2. It is easier for the patient to become accustomed to the anterior **film holder**.
3. The anterior film placements are less likely to cause the patient to **gag reflex**.

Anterior exposure sequence: Ↄ

- Begin with the maxillary right canine (tooth #6).
- Expose all of the maxillary anterior teeth from right to left.
- End with the maxillary left canine (tooth #11).
- Next, move to the mandibular arch.
- Begin with the mandibular left canine (tooth #22).
- Expose all of the mandibular anterior teeth from left to right.
- Finish with the mandibular right canine (tooth #27).

1 Maxillary right canine.	2 Maxillary incisors.	3 Maxillary left canine.
6 Mandibular right canine.	5 Mandibular incisors.	4 Mandibular left canine.

Posterior exposure sequence:

After completing the anterior teeth, begin the posterior teeth.

Always expose the premolar film before the molar film because:

1. Premolar film placement is easier for the patient to tolerate than molar film placement.
2. Premolar exposure is less likely to evoke the gag reflex.

2 Maxillary right molars	1 Maxillary right premolars	5 Maxillary left premolars	6 Maxillary left molars
8 Mandibular right molars	7 Mandibular right premolars	3 *Mandibular left premolars	4 Mandibular left molars

*You do not have to ~~reassemble~~ the film holder for this area

Positioning using solid-state digital sensors in parallel technique:

Clinical positioning of holders for the **paralleling technique** when using solid-state digital sensors can be more difficult because of:

1. The **bulk and absolute rigidity** of the sensor.
2. Those systems employing **cables** also require extracare with regard to the position of the cable to avoid damaging it.

Once the holder is inserted into the mouth, the positioning of the tubehead is the same as described previously when using other types of image receptors and is shown in Fig. 17 for different parts of the mouth.

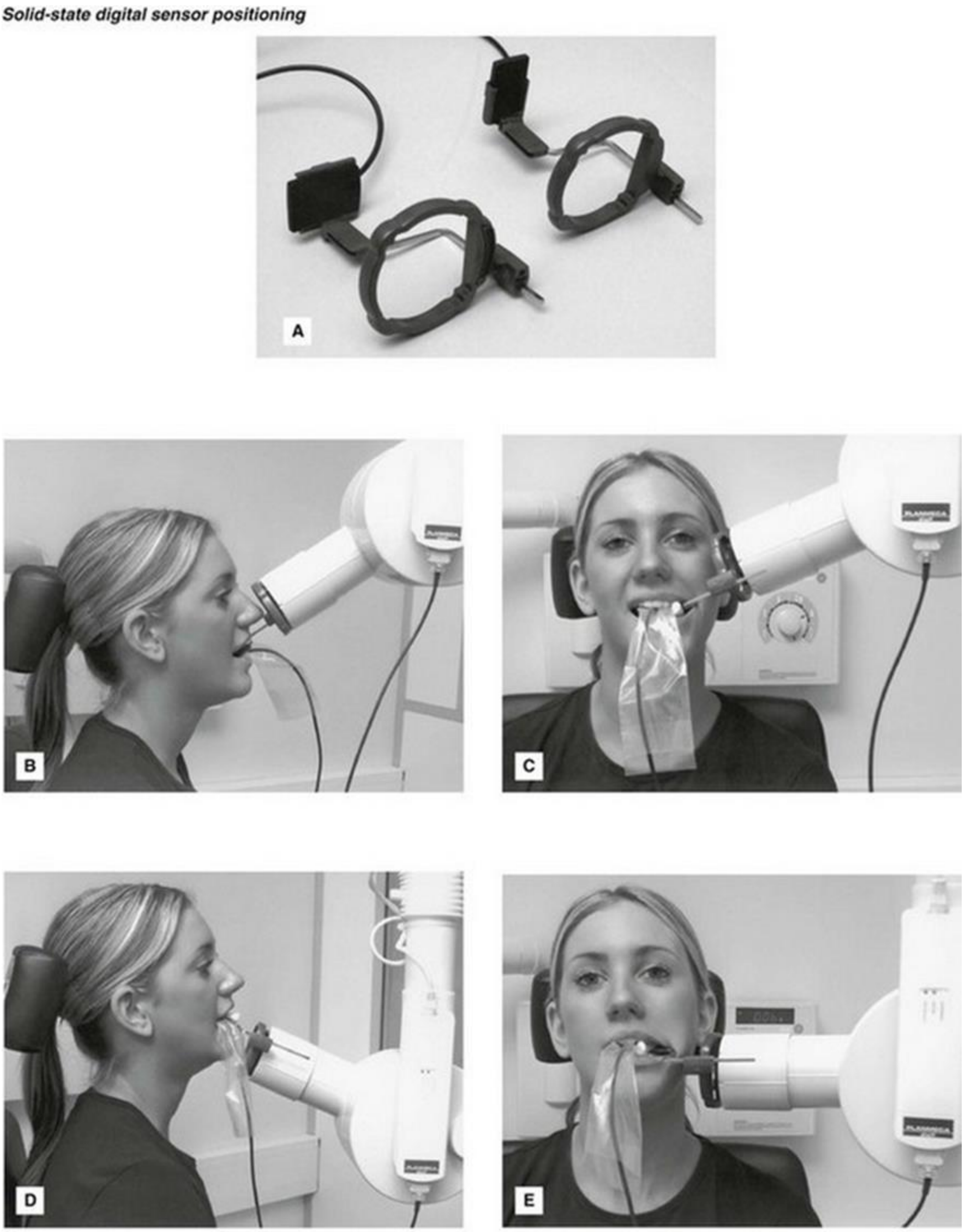


Figure 17: (A) Anterior and posterior Planmeca solid-state sensor holders and their clinical positioning for (B) maxillary incisors. (C) Maxillary molars. (D) Mandibular incisors. (E) Mandibular molars.

X-ray beam alignment in parallel technique:

The x-ray beam must be aligned so that it is perpendicular to the film and long axes of the teeth in both the vertical and horizontal planes.

1. **The vertical angulation** of the beam can be adjusted by pointing the PID up or down. Vertical angles are usually **indicated on a scale** along the sides of the tubehead. Positive angles are formed when the PID points down, and negative angles are formed when it points up (Fig. 18, A).
2. **The horizontal angulation** of the x-ray beam is adjusted by directing the PID to the left or right in the horizontal plane. This angulation is **not marked** on the tubehead (Fig. 18, B).
   - The film should be placed so that the x-ray beam passes through the interproximal contacts of the teeth and is perpendicular to the film and long axes of the teeth. If the beam is misdirected in the horizontal plane, the proximal aspect of one tooth will be projected over the proximal aspect of another, creating an overlapped contact.
   - Correct horizontal angulation allows clear visualization of the interproximal areas; these contacts are said to be open. The horizontal angulation remains the same whether you are using the paralleling or bisecting technique. The central ray is directed perpendicular to the curvature of the arch and through the contact areas of the teeth.
3. The beam should be centered on the film packet so that the entire film is exposed to the radiation. A misaligned beam that covers only a portion of the film results in a partial image on the film. The portion of the film that is unexposed will have no image, and the unexposed area is often called a "cone cut".
4. As was previously mentioned, many commercial film-holding devices have beam alignment indicators attached to them, making the task of beam alignment easier. However, these devices are not foolproof. Care must still be taken to ensure that the beam is perpendicular to the film and teeth.
5. Some film holders collimate a circular beam to a rectangle only slightly larger than the film. Particular care must be taken so that the beam is aligned perpendicular to the film in both the vertical and horizontal planes, so that a partial image is avoided.
6. Some x-ray units have rectangular PIDs to reduce patient exposure, and the use of a film holder with an alignment indicator makes proper imaging easier. Because the beam of radiation is only slightly larger than the film in a unit with a rectangular PID, the PID must be carefully aligned with the film to avoid partial images.

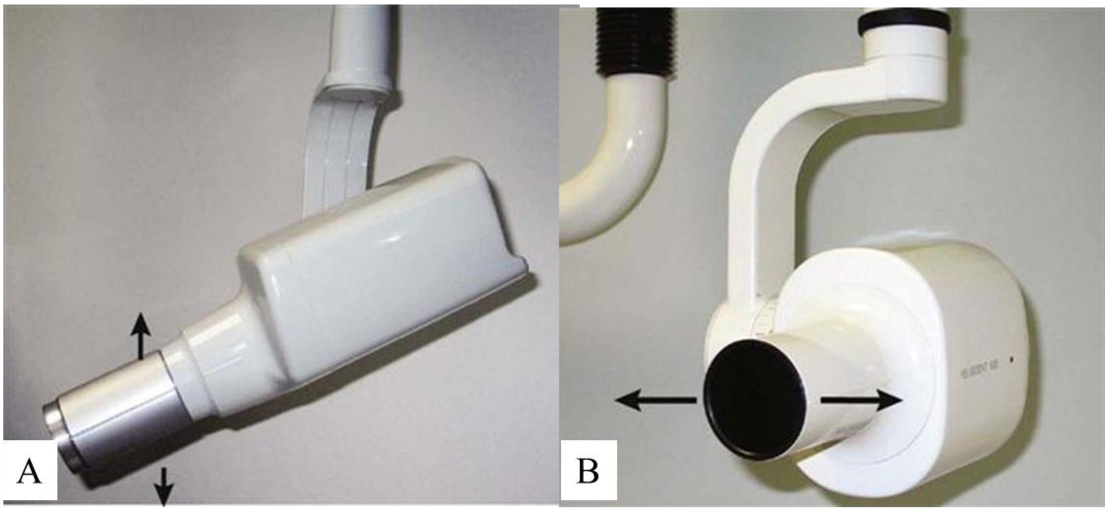


Figure 18: (A) Vertical angulation of the PID refers to PID placement in an up-and-down direction. (B) The arrows indicate movement in a horizontal direction.

Seating the Patient in parallel technique:

1. The patient should be comfortably seated, in an **upright position** if possible. The **supine position** may be used for a few films during an endodontic or surgical procedure. The patient's head and back should be supported.
2. The patient's **medical history** should be briefly reviewed if it has not been previously addressed by the radiographer.
3. The patient should be asked to **take out all removable items from the mouth** (including chewing gum), and eyeglasses should be removed.
4. The patient must always be draped with a **lead apron and thyroid collar**, even if only one exposure is to be made.
5. The oral cavity should be inspected for the presence of **any anatomic variations** or other abnormalities that might radiographs are positioned in the mouth.

Preparing the Unit:

1. Exposure factors should be checked and set prior to placing the film in the patient's mouth.
2. It is also advisable to place the tubehead near the area of interest, so that fewer alignment movements are made with the film in the patient's mouth.

General Procedures for Film Placement:

1. Start by taking any anterior periapical films first. If #1 size films are used, they are smaller and easier for most patients to accommodate. This will enable the patient to

grow accustomed to the procedure before the posterior films are placed. The relative ease of the procedure in the anterior will allow you and your patient to tackle the posterior placements with greater confidence.

2. Films for anterior teeth (cuspids and incisors) are always placed with the long portion of the film in a vertical direction; posterior films (for premolars and molars) are always placed in a horizontal orientation.
3. The all-white side of the film packet should face the lingual aspect of the teeth. Place the film packet firmly into the film holder so it will not be dislodged during placement.
4. **~~In the maxilla,~~** remember to keep the film packet away from the teeth, toward the midline of the oral cavity, into the highest portion of the palatal vault.
   a) **Initially,** place the film holder so that a V is formed over the teeth. Then bring the horizontal portion of the film holder into contact with the teeth you are imaging. Then ask the patient to "slowly close." Try to say "slowly" first; avoid the word "bite." The command "bite down" may bring an unwanted response down on your fingers!
   b) If the film holder seems unstable because of the patient's occlusion, a cotton roll may be inserted under the holder, against the lower teeth if upper teeth are being imaged. Try not to allow the film to bend against the palate. Keeping the film in the highest portion of the vault and having the patient close gently will help to prevent film bending.
   c) Remember that a film that is placed parallel with the long axes of the teeth will not be parallel with the patient's midsagittal plane in the maxilla.
5. **~~Mandibular films~~** must be placed between the teeth and the patient's tongue. In order to capture the images of the apices of the teeth, the musculature in the floor of the mouth must be displaced by the film holder. This may be uncomfortable if the muscles are tense. In addition, the mucosa overlying the lingual aspect of the

alveolar bone is thin, fragile, and easily abraded. Keeping your patient as comfortable as possible will make film placement easier.

a) **Remember** to keep the film away from the teeth and alveolar ridges. Place the film under the tongue at an angle, with the "**elbow**" of the film holder above the teeth.

b) Gently depress the floor of the mouth while uprighting the film to a parallel position and ask the patient to **"slowly close."** As the patient starts to close his or her jaw, the floor of the mouth will drop slightly and the film holder should then contact the teeth to be imaged.

c) As in the maxilla, a **cotton roll** may be used for stability, this time against the upper teeth.

General steps of film placement in paralleling technique:

1. Film size: #1 anterior, #2 posterior.
2. White on white.
3. Dot in the slot.
4. Vertical anterior, horizontal posterior.
5. Bite-block in contact.
6. Cotton roll if opposing arch is edentulous.

Advantages of Paralleling Technique:

1. Increased dimensional accuracy and reduced dimensional distortion.
2. Diagnosis of caries and bone level accurately.
3. No superimposition of zygomatic arch over the maxillary molars.
4. Relative position of film, teeth and x-ray beam are always maintained.
5. Simple beam alignment (vertical and horizontal angulation automatically determined).
6. Reproducible radiograph when placed in holder.

Disadvantages of Paralleling Technique:

1. Accurate film placement may be difficult at times for the radiographer to achieve specially in a small mouth or shallow palate. Also film placement can be sometimes difficult for the patient to tolerate (it hurts) and sometimes film holder can cause patient discomfort.
2. Not disposable- most holders have to be sterilized.
3. Rings are a "guide" only-radiographer must have skill to access accuracy.
4. Longer exposure time.

Supplemental Periapical Techniques:

Bisecting Angle Technique: *(Finger holding method, short cone technique, digital method, calibrated scale technique):*

Patient Preparation:

1. Infection control procedures.
2. Explain procedure.
3. Seat the patient.
4. Position the patient upright in the chair.
5. Adjust headrest.
6. Place lead apron, thyroid collar.
7. Remove all objects from the mouth.

Theory of bisecting technique:

The bisecting angle technique is based on the geometry of triangles. ***Two triangles will be equal if they share a common side and have two equal angles.*** This will make all corresponding sides equal. Therefore, a tooth and its image on the film will be equal in length if they share a common imaginary line between them.

1. To achieve the equal triangles, operator envisions an imaginary bisector of the angle formed by the long axis of the tooth and the long axis of the film, this angle is formed where the film contacts the tooth crown and extends at an angle into the palate or floor of the mouth.
2. Operator direct the central ray of the beam through the apex of the tooth so central ray strikes the bisector at 90˚, two equal triangles are formed**,** such angulations if properly employed results in a tooth image that is exactly the length of the object.

In this technique, as a result of lack of parallelism between the tooth and the film since the film is in contact with the tooth crown, we have all the areas below the apex of the tooth as well as above are distorted and the degree of distortion can reduced by the use of long cylinder because the longer distance between the source of radiation and the object the more is the parallel will be the rays.

The film packet should extend approximately **1/8 inch - *1/4inch* (2-3 mm)** beyond the incisal or occlusal aspect of the teeth or in the biteblock if film holder is used.

- Film holders for bisecting angle technique including some with beam-alignment indicators, are available commercially.
- In a pinch, the film may be held in place by the patient's finger, but care must be taken to instruct the patient to use gentle pressure near the crowns to avoid bending the film.

Similar projections are used in the **bisecting angle** technique as in the **paralleling** technique. However, **#2 size** film is traditionally used in both the **anterior (in a vertical orientation)** and **posterior (in a horizontal orientation)** regions.

All **four maxillary incisors can be imaged on a #2 size film**, so only **three, as opposed to five,** projections are needed in the maxillary anterior region.

Beam alignment can be a challenge with bisecting angle technique if film holders with alignment indicators are not used. The beam should pass between the contacts of the teeth being imaged in the horizontal dimension, just as it does in the paralleling technique.

The vertical angle, however, must be directed at 90° to the imaginary bisecting line. Too much vertical inclination will produce images that are too short (foreshortened), and too little vertical inclination will result in images that are too long (elongated).

The beam must be centered over the film to avoid cone cutting. A round PID is most often used when bisecting the angle; a rectangular PID greatly increases the chances of generating a partial image.

Usually a shorter (8-inch) PID (therefore shorter exposure times) is used when employing the bisecting angle technique.

Radiographers may have difficulty imagining the bisecting line and then directing the beam perpendicular to that bisector. Although the best results will be produced if each film placement in every patient is analyzed individually, **the following guidelines may be helpful in allowing the radiographer to determine if he or she is approximating the correct beam alignment.**

1. The patient's **midsagittal** plane should be **perpendicular** to the **floor,** and the **occlusal** plane of the arch that is being imaged should be **parallel** to the **floor.**
2. This means that the patient's head is upright for maxillary films and tipped back slightly for the mandibular arch.

Remember that a positive angulation occurs when the PID is tipped downward, and a negative angle occurs when the PID is tipped upward.

The advantage of the bisecting angle technique is that: ↑It can be used when a patient's anatomy precludes the paralleling technique. For example, it is very difficult to place films in a position parallel to the teeth:

1. When the patient's palatal vault is very shallow.
2. In the mandibular incisor area in a patient with a very short lingual frenum.
3. When there is a palatal or mandibular torus present.

Identification dot: It's a round raising dot present in the corner of each film, allows rapid and proper film orientation and placement. The manufacturer orients the film in the packet so that the convex side of the dot is toward the front of the packet and faces the source of radiation. During film exposure, the film oriented to place the dot 2-3 mm away from the incisal or occlusal surface.

Advantages of Bisecting Angle Technique:

1. More comfortable; Film holder not essential.
2. Shorter exposure time.
3. ↑Easier film placement in shallow palates, bony growths, shallow/tender floor of mouth.

Disadvantages of Bisecting Angle Technique:

1. The major disadvantage the image produced is not as accurate as that obtained with the paralleling technique. **Image distortion due to:**
   a. Incorrect beam alignment.
   b. Patient using excessive force to stabilize the film.
   c. Short PID resulting in increased divergence of X-rays.
2. If a short, round PID is used, the patient is exposed to more ionizing radiation than when a long, rectangular PID is used.
3. Harder beam alignment (without a film holder and aiming ring).
4. Film less stable (if a film holder isn't used).
5. Unnecessary exposure of patient's finger (if a film holder isn't used).

It is preferable to use the paralleling technique whenever possible, but diagnostic films can be obtained with the bisecting technique when necessary.

Beam entry and angulations guidelines for bisecting angle projections when occlusal plane of Maxillary arch is oriented parallel with the floor:

Maxillary incisors:

- **Direct the central ray at the tip of the nose** (*direct the central ray high on the lip, in the midline, just below the septum of the nostril).*
- + 40 to +50

  ***Lateral incisors**: Orient the central ray to enter high on the lip about 1 cm from the midline.*

Maxillary canine:

- Direct the central ray at the ala of the nose.
- + 45 to +55

Maxillary premolars:

- Direct the central ray at the intersection of a vertical line passing through the pupil and the ala tragus line.
- + 30 to +40

Maxillary molars:

- On the cheek below, direct the central ray at the intersection of a vertical line passing through the outer canthus of the eye and the ala tragus line.
- + 20 to +30

Beam entry and angulations guidelines for bisecting angle projections when occlusal plane of mandibular arch is oriented parallel with the floor:

Mandibular incisors:

- Direct the central ray at the chin.
- -15° to - 25°

Mandibular canine:

- Direct the central ray at the intersection of a vertical line passing through the ala of the nose and a horizontal line 1 cm above the inferior border of mandible.
- -20° to -30°

Mandibular premolars:

- Direct the central ray at the intersection of a vertical line passing the pupil and a horizontal line 1 cm above the inferior border of mandible.
- -10 to - 15

Mandibular molars:

- Direct the central ray at the intersection of a vertical line passing through the outer canthus of the eye and a horizontal line 1 cm above the inferior border of mandible.
- -5 to 0

Infection control in dental radiography:

Dental radiographic procedures present special infection control challenges. The operator contacts the patient's saliva while placing and removing the film packets or sensors, and touches many things while exposing and processing film. Protective measures and barriers used while producing radiographs are illustrated in Fig. 19. Dental film is now available with plastic barriers over the packet. The film is exposed as usual, and then the plastic barrier cover is removed before entering the darkroom for processing. The infection control protocol is more efficient and effective when the dental assistant plans for the procedure before the patient is seated.

Infection control guidelines for dental radiology:

1. Wear gloves when exposing radiographs and handling contaminated film packets. Use other PPE (e.g., protective eyewear, mask, and gown) as appropriate if spattering of blood or other body fluids is likely.
2. Use heat-tolerant or disposable intraoral devices whenever possible (e.g., film-holding and positioning devices). Clean and heat-sterilize heat-tolerant devices between patients.
3. Transport and handle exposed film in an aseptic manner to prevent contamination of the developing equipment.
4. The following apply for digital radiography sensors:

a) Use FDA-cleared barriers.
b) Clean and heat-sterilize, or high-level disinfect, between patients; barrier protect semicritical items. If an item cannot tolerate these procedures, then at a minimum, between patients protect with an FDA-cleared barrier, and clean and disinfect with an EPA-registered hospital disinfectant with intermediate-level (i.e., tuberculocidal claim) activity. Consult the manufacturer for methods of disinfection and sterilization of digital radiography sensors and for protection of associated computer hardware.

Figure 19: (A) X-ray equipment (control panel) with barriers in place. (B) Radiography operatory (dental X-ray machine and chair) with barriers in place. (C) Protective barrier on x-ray film.

Lecture 5 Intraoral Examination Techniques

Bitewing and occlusal radiography

By

Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.

Oral Radiology Teacher, Anbar University

Bitewing Radiographs:

Bitewing radiographs take their name from the original technique which required the patient to bite on a small wing attached to an intraoral film packet. Modern film holders, as shown later, have eliminated the need for the wing ***(now termed a tab)***, and digital image receptors **(solid-state or phosphor plate)** can be used instead of film, but the terminology and clinical indications have remained the same. An individual image is designed to show the crowns of the premolar and molar teeth on one side of the jaws.

Bitewing radiographs are probably **the most common types** of films ordered by the dentist for patients because of the nature of the information available on them. **One can see** [1]the crowns of both the maxillary and mandibular teeth, [2]the interproximal areas, and [3]the crest of the alveolar bone, all on one film. Although producing a bitewing of diagnostic quality seems to be a relatively easy task, the technique is quite error-sensitive and can be challenging in some patients.

So the main clinical indications can be listed as follow:

1. Detection of dental caries.
2. Monitoring the progression of dental caries.
3. Assessment of existing restorations, e.g. determination the proper fit of a crown (a cap that completely encircles a tooth) or other restorations such as bridges.
4. Assessment of the periodontal status.

In general, **two #2 size bitewings** are taken per side of the patient: a premolar film and a molar film. Some practitioners may prefer **one #3 size film per side,** although the molars and premolars sometimes require different horizontal angulations in order to open the proximal contact areas.

In children of 12 years old often we need only **one #2** size bitewing per side, and small children with primary dentitions may require a **#1 or #0** size film.

Film Placement:

The premolar bitewing radiograph should include the distal half of the crowns of the cuspids, both premolars, and often the first molars in both the maxilla and mandible.

The molar film should be centered over the second molars. The films are held in place either with [1]cardboard tabs or [2]paralleling instruments.

Paralleling instruments decrease the amount of beam misalignment often seen on bitewings; however, the patient's teeth remain farther apart owing to the thickness of the bite block, and therefore less alveolar bone is seen with this method.

When tabs are used:

1. The film should be placed so that the tab protrudes over the occlusal aspect of the mandibular teeth.
2. The radiographer should hold the tab as the patient slowly closes. Placing a downward fold in the tab before placing the film may help in keeping the film in place.
3. Take care not to let the patient catch the finger tip of your glove as he or she closes.
4. Additionally, **do not pull the film** too tightly against the lower teeth as the patient closes his or her mouth. **The upper edge** of the film may catch on the lingual aspect of the maxillary alveolar ridge or even the maxillary teeth, and the film will be forced down into the floor of the mouth. The upper half of the film should slide into the palatal vault so that both arches are equally covered by the film.

When using a paralleling instrument:

1) The film should be placed **away from the ridges** so that the film and the holder will settle equally into the floor of the mouth and palatal vault.
2) Placing the holder toward **the midline** of the oral cavity will also allow placement of the film forward enough to include the distal half of the cuspids in the premolar view.
3) If the film and holder are **too close to the teeth**, the holder will bump into the alveolar ridge where the arch curves in the vicinity of the cuspid, making capture of the cuspid image difficult. The film should be placed so that it parallels the alignment of the teeth in the arch.

The image receptor should be positioned with its long axis horizontally for a horizontal bitewing or vertically for a vertical bitewing (Fig. 1).

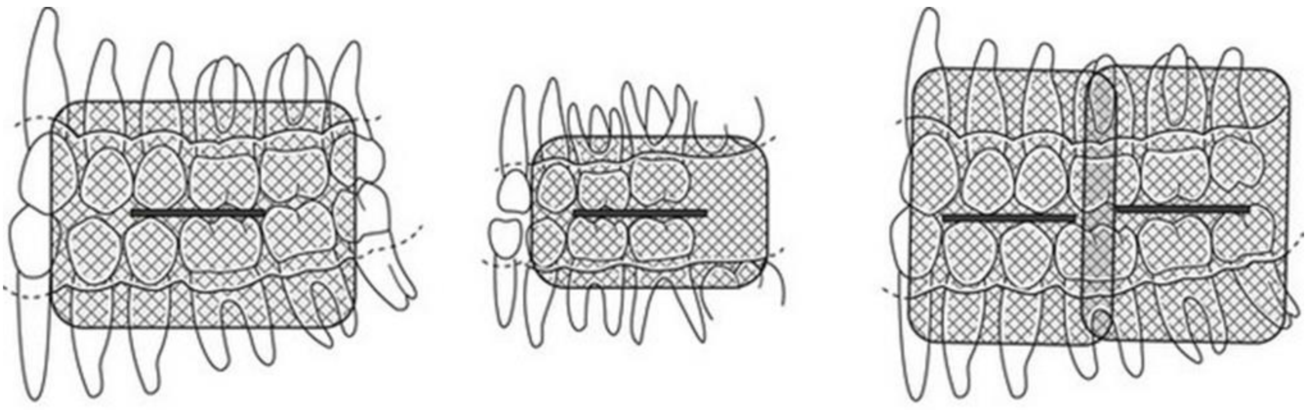


Figure 1. Diagrams showing the ideal image receptor position for different types of bitewings.

Beam alignment for bitewings:

Beam alignment is fairly simple for bitewings taken ***with paralleling instruments.*** **The beam** should be *aligned* with ~~the indicator ring~~ and be *parallel* with ~~the indicator bar,~~ so that the beam is perpendicular to the film and passes through the contacts of the teeth. Beam alignment is more challenging when tabs are used.

The patient's **midsagittal plane** must be perpendicular to the floor, and the occlusal plane should be parallel to the floor. The vertical angulation should be set so that +10° (approximately 5°–8° downward) is indicated on the tubehead (Fig. 2). This small vertical angle compensates for the fact that the upper half of the film tends to be lingually inclined against the palate. A vertical angulation of +10° places the beam so that it is nearly perpendicular to both the upper and lower halves of the film.

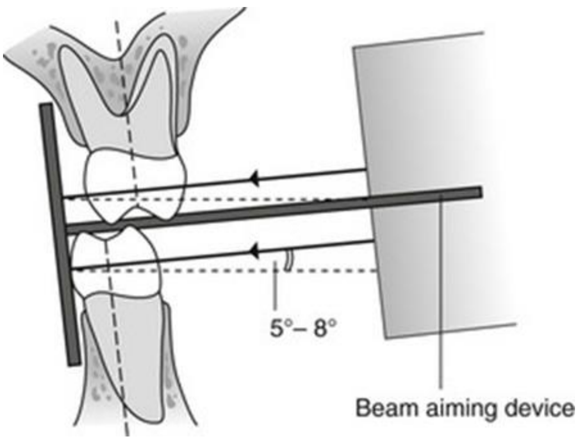


Figure 2. Diagram showing the ideal image receptor position and the approximate 5°–8° downward vertical angulation of the X-ray beam (determined by the beam-aiming device) compensating for the curve of Monson.

It is sometimes not possible to use an image receptor holder (with beam-aiming device) and achieve these ideal technical requirements particularly in children. Dental care professionals therefore still need to be aware of the original technique of using a tab attached to the film packet or phosphor plate and aligning the X-ray tubehead by eye.

Correct horizontal angulation ensures that the contacts between the teeth being radiographed are open (not overlapped) on the film. The beam should be perpendicular to the film and pass directly between the contact points. The horizontal angles will be similar for the molar and premolar bitewings, although some adjustment may be necessary in moving from one to the other, because of the curvature of the dental arches. The beam must be centered over the film to avoid cone-cutting Fig. 3, C .

The posterior teeth and the image receptor should be in contact or as close together as possible. The posterior teeth and the image receptor should be parallel – the shape of the dental arch may necessitate two separate image receptor positions to achieve this requirement for the premolars and the molars Fig. 3.

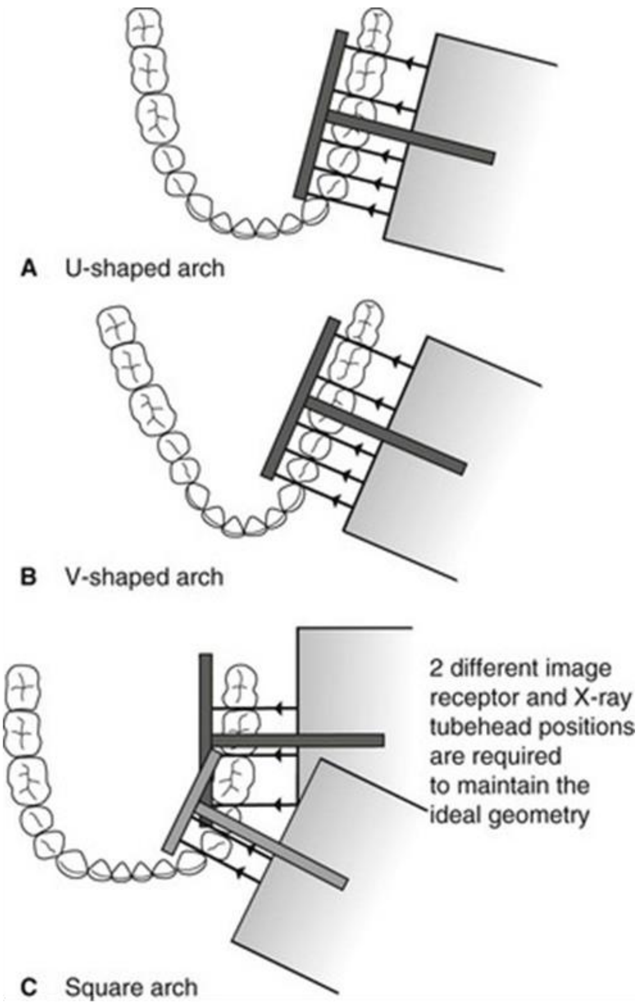


Figure 3. Diagrams showing the ideal image receptor and X-ray tubehead positions (determined by the beam-aiming device) for different arch shapes.

Using Image Receptor Holders With Beam-Aiming Devices:

Several image receptor holders with different beam-aiming devices have been produced for use with film packets or digital phosphor plates and with digital solid-state sensors, held either horizontally or vertically. A selection of different holders is shown in Fig. 4. As in periapical radiography, the choice of holder is a matter of personal preference and dependent upon the type of image receptors being employed. The various holders vary in cost and design but essentially consist of the same three basic components that make up periapical holders ***(see L4, Fig. 4)***.

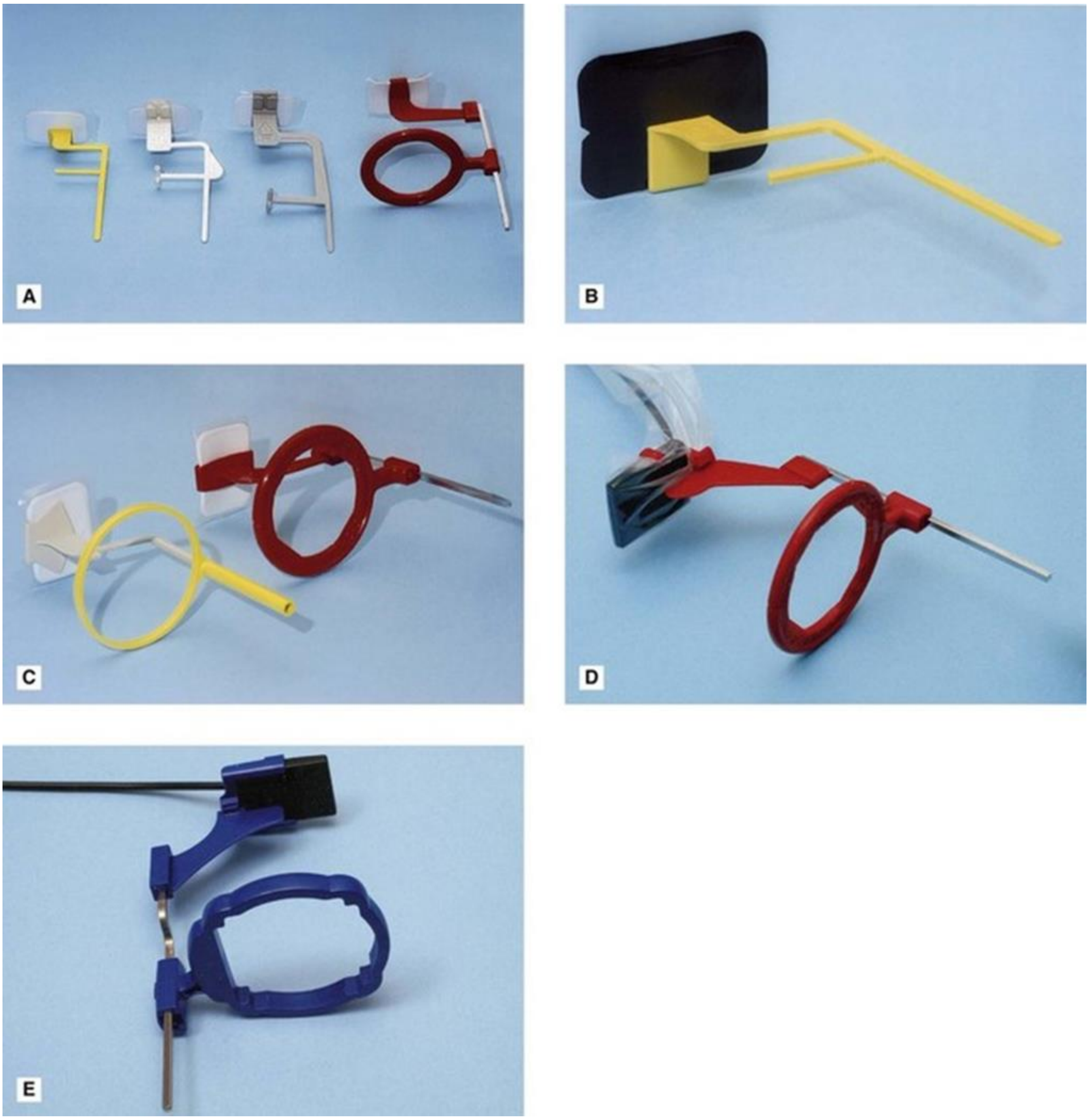


Figure 4. Bitewing image receptor holders with beam-aiming devices. **(A)** A selection of horizontal bitewing holders set-up using a film packet as the image receptor – note the red colour coding for the Rinn XCP System. **(B)** The Hawe–Neos Kwikbite horizontal holder set-up using a digital phosphor plate. **(C)** Vertical bitewing holders – the red Rinn XCP holder and the yellow Hawe–Neos Parobite holder set-up using film packets. **(D)** The red Rinn XCP-DS horizontal bitewing solid-state digital sensor holder. **(E)** The Planmeca horizontal bitewing holder designed specifically for use with their dixi2 solid-state digital sensors.

The radiographic technique of bitewing technique can be summarized as follows:

1. The **desired holder** is selected together with an **appropriate-sized** image receptor, typically a 31 × 41 mm[#2] film packet or phosphor plate or the equivalent sized solid-state sensor.
2. The patient is positioned with the head supported and with the occlusal plane horizontal and the midsagittal plane perpedicular to the floor..
3. The holder is inserted carefully into the lingual sulcus opposite the posterior teeth.
4. The anterior edge of the image receptor should be positioned opposite the distal aspect of the lower canine. In this position the image receptor extends usually just beyond the mesial aspect of the lower third molar Fig. 5.
5. The patient is asked to close the teeth firmly together onto the bite platform. (Note: Extra care needs to be taken of solid-state sensor cables.)
6. The posterior teeth and the image receptor should be in contact or as close together as possible. The posterior teeth and the image receptor should be parallel.
7. The X-ray tubehead is aligned accurately using the beam-aiming device, so that the beam is **perpendicular to the film** and *passes through the contacts of the teeth*.

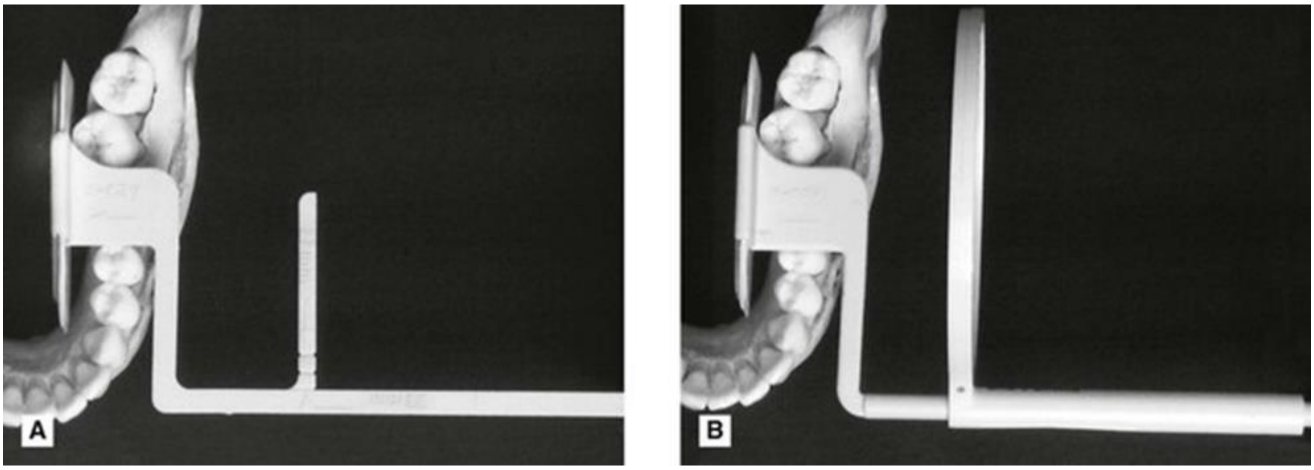


Figure 5. **(A)** Position of the simple Hawe–Neos Kwikbite holder in relation to the teeth. **(B)** Position of the Hawe–Neos Kwikbite holder (with circular beam-aiming device) in relation to the teeth.

Periapical and bitewing radiographic X-ray process:

The radiography process is relatively simple for both periapical and bitewing radiographs. Below is a list of steps taken to ensure comfort and safety.

1. Patients will sit upright in a dental chair.
2. The radiographer will insert a film holding device into the patient's mouth, designed for the patient to bite firmly with their teeth so as to secure it in position. This is necessary to ensure optimal image quality.
3. Once the patient is able to hold the correct position, the radiographer will leave the room and activate the machinery used to expose the film to radiation.
4. This process may be repeated for different areas of the mouth.
5. We'll then save the images, making sure that all prescribed areas of the mouth are adequately visible.

Importantly, radiation exposure during the process is minimised to the greatest extent possible whilst maintaining the required diagnostic value. The level of radiation emitted from the periapical and bitewing methods of radiography is roughly equivalent to that received daily from the natural environment.

Occlusal Radiographs:

Occlusal films are often supplemental to periapical and bitewing films, they are useful when larger areas are to be visualized, **for pediatric or edentulous patients**, and to aid in the localization of a foreign object or impacted tooth. A #4 size film is used for adults; a #2 size film is often sufficient for children.

Occlusal radiography is intraoral radiographic techniques taken using a dental X-ray set where the image receptor is placed in the occlusal plane. The film packet (5.7×7.6 cm).

Indications (diagnostic objectives) of occlusal radiography:

1. To identify and determine the full extent of disease (e.g., cysts, osteomyelitis, malignancies) in the jaws, palate, and floor of the mouth.
2. To visualize a relatively large segment of a dental arch.
3. Periapical assessment of the upper anterior teeth for children unable to tolerate periapical holder.
4. To precisely located roots, supernumerary, unerupted, odontomes, and impacted teeth especially canine and 3rd molar.
5. To locate salivary stones (sialoliths) in the ducts of sublingual and submandibular salivary glands.
6. To localize foreign bodies in the jaws and floor of the mouth.
7. To evaluate and monitor changes in the midpalatal suture during orthodontic palatal expansion.

8. To identify expansion of mandibular cortical plate in case of any pathology such as cysts, tumors, and osteomyelitis.
9. Assessment of fractures of anterior teeth, alveolar bone, and maxilla and mandible.
10. To demonstrate and evaluate the integrity of the outline of maxillary sinus, and localization of object.
11. To aid in examining patients with trismus who can open their mouth only a few millimeters.
12. To examine cleft palate.

Types of occlusal projection:

1. Maxillary occlusal projections.
2. Mandibular occlusal projections.

Maxillary occlusal projections include:

A. Upper standard (anterior, topographic) occlusal.
B. Upper oblique occlusal.
C. Vertex occlusal.

A. Upper standard (anterior, topographic maxillary) occlusal:

This projection shows the anterior part of maxilla and upper anterior teeth and is taken with a technique similar to bisecting the angle.

The technique:

1. Patient position where the **occlusal plane** horizontal and parallel to the floor and the midsagittal plane perpendicular to the floor.

2. Film placed on to the occlusal surfaces of lower teeth, white side against the maxillary teeth and patient asked to bite together gently. The film is placed centrally in the mouth **(the long axis crossways).**

3. X-ray tube positioned above the patient in the midline directed downward through **the bridge of the nose** and perpendicular to the imaginary line bisecting the angle formed by the maxillary incisors and the film at **65°-70°** to the film packet.

The horizontal angle should be such that the beam passes **between the central incisors.** The PID should be centered over the film. A round PID will allow greater coverage of the film and anatomic structures than a rectangular PID. Exposure factors will be similar to those for a maxillary incisor periapical film.

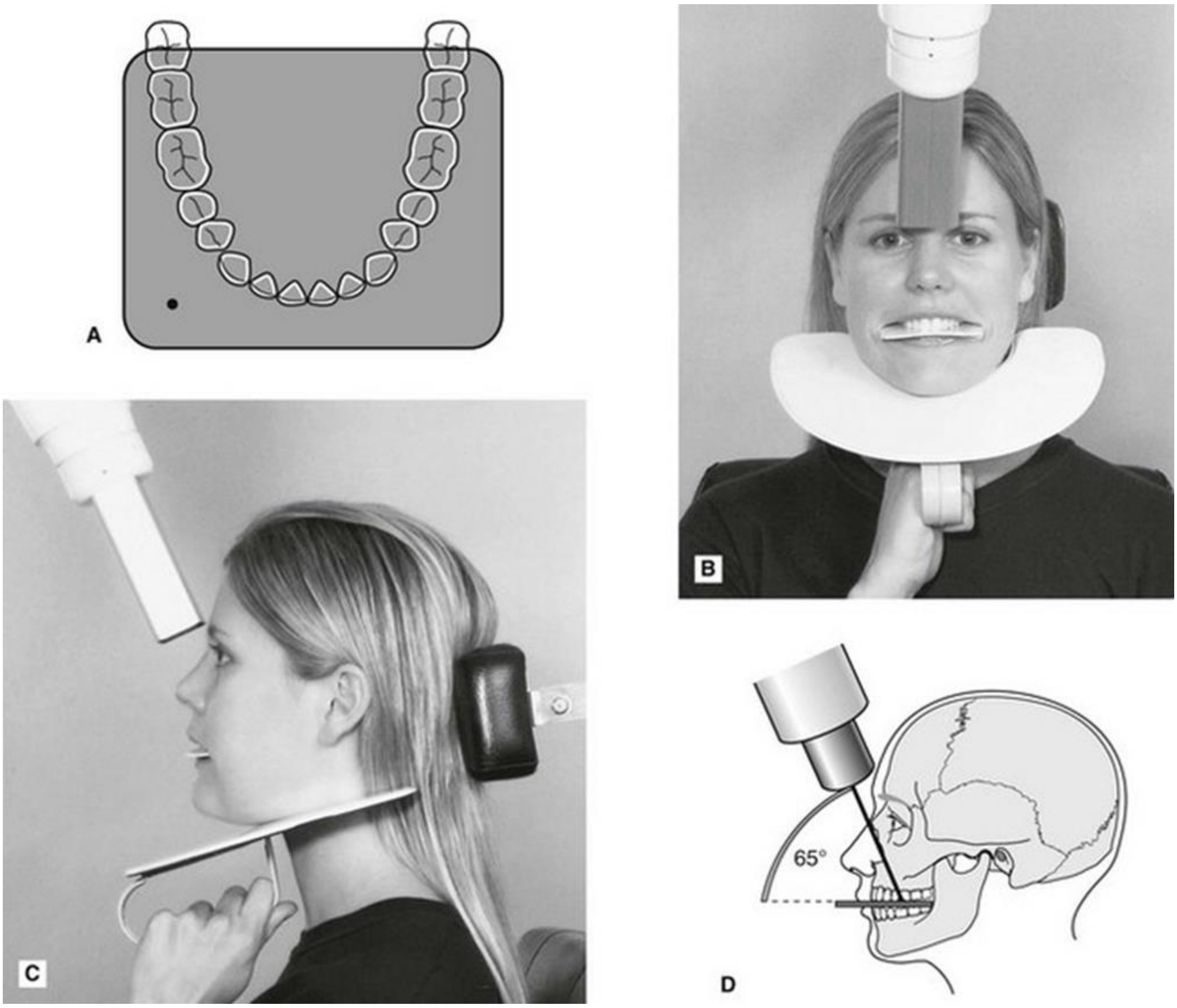


Figure 6. **(A)** Diagram showing the position of the image receptor in relation to the lower arch. **(B)** Positioning from the front; note the use of the protective thyroid shield. **(C)** Positioning from the side. **(D)** Diagram showing the positioning from the side. The resultant radiograph is shown in Fig. 7.

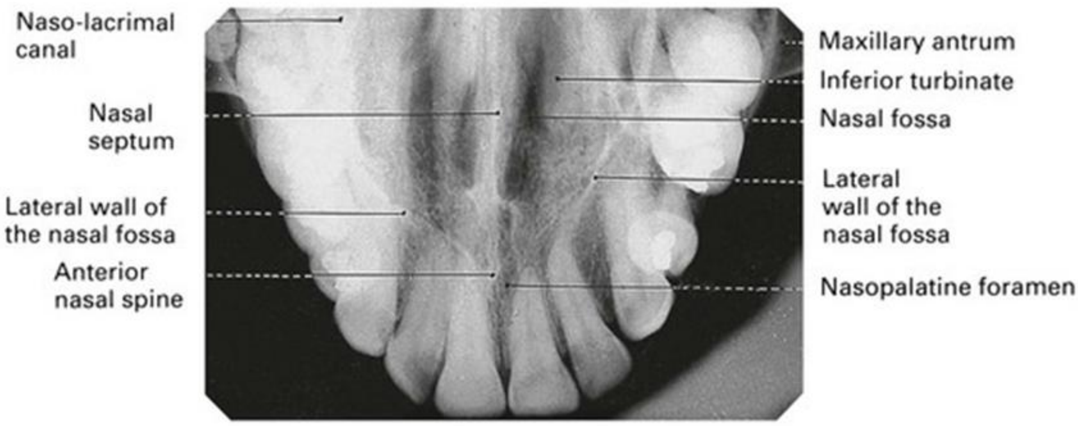


Figure 7. An example of an upper standard occlusal radiograph with the main anatomical features indicated.

B. Upper oblique (maxillary lateral) occlusal:

This projection shows the posterior part of maxilla and the upper posterior teeth. The lateral occlusal view allows a topographic view of the more posterior aspect of the maxillary arch. This view is generally not employed in the mandible. ***A lateral oblique jaw*** projection provides similar coverage in the mandible.

The technique:

1. Patients position where the **occlusal plane** horizontal and parallel to the floor and the midsagittal plane is perpendicular to the floor

2. Film placed on the occlusal surfaces of lower teeth with long axis **anteroposteriorly** and the white side against the maxillary teeth. It placed to the side of the mouth under examination and patient asked to bite gently. The edge of the film should extend about **1/4 to 1/2 inch** beyond the cusp tips of the molars.

3. X-ray tube positioned at the side of patients face directed downwards through the cheek at **65°-70°** to the film and centered over the film so that the center of the beam passes between the proximal contacts, similar to a periapical film. The exposure factors are similar to those for a molar periapical film.

Figure 8. **(A)** Diagram showing the position of the film packet in relation to the lower arch for a left upper oblique occlusal. (B) Positioning for the left upper oblique occlusal from the front; note the use of the protective thyroid shield. (C) Diagram showing the positioning from the front. The resultant radiograph is shown in Fig. 9.

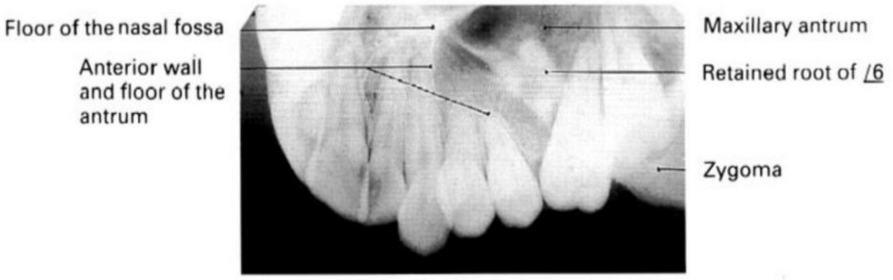


Figure 9. An example of an upper oblique occlusal radiograph with the main anatomical features indicated.

C. Maxillary cross-sectional (vertex occlusal) projection:

This projection shows a **plan view of teeth bearing area** of maxilla from above to assess the bucco-palatal position of unerupted canines. *Cross-sectional views in the maxilla* are difficult to obtain, because a beam that is perpendicular to the maxilla would have to pass through the top of the cranium, no longer used.

The technique:

1. The patient is seated with occlusal plane horizontal and parallel to the floor.

2. The film placed on the occlusal surfaces of lower teeth with its long axis anteroposteriorly and patient asked to bite on to it.

3. X-ray tube is positioned above the patient in the midline directed downwards through the vertex of the skull.

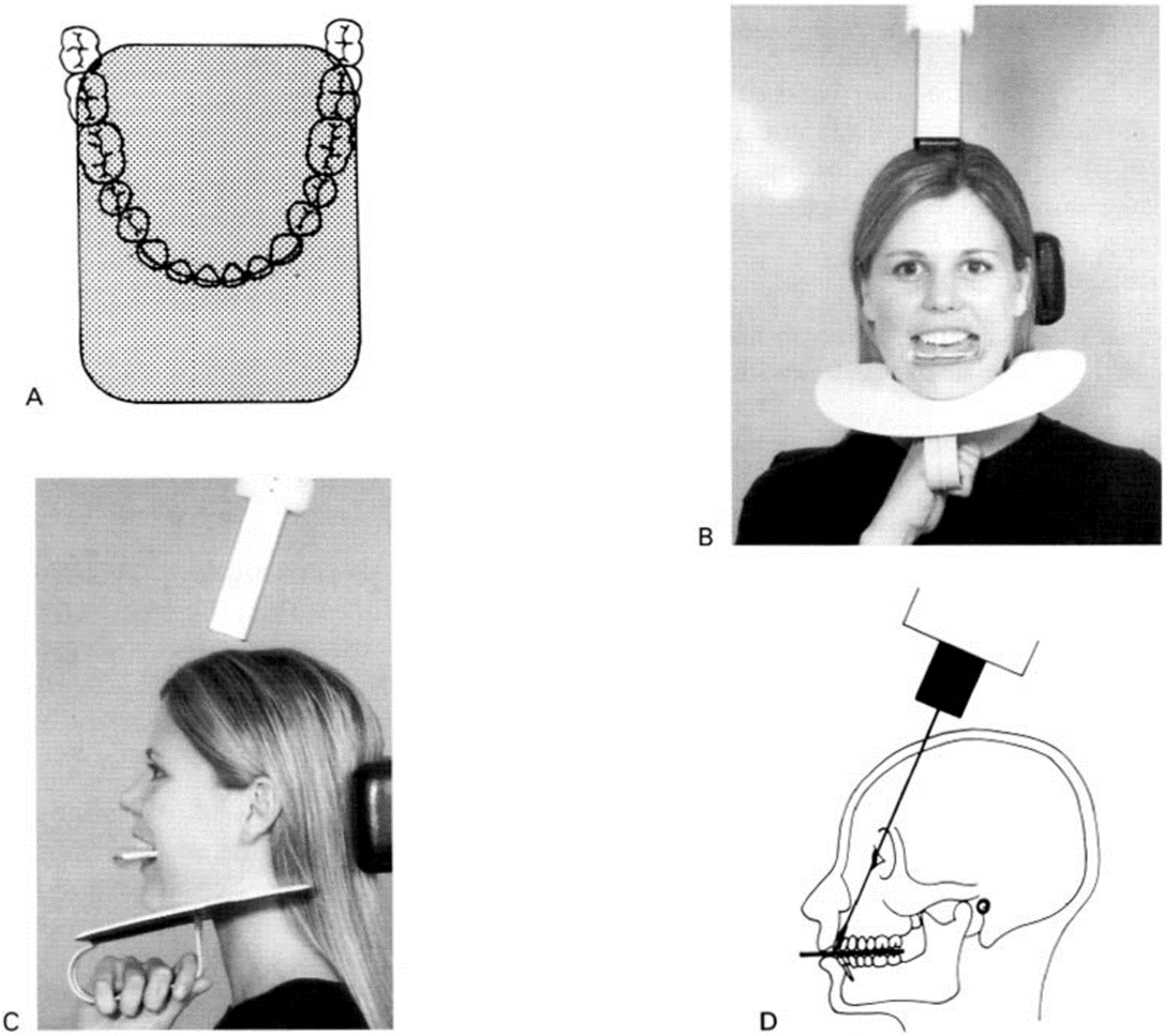


Figure 10. **(A)** Diagram showing the position of the image receptor in relation to the lower arch. **(B)** Positioning from the front; note the use of the protective thyroid shield. **(C)** Positioning from the side. **(D)** Diagram showing the positioning from the side. The resultant radiograph is shown in Fig. 11.

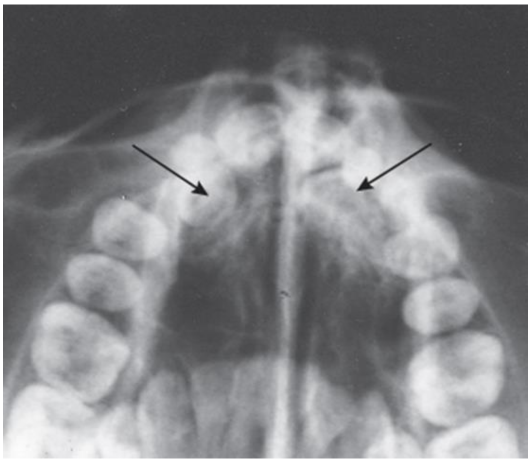


Figure 11. A true vertex occlusal, showing two palatal canines. The right canine is close to the arch and almost vertical. The crown of the left canine reaches the midline suture, while its root apex is close to the line of the arch.

Mandibular occlusal projection:

A. Lower 90˚ occlusal (cross-sectional, true occlusal).
B. Lower 45° (or anterior) occlusal (standard occlusal).
C. Low oblique occlusal.

A. Lower 90˚ occlusal (cross-sectional, true occlusal):

This projection used to show a plan view of the **tooth bearing area of mandible** (the buccal-lingual dimension of the mandible) or to evaluate the presence of objects in the **floor of the mouth**.

The technique:

1. Patient tips his head backward as far as comfortable, where it is supported. The patient's midsagittal plane should be perpendicular to the floor. The position of the occlusal plane is less critical, because the beam is directed 90° to the film. In fact, it is often easier to have the patient tip the head backward somewhat.

2. The film is placed with the white side against the mandibular teeth. It may be positioned with the long axis in a **buccal-lingual direction (crossways)** for imaging the more anterior portions, or it may be directed with the long axis toward the molar region (**anteroposteriorly**), often over only the left or right side of the jaw.

3. X-ray tube placed below the patients chin in midline centering on imaginary line joining the first molar at 90˚ to the film and the beam should be centered over the film.

Exposure factors should be similar to a mandibular periapical film. Slightly less exposure is required for a soft-tissue examination of the floor of the mouth.

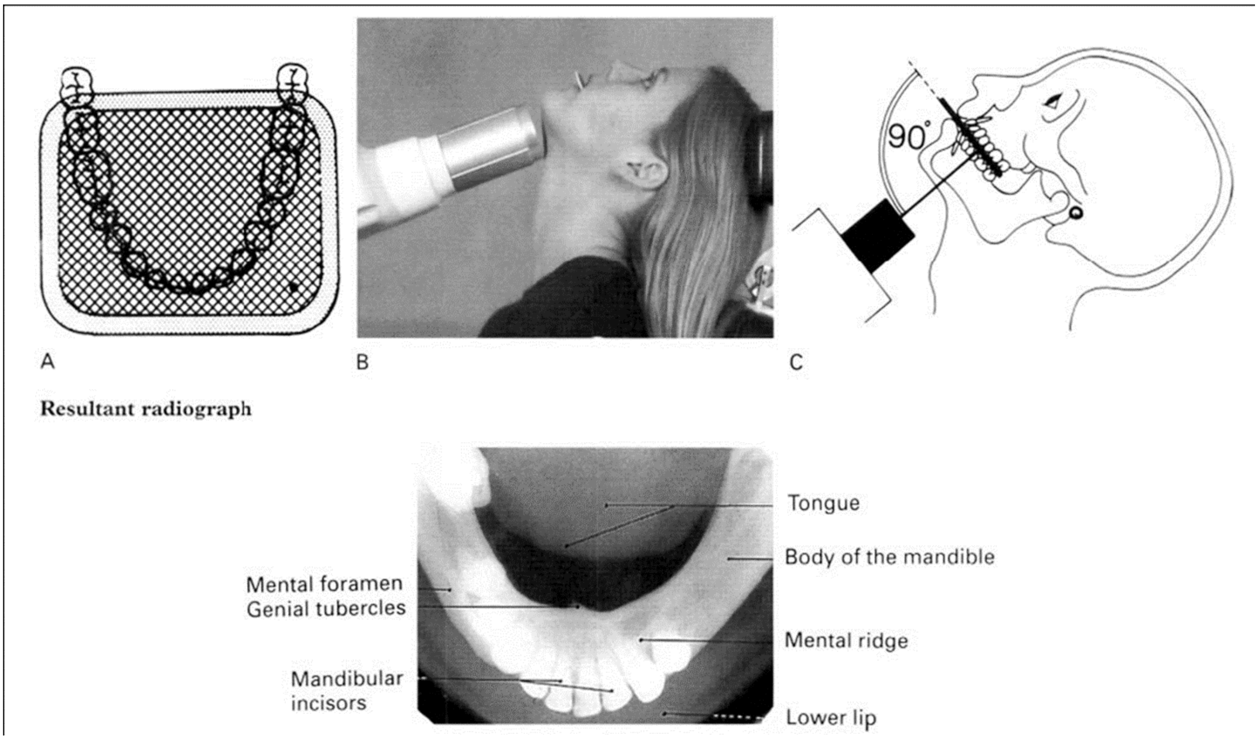


Figure 12. **(A)** Diagram showing the position of the image receptor in relation to the lower arch. **(B)** Positioning from the side. **(C)** Diagram showing the positioning from the side. **(Bottom)** The resultant radiograph.

B. Lower standard occlusal:

This projection is taken to show **lower anterior** teeth and anterior part of mandible.

Technique:

1. Patient is seated with the head supported and **occlusal plane** horizontal and parallel to the floor. The midsagittal plane should be perpendicular to the floor.

2. Film placed centrally into the mouth with the long axis **anteroposteriorly** and the white side against the mandibular then the patient gently closes on the film packet.

3. X-ray tube positioned in midline centering the beam through **the prominent chin point** (mentum) and should correspond to the bisecting angle principle at **45°** centered over the film. Exposure factors are similar to those for a mandibular incisor periapical film.

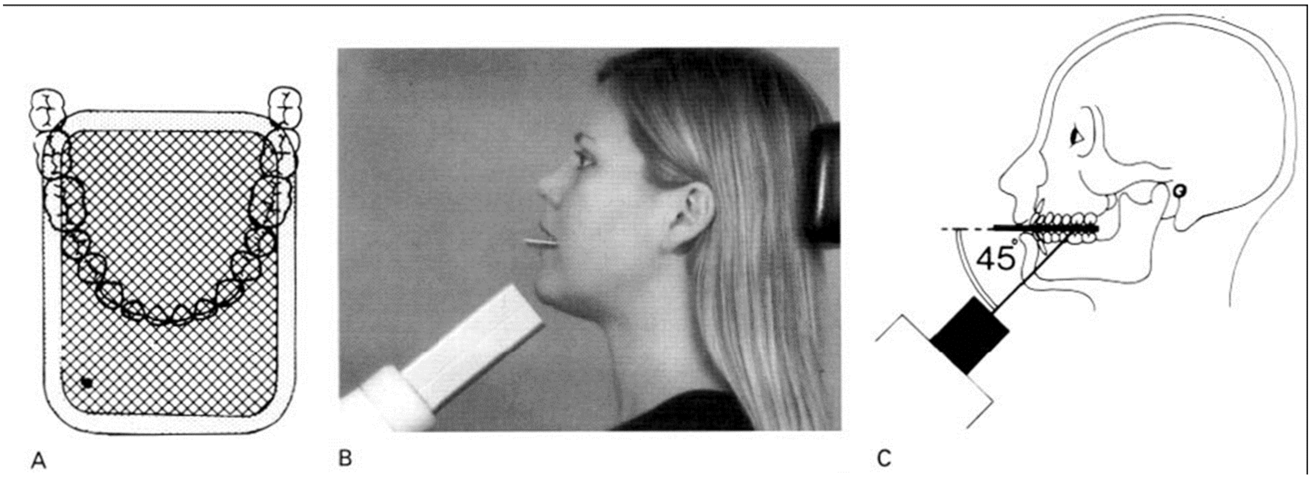


Figure 13. **(A)** Diagram showing the position of the film packet in relation to the lower arch. **(B)** Positioning for the lower 45° occlusal from the side. (C) Diagram showing the positioning from the side.

C. Lower oblique occlusal:

This projection shows the submandibular salivary gland on the side of interest.

The technique:

1. Patients head is **supported and rotated away** from the side under investigation and raised.
2. The film placed on occlusal surfaces of lower teeth over to the side under investigation with long axis **anteroposteriorly** then the patient bite on the film gently.
3. X-ray tube directed **upwards and forwards toward** the film from below and behind the angle of mandible and parallel to the lingual surface of the mandible.

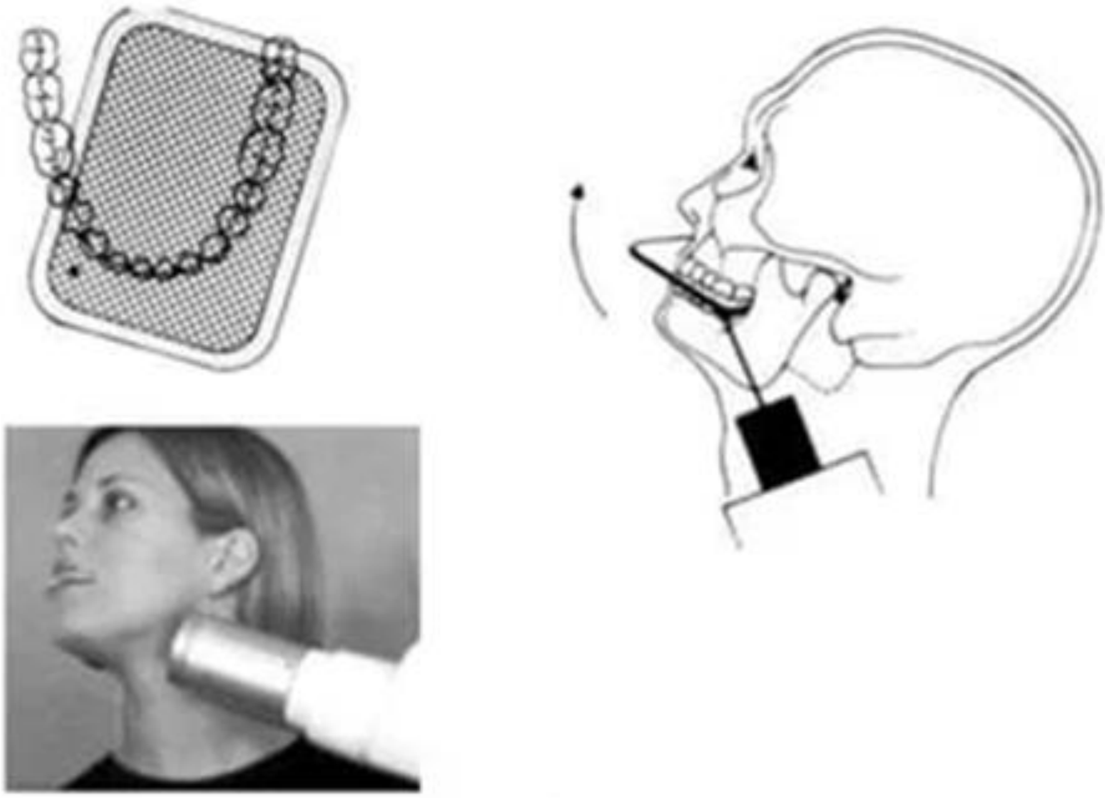


Figure 14. **(A)** Diagram showing the position of the film packet in relation to the lower arch. **(B)** Diagram showing the positioning from the side. **(C)** Positioning from the side.

L.6 # Radiography of patients with special needs

By

Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.

Oral Radiology Teacher, Anbar University

Not all dental radiographic techniques can be successfully performed on all patients. Radiographic examination techniques must often be modified to accommodate patients with special needs. The dental radiographer must be competent in altering radiographic techniques to meet the specific diagnostic needs of individual patients.

The main difficulties encountered involve:

1. Mandibular third molars.
2. Endodontic.
3. Edentulous alveolar ridge.
4. Children.
5. Gagging reflex.
6. Patients with disabilities.

1. Mandibular third molars:

The difficulty is placement of the film sufficiently posteriorly to record the entire mandibular third molar. The solution is by using a **surgical needle holder** to hold and position the film in the mouth:

1. **The needle holder is secured** onto the top edge of the film packet. With the mouth open, the film packet is positioned gently in the lingual sulcus as far posteriorly as possible.
2. **The patient is asked to close the mouth** onto the handles of the holder (which relaxes the tissues of the floor of the mouth) and at the same time the film packet is eased further into the mouth until its front edge is opposite the mesial surface of the mandibular first molar. The patient is asked to support the handles of the needle holder in position.
3. **X-ray tubehead is positioned** at right angle to the film packet and centered 1 cm above the lower border of the mandible on a vertical line dropped from the outer corner of the eye.

4. **Sometimes it is difficult to get the film far enough back** to cover the third molar region due to gagging or anatomy, and all of the third molar will not be seen on the film when taken the film with proper technique and angulation **(straight on angulation)** see Fig. 1, A. By rotating the tubehead so that the beam is directed more anteriorly (distal shift technique) see Fig. 1, B. The third molar is projected onto the film, giving us the needed information. Note, however, the increase in overlap that results.

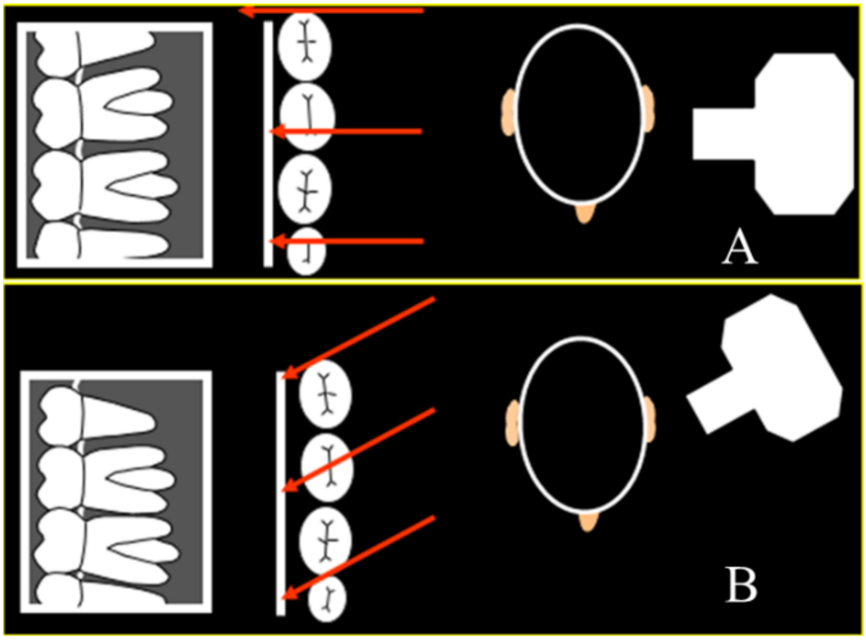


Figure 1. Diagram demonstrating; **(A)** all of the third molar will not be seen on the film when horizontal angulation directed perpendicular on contact points between teeth. **(B)** By rotating the tubehead, so that the beam is directed more anteriorly (distal shift technique), the third molar is projected onto the film.

2. Problems encountered during endodontics:

The main difficulties involve:

1. Film placement and stabilization when endodontic instruments, rubber dam and rubber dam clamps are in position.

The problem of film packet placement and stabilization can be solved by taping the film packet to one end of a wooden tongue spatula that positioned in the mouth and then held by the patient or using an endodontic film holder.

2. Identification and separation of root canals.

The problem of identifying and separating the root canals can be solved by taking at least two radiographs with different horizontal angulation (buccal object rule).

3. Assessing root canal lengths from foreshortened or elongated radiographs.

The problem of calculating the actual length of a root canal from a periapical radiograph with bisecting angle technique and the instrument within the root canal as follow:

1. Measure the ~~radiographic tooth length~~ by taking an accurate periapical radiograph with paralleling technique preoperatively and measuring the lengths of the roots directly from the radiograph before beginning the endodontic treatment. The amount of distortion on a subsequent periapical radiograph with bisecting angle technique can then be assessed.
2. Measure the radiographic instrument length from the bisecting angle technique.
3. Measure the actual instrument length by **endodontic ruler.**
4. Use the formula to find the actual tooth length.

Actual tooth length= ~~radiographic tooth length~~ (parallel technique) × actual instrument length (**endodontic ruler**) / radiographic instrument length (bisecting technique)

3. Techniques for edentulous patients:

A completely edentulous patient may require dental radiographs for the following reasons:

1. To detect any pathologic lesion, e.g. the presence of retained root tips and impacted teeth.
2. To determine the position and proximity of the maxillary sinuses or the mandibular canals to the crest of alveolar ridge.
3. To observe the quantity and quality of bone that is present.

The radiographic examination of edentulous patient may include;

1) Panoramic radiograph: is the most common way of imaging edentulous arches, its quick and easy. If the panoramic technique reveals any root tips, impacted teeth, foreign bodies or lesions in the jaw, a periapical film of that specific area must be used.
2) Periapical radiograph: it has more definition and permits the area in question to be examined in greater detail. If paralleling instruments are used, cotton rolls must be placed on both sides of the bite block to take the place of missing teeth for support

and comfort. The "cotton roll" technique is also useful in partially edentulous patients, the deficiency can be built up using cotton rolls.

- Edentulous areas may require less exposure because of the absence of the teeth.
- If the alveolar ridge is severely absorbed (shallow palate or loss of lingual sulcus depth), bisecting angle technique is used. Periapical radiograph should be taken using a *modified bisecting angle technique*.

3) Occlusal radiograph: to examine the tooth bearing area and detection of bone lesions not recognized by panoramic radiograph.

4. Techniques for children:

The type of radiographic survey needed for children is variable. Selection of **the types, sizes, and quantity of films** depends on the **child's dental health, age, and ability** to cooperate with the procedures.

Children are unlikely to be suggested to x-ray until five to six years old, except in cases of trauma and injury usually for upper anterior teeth.

Most children are eager to cooperate and respond very well to praise for a job well done. You may, however, need to be extra-patient and imaginative in some instances.

Keep in mind that children have a very short attention span and have a hard time remaining still for any length of time, so work quickly yet accurately.

1) Demonstrating the **equipment** and explaining the **procedure** in detail before attempting the real thing will increase your level of success.
    a. Describe the **x-ray machine** to the child; let him touch them before examination to be familiar with the film and machine.
    b. Show him a **radiograph** of another ***child's teeth*** and let him see the radiographic procedure on ***another member of the family***.
    c. A **mirror** enabling the child to observe the procedure, maybe helpful.
2) Use conveniently **small intraoral films**.
3) Young, growing tissues of child's organs are particularly vulnerable to the effects of **ionizing radiation** and must be protected, so lead apron and thyroid collar must be placed on the child every time prior to the x-ray exposure.
4) Because of a child's smaller size, the **exposure factors** (mA, kVp, exposure time) should be reduced; the ideal choice for exposure reduction is a decrease in the exposure time, because a shorter time will decrease the chance of movement artifact (blurring image).

5) **Extraoral films** can be used instead of intraoral.
6) Radiographic procedures should **not be hurried nor** should the child be apprised of any negative possibility like you might hurt a bit or you may gag.
7) **Do not expose** the young child to two or more circumstances simultaneously.
8) If the child **cannot hold or stabilize** the film, ask his parent for assistance.

5. Gagging Reflex:

A gag reflex is a protective mechanism of the body that serves to clear the airway of obstruction. Obtaining diagnostic films on a gagging patient is a real challenge, and it is a relatively common problem encountered in intraoral radiography.

This makes the film placement in the desired position particularly difficult especially in molar regions patients may unconsciously activate this reflex as a defense against anticipated unpleasantness. The areas that are most likely to elicit the gag reflex are the soft palate and the lateral posterior third of the tongue. The gag reflex is a physiologic one, but it can be influenced by a number of psychologic factors.

The precipitating factors that are responsible for initiating the gag reflex include (***psychogenic*** stimuli-originating in the mind) and (***tactile*** stimuli-originating from touch).

Patient management: there are some important hints and management strategies may increase your chances of success and reduce gagging reflex, such as:

a. Operator attitude:

Most gagging can be controlled through the creation of the **patient confidence** or by- **diverting the patient's concentration** away from gagging reflex.

So the concentration of the patient on ***another activity*** decreases the attention paid to gagging like asking the patient to breathe deeply through the nose or moving his/her arm or having the patient raise one foot may also work. It may be helpful to have the patient breathe through his or her mouth while you place your finger for a few seconds in the area where the film will rest.

If the **patient gags**, remove the film and reassure the patient. Some people are very ***embarrassed*** by the fact that they gag, and you need to assure them that it is not unusual.

b. Patient and equipment preparations:

In a patient with hypersensitive gag reflex, every effort should be made to limit the amount of time that a film remains in the mouth. The longer a film stays in the mouth, the more likely the patient to gag.

c. Exposure sequencing:

Start with the anterior periapical films; these are easily tolerated by most people. The fact that you can obtain these films will give you and the patient more confidence to try the posterior areas; with posterior exposure the dental radiographer should always expose the premolar before molar.

Prepare the unit exposure factors and approximate placement of the tubehead before placing the film in the patient's mouth.

d. Film placement and technique:

Each film must be placed and exposed as quickly as possible. Placement and technique modification include the following:

1. Avoid the palate:
    - A. Position the film lingual to the teeth and then firmly bring the film into palatal tissue using one decisive motion.
    - B. Placing the film packet flat in the mouth (in the occlusal plane) so it does not touch the palate and applying the principles of bisected angle technique.
2. Demonstrate film placement: in the areas that are most likely to elicit the gag reflex, **rub** a finger along the tissues near the intended area of film placement, while telling the patient, “This is where the film will be positioned.” Then quickly place the film. **Rubbing** your finger in the area where the film will rest provides two functions: [1]it lets the patient know where to expect the film, and [2]it desensitizes the area somewhat.

e. Using topical anesthetic agent:

When the cause of gag reflex is **tactile**, we can use local anesthesia. Patient sucking a local anesthetic lozenge before attempting to position the film packet. Topical anesthetic sprays may be used in severe cases. Caution must be used to ensure that the patient does not inhale the spray or that it is not placed too far down the throat to impair swallowing.

Having the patient place some salt on his or her tongue/palate or briefly dipping the film in some mouthwash may alleviate some gagging.

f. Maintain an air of confidence in yourself:

You may not always feel confident and in control, but it is important that the patient believes you have performed the procedure hundreds of times. Relax, and try to relax the patient with casual conversation. Explaining the procedure to the patient will eliminate surprises and reinforce the idea that you are familiar with the procedure to both the patient and yourself! ***Do not bring up the subject of gagging***.

g. The power of suggestion is strong:

The patient may say, "I'm a gagger," in which case you are forewarned and should bring out your best bag of tricks to control the situation.

h. Be as gentle as possible, but place films accurately and quickly:

There will be times when you will not be satisfied with the film placement, and it is perfectly acceptable to begin again. Placing the film exactly where you want it the first time eliminates small adjusting movements that may tickle the palate or tongue and elicit a gag reflex.

i. Use of extraoral radiograph:

There are some people whose gag reflex is so strong and uncontrolled that diagnostic quality intraoral films are impossible to obtain. Extraoral films are indicated for these individuals such as panoramic or lateral jaw radiographs.

6. Physical Disabilities:

Vision impairment: if a patient is blind, we must communicate using clear verbal explanations. The dental radiographer must keep the patient informed of what is being done and explain each procedure before performing it.

Hearing impairment: if a person is deaf or hearing impaired, the dental radiographer may ask the caretaker to act as interpreter, or use written instructions. When the patient can read lips, the dental radiographer must face the patient and speak clearly and slowly.

Mobility impairment: if a person is in a wheelchair and does not have use of the lower limbs, assist the patient in transferring to the dental chair. If a transfer is not possible, we perform the procedure with the patient seated in the wheelchair. If a person does not have use the upper limbs and a holder cannot to stabilize the film placement, ask the caretaker to assist with film holding. **The dental radiographer must never hold a film during exposure.**

7. Developmental Disabilities:

Is a substantial impairment of mental physical functioning that occurs before the age of 22 and is of indefinite duration. (Autism, cerebral palsy, epilepsy, mental retardation and other neuropathies).

A person with a developmental disability may have problems with coordination or comprehension of instruction. As a result the dental radiographer may experience difficulties in obtaining intraoral films. If coordination is a problem, mild sedation may be useful. If comprehension is a problem and the patient cannot hold a film, the caretaker may be asked to assist with film holding.

It's important that the dental radiographer recognize situations in which the patient cannot tolerate intraoral exposure. In such cases no intraoral films must be used and change to extraoral films.

8. Neuromuscular problems:

Refer to patient inability to remain immobile.

1. Speed is essential in radiographic procedure. ***Minimization of the exposure interval through one or more of the following:***
   a. The use of fast films.
   b. Decrease the source-object distance.
   c. Maximally kVp.
   d. Highest mA.
2. Using of films holders that can be stabilized by another person **but not by dental office staff.**
3. Extraoral films may be useful supplemented by intraoral films.
4. Sedation sometimes is essential.
5. Radiograph can be performed under anesthesia.

Localization techniques:

It's a methods used to locate the definite position of a tooth or object in the jaws. The dental radiograph is a two dimensional picture of a three dimensional object, a radiograph depict in superio-inferior and anterio-posterior relationship, so the dental radiograph does not depict the bucco-lingual relationship, or depth of an object. There are many times when it is necessary to establish the depth of the structure , such as a foreign object or impacted tooth within the jaws , LOCALIZATION TECHNIGUES can be used to obtain this dimensional information , so we can use it to locate the to locate the followings:

1. Foreign bodies.
2. Impacted teeth.
3. Retained roots.
4. Salivary stones.
5. Root positions.
6. Jaw fractures.
7. Broken needles, broken instruments, and filling materials.

Prior to exposing localization films, infection control procedures must be carried out. Step-by-step procedures for localization techniques include patient and equipment preparations and film placements and comparisons. So techniques for doing this are discussed as follows:

- **A. Right angle technique/Miller's technique.**
- **B. Tube shift technique/Clark's rule.**
- **C. Use of radio-opaque media.**
- **D. Stereo radiography**

The first two technique are the basic techniques and more used because of their simplicity and accuracy.

A. Right angle technique/Miller's technique:

This technique involve the use of at least two films taken at right angle to each other. One periapical film is exposed using the proper technique and angulation to show the position of the object in a superior-inferior and anterior-posterior relationship. An occlusal film is exposed directing the central ray at right angle to the film. The occlusal film shows the object in a bucco-lingual and anterior-posterior relationship.

After the two films have been exposed and processed, the radiographs are compared to locate the object in three dimensions, Fig. 2.

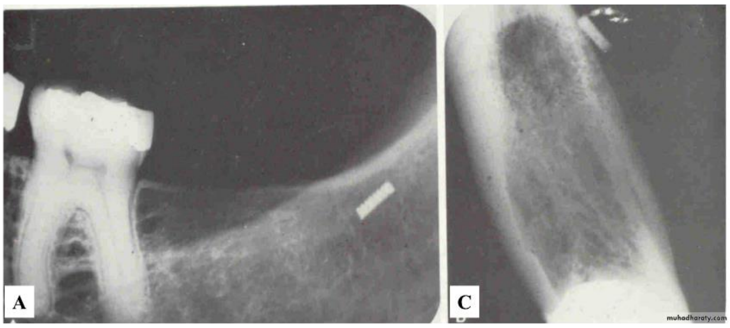


Figure 2. **(A)** Periapical radiograph identify the location of an object vertically (superio-inferior) and in a horizontal (mesiodistal) direction, since it is a 2D. **(B)** Lower 90˚ occlusal locating objects in a buccolingual direction.

Another example: lateral skull projection demonstrates the anterio-posterior and superio-inferior positions of an object. So posterior-anterior skull projection demonstrates the superio-inferior and mediolateral positions of that object and here the object could be located.

B. Tube shift technique/Clark's rule/ buccal object rule/ object Localization technique or SLOB rule:

It allows the dentist to determine the position of an object from two films taken at slightly different angles. This governing the orientation of structure portrayed in two radiographs exposed at different angulations.

One periapical or bitewing film is exposed using proper technique and angulation, a second periapical or bitewing film is then exposed after changing the direction of the x- ray beam. A different horizontal or vertical angulation is used.

For example a different horizontal angulation is used when trying to locate vertically aligned images (root canals), whereas a different vertical angulation is used when trying to locate a horizontally aligned images (mandibular canal) after the two films have been exposed and processed, the radiographs are compared with each other.

If foreign body or impacted tooth present in jaw, the area in question is anesthetized, a small hypodermic needle is inserted in vertical position in mucobuccal fold near the object in question, a radiograph is taken using proper technique and angulation, then insert another film and second radiograph is taken **with mesial shifted tube**. The 2 films are processed and compared.

If the object in the second radiograph appears more mesially, that means the object is located far lingualy or palatally, while if it is more distally (in relation to the needle) it means it is buccaly positioned, and if it is not move it means that it is close to the needle. When the object in question is close to a tooth or surface of a crown so that there is no need for insertion of a needle.

For another example, if the tubehead is shifted distally for the second view and the object moves mesially (opposite), then the object is on the buccal. Conversely, if the tubehead is shifted distally in the second view and the object moves distally (same), then the object is on the lingual.

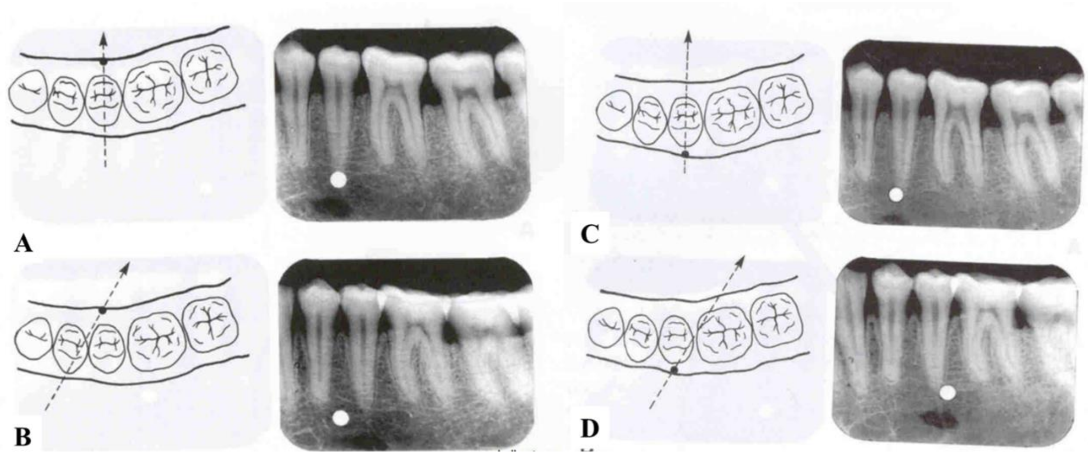


Figure 3. (A&B) Lingual body moves in same direction (measially) with mesial shifted tube. **(C&D)** Buccal body moves in opposite direction (distally) with mesial shifted tube. Keep in your mind the word (SLOB) Same = Lingual, Opposite = Buccal.

C. Use of radio-opaque media:

Radiopaque media are chemical compounds containing elements of high atomic number which will stop the passage of X-ray. These types of compounds are used as diagnostic aids in radiology. The most common radiopaque contain barium and iodine. Barium sulfate is the agent of choice in radiographic studies of gastrointestinal tract.

Radiopaque media such as barium sulfate, lipiodol and dionsite can be used to demarcate cavernous area within hard and soft structure. Such materials are also used to outline soft tissue peripheries such as the profile of the face and neck. After the injection of the radio-opaque media (mostly lipiodol) in cyst for example, film exposed, processed and viewed to see the extension of the cyst. Radio-opaque media also used in sialogram to demonstrate the salivary glands and their duct.

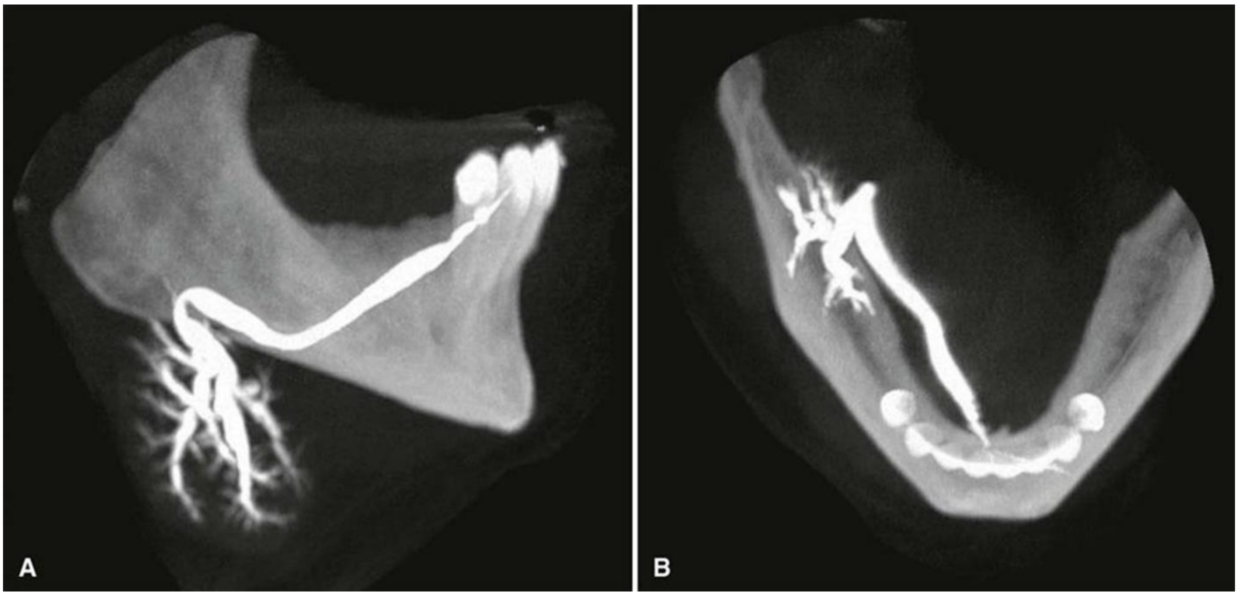


Figure 4. Conventional sialography of a submandibular gland imaged with CBCT imaging. The images are rendered in lateral **(A)** and axial (B) views.

D. Stereo radiography:

This not a widely used because it is time consuming, and the film taken with this technique require a special device, however the operator can train himself without such device.

Finally, The localization of an object, such as an impacted tooth, or the need for the clinician to know if there is expansion of the buccal (facial) or lingual cortices requires that additional radiographs be taken. In the case of expansion, the radiographer need only take an additional occlusal radiograph, if the clinician has access to computed tomography imaging, then additional information in the third plane is available at multiple levels.

Radiographic survey:

An examination of **a part or an area** designed to determine whether any abnormal changes exist within this part or area. It is either routine scanning procedure, or *specific purpose survey for example cephalometric films* designed to study growth pattern.

Routine: A full-mouth radiographic survey consists of a specified number of periapical and bite-wing views. *A complete full-mouth survey may have as few as 10 or as many as 18 periapical views, plus whatever bitewing views are indicated*. "In other words" For children, adult and edentulous 14-17 periapical films with 2-4 posterior bitewing films are necessary for adequate interpretation of oral conditions.

Alternate: lateral jaw projections for posterior teeth, *anterior periapical mandibular and maxillary views* with bitewing for posterior teeth. For edentulous patients topographic occlusal films could be used instead of periapical films as alternative survey method.

The number and size of the film/sensor to be used in a full-mouth radiographic survey depend on:

1. The dentist's instructions.
2. Number of teeth present.
3. Size of the oral cavity.
4. Anatomic structures within the mouth.
5. Age of the patient.
6. Level of patient cooperation.

The procedure described here (see the following box) includes **positioning and steps** for each exposure in one half of the maxillary arch and one half of the mandibular arch with use of the paralleling technique and XCP film/sensor-holding instruments.

Guidelines for Film Placement:

1. The white side of the film always faces the teeth.
2. Anterior films are always placed vertically.
3. Posterior films are always placed horizontally.
4. The identification dot on the film is always placed in the slot of the film holder (dot in the slot).
5. The film holder is always positioned away from the teeth and toward the middle of the mouth.
6. The film is always centered over the areas to be examined.
7. The film is always placed parallel to the long axis of the teeth.

When the opposite side of each arch is radiographed, the same procedures are followed. The completed radiographic survey is shown in Fig. 5.

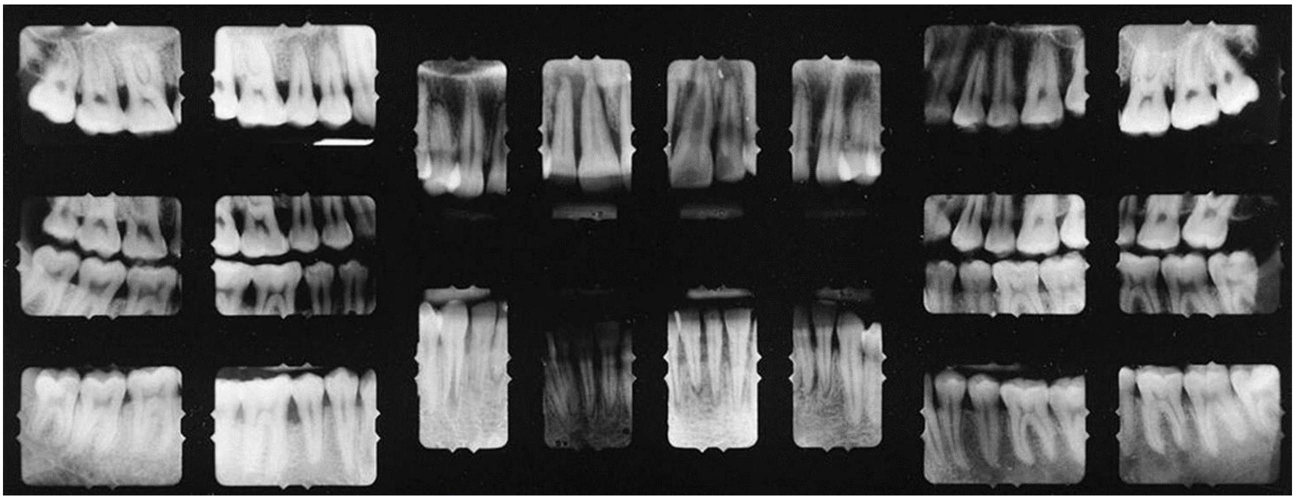


Figure 5. Mounted full-mouth series with eight anterior films using the paralleling technique.

Number of Films:

	Anterior	Posterior
Paralleling	7 films #1	8 films #2
Bisecting Angle	6 films #2	8 films #2
Horizontal BW	None	4 films #2
Vertical BW	3 films #2	4 films #2

Full mouth survey for Adults edentulous (FM 10E):

10 periapical films size 2 as follows:
4 molars area
4 premolars area
2 incisors area
2 occlusal films as follows:
1 topographic maxillary occlusal view for anterior area
1 topographic mandibular occlusal view for anterior area

Full mouth survey for Adults with one arch completely edentulous:

12 periapical films size 2 as follows:
Edentulous arch; 5 periapical films size 2 as follows:
2 molars area
2 premolars area
1 incisors area
1 topographic occlusal film for anterior area of the edentulous arch
Other arch: 7 periapical films size 2 as follows:
2 molars area
2 premolars area
2 canine area

1 incisors area
Bitewings as indicated.

Full mouth survey for children (primary or mixed dentition) (FM 10/2 C)

10 periapical films size 2 or 0 as follows:
4 premolars area or primary molars area
4 canine area
2 incisors area
2 bitewing films size 2 or 0.

Figure 6. Full-mouth series, bisecting angle technique fully or partially dentulous adults; FM 14/4 (18 films) 14 periapicals size 2 and 4 bitewings size 2.

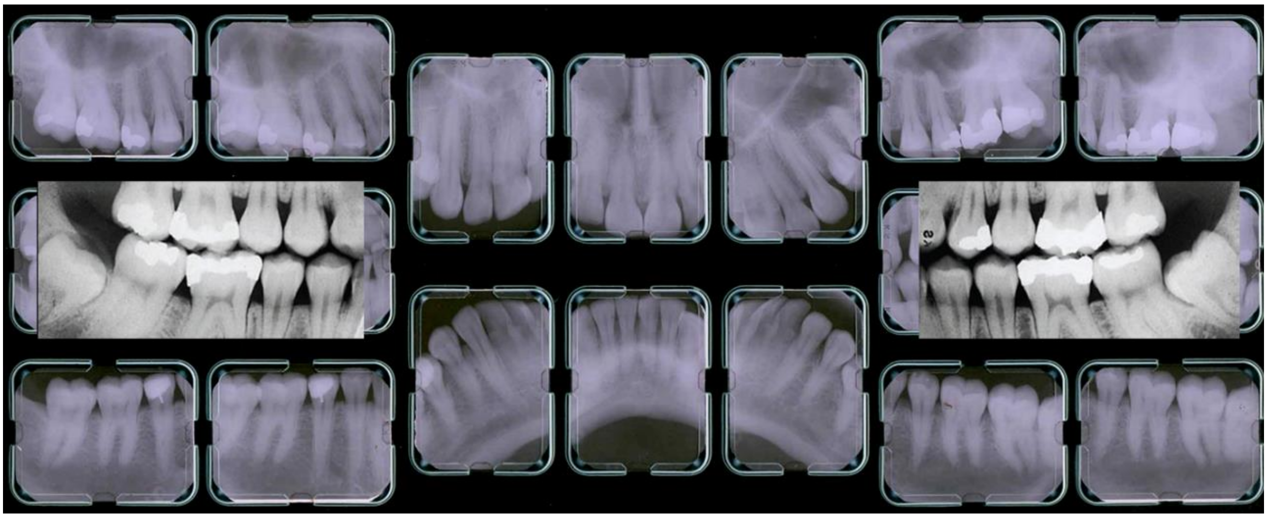


Figure 7. Full-mouth series, bisecting angle technique fully or partially dentulous adults; FM 14/2 (16 films) 14 periapicals size 2, 2 bitewings size 3.

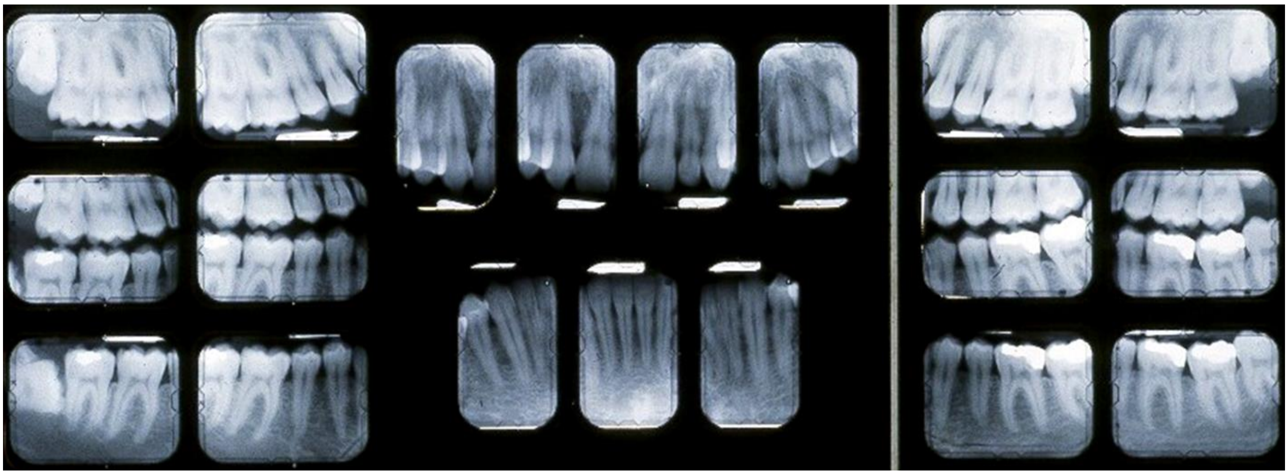


Figure 8. Adult full-mouth series, Paralleling Technique FM 15 (8 films #2 posterior 7 films # 1 anterior)/4 bitewings size 2 (19 films).

L.7 # Dental X-ray film processing

By

Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.

Oral Radiology Teacher, Anbar University

Introduction:

Film processing refers to a series of steps that produce a visible permanent image on a dental radiograph.

Radiolucent: A Radiolucent structure is one that readily permits the passage of X-ray beam and allows more X-ray to reach the film ⇨ deposits of black metallic silver ⇨ dark.

Radiopaque: A Radiopaque structure is one that resists the passage of the X-ray beam and restrict or limits the amount of X-rays to reach the film ⇨ no deposition of metallic silver is seen ⇨ appear white.

What will happen during exposure of radiographic film to X-radiation?

X-ray photons interact with electrons of the atoms of the chemical emulsion in the X-ray film so the result is analog image, analog means the image appears identical to the original.

Latent image formation:

The AgBr crystals in the film emulsion are changed whenever they absorb X-ray photons, the result of absorption is precipitation of speck of silver in each exposed AgBr crystal to X-ray, collectively these specks are called latent image which is invisible and in order to convert to visible image X-ray film must be processed.

Film processing:

〉 Aims of Processing:

1. To convert the latent image (invisible) on the film into a visible image.
2. To preserve the visible image so that it is permanent and does not disappear from the dental radiograph.

〉 Processing Techniques:

1. Manual processing;
    a. Sight or visual method.
    b. Time-temperature method.
2. Rapid processing chemicals.
3. Injectable intra-oral films.
4. Self-processing intra-oral films.
5. Automatic film processing.
6. Filmless radiographic technique (direct digital radiography).

〉 Manual Processing:

1. Replenish solutions.
2. Check solutions levels.
3. Stir solutions.
4. Check temperature.
5. Mount films on hangers.
6. Set the timer.
7. Developer (5 minutes at 68 F, agitate for 5 seconds).
8. Rinse for 30 seconds (agitate continuously).
9. Fixer for 4 minutes (agitate intermittently, 5 seconds/30 seconds).
10. Wash for at least 10 minutes in running water.
11. Dry.

Manual Film Processing Steps:

- Consists of following five steps:
    1. Developer (5 minutes at 68 F, agitate for 5 seconds).
    2. Rinse for 30 seconds (agitate continuously).
    3. Fixer for 4 minutes (agitate intermittently, 5 seconds/30 seconds).
    4. Wash for at least 10 minutes in running water.
    5. Dry.

MANUAL PROCESSING PROCEDURE (time-temperature method):

1) The film is placed in the **developer** for a specific time (5 min. at 68 degrees Fahrenheit = 20 degrees Celsius) with the lid in place to keep out light. The developer turns the silver halide crystals into black metallic silver.
2) After the proper time in the developer, the lid is removed and the film hanger is placed in the water bath to **rinse off the developer** (agitate for 30 seconds).

3) The films are then placed in the **fixing solution** (agitate for 5 seconds every 30 seconds).
4) After the proper time in the fixer (4 minutes), the film hanger is placed in the water bath (at least 10 minutes) to wash off any remaining solutions.
5) The films are then hung to dry.

Processing films at temperatures higher or lower than recommended or for longer or shorter times than recommended result in decreased film contrast.

Thermometer should contain alcohol not mercury because they could break and contaminate the processor solutions.

Temperature	**Development time**
68 °F=20 °C	5 min
70 °F	4.5 min
72 °F	4 min
76 **°F**=24.44 **°C**	3 min
80 °F	2.5 min

Development: It is the chemical process and the stage of film processing during which the latent image is converted to a visible image.

The X-ray film is placed in alkaline developer solution, the action of developing agents are on exposed AgBr crystals to continue the process of precipitating the specks of silver until all silver is deposit at the site of crystal. A chemical solution developer is used in the development process.

Purpose of Developer:

1. The exposed, energized silver halide crystals chemically converted into black metallic silver.
2. Softens the film emulsion during the process.

- The X-ray film is placed in alkaline developer solution. The developer reduces all the silver ions in the exposed crystals to grains of metallic silver (continue the process of precipitating the specks of silver) and the bromine is released into the developing solution causing softening of the X- ray film emulsion. This process must be restricted to the exposed crystals only.

The metallic silver at the latent image site acts as a **bridge** by which electrons from the developing solution reach silver ions in the crystal and convert them to metallic silver.

Individual crystals are developed completely or not at all. Variations in **density** on the processed radiograph are the result of different ratios of developed and undeveloped crystals.

The crystals that **do not have exposure centers** are not affected by the developer if films are in the developer for the correct amount of time and the temperature of the developer is correct.

However, if the films are left in the developer **too long**, or the temperature is **too high**, the developer will start to act on the crystals that were not exposed by x-rays (with no exposure centers) and these crystals will also be converted to black metallic silver. This results in the film being darker than ideal (chemical fog).

Rinsing:

Films should be rinsed in water for 30 seconds with continuous gentle agitation which is necessary after developing before they are placed in the fixer (***the purpose of rinsing***):

1. It dilutes the developer and slowing the development process (**to stop the developer action**).
2. **It removes the chemicals from emulsion** (alkaline activators) to prevent neutralization and contamination of the acidic fixer.

- Not used with automatic processing.

Fixing:

A chemical solution fixer is used in the fixing process.

Purpose of Fixer:

1. **Remove** the unexposed (unenergized) or undeveloped silver halide crystals from the film emulsion.
2. **Hardens** the film emulsion during the process.

After fixing the film washed in ***running water*** and finally drying.

Washing:

Necessary to thoroughly **remove all the excess chemicals from the emulsion**. The film is washed in a ***sufficient flow of water from*** 15 to 20 minutes (at least 10 minutes). To remove all thiosulfate ions and silver thiosulfate complexes.

Any silver compounds or thiosulfate that remains because of improper washing causes yellowish brown stains which are most apparent in the radiopaque areas. This discoloration results from the thiosulfate reacting with silver to form brown silver ***sulfide*** (***sulphide***).

The final in film processing is the drying of the films. Films may be air-dried at room temperature in a dust free area or placed in a heated drying cabinet.

Drying:

1) After the films have been washed, **surface moisture** is removed by gently shaking excess water from the films and hanger. If the films are dried rapidly with small drops of water clinging to their surface, the areas under the drops dry more slowly than the surrounding areas. This uneven drying causes distortion of the gelatin, leaving a drying artifact.
2) The radiograph may be dried in open air or in an automatically heated (**moderately warm**), circulating air dryer. Excessive heat must be avoided as it may damage the emulsion.
3) Drying air should be **filtered** and free of dust and lint, since these particles may stick to the wet film as it dries and produce undesirable artifacts. Drying can be done using an electric fan or cabinet driers.
4) Films must be completely dried before they can be handled form mounting or viewing.

Developing composition:

1. Developing agent:

Hydroquinone: converts exposed silver halide crystals to black metallic silver, slowly generates the black tones and contrast in the image.

Eion: converts exposed silver halide crystals to black metallic silver, quickly generates the gray tones in the image.

2. Preservation:

Sodium sulfite: prevent rapid oxidation of the developing agents.

3. Accelerator:

Sodium carbonate: activates developer agents provide necessary alkaline environment for the developing agents, soften gelatin on the film emulsion.

4. Restrainer:

Potassium bromide: prevents the developer from developing the unexposed silver halide crystals.

Fixer composition:

1. Fixing agent:

Sodium thiosulfate, ammonium thiosulfate: Removes all unexposed undeveloped silver halide crystals from the emulsion.

2. Preservative:

Sodium sulfite: prevent deterioration of fixing agent.

3. Hardening agent:

Potassium alum: shrinks and harders the gelatin in the emulsion.

4. A cidifier:

Acetic acid; sulfuric acid: neutralizes the alkaline developer and stops further development.

Processing room requirements:

Darkroom:

The darkroom or processing room is a place where the necessary handling and processing of radiographic films can be carried out safely and efficiently without hazard of producing film fog by accidental exposure to light or x-ray. It may exclude all outside light and provides the artificial safelight only.

- A well planned dark room makes the processing easier, which should be of at least 4 × 5 feet (1.2 × 1.5 m).

- Light proof.
- Well ventilated.
- Safe lighting.
- White illumination.

Characteristics of darkroom:

1. Convenient location and adequate size.
2. Ample working space with adequate storage.
3. Lighting.
4. Temperature and humidity controlled.
5. Darkroom plumbing.
6. Miscellaneous.

Size and location of darkroom:

Whenever possible oral radiography darkroom should be designed when the dental office is planned and the x-ray units are installed. It should be convenient and easy to work with.

Darkroom size is determined by the following factors:

1. **Volume of radiographs to be processed (type and amount of the films)**; the greater workload need larger darkroom. Large films need large processing tanks, so it takes more space in the darkroom.
2. **Number of persons using the room;** extra space must be provided if more than one person works with, 9 square foot for one person is enough but it is advisable to have at least 20 square foot of floor space for average dental office.
3. **Working Space:** Adequate counter area where films can be unwrapped. A clean, organized work area is essential which should be free of processing chemicals, water, dust, and debris.
4. **Storage Space:** Adequate space for storage for chemical processing solutions, film cassettes etc.
5. **Lighting:** The room must be completely dark and must exclude all visible light. Any leaks of white light in the darkroom causes film fog.

While for the location of darkroom, many requirements should be taken in consideration:

1) It can be conveniently reached from the rooms where the films exposed and examined.
2) Darkroom should be located where room temperature fluctuates as little as possible because the temperature of the processing solution must kept constant .It should be located in cool part of the clinic .
3) Humidity retards drying of the processed films and damages unused films stored in opened films boxes.
4) The darkroom should be accessible to plumbing and power lines.
5) The darkroom must also be well ventilated to provide a comfortable working environment.

Illumination of dark room:

Two types of lighting are essential in darkroom.

1. **A ceiling light** (room lighting) to provide ordinary white illumination in the darkroom, its switch must be placed high enough on the wall to prevent the operator from accidentally turning it on during processing.
    - Room lighting: Incandescent room lighting is required to perform task such as cleaning, stocking materials and mixing chemicals, this is not associated with the act of processing films.
2. **Safelight;** it consist of a filtered light beam. This light is safe only when the correct watt-bulb is used and the fixture is placed at or beyond the recommended distance from the work area. So it should be mounted at least 4 feet (1.2 meters) above the surface where films are handled.
    - **Safelight** is a special kind of lighting of relatively long wavelength and low intensity illumination that does not rapidly affect open film but permits one to see well enough to work in the area. To minimize the fogging effect of prolonged exposure, the safe light should have a 15 W bulb and a safe light filter (red GBX-2 filter).
3. **Red warning light** which is placed outside the entrance to the room, it should be wired so that it is illuminated whenever the safelight is turned on.

Testing for safe light:

Turn off all lights including the safe light and wait a maximum of 5 min to obtain a fair degree of adaptation to eyes, than look for any place where light is getting into the room from the outside, these light leaks should be obliterated.

Penny test: A small coin is placed on the film and the safe light is turn on, then the film is left for a length of time equal to the time that any unwrapped film of this type can be left before processed, then the film is process .If the image or the outline of the coin can be seen, the darkroom is not safe and the safelight should be rectified, Fig.1.

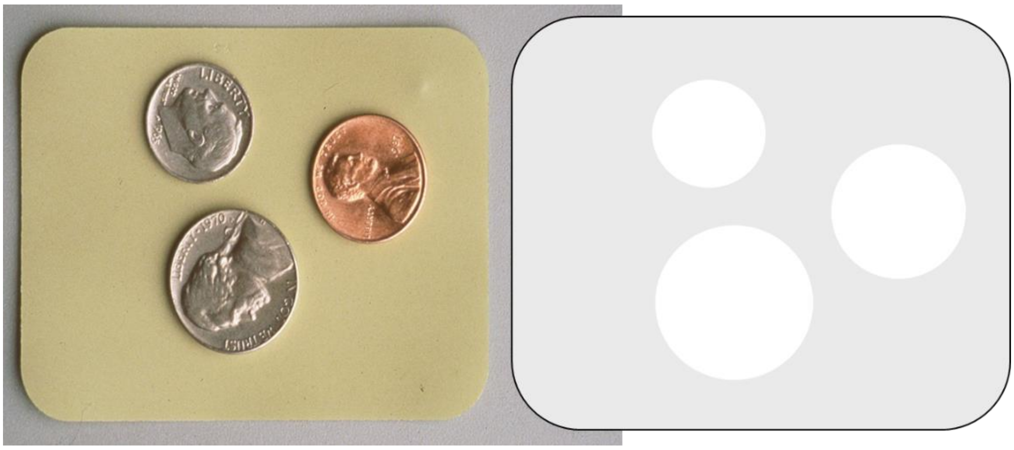


Figure 1. Safelight test, coin or penny test.

Film storage:

1. Film must be stored away from excessive heat and humidity.
2. Chemicals must not be allowed to come in contact with stored films.
3. Objects should not be placed on top of stored films because pressure can cause film artifacts.
4. The boxes of stored films should be lead lined or made of steel to prevent stray radiation from fogging the films.

Temperature and humidity: Should be controlled to prevent film damage. **Room temperature** of **70 °F** is recommended; if exceeds **90 °F** film fog results.

Humidity level of between **50 and 70** percent should be maintained; when too high, film emulsion does not dry; when too low, static electricity becomes a problem and causes film artifacts.

Darkroom plumbing: Must include both hot and cold running water along with mixing valves to adjust the water temperature in the processing tanks with utility sink.

Miscellaneous requirements:

i) Wastebasket for disposal of all film wrappings.
ii) X-ray view box used to examine radiographs.

Equipment requirements:

1. Manual processing tanks.
2. Timer.
3. Thermometer.
4. Film hangers, and miscellaneous equipment.

Manual or wet processing:

It is a simple method that is used to: develop, rinse, fix, and wash dental x- ray films. The essential piece of equipment required for manual processing is a processing tank

Manual processing tank: Is a container divided into compartments to hold the developer solution, water bath, and fixer solution. Has 2 insert tanks and 1 master tank Fig. 2.

Master tank: Filled with circulating water. An overflow pipe is used to control the water level in the master tank.

Insert tanks: 2 removable 1-gallon (3.8 L) insert tanks hold the developer and fixer solutions, placed in master tank. Constructed of stainless steel. Does not react with processing solutions and easy to clean. Practical size for a master tank in dental office is about 20 × 25 cm,. Developer solution is placed on the left and fixer solution placed on right in the master tank. Water in master tank separates the two insert tanks.

Timer: A timer is use to signal the radiographer that the films must be removed from the current processing solution. Development time depends on the temperature of the developer solution.

Thermometer: Use to determine the temperature of developer solution. Optimum temperature is 68 **°F**; below 60 **°F,** chemical works too slowly, results in under development; above 80 **°F** chemical works too rapidly, will cause film fog. Floating thermometer or one that is clipped to the side of the developer tank may be used. Temperature of developer solution determine the development time.

Film hangers: Also known as processing hangers. Device equipped with clips used to hold films during processing. Made up of stainless steel. Available in various sizes and can hold up to 20 intraoral films.

Miscellaneous equipment:

i) **Stirring rods;** made up of plastic or glass use to stir the developer and fixer solutions and to equalize the temperature of the solutions.

ii) **Plastic apron;** use to protect clothing during the processing of films and mixing of chemicals.

Changing solutions:

Exhaustion of the developer results from:

1. Oxidation of the developing agent.
2. Depletion of hydroquinone.
3. Buildup of bromide.

- Exhausted developer results in films with low density and contrast.
- When fixer becomes exhausted, silver thiosulfate complexes form and halide ions build up.
- Increased concentration of silver thiosulfate complexes decreases the rate of diffusion of these complexes out of the emulsion.
- The halide ions slow the rate of clearing of unexposed crystals.
- Exhausted fixer results in incompletely cleared films that turn brown with age.

When to change the processing solutions?

1. **A double film packet** is exposed for the first patient radiographed after new solutions have been prepared.
2. **One** film is placed in the patient's chart and **the other** is mounted on a view box in the darkroom.
3. As successive films are processed they are compared with **this reference film**.
4. **Loss of image contrast and density** becomes evident as the solutions deteriorate indicating when the time has come to change them.

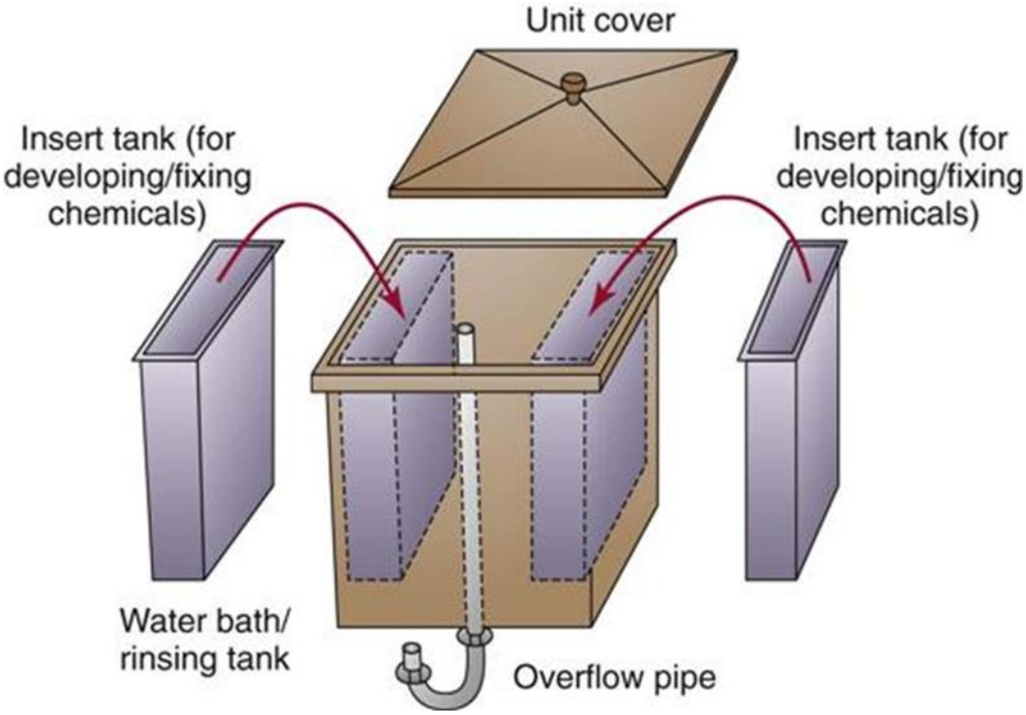


Figure 2. Processing tanks showing developing and fixing tank inserts in bath of running water.

Rapid processing chemicals:

– Advantageous in endodontics and emergency.
  - ➢ More concentrated solutions.
  - ▪ Developed film in 15 seconds.
  - ▪ Fix film in 15 seconds.
  - ▪ At room temperature.
  - – Doesn't have the same degree of contrast as conventionally processed film.
  - – They discolor over time.
  - – Conventional solutions are preferred for routine use.
  - – To improve the contrast and keep them stable in storage, rapidly processed films are placed in conventional fixing solution for 4 minutes and washed for 10 minutes after viewing.

Automatic Film Processing:

Advantages:

- Time saving (takes 4 to 6 minutes to process a film).
- Doesn't require a dark room because it has a daylight loader.
- Consistent density and contrast.

In order to process the films rapidly:

- The chemical composition of the developer and fixer are modified to operate at higher temperatures than those used for manual processing.
- Higher concentration solutions are used.
- Regular automatic replenishment system is used.
- Rinsing step is eliminated.

The fixer has an additional hardener to help the emulsion withstand the transport system.

Disadvantages:

1. Expensive.
2. Needs regular maintenance.
3. Must process a certain number of films per day, otherwise it will not perform efficiently.
4. High temperature tends to produce chemical fog and rapidly deteriorates the strength of the solutions.

Automatic Processor Rollers:

1. Transport the film through the developing solutions.
2. Their motion keep the solutions agitated which results in uniform processing.
3. They press on the emulsion, forcing some solution out of it and the emulsion rapidly fills again with solution thus promoting solution exchange.
4. Rollers at the crossover point between the developer and fixer minimize the carryover of developer into the fixer tank which maintains the uniformity of the processing chemicals.

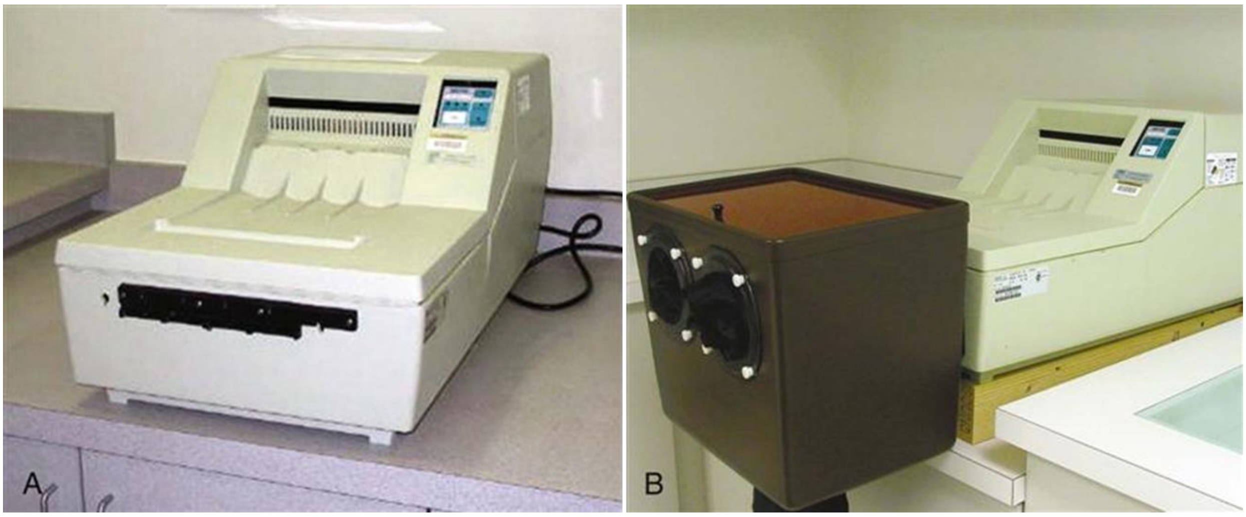


Figure 3. **A**, An automatic film processor. **B**, An automatic film processor equipped with a daylight film loader.

INJECTABLE INTRA-ORAL FILMS:

1. Rapid film development, enhancing efficiency.
2. Chairside processing for immediate results.
3. Space savings in the dental clinic; no processing equipment required.
4. Thinner packets mean enhanced patient comfort.

Processing information:

- Take the dental film by normal procedure
- Simply inject the monobath processing solution into the dental film bag from the upper left corner with a syringe and taking care not to scratch the film.
- Press on the pinhole, shake or knead the dental bag properly to coat the processing solution on the film evenly with gently massage of the packet, tear off film bag after around 90s, open and remove the film.
- Rinse the film for 10 minutes with clean water.
- Finally, dry and view the radiograph.

Figure 4. Carestream injectable intra-oral film technology.

Self-processing Intra-oral films:

Self-developing films are an alternative. If the self-developing film is presented in a special **sachet**, containing developer and fixer, Fig. 5, A. Following exposure the **developer tab** is pulled, unveiling developer solution, which is milked down towards the film and massaged around it gently. After about 15 seconds, the **fixer tab** is pulled to release fixer solution, which is similarly milked down to the film. After fixing the used **chemicals are discarded** and the film is **rinsed** thoroughly under running water about 10 minutes.

In case the self-developing film with monobath processing solution without separated developer and fixer solutions (Fig. 5, B). Pressing the pouch to activate the monobath processing solution, after that start squeezing of the monobath onto the opposite film end portion for developing and fixing the film immediately after having activated the monobath pouch. Keep squeezing repeatedly and continuously for 50 seconds. Minimum by using good pressure in sliding your fingers from top to the bottom of the film. Turn the film upside down and push the monobath back to its original opposite place. Open the film by prising apart, remove the film and start rinsing under running water. Start rinsing the radiograph immediately under running water about 10 minutes after 50 seconds of activation of monobath processing solution in order to avoid the oxidation yellowish of the image. In order to speed this procedure and to get perfect archival quality, fingers may be slide on the radiograph to ensure that all the monobath residual has been removed.

Advantages:

1. No darkroom is needed.
2. Time saving.

Disadvantages:

1. Poor image quality.
2. Image deteriorates rapidly with time.
3. No lead foil inside film packet.
4. Film packet is very flexible and easily bent.
5. Difficult to use with film holders.
6. Expensive.

A rigid plastic backing was manufactured to help reduce the problems of flexibility and lack of lead foil.

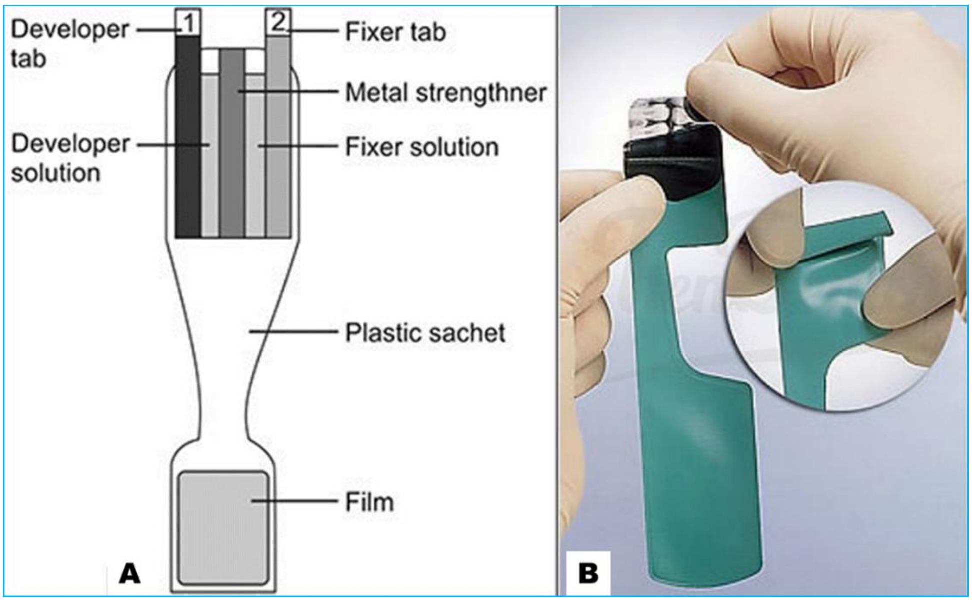


Figure 5. **A**, a diagram showing self-developing film construction containing developer and fixer solution with tab to each solution. **B, another design** of self-developing film with monobath processing solution; **LEFT**, prising apart of film bag and the film is pulled. **RIGHT**, pressing the pouch to activate the monobath processing solution.

MOUNTING RADIOGRAPHS:

Mounts are made of plastic or cardboard and may have a clear plastic window that covers and protects the film. The operator can arrange several films from the same individual in a film mount in the proper anatomic relationship.

Direct Digital Radiography:

Advantages:

1. Lower radiation dose is required.
2. Computer manipulation of the image.
3. Automated image analysis.
4. No need for conventional processing, thus avoiding all processing film faults and the hazards associated with handling the chemical solutions.
5. Storage and archiving of patient information.
6. Teleradiology (transference of images between institutions).

Disadvantages:

1. Expensive.
2. In Direct Digital systems the sensor and the computer have to be connected directly and the connecting cable can make intraoral placement of the sensor difficult.
3. Reduced resolution.
4. Image manipulation can be time consuming and misleading to the inexperienced.
5. Hard copy images may fade with time.
6. Computed or digital images are still 2 dimensional representations of 3 dimensional objects.

Lecture 8 **Image Characteristics**

By

Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

Image characteristics:

Visual characteristics

1) Density.
2) Contrast.

Geometric characteristics

1) Sharpness.
2) Magnification.
3) Distortion.

Film Density:

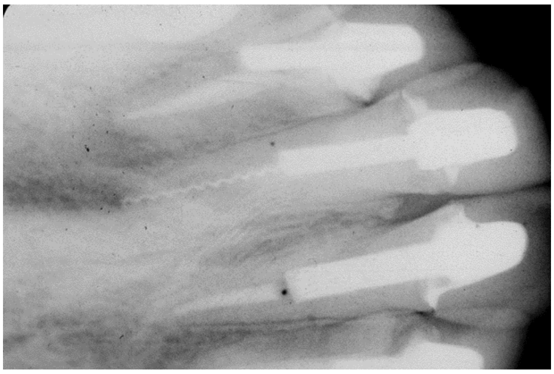
It is the amount of incident light that passes through a radiograph. It represents the degree of darkness of an exposed film (after processing). White areas (e.g., metallic restorations) have no density and black areas (e.g., air spaces) have maximum density. The areas in between these two extremes (tooth structure, bone) are represented by various shades of gray.

Factors affecting film density:

1. Exposure factors.
   a. Milliamperage.
   b. Kilovoltage peak.
   c. Exposure time.
2. Source-object distance.
3. Filtration.

4. Collimation.
5. Patient size.
6. Film processing.
7. Subject thickness.
8. Subject density.

1) **Exposure factors:** (mA, kVp, exposure time). An unnecessary increase in any of these factors results in an increase in film density.
2) **Source-object distance:** the longer the source-object distance, the lower the film density.
3) **Filtration:** The more the filtration, the lower the film density.
4) **Collimation:** The more the collimation, the lower the film density.
5) **Patient size:** the larger the patient's head, the more x-rays that are needed to produce an ideal film density.
6) **Film processing:** When the developing time or temperature increases, film density increases.
7) **Subject thickness:** film density decreases (appears lighter) when subject thickness increases.
8) **Subject density:** determined by type of material (metal, tooth structure, composite, etc.) and by amount of material. Film density decreases (film gets lighter) when subject density increases. In the following radiograph, the post and core in each tooth has a high object density, resulting in low film density.



Radiographic density values:

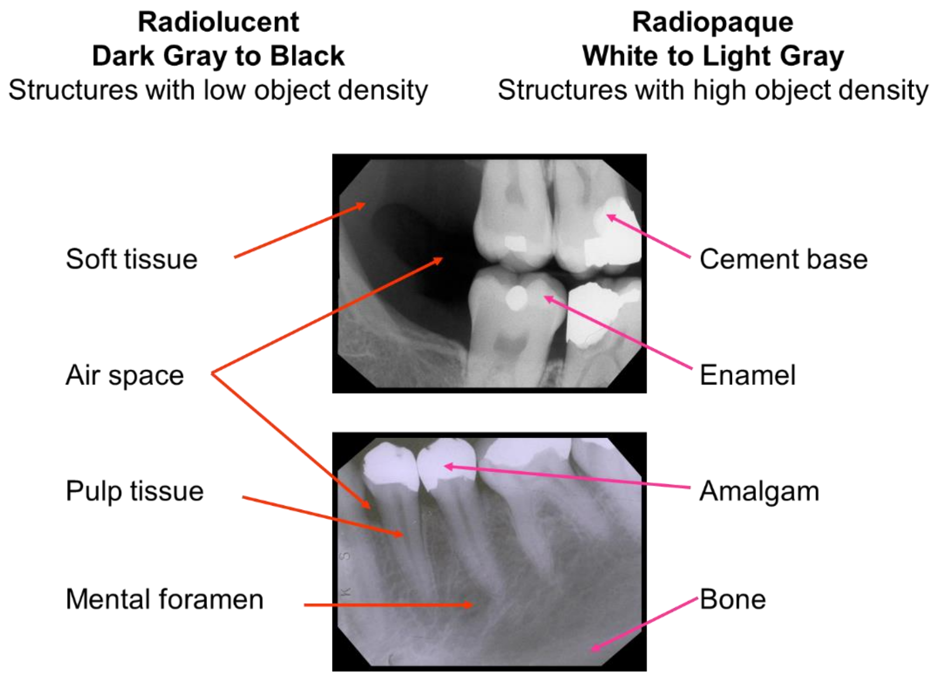
$$D = \text{Log}\ \frac{I}{T}$$

I: quantity of incident viewing light, T: quantity of transmitted light.

If the quantity of incident viewing light is considered to be 100% and if 99% of the incident viewing light is blocked or absorbed, then 1% of the incident light is transmitted; therefore, D = Log 100/1 = 2

Radiolucent: Refers to dark areas of a radiograph (high film density); dark gray to black. Represents with little or no object density such as soft tissue, air, etc.

Radiopaque: Refers to light areas of a radiograph (low film density); light gray to white. Represents areas which have higher object density, such as gold crown, amalgam, etc.

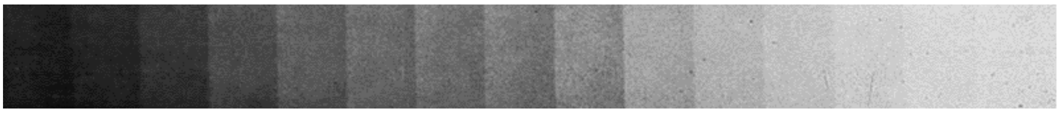


Contrast:

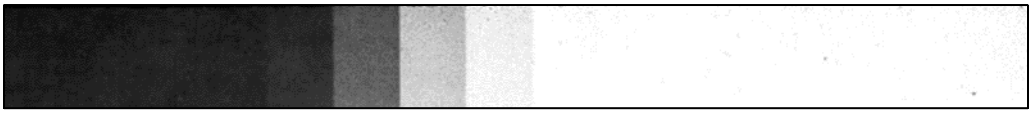
Image contrast is the difference between adjacent densities. How sharply dark and light areas are differentiated or separated on an image.

The ability to distinguish between densities enables differences in anatomic tissues to be visualized. An image that has sufficient density but no differences in densities would appear as a homogenous object.

Low Contrast: With low contrast, there are many shades of gray seen on the film, with little differences among them. This is also known as long scale contrast.



High Contrast: With high contrast, there are few densities seen on the film, with great differences among them, the predominant densities being either very light or very dark. High contrast is also known as short scale contrast.



Radiographic Contrast:

Contrast is the difference in density or difference in the degree of grayness between areas of the radiographic image.

The radiographic contrast depends on the following factors:

1. **Subject Contrast:**
   a) **Thickness difference:**
   b) **Density difference:**
   c) **Atomic number difference:**
2. **Exposure factors:**
3. **Filtration:**
4. **Receptor Contrast:**

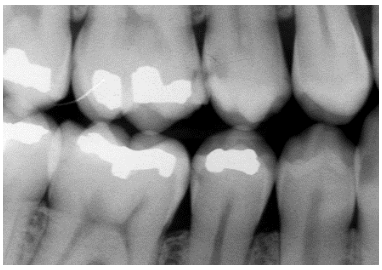
1. **Subject Contrast:** it refers to the difference in the intensity transmitted through the different parts of an object. For example, in an intraoral radiograph, enamel will attenuate x-rays more than dentin.

Subject contrast is affected by the following factors:

a) **Thickness difference:** if the x-ray beam is attenuated by 2 different thicknesses of the same material, the thicker part will attenuate more x-rays than the thinner part.

b) **Density difference:** this is also known as the mass per unit volume. It is the most important factor contributing to subject contrast. A higher density material will attenuate more x-rays than a lower density material.

In order to see an image on the film, the objects being radiographed must have different object densities. In the radiographic film below, the teeth, restorations, bone, air spaces, etc., all have different object densities, allowing us to see them on the film. The higher the subject contrast, the higher the image contrast.



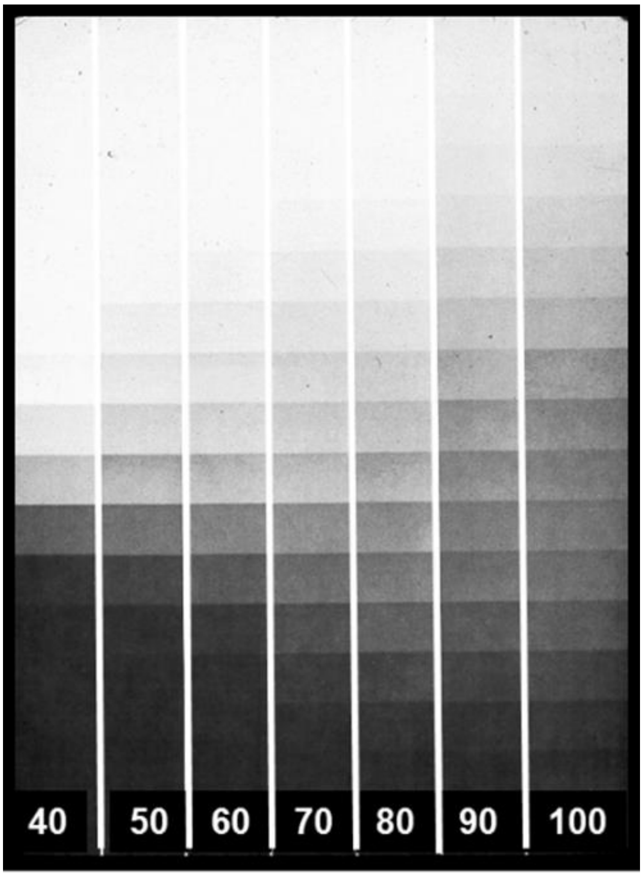
c) **Atomic number difference:** A higher atomic number material will attenuate more x-rays than a lower atomic number material.

2. Exposure factors:

kVp or Radiation quality: it has a great effect on subject contrast. A lower kVp will make the x-ray beam less penetrating. This will result in a greater difference in attenuation between the different parts of the subject, leading to higher contrast (short scale). A higher kVp will make the x-ray beam more penetrating. This will result in less difference in attenuation between the different parts of the subject, resulting in many shades of gray leading to lower contrast (long scale contrast).

Milliampere-seconds (mAs): When the mA or exposure time increases, the number of x-ray photons generated at the anode increases linearly without increasing beam energy. The result will be a higher number of photons reaching the receptor, and this leads to an overall increase in the density of the radiographic image; therefore, when the mAs increases, image density increases, which decreases image contrast. When mAs decreases, image density decreases, which also decreases image contrast.

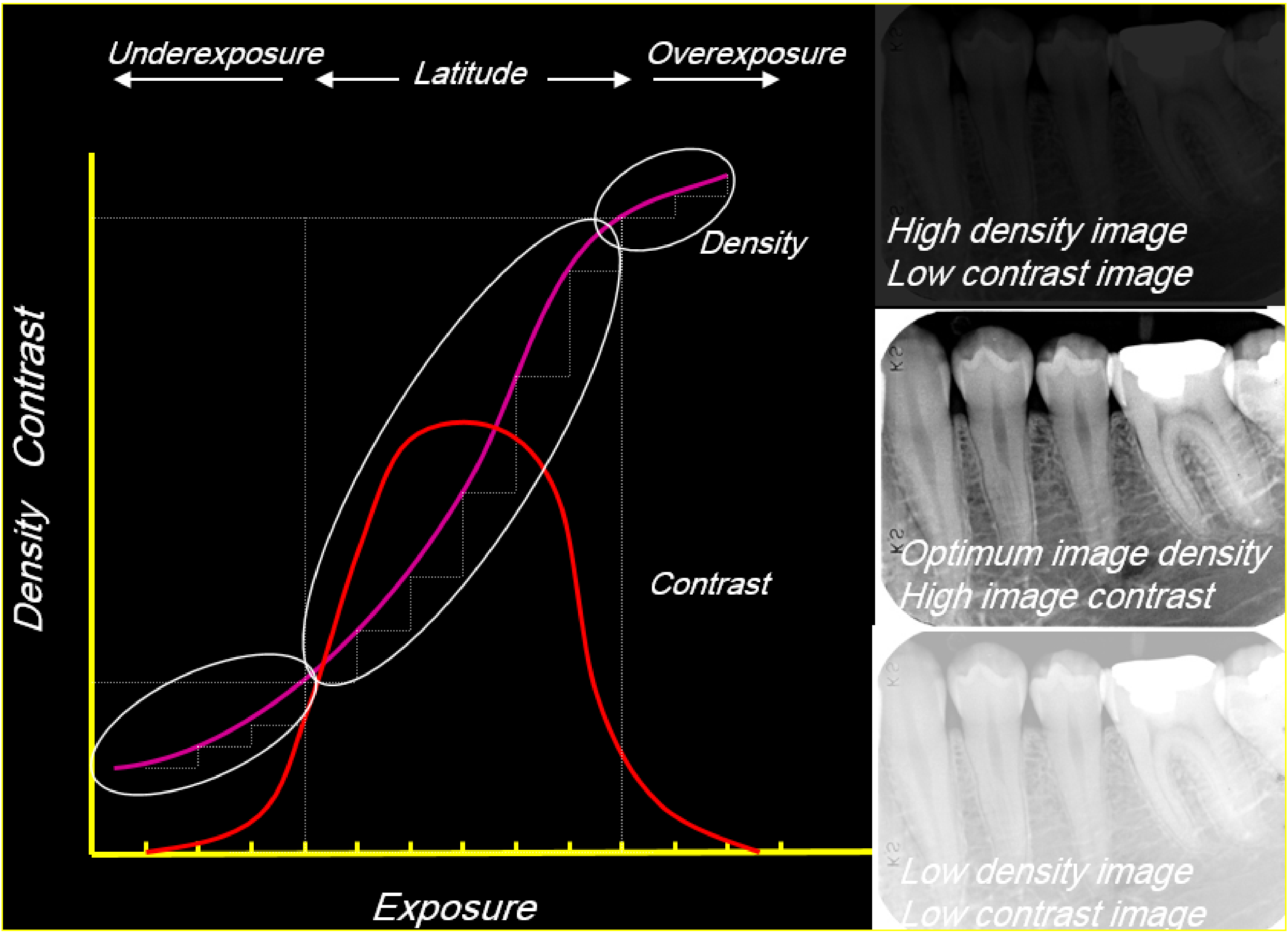
3. Filtration: The result of filtration of X-ray beam is hardened beam (more short wave-length photon with high penetration power) so increase the half-value layer, also increase filtration affect the contrast and density but in different way. The more the filtration, the lower the contrast (long scale) like the effect of increase kVp.



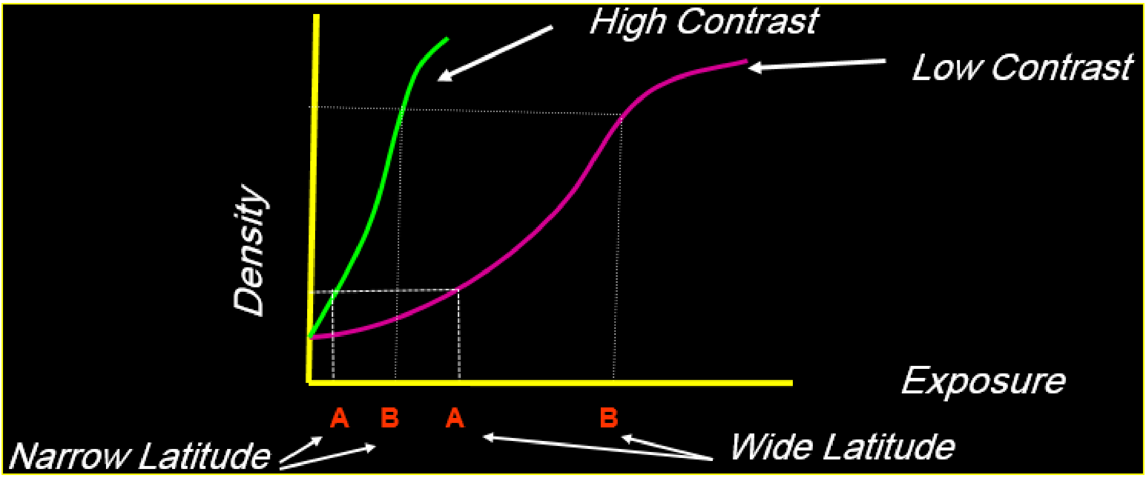
kVp settings

Scattered radiation: Scattered radiation causes film fogging, which increases overall image density, which decreases image contrast; however, **collimation** can counterbalance this effect.

Film fog: Film fogging increases image density, which decreases image contrast.

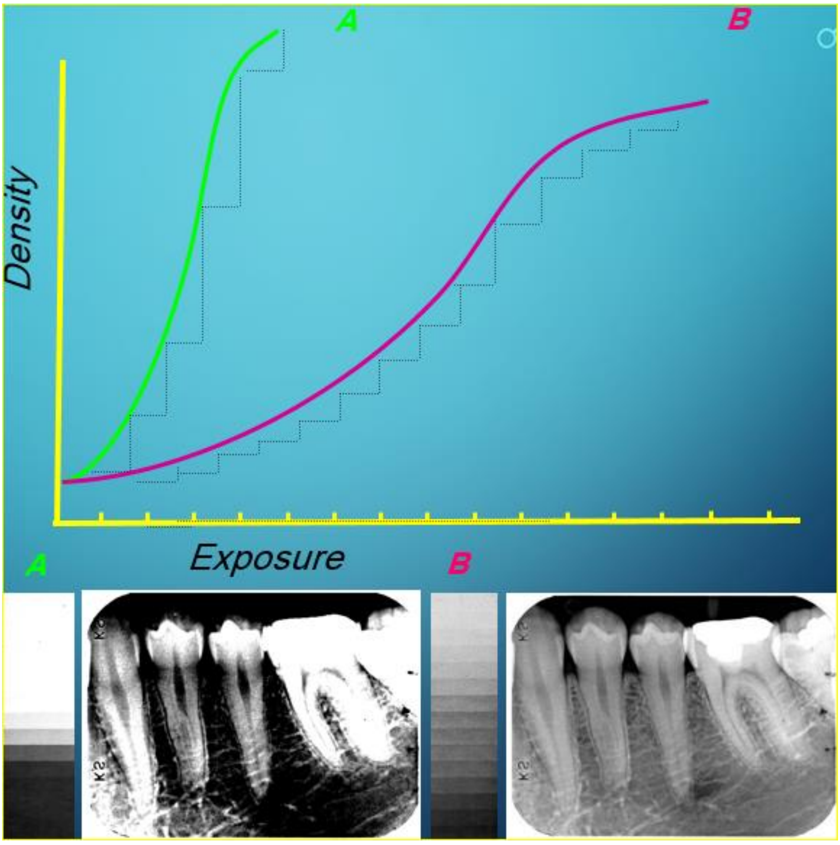


Film Latitude:



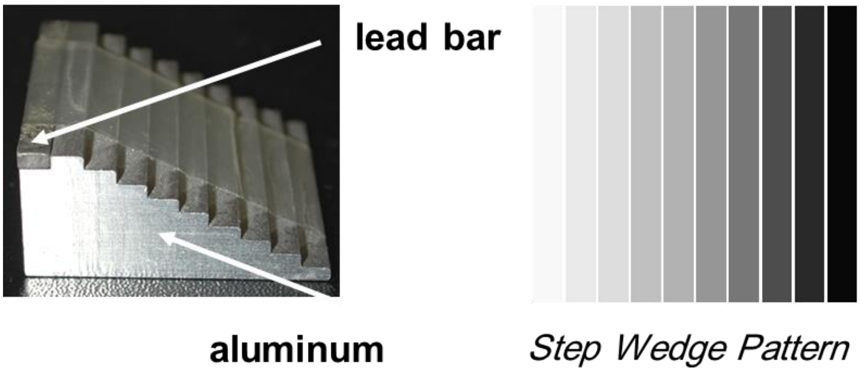
The latitude of a film represents the range of exposures that will produce diagnostically acceptable densities on a film. As the latitude of a film increases, the contrast of the film decreases. In general, high film contrast (**green curve**) requires very precise exposure of the film; if it is too high or too low, the film will be too dark or too light, resulting in a non-diagnostic film. With low film contrast (**purple curve**) the film will be diagnostic over a broader range of film exposure.

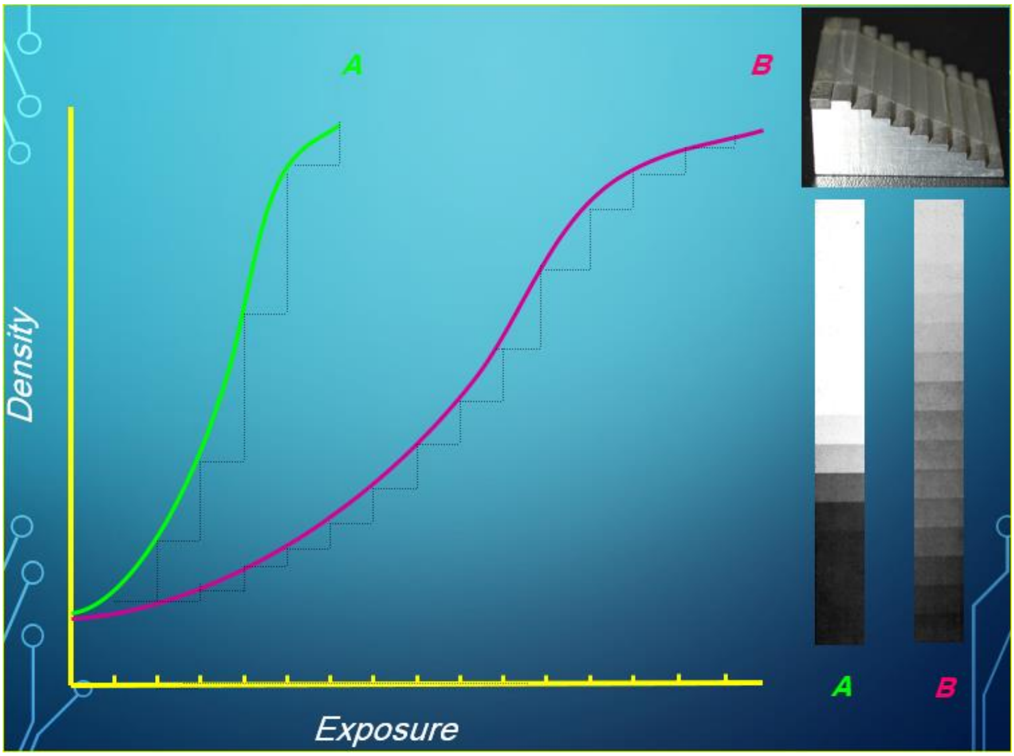
4. Receptor Contrast: it refers to the ability of a receptor to show adequately the information that the photons transmitted through the subject. ***In conventional radiography, the contrast depends on the size of the grains, the development time, the concentration and temperature of the developing solution, and overall film density.*** Increasing developing time or temperature, increases image density, which decreases contrast.



Film A with high contrast, while film B with low contrast.

Stepwedge is a device used to demonstrate film densities and contrast scales. It can be used to demonstrate short scale and long scale contrast. When a stepwedge is placed on top of a film and exposed to X-rays, the different steps absorb varying amount of X-rays. As a result different film densities appear on a dental radiograph.





Background fog density Gross fog – Base plus fog:

This is a small degree of blackening evident even with zero exposure.

It is due to:

- The color/density of the film base.
- The development of some unexposed silver halide crystals.

Background fog density should be less than 0.2.

Film fog: This is an increased in film density resulting from causes other than exposure to the primary x-ray beam.

Any density in a film that is not produced as part of the image-forming exposure is generally referred to as fog.

There are several potential sources of film fog.

Causes of fog:

1. Inherent
2. Prolonged development.
3. Radiation exposure and unsafe light (light leak, improper safelight).
4. Expired film.
5. Improper film storage.
6. Contaminated developer.

Film fog makes the whole film darker, making it harder to see the density differences (decreased contrast).

Inherent:

All film, even under the best conditions, shows some density even if it has received no radiation exposure. This density comes from the film base and from the unexposed emulsion, and is the density observed if a piece of unexposed film is processed. This is typically referred to as the base plus fog density and is generally in the range of 0.15 to 0.2 density units for radiographic film.

Prolonged development (chemical):

If a film is over processed, abnormally high densities will be developed by chemical action in image areas that received little or no exposure. This results from chemicals in the developer solution interacting with some of the film grains that were not sensitized by exposure.

Radiation exposure and unsafe light (light leak, improper safelight). It is not uncommon for film to be fogged by accidental exposure to either x-radiation or light. Light-exposure fogging can result from light leaks in a darkroom, the use of incorrect safelights, and cassettes with defective light seals around the edges.

Film darkrooms and storage areas should be properly shielded from nearby x-ray sources.

Heat and age:

Fog will gradually develop in unprocessed film with age; therefore, film should not be stored for long periods of time. Each box of film is labeled with an expiration date by the manufacturer. When stored under proper conditions, film should not develop appreciable fog before the expiration date. When film is stored in a clinical facility, the stock should be rotated on a first-in, first-out basis.

The development of film fog with age is accelerated by heat; therefore, film should not be stored in hot areas. Refrigeration can extend the useful life of unprocessed film.

Film speed:

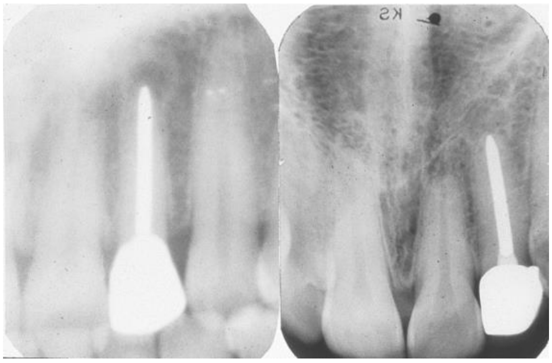
This is the exposure required to produce an optical density of 1.0 above background fog density. The higher the speed, the less the exposure required for a given film density and the lower the radiation dose to the patient.

The larger the crystals, the faster the film, but the poorer the image sharpness.

Sharpness (Definition):

The sharpness of an image is a measure of how well the details (boundaries/edges) of an object are reproduced on a radiograph (refers to the capability of the receptor to reproduce the distinct outlines of an object, influenced by focal spot size, film composition, and movement).

The sharpness of an image is dependent on the size of the penumbra.

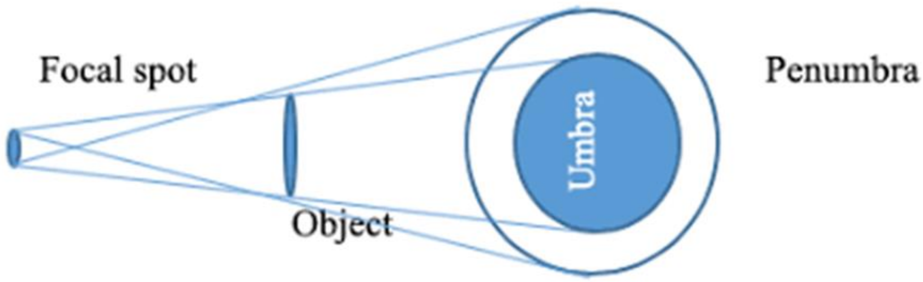


Penumbra:

The area on the film that represents the image of a tooth is called the umbra, or complete shadow.

The area around the umbra is called the penumbra or partial shadow.

The penumbra is the zone of unsharpness along the edge of the image; the larger it is, the less sharp the image will be.

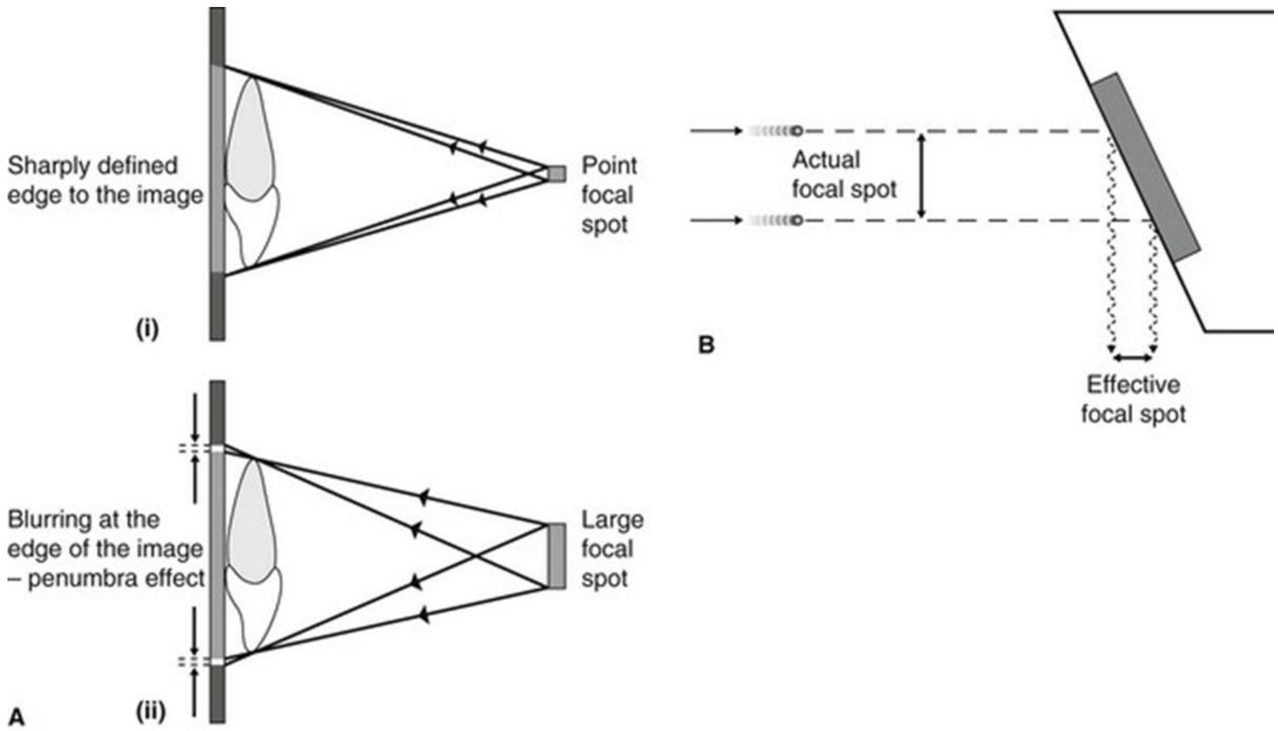


Factors affecting Sharpness:

1. Focal spot size.
2. Film composition.
3. Patient movement.
4. Source-object distance.
5. Object-film distance.

***Decreasing focal spot size, increases sharpness*:**

The focal spot (the source of the X-rays) should be ideally a point source to reduce blurring of the image, the penumbra effect. However, the heat produced at the target by the bombarding electrons needs to be distributed over as large an area as possible. These two opposite requirements are satisfied by using an angled target and the principle of line focus, as shown in.

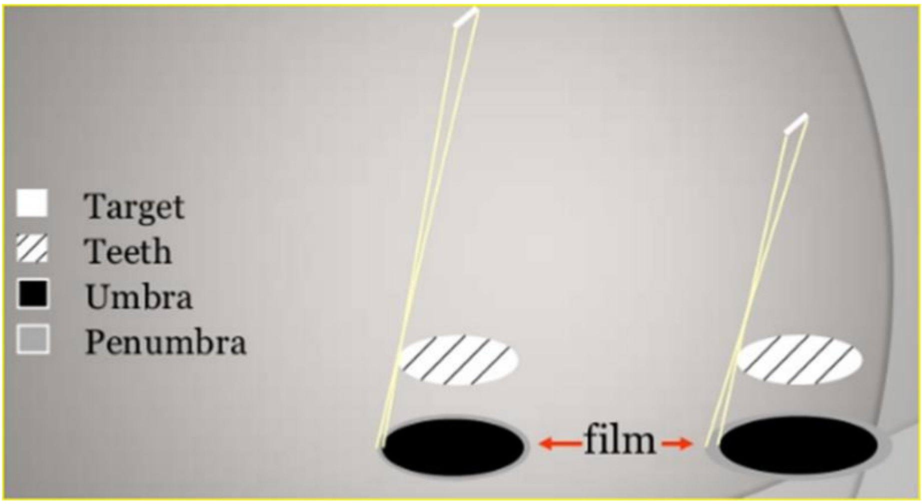


A Diagrams showing the effect of X-ray beam source (focal spot) size on image blurring (i) a small or point source, (ii) a large source. B The principle of line focus: diagram of the target and focal spot showing how the angled target face allows a large actual focal spot but a small effective focal spot.

Film Composition:

The larger the crystal size, the less the sharpness. Slow films with small crystal sizes produce sharper images than fast films with larger crystals sizes.

Increasing source-object distance, increases sharpness:

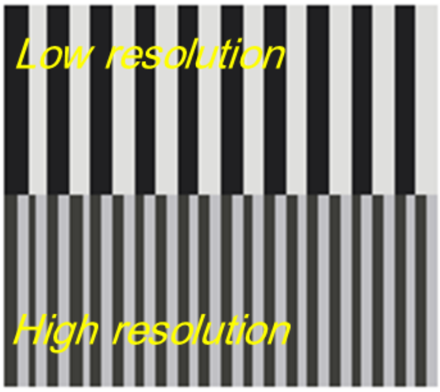


Methods for minimizing loss of image clarity and improving image quality (improving image sharpness):

1. Using a small effective focal spot size.
2. Using a slower speed film (film composition).
3. Avoid patient movement.
4. Increasing Source-object distance.
5. Decreasing Object-film distance.

Resolution:

It is the ability to distinguish between different structures that are close together. Resolution is expressed in terms of line pairs per millimeter (Lp/mm). In the space of 1 mm, the number of line pairs that could be distinguished determines the amount of resolution. Each line pair is made up of a line and a space. Human eye is able to discern 5 Lp/mm. Resolution depends on film composition: the larger the crystal size, the less the resolution. Slow films with small crystal sizes produce higher resolution images than fast films with larger crystals sizes.



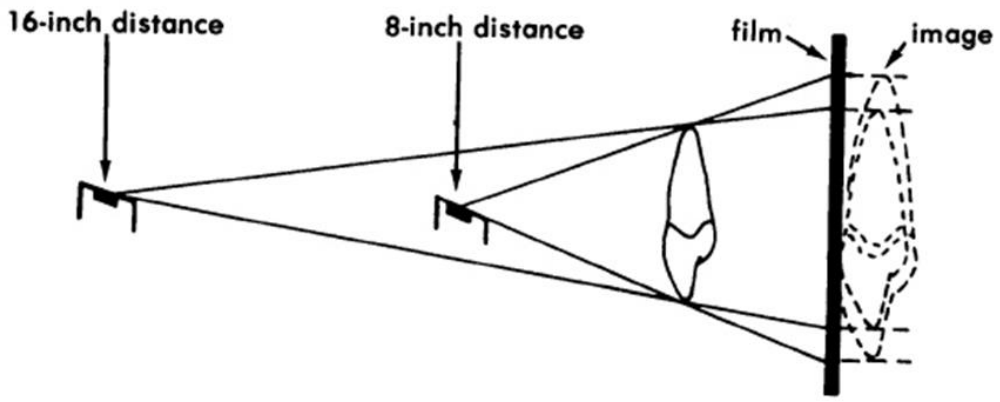
Magnification:

Magnification is the increase in the size of an object. It is caused by the divergence (spreading out) of the x-ray beam as it moves away from the target.

Factors affecting magnification:

1. Object–film distance.
2. Source–film or Source-Object distance.

Increasing source-object distance, decreases magnification:



Decreasing object-film distance, decreases magnification:

Calculating magnification:

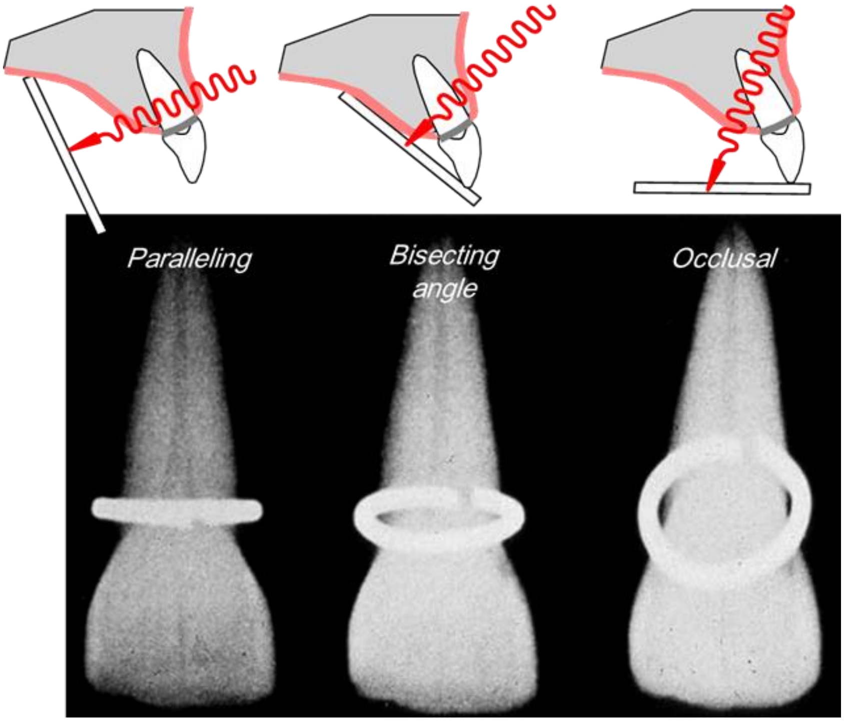
$$\text{Object size} = \frac{\text{Source-object distance x tooth image length on the radiograph}}{\text{Source-film distance}}$$

What is the true size of a tooth when the source-film distance is 16 inches, the source-object distance is 15 inches and the tooth image length on the radiograph is 28 mm?

Object size = 15 x 28 / 16 = 26.25 mm

Distortion:

Distortion is the variation in the true size and shape of the object being radiographed



Factors affecting Distortion:

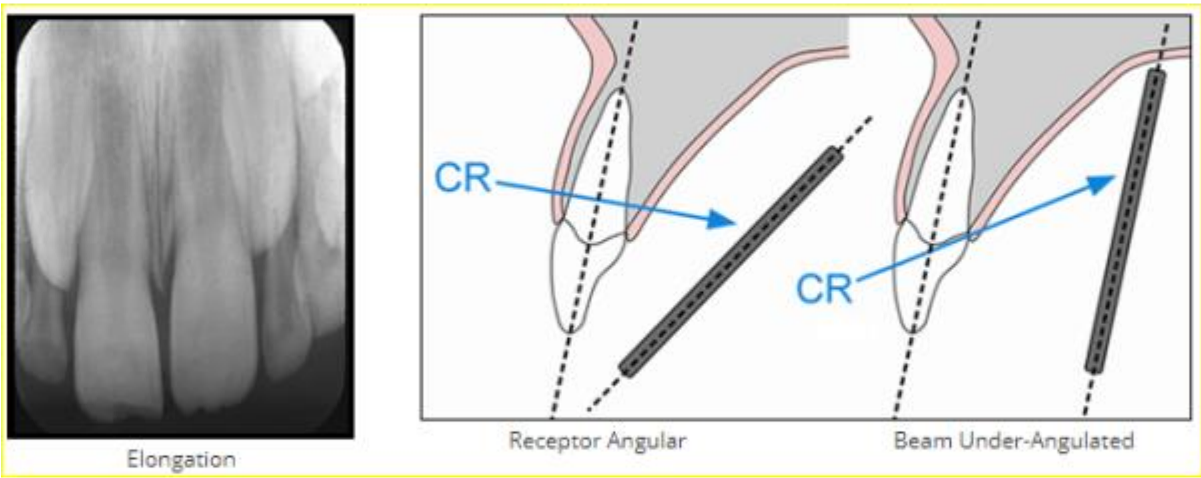
1. The object-film alignment (angle between the film and teeth).
2. The x-ray beam alignment (the angle the x-ray beam forms with both the film and the teeth).

To minimize distortion:

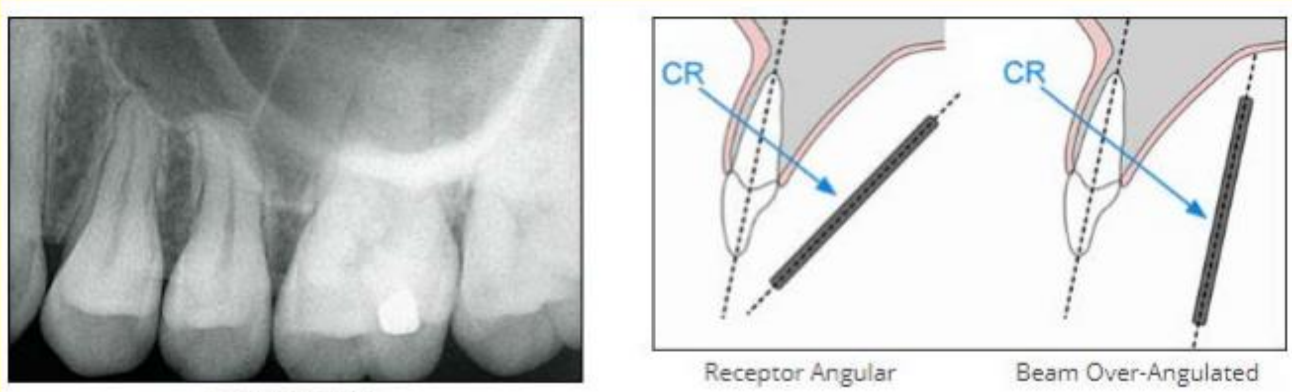
The object and film must be parallel to each other

The X-ray beam must be directed perpendicular to the tooth and the film.

Elongation:



Foreshortening:



Foreshortened

Receptor Angular

Beam Over-Angulated

Five rules for accurate image formation:

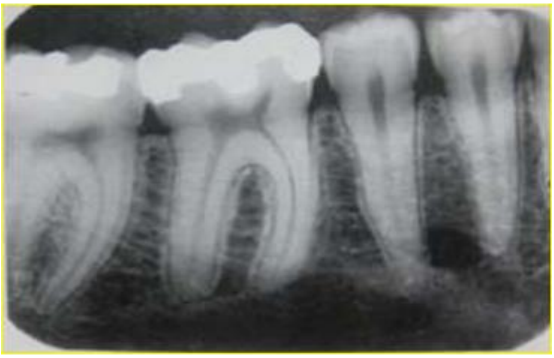
1. The radiation source should be as small as possible.
2. The source-tooth distance should be large.
3. The tooth-film distance should be small.
4. The tooth and film should be parallel.
5. The x-ray beam should be perpendicular to tooth/film.

Diagnostic image: Image that has proper density and contrast, sharp outlines, and is the same shape and size as the object.

Ideal radiograph:

In the ideal radiograph, the image is the same size as the object, has the same shape and has a sharp outline with good density and contrast. Because the receptor must always be at some distance from the object, with bone and soft tissue in between, the object will always be magnified to some degree. Though magnified, the image of the object will usually have the same shape as the object when using the paralleling technique. The sharpness, density and contrast are maximized by using a longer distance between the X-ray source and the tooth and proper exposure factors.

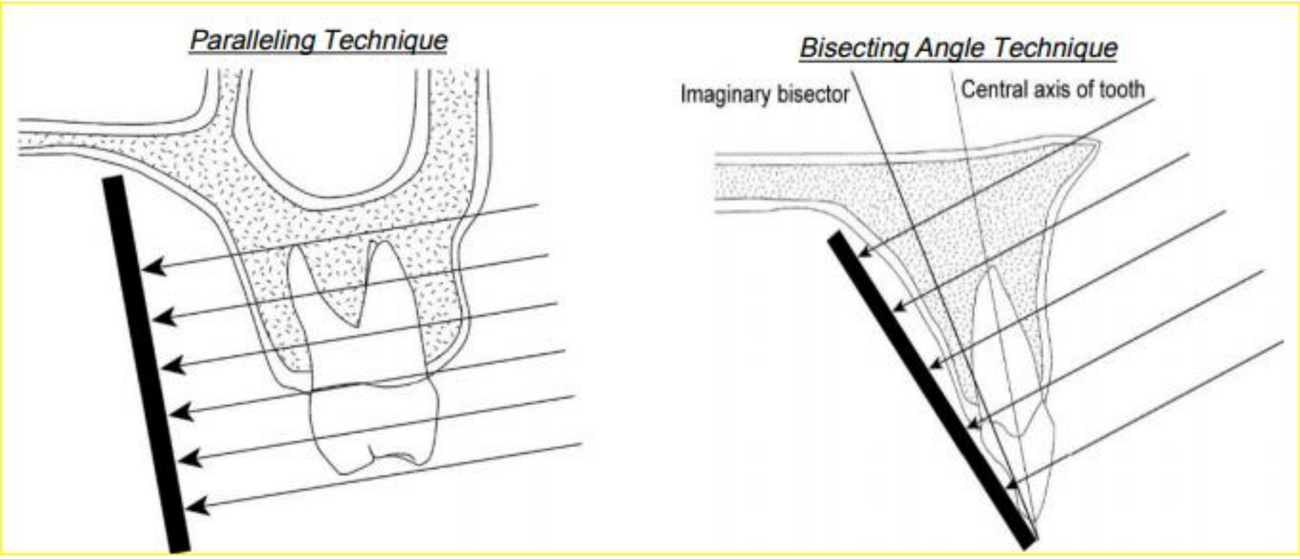
The mandibular molar periapical image below comes closest to satisfying the properties of an ideal radiograph (either paralleling or bisecting). The receptor is closer to the teeth in this location than in any other part of the mouth and the receptor is usually parallel with the teeth.



Avoiding image distortion:

The two most common techniques to avoid distortion are the paralleling technique and the bisecting angle technique.

1. Paralleling technique: The object (tooth) and image receptor are parallel to each other and the central ray of the x-ray beam is directed to intersect both the image receptor and the tooth perpendicularly.
2. Bisecting angle technique: The x-ray beam is perpendicular to the imaginary line that bisects the angle formed between the central axis of the object (tooth) and the image receptor.



Lecture 9 Factors relating to the production of radiographic image

By

Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.

Oral Radiology Teacher, Anbar University

Radiation Quantity: is the number of X-ray photons in the useful beam. The factors affecting X-ray quantity are:

1. **Exposure factors.**
    a. *Kilovoltage peak (kVp).*
    b. *Milliamperage.*
    c. *Exposure time.*
2. **Distance:** X-ray quantity varies inversely with distance.
3. **Filtration:** X-ray quantity is reduced by filtration, which absorb the low energy photons of the beam.

Radiation Quality: is the penetrating power of the X-ray beam, which is quantified by half value layer.

The factors affecting X-ray quality are:

1) **kVp:** X-ray penetrability is increased as kVp is increased.
2) **Filtration:** X-ray penetrability is increased when filters added to the beam.

Inverse square law: the low stated that the intensity of radiation inversely proportional with the square of distance measured from the source of radiation to the point of measuring the radiation intensity.

I: intensity
D: Distance

$$I = \frac{(D_2)^2}{(D_1)^2}$$

Factors relating to the production of radiograph:

A. Factors related to the radiation beam.

B. Factors related to the object.

C. Factors related to the X-ray film.

A. Factors related to the radiation beam.

1) **Exposure factors:**
   a) **Exposure time:** It's the interval during which X-rays are being produced. Exposure time is directly related to the total photon production thus increase exposure time cause increase in the quantity of X-radiation that's why exposure time has direct effect on film density.
   b) **Milliamperage:** It's related to amount of electricity pass through the filament circuit. So it's directly control the rates of X-ray photon production. Thus it has direct effect on film density.
   c) **Kilovoltage peak:** kVp refers to the potential difference between cathode and anode in the X-ray tube. The higher kVp, the greater is the potential difference and the greater is the energy of X-ray photons.
2) **Tube-film distance:** this distance consist of (tube-object distance) and (object-film distance). The tube-film distance affect the intensity of radiation (according to inverse square law.

   The tube-film distance affect the exposure time directly. The distance proportion inversely with the intensity of radiation. The distance affect the dose of radiation because decrease the tube-film distance make the X-ray beam more diverge behind the skin area and more tissue is irradiated. While increase the distance makes the beam less diverges and reduces the amount of tissue irradiated.

3) **Focal spot size:** The focal spot or called the source of radiation must be as small as possible to get best image quality. So any movement in the head of X-ray machine affect the focal spot size.
4) **Collimation:** Collimator used to control the size and shape of the beam.

   Effect of collimation: Reduce the amount of tissue irradiated. Minimize the production of secondary radiation fog.

   Fog: It is the unwanted film density (blackening) and thus reducing radiographic contrast.

5) **Filtration:** The effect of filtration is the absorption of long wave length X-ray photons that have low penetrating power (can't penetrate the hard calcified tissue). The result of filtration of X-ray beam is hardened beam (more short wave-length photon with high penetration power), so increase the half-value layer. Also increase filtration affect the contrast and density but in different way, the contrast is

decreased (long scale) like the effect of increase kV, while the density is decreased because when filtration increase the result is the absorption of not only long wave length photons but even some of short wave length photons so the number of X-ray photons or the quantity of radiation is reduced so the density is reduced.

6) **Equipment efficiency:** Dental X-ray machine differ in construction and efficiency; therefore, the quality and quantity of X-ray beam vary from machine to another.

B. Factors relating to the object:

The object is basically an absorbing X-ray medium, so 2 points important about the object during exposure to X-ray:

1. **Thickness of the object:** Thick object required more radiation to make a radiographic image so it's often advisable to increase kVp or mA and /or exposure time in order to increase the amount of X-ray photons.

2. **Density of the object:** Density refers to weight per unit volume of the object. In dental radiography enamel of the tooth has highest density of all body tissues. Increase the density of the object increase its ability to absorb X-ray. So hard tissue like enamel absorb great amount of radiation when compared with absorption of soft tissue like pulp because of object density.

C. Factors relating to the X-ray film:

1. **Reduction of secondary radiation:** Secondary radiation include scattered, stray leakage or any other radiation that not belong to primary X-ray. Secondary radiation is undesirable because it reaches all parts of the film and produces film fog.

Several ways to minimizing this radiation like:-

a. Using as small beam of radiation as possible.
b. Proper collimation.
c. In intraoral film a sheet of lead foil is placed behind the film in the film packet.
d. In extra oral film a grid is placed between the object and the film. The grid is an extremely effective device for reducing the amount of scattered radiation that exiting an object and reaching the film. It's composed of alternating strips of a radiopaque material (usually lead) and strips of radiolucent material (often plastic). So the grid transmit only those X-rays whose direction is on straight line from the source to the film (image receptor) and absorb the remnant scattered radiation (Fig. 1).

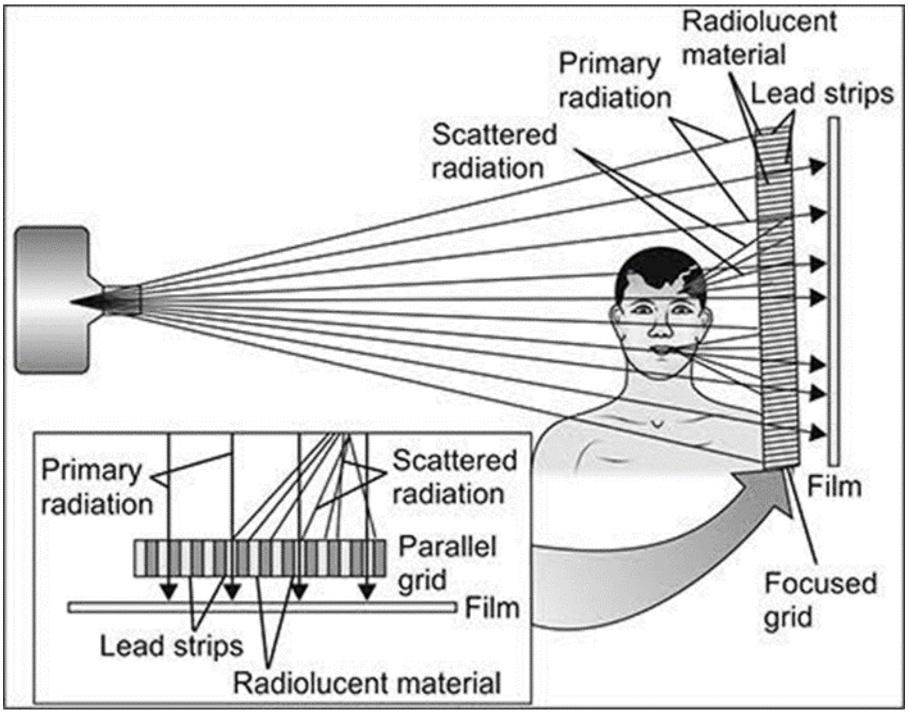


Figure 1: extra oral grid demonstrating the lead strips and the scattered radiation elimination.

2. **Film and film storage:** X-ray film must be stored in light-tight containers because the Ag Br Crystals in the emulsion are sensitive to light as well as to X-ray. Also film must be stored in lead lined box to keep the films away from the stray radiation, also stored in place away from excessive temperature or humidity and we should be used it before the expiration.

3. **Intensifying screen:** It is a device that convert the energy of X-ray beam into visible light, which interact with X-ray film and forming the latent image. Intensifying screen used in extra oral film to reduce patient dose by converting the X-ray to light so one X-ray photon give rise to many light photons, the number of X-rays required to produce the same density on the film is markedly reduced.

4. **Film processing:** The latent image is formed when silver halide grains are exposed to X-ray, then only the exposed grain will form the visible image by development. While the unexposed grains removed from emulsion by fixing and make a permanent image.

As mentioned in film processing lecture, its either automatic or manual processing steps, the automatic processing is preferred because it faster and resulted in better image quality.

Ideal radiographic projection:

The term image quality describes the subjective judgment by the clinician of the overall appearance of a radiograph. It depends on density, contrast, latitude, sharpness, resolution and other factors. Ideal radiograph demonstrates certain image qualities include:

1. Radiographic image that is sharp.
2. Radiographic image that is shaped like the object.
3. Radiographic image that is the same size as the object.

Image size distortion (magnification): is the increase in size of the image on the radiograph compared with the actual size of the object.

Penumbra: Is the amount of unsharpness of the image so penumbra is the area of partial shadow.

Umbra: Is the area of total shadow and it exist only when the object absorb all of X-rays.

Penumbra is created by the size of focal spot (source of radiation), the larger the spot size the greater is the penumbra (the amount of unsharpness) (Fig, 2). Penumbra not only affected by focal spot size but also affected by tube-object distance and object-film distance so the closer tube-object distance the greater is the penumbra while the closer object-film distance the lesser is the size of penumbra (Fig. 3).

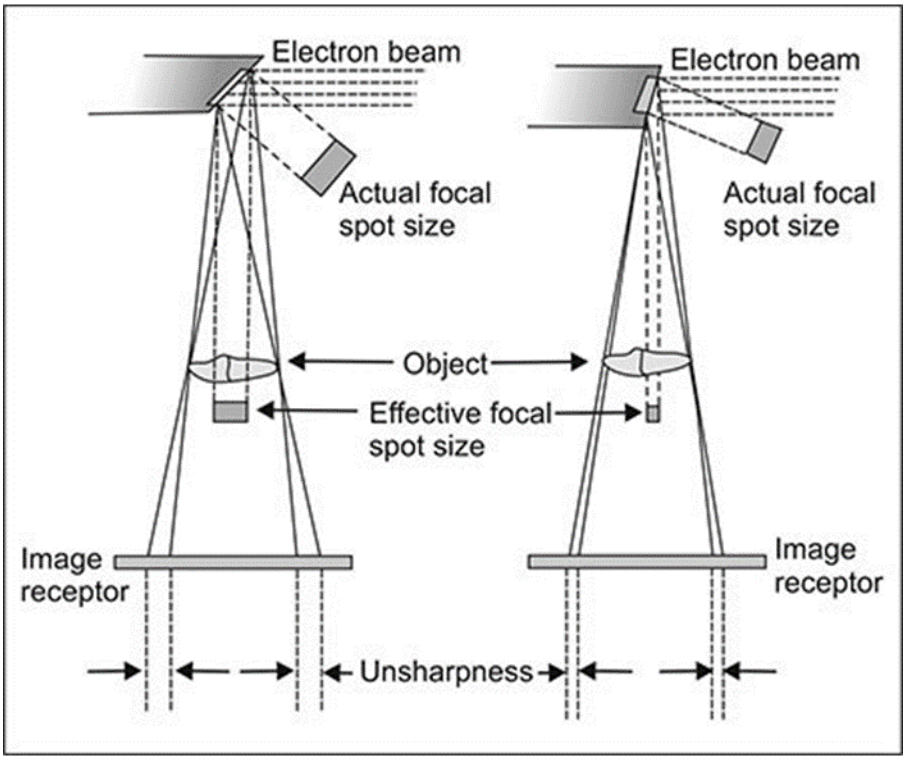


Figure 2. Effect of focal spot size on penumbra and umbra.

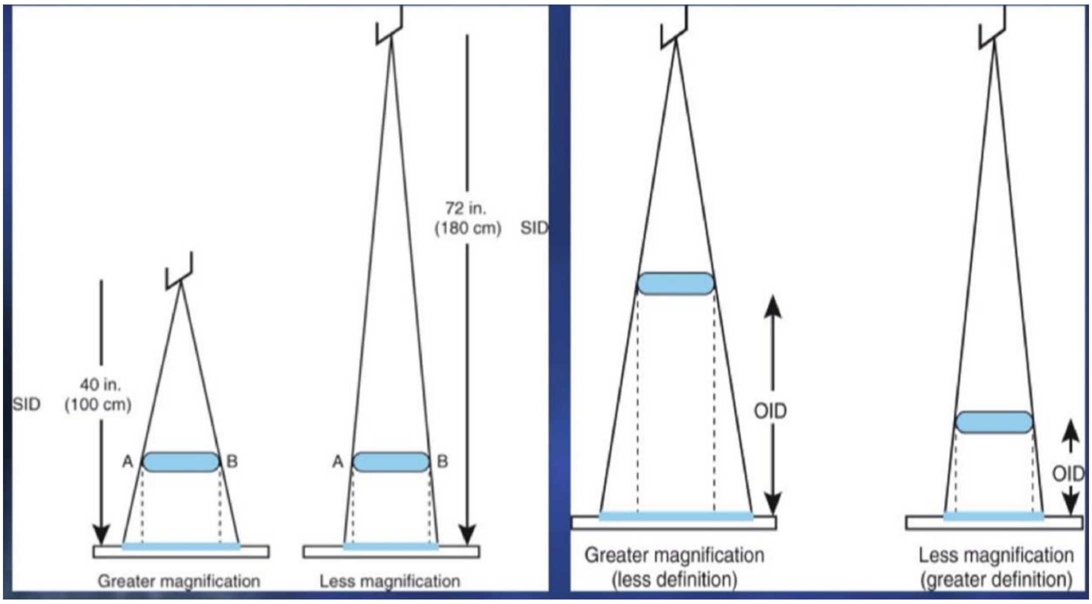


Figure 3. Effect of tube-object distance; LEFT and object-film distance; RIGHT on umbra and penumbra.

Basic principles of projection geometry for radiography:

1. Source of radiation should as small as possible.

2. Tube-object distance should be as great as possible.

3. Object-film distance should be as small as possible.

4. Film should be parallel to an easily identifiable plane of the object.

5. Central ray of the beam should be perpendicular to the film.

The first 3 principles deal with the image sharpness while the last 2 principles required during exposure as a technique.

Lecture 10 Intraoral Technique, Projection and Processing Errors

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

Radiographic Artifact Defined:

- Any opacity on the radiograph that does not correspond to an actual anatomic structure.
- Any misrepresentation of an actual anatomic structure.
- Anything decreasing radiographic quality.

Quality evaluation criteria of periapical radiograph:

1. All radiographs must have **acceptable image** (details, definition, density and contrast).
2. All **crowns and roots** including apices are fully depicted together with interproximal alveolar crests, tooth contact areas, and surrounding apical bone regions.
3. Image of all teeth and other structures are shown in proper relative **size and contour** with minimal distortion and without overlapping images, where anatomically possible.
4. The radiograph is **free** from film handling and processing errors.

Bitewing Radiography Evaluating Criteria:

1. The **interproximal contacts** should not be overlapped from the distal surface of the canine to the mesial surface of the third molar, to the extent that interpretation is impossible.
2. The **crown** of the maxillary and mandibular teeth should be centered in the image from top to the button.

3. The **crest** of alveolar bone should be visible with no superimposition of the crowns of adjacent teeth.
4. The **occlusal plane** should be as horizontal as possible.
5. The buccal and lingual **cusps** should not be excessively separated.

Films with errors should be avoided due to the following reasons:

Retake will lead to:

1. Expose the patient to unnecessary radiation.
2. Waste film and time (money).
3. Interfere with accurate interpretation and diagnosis.

Practical factors influencing film-based image quality:

In practical terms, **the various factors** that can influence overall film-captured image quality can be divided into factors related to:

1) The X-ray equipment.
2) The image receptor-film or film/screen combination.
3) Processing.
4) The patient.
5) The operator and radiographic technique.

As a result of all these variables, film faults and alterations in image quality are **inevitable**. However, since the diagnostic yield from radiography is related directly to the quality of the image, regular checks and monitoring of these variables are essential to achieve and maintain good quality radiographs. It is these checks which form the basis of quality assurance.

Dental care professionals need to be able to recognize **the cause of the various film faults** so that appropriate corrective action can be taken.

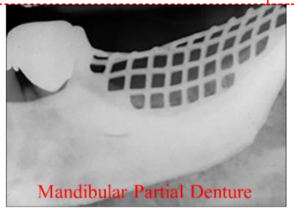
The majority of errors produced can be categorized into three groups:

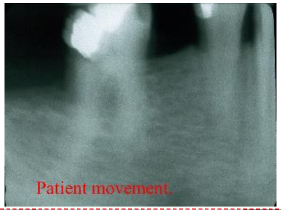
I. **Technique and projection artifacts (errors).**
II. **Exposure artifacts.**
III. **Processing artifacts.**

Technique and projection artifacts:

A. Patient Preparation Errors:

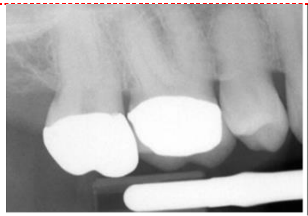
1. Radiopaque artifact.
2. Blurred image.
3. Pressure mark.

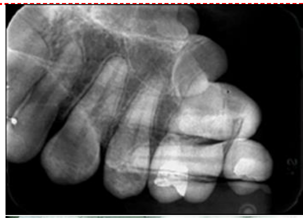




B. Film Placement Error:

1. Apex cut off.
2. Crown cut off.
3. Dropped film corner.
4. Finger artifact/ phalangioma.
5. Double image.
6. Area of interest not shown.
7. Reversed film.
8. Dot artifact.



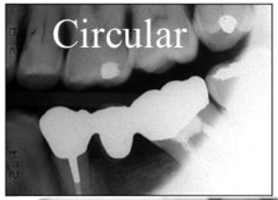


C. Film Handling Errors:

1. Film bending.
2. Film creasing.

D. PID Alignment Errors:

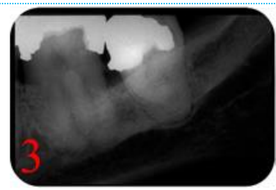
1. Cone cut with film holder.
2. Cone cut without film holder.
3. Incorrect horizontal angulation.
4. Foreshortened image.
5. Elongated image.
6. Negative angulation in bitewings.

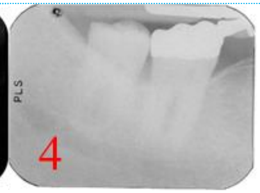


✖

Exposure artifacts:

1. Unexposed film.
2. Film exposed to light.
3. Overexposed film.
4. Underexposed film.



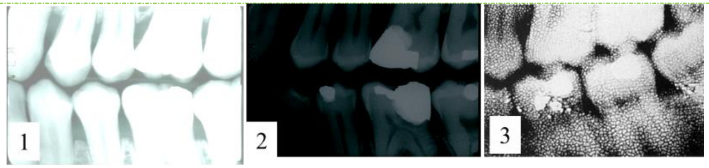


≥

Processing artifacts:

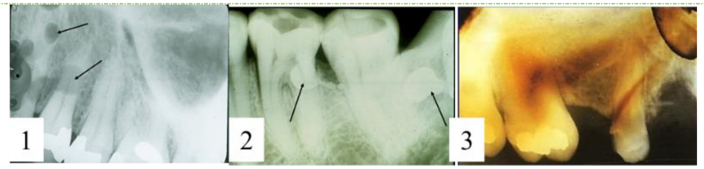
A. Time and temperature problem:

1. Underdeveloped film.
2. Overdeveloped film.
3. Emulsion Reticulation.



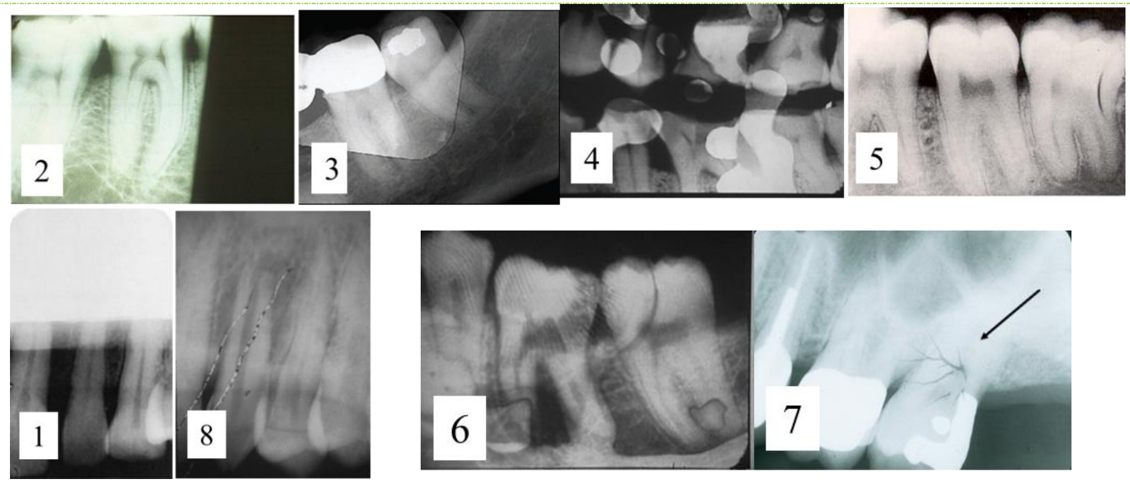
B. Chemical contamination problems:

1. Developer spots.
2. Fixer spots.
3. Yellow brown stains.



C. Film handling problems:

1. Developer cut off.
2. Fixer cut off.
3. Overlapped films.
4. Air bubbles.
5. Fingernail artifact.
6. Fingerprint artifact.
7. Static electricity.
8. Scratched film.
9. Developer spots.
10. Fixer spots.
11. Yellow brown stains.



D. Lighting problems:

1. Light leak.
2. Fogged film.

®

Technique and projection artifacts:

A. Patient Preparation Errors:

Error	Appearance	Problem/ Cause	Solution/ Correction
Radiopaque artifact.	As radiopaque artifact superimposed over the dental image.	Metal dental appliances left in the mouth during exposure, ear rings, nose rings, jewelry, and eye glasses.	The patient should be removed any metallic objects intra-orally or extra-orally before placing the film.
Blurred Image.	Blurred image appears on the film.	1. The patient move during exposure of the film. 2. Movement of the tube. 3. Movement of the film.	Stabilize the patients head, tube, and film, before exposing the film. Never expose a film when a patient is moving.
Pressure mark	May appear black or white.	Pressure from the incisal edges and cusps of teeth mostly in pediatric occlusal radiography.	Ask the patient to bite gently.

B. Film Placement Errors:

Error	Appearance	Problem/ Cause	Solution/ Correction
Apex cut off.	Absence of apical structures and no apices appear on the film. Excessive black margin.	Film was not positioned in the patient's mouth to cover the apical regions of teeth.	Make sure that no more than 1:8 inch of the film edge extend beyond the incisal-occlusal surfaces of the teeth such film placement ensure adequate coverage of the tooth apices.
Crown cut off.	Cutting off the crowns of teeth on the film.	Film was positioned in the patient's mouth too far below occlusal plane.	Make sure the teeth are covered with the film and there is enough film extending occlusally.
Dropped film corner.	Occlusal plane tipped or tilted on the radiograph.	The edge of the film was not placed parallel to the inciso-occlusal surfaces of teeth.	Make sure the edge of the film is parallel to the incisal-occlusal surfaces of teeth.

		The patient was not instructed to hold the film firmly against the tooth (this error occurs with the finger holding method of bisecting technique).	Instruct the patient to hold the film firmly in place.
Finger Artifact/ Phalangioma.	Patient's finger appears on film	Patient's finger was placed in front of the film instead of behind. Occurs with finger holding method of bisecting technique.	Make sure patient's finger used to stabilize the film is placed behind the film and not in front of it.
Double Image.	A double image appear on the film. The images may appear superimposed, (parallel) at ninety degree angles to each other or upside-down.	Film was exposed in the patient's mouth twice. The film will have 2 superimposed images. It results in two retakes, one for each area previously exposed.	Always separate exposed and unexposed films.
Area of interest not shown.	Distal surface of the canine not visible on premolars films Third molar region is not visible on molars films.	Incorrect anteroposterior film placement. 1. The film was positioned too far posterior 2. The film was positioned too far anterior. This is the result of not placing the film to cover all the teeth in the area of interest and not centralizing the film over the area of interest.	Make sure the anterior edge of premolars films is positioned at the midline of the canine. Make sure the anterior edge of molars films is positioned at the midline of the second premolar, even when no erupted third molars are present.
Reversed film.	A light image with a herringbone pattern or tire-track, appearance of the film.	The film is exposed from non-exposed side. The X-ray beam is attenuated by the lead foil backing in the film packet.	Always note the front and the back sides of the film before placing it in the patient's mouth. Always place the white side of the film adjacent to the teeth.

Dot artifact.	Circular radiolucent artifact interferes with radiographic interpretation.	Improper placement of the dot coronally.	Bisecting technique: place the dot towards the occlusal surface. Parallel technique: place the dot in the slot.

$A = \pi r^2$

C. Film Handling Errors:

Error	Appearance	Problem/ Cause	Solution/ Correction
Film bending	Images are stretched and distorted.	Film was bent excessively due to the curvature of the hard palate or heavy finger pressure on the film. Bending of the film to eliminate patient's discomfort especially in the lower premolars and upper central incisors.	Cotton rolls can be placed between the film and the palate Instruct the patient to stabilize the film gently Film holding devices are helpful.
Film creasing	Thin radiolucent line. Crescent shaped black lines:	Due to excessive bending of the film prior to its placement inside the patient's mouth. Pressure causes ionization of silver halide upon processing will be darker. Film was creased and emulsion was cracked.	Do not bend or crease the film excessively. Gently soften the corners of the film before placing in the patient's mouth.

϶

D. PID Alignment Errors:

Error	Appearance	Problem/ Cause	Solution/ Correction
Cone cut with film holder.	A clear unexposed area appears on film.	X-ray beam did not expose the entire film because the PID was not properly aligned with the periapical film holder.	Make sure the PID is properly aligned with the film holder and the x-ray beam is centered over the film If aiming ring is used, make sure the PID and aiming ring are properly aligned.

Cone cut without film holder.	A clear unexposed area appears on film.	PID was not directed at the center of the film.	Make sure the x-ray beam is centered over the film.
Incorrect horizontal angulation.	Overlapped contacts	Central ray was not directed through the interproximal spaces	Direct the x-ray beam through the interproximal regions.
Foreshortened image.	Short teeth with blunted roots	Steep vertical angulation. Occurs with bisecting technique.	Do not use excessive vertical angulation with the bisecting technique Using Rinn instruments minimizes this error.
Elongated image.	Long distorted teeth	Vertical angulation was too flat Occurs with bisecting technique.	Use adequate vertical angulation with the bisecting technique. Using Rinn instruments minimizes this error.
Negative angulation in Bitewings.	Radiograph shows the roots of the lower teeth and the occlusal surface of the upper teeth.	Negative vertical angulation.	Always use a +10 vertical angulation to compensate for the slight tilt of the upper teeth and the slight lingual bend of the upper half of the film caused by the hard palate

Exposure Errors:

Error	Appearance	Problem/ Cause	Solution/ Correction
Unexposed film.	Clear film.	1. Failure to turn on the x-ray machine. 2. Electrical failure. 3. Malfunction of the x-ray machine.	Make sure the x-ray machine is turned on and listen to the audible exposure signal.
Film exposed to light.	Black.	Film was accidently exposed to white light.	1. Do not unwrap the film in a room with white light. 2. Check the darkroom for possible light leaks. 3. Turn off all lights in the darkroom (except for the safelight) before unwrapping the film.

Overexposed film	Dark image	Excessive exposure time, kilovoltage, milliamperage, or a combination of these factors.	Check the exposure time, kilovoltage and milliamperage settings on the x-ray machine before exposing the film.
Underexposed film	Light image	Inadequate exposure time, kilovoltage, milliamperage, or a combination of these factors.	Check the exposure time, kilovoltage and milliamperage settings on the x-ray machine before exposing the film.

ϪΣ

Exposure errors with intensifying screen:

Error	Appearance	Problem/ Cause	Solution/ Correction
Cracked intensifying screen.	Crescent shaped white lines:	During exposure to x-rays, an irregular light emission results where the screen is damaged.	It is extremely important that phosphor layer not change in thickness, crack, or discolor with age.
The debris on the screen.	Radiopaque artifacts	Any foreign material caught in the cassette between the intensifying screen and the film will alter the exposure to the film and cause radiographic errors.	The need for subsequent screen cleaning.

@

Processing Errors:

A. Time and temperature problems:

Error	Appearance	Problem	Solution
Underdeveloped film.	Light	1. Inadequate development time. 2. Developer solution too cool. 3. Inaccurate timer or thermometer. 4. Depleted developer solution.	1. Check development time. 2. Check developer temperature. 3. Replace faulty timer or thermometer. 4. Replenish developer with fresh solutions as needed.
Overdeveloped	Dark	1. Excessive developing time.	1. Check development time.

film.		2. Developer solution too hot. 3. Inaccurate timer or thermometer. 4. Concentrated developer solution.	2. Check development temperature. 3. Replace faulty timer or thermometer. 4. Replenish developer with fresh solutions as needed.
Emulsion Reticulation.	Cracked emulsion.	The emulsion contracts with time when subjected to great and sudden changes in temperature between developer and water bath.	1. Check temperature of processing solutions and water bath. 2. Avoid drastic temperature changes (difference of at least 15 degrees) between the different processing solutions.

ɣ

B. Chemical contamination problems:

Error	Appearance	Problem	Solution
Developer spots.	Radiolucent (Dark) spots.	Developer comes in contact with film before processing.	Use a clean work area in the dark room.
Fixer spots.	White spots.	Fixer comes in contact with film before processing.	Use a clean work area in the dark room.
Yellow brown stains.	Yellow brown color.	1. Exhausted developer or fixer. 2. Insufficient fixation time. 3. Insufficient washing.	1. Replenish chemicals with fresh solutions as needed. 2. Use adequate fixation time. 3. Wash for a minimum of 20 minutes.

〉

C. Film handling problems:

Error	Appearance	Problem	Solution
Developer cut off.	Straight white border.	Undeveloped portion of film due to; low level of developer or incomplete immersion of film in developer.	Check developer level before processing.

Fixer cut off.	Straight black border.	Unfixed portion of film due to low level of fixer.	Check fixer level before processing.
Overlapped films.	White or dark areas appear on film where overlapped.	Two films contacting each other during processing.	Separate films so that no contact takes place during processing.
Air bubbles.	White (Clear) spots.	Air trapped on film surface after being placed in the processing solutions.	Gently agitate film racks after placing in processing solutions.
Fingernail artifact.	Black crescent shaped marks.	Film emulsion damaged by operator's fingernail during rough handling.	Gently handle films by the edges only.
Fingerprint artifact.	Black fingerprint.	Film touched by fingers that are contaminated with fluoride or developer.	Wash and dry hands thoroughly before processing.
Static electricity.	Thin black branching lines.	1. Occurs when a film packet is opened quickly. 2. Occurs when a film packet is opened before the radiographer touches a conductive object. 3. Films forcibly unwrapped or excessive flexing of film. Seen more often in dry, hot environment. Black "lightning" marks.	Open film packets slowly. Touch a conductive object before unwrapping film.
Scratched film.	White lines.	The soft emulsion during processing removed from film by a sharp object. Long fingernails, careless handling during manual processing, wet films touching other films while being processed or drying.	Use care when handling films and film racks.
Developer	Dark	Developer comes in contact with film before processing.	Use a clean work area in the dark room.

spots.	(Radiolucent) spots.		
Fixer spots.	White spots.	Fixer comes in contact with film before processing.	Use a clean work area in the dark room.
Yellow brown stains.	Yellow brown color.	1. Exhausted developer or fixer. 2. Insufficient fixation time. 3. Insufficient washing.	1. Replenish chemicals with fresh solutions as needed. 2. Use adequate fixation time. 3. Wash for a minimum of 20 minutes.

D. Lighting problems:

Error	Appearance	Problem	Solution
Light leak.	Exposed area appears black.	Accidental exposure of the film to white light.	1. Examine film packets for defects before using. 2. Never unwrap films in the presence of white light.
	Completely Black film.	Completely exposed to light.	1. Examine film packets for defects before using. 2. Never unwrap films in the presence of white light.
	Black on one side of the film.	Hands taken out of automatic processor too soon.	Use care when handling films and check time.
Fogged film.	Gray film with lack (loss) of detail and contrast.	1. Improper safe lighting. 2. Light leaks in dark room. 3. Outdated films. 4. Improper film storage. 5. Contaminated solutions. 6. Developer solution too hot. 7. Exhausted fixer. 8. Insufficient time in fixer solution.	1. Check the filter and bulb wattage of the safe light. 2. Check the dark room for light leaks. 3. Check the expiration date on film packages. 4. Store films in a cool dry protected area. 5. Avoid contaminated solutions by covering tanks after each use. 6. Check temperature of developer.

⇨

Some Miscellaneous Processing Errors on radiographic Film:

Error	Appearance	Problem	Solution
	Completely clear film:	1. Machine not switched on. 2. Malfunction of machine. 3. Placing film in fixer before developer solution. 4. Film not exposed.	
	Streaks:	1. Improper washing of film hanger. 2. Dirty rollers. 3. Heating pad in automatic processor not functioning.	
	Black spots	Dirt in the duplicating machine (developer drops will be dark).	
	Radiolucent spots: Small, round, irregular, dark dots similar to static electricity:	Marks due to powder from gloves.	
	Clear spots	1. Air bubbles sticking to film during processing. 2. Fixer splashed on film prior to developing. 3. Dirt in the intensifying screens.	
	Brown film	1. With time the film will go brown if not left in fixer solution or water bath (final wash) for the required amount of time with manual processing. 2. Also with exhausted fixer solution with automatic processing. When the radiograph is initially processed it will appear "normal".	

Lecture 11 Dental Digital Imaging

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

Digital radiography in dentistry:

The term digital imaging refers to the numeric format of the image content. Digital radiography is unlike conventional dental radiography, in digital radiography no films or processing chemicals is used, instead digital radiography uses an electronic sensor and computerized imaging system.

Definitions:

Charge coupled device (CCD): A solid-state detector used in many devices (e.g., fax machine, home video camera); in digital radiography, a CCD is an image receptor found in the intraoral sensor.

Digital radiography: A filmless imaging system, a method of capturing a radiographic image using a sensor, breaking the image into electronic pieces, and presenting and storing the image using a computer.

Pixel: A discrete unit of information; a picture element.

Sensor: a small detector that is placed intraorally to capture a radiographic image.

Purpose and use:

1. To generate image used in diagnosis and assessment of dental disease.
2. To obtain information about the teeth and supporting structures.

More about the uses:

1. To detect lesions, disease, condition of teeth and surrounding structures.
2. To confirm or classify suspected disease.
3. To provide information during dental procedures (e.g. root canal therapy and surgical placement of implants).
4. To evaluate growth and development.

Fundamentals:

- Digital radiography refers to a method of capturing a radiographic image using a sensor.
- In digital radiography the patient is exposed to X-radiation similar to that used in conventional radiography.
- The resulting image is displayed on a computer screen rather than on a film that must be processed in a darkroom.

Components of a digital radiographic system:

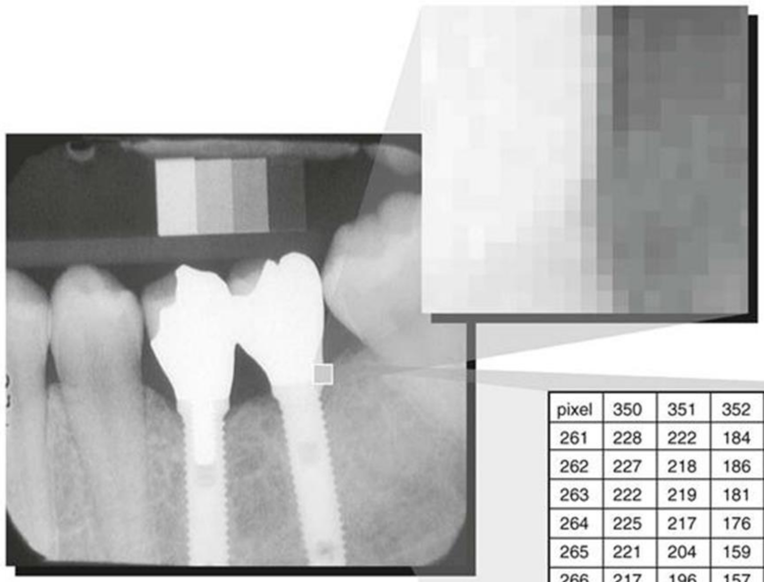
1. **X-ray source:** Always the conventional X-ray source can be used for digital imaging system. However, the x-ray unit timer must be adapted to allow exposures in a time frame of 1/100 of a second. A standard X-ray unit that is adapted for digital radiography can be functional for conventional radiography.
2. **Intraoral sensor:** The sensor is a small detector that is placed in the mouth of the patient and used to capture the radiographic image. It measures the photon intensity of the x-ray beam and convert it into electrical signal (analog signal) using analog-to-digital converter (ADC) or digitizer that based on the binary number system recognizable by the computer. **Intraoral sensors may be wired or wireless.** Wired refers that the sensor is linked by a fiber optic cable to a computer that records the generated signal. Wireless refers to a sensor that is a phosphor coated, it is not linked by a capable.
3. **Data processing unit:** It is consisting of computer and output device as computer monitor, laptop or flat panel, printer.

Digital Image theory:

A computer is used to store the incoming electronic signal. The computer is responsible for converting the electronic signal from the sensor into a shade of gray that is viewed on the computer monitor. Each pixel is represented numerically in the computer by location and level of color of gray. Digital images are numeric (because computers deal with numbers and not pictures). A digital image consists of a large collection of individual pixels organized in a matrix of rows and columns. At each pixel of an electronic detector, the absorption of x-rays generates a small voltage.

As a radiographic image within a computer is represented as a sequence of numbers. Each pixel has an x and y axis. Each number, and hence each pixel has an appropriate shade of grey.

Most current dental system operates with an 8-bit scale (2^8 shades of grey) which means that all images were converted into a smaller range pixel gray scale, containing 256 shades of grey (referred to as a pixel's gray scale resolution), 0 representing black, 255 representing white and all others are different shades of grey (In between 0 and 255, there are different shades of gray, with varying intensity). The computer digitizes, processes and stores information received from the sensor. An image is recorded on a computer monitor in (0.5 to 120) seconds. The image may be stored permanently in the computer, printed on a hard copy for the patient record (fig. 1).



pixel	350	351	352	353	354	355	356	357
261	228	222	184	107	76	92	90	98
262	227	218	186	110	90	104	103	98
263	222	219	181	107	97	107	102	104
264	225	217	176	107	98	100	100	107
265	221	204	159	107	105	101	107	102
266	217	196	157	114	105	104	106	100
267	209	190	154	114	107	103	97	100
268	202	195	166	118	102	102	92	94
269	197	196	168	122	98	102	90	94
270	195	190	166	130	104	105	92	97
271	199	190	172	144	111	107	100	106
272	201	193	177	160	120	103	112	106
273	203	195	181	166	129	102	111	106
274	201	200	186	172	133	110	112	102

Figure 1 .A digital image is made up of a large number of discrete picture elements (pixels). The size of the pixels is so small that the image appears smooth at normal magnification. The location of each pixel is uniquely identified by a row and column coordinate within the image matrix. The value assigned to a pixel represents the intensity (gray level) of the image at that location.

Digital image manipulation and viewing:

The coordinates of pixels may be changed also, and the pictures can be changed by giving the pixels different numbers (the shades of grey will be altered) or using different colors. These variables are the basis for what is called image processing or image manipulation (fig. 2).

Despite being able to alter the final image, the computer cannot provide any additional real information to the original image. It should be remembered that although enhancement may make images look aesthetically more pleasing, it may also cause clinical information to be lost and diagnoses compromised.

There are many viewing features such as split screen technology that allows the operator to view and compare multiple image on the same screen for comparison and evaluation of disease progression. Another viewing feature allows specific images to magnify up to 4 times their original size for evaluation of apical area of a tooth. Linear and angular measurements can be also be obtained a features that is helpful in measuring the length of the root.

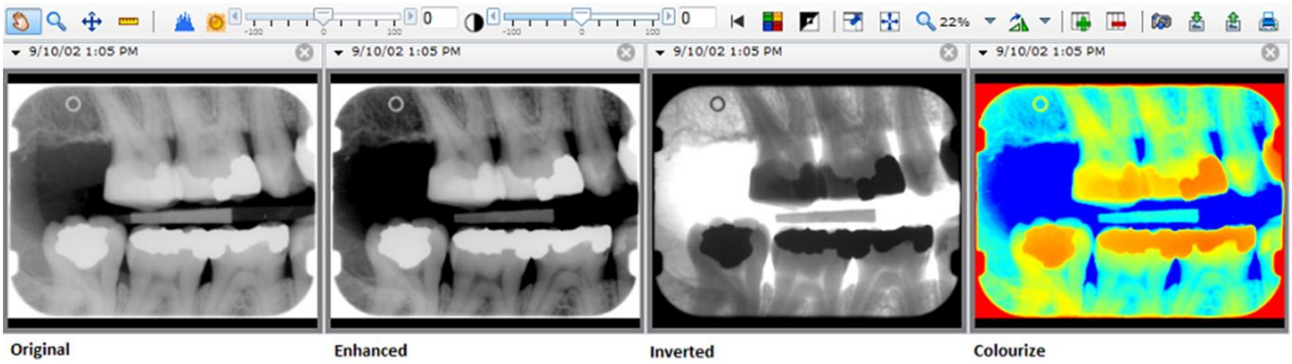


Figure 2. Digital image enhancement and processing. Digital Imaging offers all the tools essential for improving the quality and diagnostic value of acquired digital radiographs. Images can be zoomed to view specific features in more detail. A measurement tool is available to measure distances between any number of points based on an image calibration, and an angle measurement tool is supplied to measure any number of angles.

Digital Image Receptors:

Digital image receptors encompass numerous different technologies and come in many different sizes and shapes. Numerous different and sometimes confusing names are in use to identify these receptors in medicine and dentistry.

The most useful distinction is that between two main technologies: (1) solid-state technology and (2) photostimulable phosphor (PSP) technology. Although solid-state detectors can be subdivided further, these detectors have in common certain physical properties and the ability to generate a digital image in the computer without any other external device.

In medicine, the use of solid-state detectors is referred to as **digital radiography**. In dentistry, intraoral solid-state detectors are often called sensors. The other main technology is PSP; consists of a phosphor-coated plate in which a latent image is formed after x-ray exposure. The latent image is converted to a digital image by a scanning device through stimulation by laser light. This technology is sometimes referred to as storage phosphor on the basis of the notion that the image information is temporarily stored within the phosphor. Other times the term image plates; which is used to differentiate them from film and solid-state detectors. The use of PSP plates in medical radiology is referred to as computed radiography (CR).

Solid-State Detectors:

Solid-state detectors collect the charge generated by X-rays in a solid semiconducting material. The key clinical feature of these detectors is the rapid availability of the image after exposure. The matrix and its associated readout and amplifying electronics of intraoral detectors are enclosed within a plastic housing to protect them from the oral environment (Fig. 3).

These elements of the detector consume part of the real estate of the sensor so that the active area of the sensor is smaller than its total surface area. Sensor bulk, although reduced by continued miniaturization of the electronic components, is a potential drawback of intraoral solid-state detectors.

In addition, most detectors incorporate an electronic cable to transfer data to the computer. The presence of a cable (1) can make positioning of the sensor more challenging and requires some adaptation. It also (2) results in increased vulnerability of the device. Manufacturers have addressed these issues in various ways. (1) Some manufacturers have changed the location of the cable attachment to the corner of the sensor. (2) Others offer sensors with magnetic connectors, induction connectors, or reinforced cables to reduce accidental damage to the device. (3) Wireless radiofrequency transmission also has been introduced to eliminate the cable altogether. Wireless radiofrequency transmission frees the detector from a direct tether to the computer, but it necessitates some additional electronic components, thus increasing the overall bulk of the sensor.

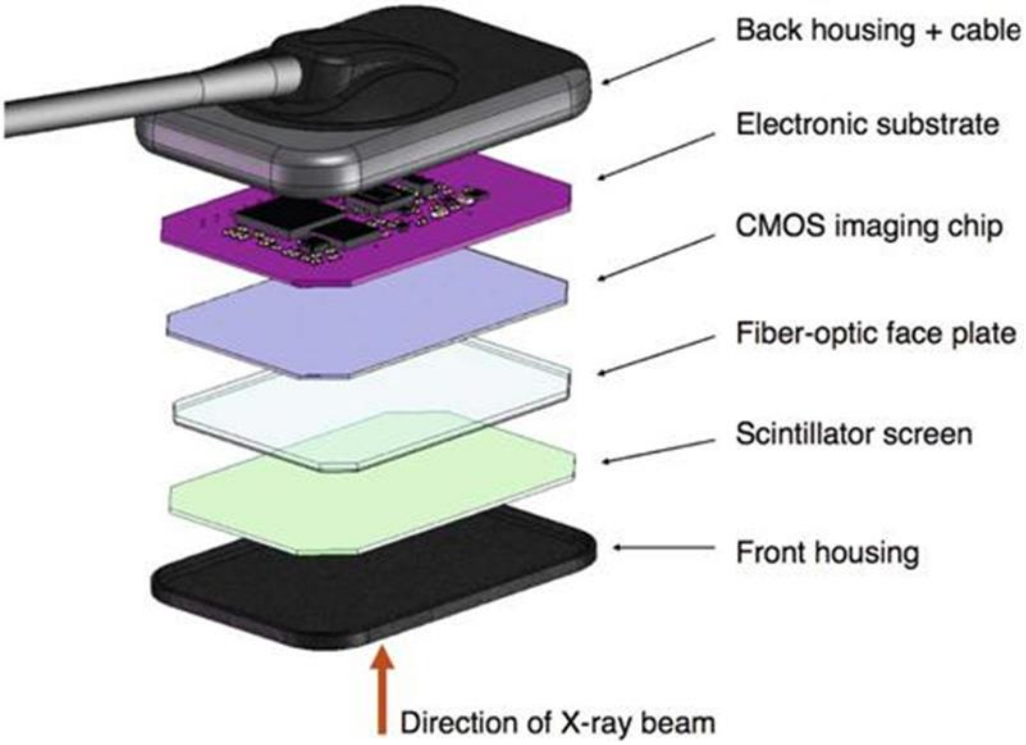


Figure 3. Exploded view of CMOS sensor. The front and back housings form a watertight and light-tight barrier to protect the sensor components. The scintillator screen fluoresces when exposed to x-rays and forms a visible light radiographic image. The fiberoptic face plate couples the scintillator screen to the CMOS chip to reduce image noise. The CMOS imaging chip captures the light from the scintillator and creates a charge in each pixel proportional to the exposure. The sensor electronics read the charge in each pixel and transmits it to a computer.

Many manufacturers produce detectors with varying active sensor areas roughly corresponding to the different sizes of intraoral film. Detectors without flaws are relatively expensive to produce, and the expense of the detector increases with increasing matrix size (total number of pixels). Pixel size ranges from less than 20 to 70 micrometers (µm).

Specially designed intraoral sensor holders similar to those used for conventional film, have been developed. When used clinically, the sensors need to be covered with a protective plastic barrier housing for infection control purposes (see L4, pages 5, 6, 20 and 21). Different sized intraoral receptor (adult size and small size sensor for children) and larger extraoral receptors for both panoramic and cephalometric radiographs are required.

Two methods of acquiring digital image:

1. **Direct digital imaging (solid-state technology):**
2. **Indirect digital imaging (PSP technology):**

Three types of solid-state sensors are in common use.

A. The CCD:

It is the most common image receptor used in dental digital radiography. The CCD is a solid state detector that contains a silicon chip with an electronic circuit embedded in it. CCD is an image sensor consisting of an array of linked, or coupled, light-sensitive capacitors built on an amorphous silicon layer. A pixel is a small box into which the electrons produced after the X-ray exposure are deposited. CCDs are generally used with indirect conversion devices. The image is read out sequentially by shifting an entire readout row of charges down into a readout buffer. When a row is moved into the readout buffer all the rows above are moved down as well. The row number gives the y coordinate. To obtain the x coordinate, the row is sampled by shifting each charge out of the readout buffer into the detection electronics, one element at a time (Fig 4).

A pixel is the digital equivalent of a silver crystal used in conventional radiography. As opposed to a film emulsion that contains a random arrangement of silver crystals, a pixel is structured in an ordered arrangement. When X-rays activate electrons and produce such electronic charges, an electronic latent image is produced, the latent image is then transmitted and stored in a computer and can be converted to a visible image on screen or printed on paper.

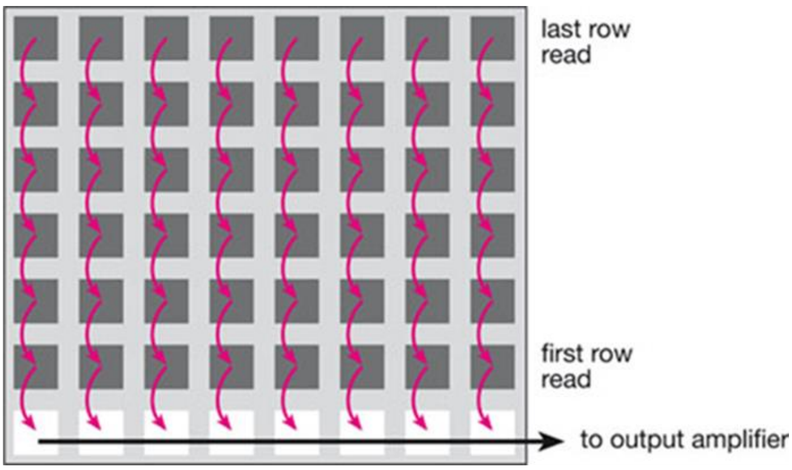


Figure 4. Schematic of the readout process of a CCD sensor.

B. Complementary Metal Oxide Semiconductors (CMOS):

These detectors are also silicon-based semiconductors but are fundamentally different from CCDs in the way that pixel charges are read. Each pixel is isolated from its neighboring pixels and is directly connected to a transistor. Similar to the CCD, electron-hole pairs are generated within the pixel in proportion to the amount of x-ray energy that is absorbed. This charge is transferred to the transistor as a small voltage. The voltage in each transistor can be addressed separately, read by a frame grabber, and stored and displayed as a digital gray value. The technology is less expensive than that used in the manufacturing of CCDs. Several manufacturers are using this technology for intraoral imaging applications (Fig. 5).

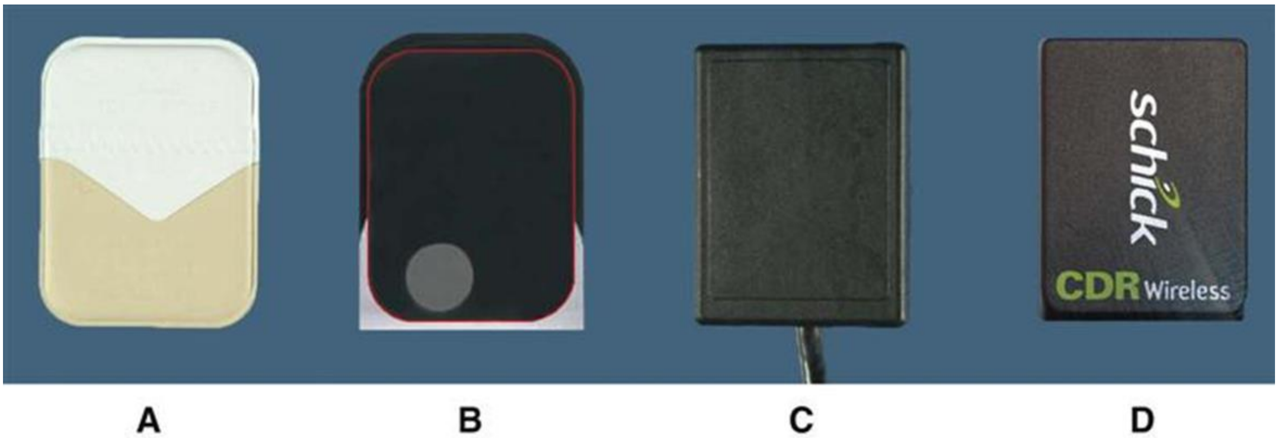


Figure 5. A, Kodak No. 2 film. B, Soredex No. 2 PSP plate (outlined in red) placed on a barrier envelope to demonstrate packaged size. C, Gendex No. 2 CCD sensor. D, Schick No. 2 CMOS wireless sensor.

C. *Flat Panel Detectors:*

Flat panel detectors are used for medical imaging but have also been used in several extraoral imaging devices. The detectors can provide relatively large matrix areas with pixel sizes less than 100 µm; this allows direct digital imaging of larger areas of the body, including the head.

Advantages of CCD and COMS:

1. The image appears on the monitor instantaneously.
2. Infection control is easier and quicker.

PSP technology:

What Does Indirect Digital Radiography Mean?

To some the term **"indirect digital imaging"** means digitizing a conventional radiograph using a flatbed scanner with a transparency adaptor. In this LECTURE, the term is used for images acquired using a photostimulable phosphor plate (PSP).

With these systems, once the PSP has been exposed, the sensor has to be scanned by a laser before the image can be displayed. As there is this additional scanning process, these systems are referred to as indirect digital systems.

Principles of indirect digital radiography:

This technology consists of a phosphor-coated plate in which a latent image is formed after x-ray exposure. The latent image is converted indirectly to a digital image by a scanning device through stimulation by laser light.

Construction of the PSP:

The PSP is similar for all systems and comprises:

1) A phosphor layer.
2) A reflective layer.
3) An electroconductive layer.
4) A polyester or polyethylene base layer.
5) A light-shielding layer.
6) Protective layers.

A cross section of a PSP illustrating these layers and their functions is shown in Fig 6. A PSP will last for several thousand exposures, so long as it remains undamaged and free of scratches.

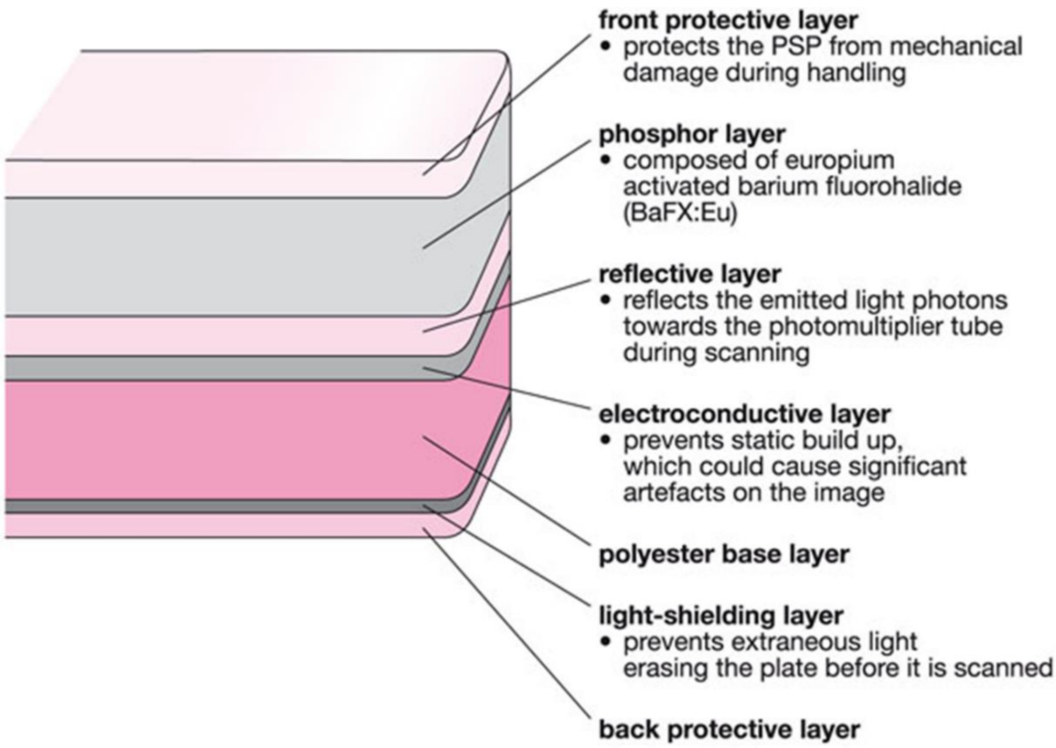


Figure 6. Cross section through a typical PSP showing the layers and their functions.

When they are manufactured in standard intraoral sizes, A range of intraoral plate sizes are available identical in size to the conventional periapical and occlusal film packet. These plates provide handling characteristics similar to intraoral film. PSP plates are also made in sizes commonly used for panoramic and cephalometric imaging. Some PSP processors accommodate a full range of intraoral and extraoral plate sizes. Other processors are limited to intraoral or extraoral formats.

The intraoral plates are inserted into protective barrier envelopes and can then be used in conventional film holders. The essential components of the indirect system are a CCD camera so the signal amplified and transferred to the computer.

Interaction of the phosphor layer with x-radiation:

When a PSP sensor exposed to X-ray photons, photoelectric interactions within the phosphor layer produce photoelectrons, which remove electrons from the europium activator. These electrons become trapped within fluorohalides at sites known as “F centers”, leaving “holes” at the original europium sites. Some of the electrons drop back almost immediately, but importantly, the remaining electrons stay trapped within the F centers (fig. 7).

The number of trapped electrons at any particular point on the PSP is proportional to the original number of X-ray photons incident on that part of the sensor, thus producing a latent image.

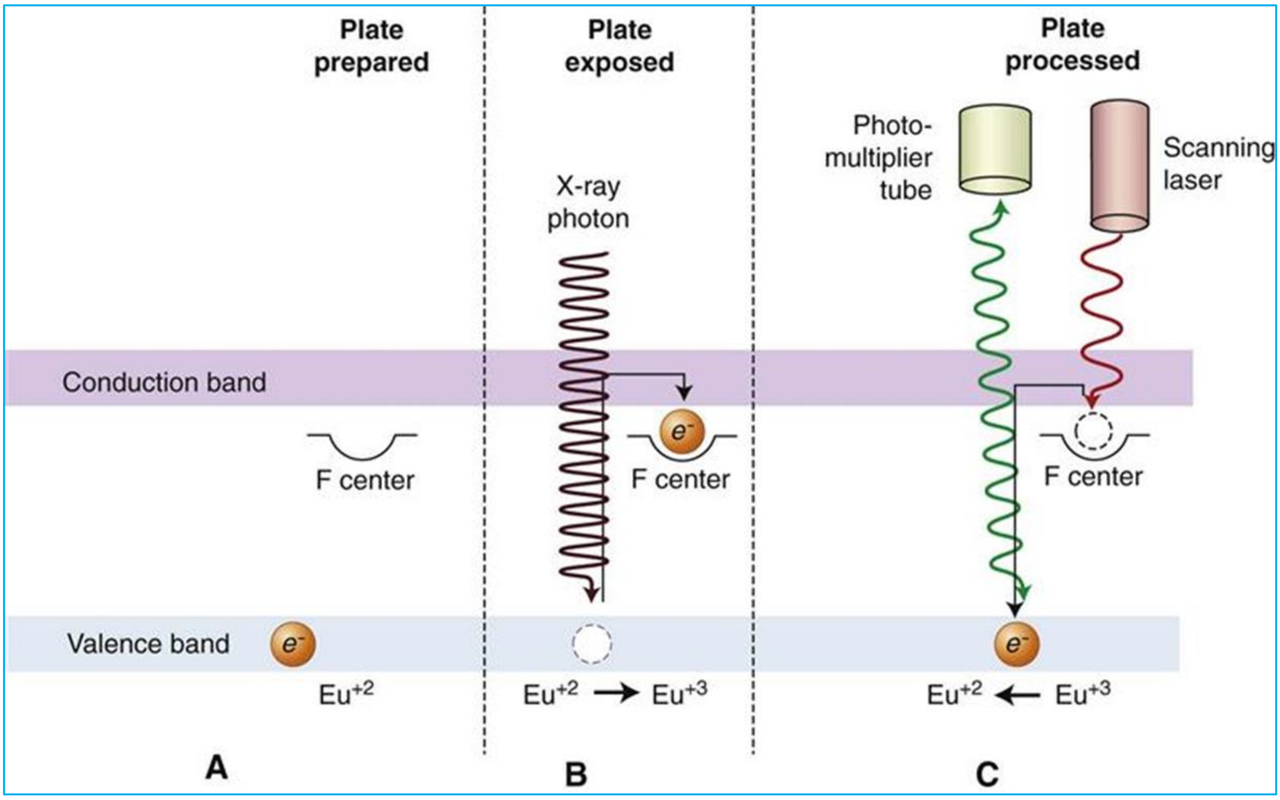


Figure 7. PSP image formation. (A) Initially, the PSP plate is flooded with white light to return all electrons to the valence band. (B) Exposure to x rays imparts energy to europium valence electrons, moving them into the conduction band. Some electrons become trapped at "F centers." (C) A red scanning laser imparts energy to electrons at the F centers, promoting them to the conduction band from which many return to the valence band. With the electron's return to the valence band, energy is released in the form of light photons in the green spectrum. This light is detected by a PMT or diode with a red filter to screen out the scanning laser light.

Scanning the PSP and displaying the image:

The PSP with the stored latent image is scanned immediately using a thin red helium–neon laser beam (Fig. 8). The laser energy causes the electrons to fall back into the europium holes, emitting light from the blue part of the visible spectrum. This process is known as "photostimulable luminance".

The blue light is detected by a photomultiplier tube (PMT). The PMT produces an amplified voltage proportional to the original light received. The voltage is converted into a digital signal by an ADC. The ADC may have an output as high as 32 bits, which corresponds to over 4 billion grey level values. Because the human eye cannot perceive this many grey levels, the image is normally displayed with 256 shades of grey (8 bits).

Scanning times vary between systems. The time taken to read the plate depends on:

1) The system being used.
2) The scanning resolution selected.
3) The size of the sensor being scanned and the number of sensors that require scanning.

Scanning times may be as short as 10 seconds for a single intraoral sensor, but for a "high-resolution" panoramic image it may be as long as 5 minutes. In general scanning times usually varies (1-5) minutes.

Erasing the PSP:

Before exposure; PSP plates must be erased to eliminate residual images from prior exposures (Fig. 8). This is because some of the electrons still remain within the F centers. This erasure is accomplished by flooding the plate with a **bright light**; this is done by placing plates on a dental view box with the phosphor side of the plates facing the light for 1 or 2 minutes. More intense light sources can be used for shorter periods of time. The PSP may also be erased using the manufacturer's dedicated erasure system where some PSP systems integrate automatic plate-erasing lights. Erased plates are placed in **light-tight containers** before exposure.

Inadequate plate erasure results in **double images** and usually renders the image undiagnostic.

In the case of intraoral plates, **sealable polyvinyl envelopes** that are impervious to oral fluids and light are used for packaging. For large-format plates, **conventional cassettes** without intensifying screens are used.

After exposure, plates should be processed as soon as possible because trapped electrons spontaneously release over time. The rate of loss of electrons is greatest shortly after exposure. The rate varies depending on the composition of the storage phosphor and the environmental temperature. **Some phosphors lose 23% of their trapped electrons after 30 minutes and 30% after 1 hour.** Because loss of trapped electrons is uniform across the plate surface, early loss of charge does not typically result in clinically meaningful image deterioration. However, **underexposed images** may have noticeable image degradation. Adequately exposed images may be stored for 12 to 24 hours and retain acceptable image quality.

A more important source of latent image fading is exposure to ambient light during plate preparation for processing. A semidark environment is recommended for plate handling. The more intense the background light and the longer the exposure of the plate to this light, the greater the loss of trapped electrons and the more degraded the resultant image. **Red safelights** found in most darkrooms are not safe for exposed PSP plates, which are most sensitive to the red light spectrum.

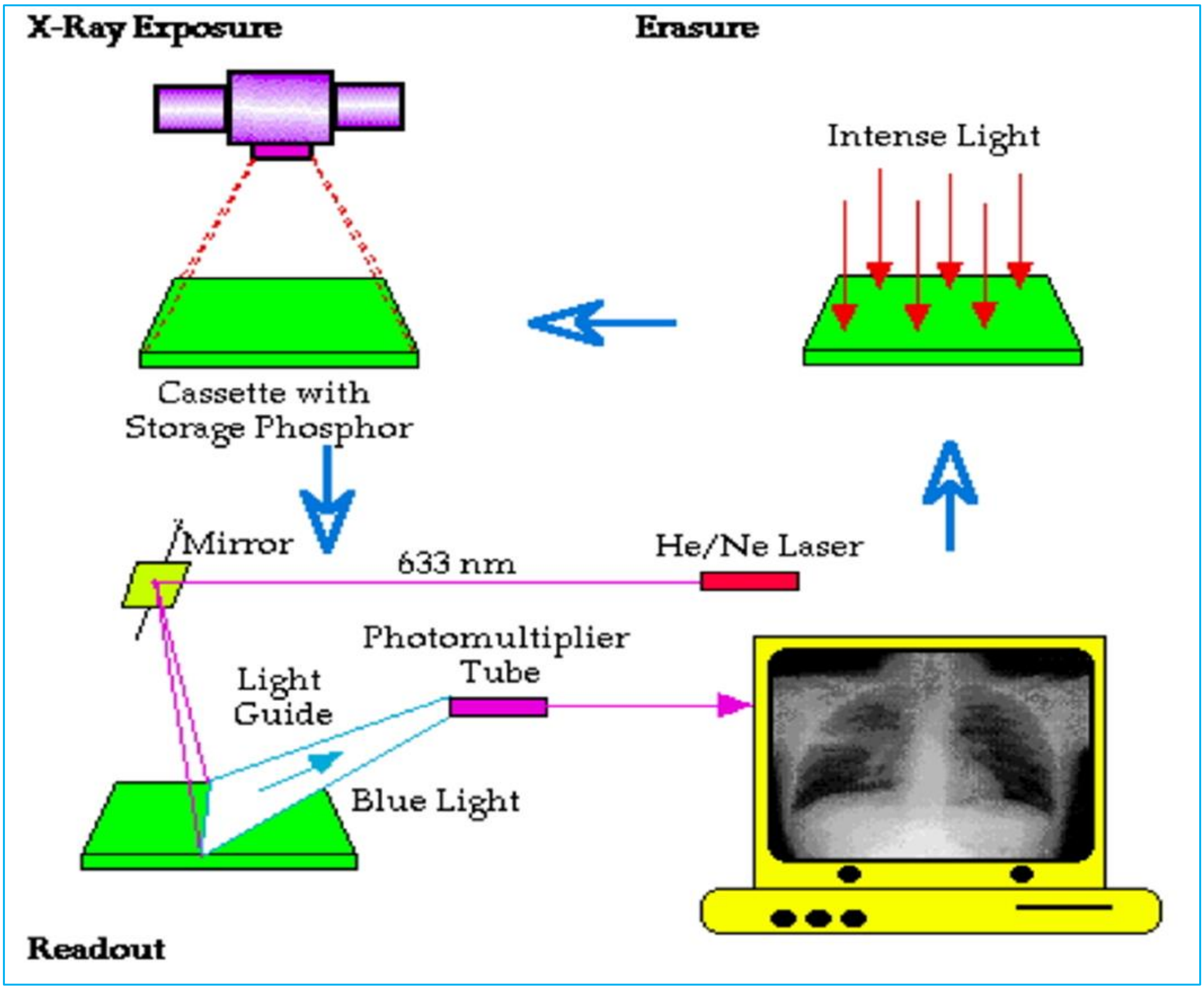


Figure 8. Illustration of the complete CR imaging process.

Advantages of PSP plate:

1. Detectors are thin and flexible, more comfortable for the patient, and easier for operator to use.
2. Cheaper and reusable.

Advantages of digital imaging over conventional film-based radiography:

1. Lower dose of radiation required as both types of digital image receptors are much more efficient at recording photon energy than conventional films.
2. No need for conventional processing, thus avoiding all processing film faults and the hazards associated with handling the chemical solutions.
3. Easy storage and archiving of patient information.
4. Easy transfer of images electronically (teleradiology) and time reduction.
5. Image enhancement and processing which include:
    a. Inversion (reversal),
    b. Alteration in contrast, brightness, sharpness, and colors (Pseudo-color)
    c. Embossing or pseudo 3-D,
    d. Magnification,
    e. Automated measurement,
    f. Image subtraction.

Digital image subtraction:

When two images of the same object are registered and the image intensities of corresponding pixels are subtracted, a new difference image is produced. This technique requires two identical images exposed at different times then subtract one image from another, leaving only the changes that occur over time between the two intact (Fig. 9).

It is useful in the diagnosis of (periodontal diseases, carious lesions, evaluation of small changes in the condylar position and assessment of dental implant).

Figure 9. Example of ideal digital subtraction radiography. (A), at a lesion. (C), the lesion itself, made more noticeable by the removal of anatomical initial radiograph. (B), second radiograph obtained a few weeks later. The arrow is pointing noise from the image.

Disadvantages of Digital Imaging:

1. Expensive, especially panoramic systems.
2. Long-term storage of the large images required more storage space although this should be solved by saving them on CD-ROM.
3. Digital image security and the need to back up data.
4. The connecting cable (or cord) can make intraoral placement of these system's sensor difficult.
5. Loss of image quality and resolution on the hard copy-out when using thermal, laser or ink-jet printers.
6. Image manipulation can be time-consuming and misleading to the inexperienced.
7. Although manufacturers provide safeguards to the original images within their own software, but it is relatively easy to access these images using cheap software and to change them.

Indications:

1. Carious lesion detection: it measures lesion depth more accurately.
2. Detection of structural changes: detection of morphological changes (periapical lesions, carious lesions) in the tissues.
3. Growth and development: useful in cephalometric analysis and growth prediction of the facial structures.
4. Research purpose and documentation: useful for a variety of scientific research approaches giving pure mathematical information applied for scientific purposes.

Step by step procedure: **Sensor preparation:** The placement of the intraoral sensor in the mouth of patient is similar to the technique used in conventional film placement, but the number and size of the sensor vary with different manufactures, each sensor is sealed and water proofed and for infection control, the sensor must be covered with a disposable barrier because it cannot be sterilized.

Sensor placement: The sensor is held by bite block attachment or devices. The paralleling technique is the preferred exposure method because of dimensional accuracy of images and the ease of standardizing such images. Paralleling technique film holders must be used to stabilize to sensor in the mouth. As with conventional intraoral film, the sensor is centered over the area of interest. As in conventional radiography, the X-ray is aimed to strike the sensor. An electronic charge is produced on the surface of the sensor, this electronic signal is converted into digital form. The digital sensor in turn transmits this information to a computer then the image is processed by a computer and stored by the software.

Summary of solid-state technology:

Solid-state detectors collect the charge generated by X-rays in a solid semiconducting material. This technology have the ability to generate a digital image directly in the computer without any other external device uses conventional x-ray machine but conventional film is replaced by solid-state detector which is of two types either a CCD or CMOS. The X-ray photons that reach the sensor are converted to light, since it consists of silicon crystals arranged in a network pattern forming a pixel matrix and picked by the CCD/CMOS sensors and converted into an electrical charge which, once produces a digital image on the monitor of the computer which connected to it via a cable or cord (so called real time and corded).

CCD:

1) Used for intraoral periapical and bitewing imaging and for extraoral panoramic and skull views. The sensor is bulky and rigid.
2) Conversion method is indirect.
3) A cable transfers the data from the sensor to the computer (direct connectivity).
4) The sensor is made of silicon arranged in rows and columns in a matrix form.
5) Silicon is covered with a scintillation layer similar to rare-earth intensifying screens. Scintillation layer converts X-ray photons into light photons.
6) Light interacts with silicon via a photoelectric effect to form charge packets. Each charge packet corresponds to one pixel. The charge packets formed represent the latent image. Charge packets are transferred from one pixel to the adjacent pixel till it reaches the end of the row.

7) At the end of the row, an amplifier amplifies the signal then sends it to the ADC.

CMOS:

1) Similar in construction to CCDs. Conversion method is indirect.
2) The reading out mechanism is different than CCD. Each pixel is isolated from its neighboring pixel and directly connected to a transistor. The charge is transferred to the transistor and read out separately.

Summary of PSP:

1) Used for intraoral periapical, bitewing and occlusal imaging and for extra-oral lateral oblique jaw, panoramic and skull imaging.
2) Conversion method is direct. They absorb and store energy from x-rays and then release this energy as light when stimulated by other light of an appropriate wavelength i.e. not directly connected to the computer (indirect connectivity).
3) They consist of barium fluorohalide phosphor on a flexible plastic base. The phosphor layer absorbs and stores the X-ray energy (latent image). The imaging plate is then placed in a reader and scanned in a laser scanner where the stored X-ray energy is released as light (phosphorescence) which is detected by a PMT.
4) A PMT converts released light photons into electrical signals proportional to the quantity of light photons.

	Phosphor plates	vs	Digital sensors?
	Which digital imaging equipment is better?		
1.	Slight delays in developing images.	1.	Quicker to develop images.
2.	More affordable.	2.	Less affordable. Slightly more expensive.
3.	Can be easily replaced.	3.	Not easily replaced since it can require different manufacturers and sensors.
4.	Easier to use due to portability.	4.	Wired sensors are bulky, restrain movement, and are not easily portable.
5.	Plates can be digitized more easily.	5.	Images are not as easily digitized relative to phosphor plates.

Lecture 12 Normal Radiographic Anatomical Landmarks

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

A number of anatomic landmarks are visible in dental radiographs. Knowledge of the location and normal appearances of these landmarks is important in identification and orientation of radiographs.

This knowledge is valuable to the dental officer in determining whether the area is normal or abnormal.

Radiolucent vs. Radiopaque:

Structures that are cavities, depressions or openings in bone such as a sinus, fossa, canal or foramen will allow X-rays to penetrate through them and expose the receptor (dental film).These areas will appear radiolucent or black on radiographic images.

Structures that are bony in origin absorb or stop the penetration of the X-rays and, therefore, do not reach the receptor. These areas appear radiopaque or white on radiographic images. Some structures partially absorb radiation and are represented in varying degrees of radiopacity.

Normal Tooth Anatomy:

Landmarks common in maxilla and mandible:

Teeth: Consist of enamel and dentin. Enamel cap covers the coronal portion and cementum covers the root surface. Tooth structures that can be viewed on dental images include the following: enamel, dentin, the dentinoenamel junction, and the pulp cavity.

Enamel: Enamel is the densest structure found in the human body (92% mineralized). Enamel is the outermost radiopaque layer of the crown of a tooth.

Dentin is found beneath the enamel layer of a tooth and surrounds the pulp cavity. Dentin appears radiopaque and makes up the majority of the tooth structure. Less radio-opaque as compared to enamel and 65% mineralized.

Cementum: Radiopacity less than enamel but similar to dentin and 50% mineralized. Cementum is not usually apparent in radiograph because cementum layer is so thin.

Pulp: Consists of pulp chamber, root canals, pulp horns and apical foramina. It contains soft tissues, blood vessels, nerves and lymphatics. The pulp appears relatively radiolucent on a dental image.

The Dentinoenamel junction (DEJ) is the junction between the dentin and the enamel of a tooth. The DEJ appears as a line where the enamel (very radiopaque) meets the dentin (less radiopaque).

Lamina dura: Is the dense cortical bone of the tooth socket that surrounds the teeth.

Alveolar crest: It is the gingival margin of alveolar process. It is the most coronal portion of alveolar bone bellow the teeth covered with dense cortical bone.

Cancellous, trabecular or spongy bone: Lies bellow the cortical plates in both jaws and forms lattice like network of inter-communicating spaces filled with bone marrow (fig. 1).

Supporting Structures:

The alveolar process, or alveolar bone, serves as the supporting structure for teeth. The anatomic landmarks of the alveolar process include the **lamina dura, the alveolar crest, and the periodontal ligament space.**

The lamina dura is the wall of the tooth socket that surrounds the root of a tooth. The lamina dura is made up of dense cortical bone.

Radiographically: On a dental image, the lamina dura appears as a dense radiopaque line that surrounds the root of a tooth.

The alveolar crest is the most coronal portion of alveolar bone found between teeth. The alveolar crest is made up of dense cortical bone and is continuous with the lamina dura.

Radiographically: On a dental image, the alveolar crest appears radiopaque and is typically located 1.5 to 2.0 mm below the junction of the crown and the root surfaces (the cementoenamel junction).

The periodontal ligament space (PDL space) is the space between the root of the tooth and the lamina dura. The PDL space contains connective tissue fibers, blood vessels, and lymphatics.

Radiographically: On a dental image, the PDL space appears as a thin radiolucent line around the root of a tooth.

In the healthy periodontium, the PDL space appears as a continuous radiolucent line of uniform thickness (fig. 1).

Types of Bone:

The composition of bone in the human body can be described as either cortical or cancellous. Cortical bone, also referred to as compact bone, is the dense outer layer of bone.

Cancellous bone (also called trabecular bone) is the soft, spongy bone located between two layers of dense cortical bone. The trabeculae in the anterior maxilla are typically thin and numerous. In the posterior maxilla the trabecular pattern is usually quite similar to that in the anterior maxilla, although the marrow spaces may be slightly larger.

In the anterior mandible the trabeculae are somewhat thicker than in the maxilla, resulting in a coarser pattern, with trabecular plates that are oriented more horizontally

In the posterior mandible the periradicular trabeculae and marrow spaces may be comparable to those in the anterior mandible but are usually somewhat larger.

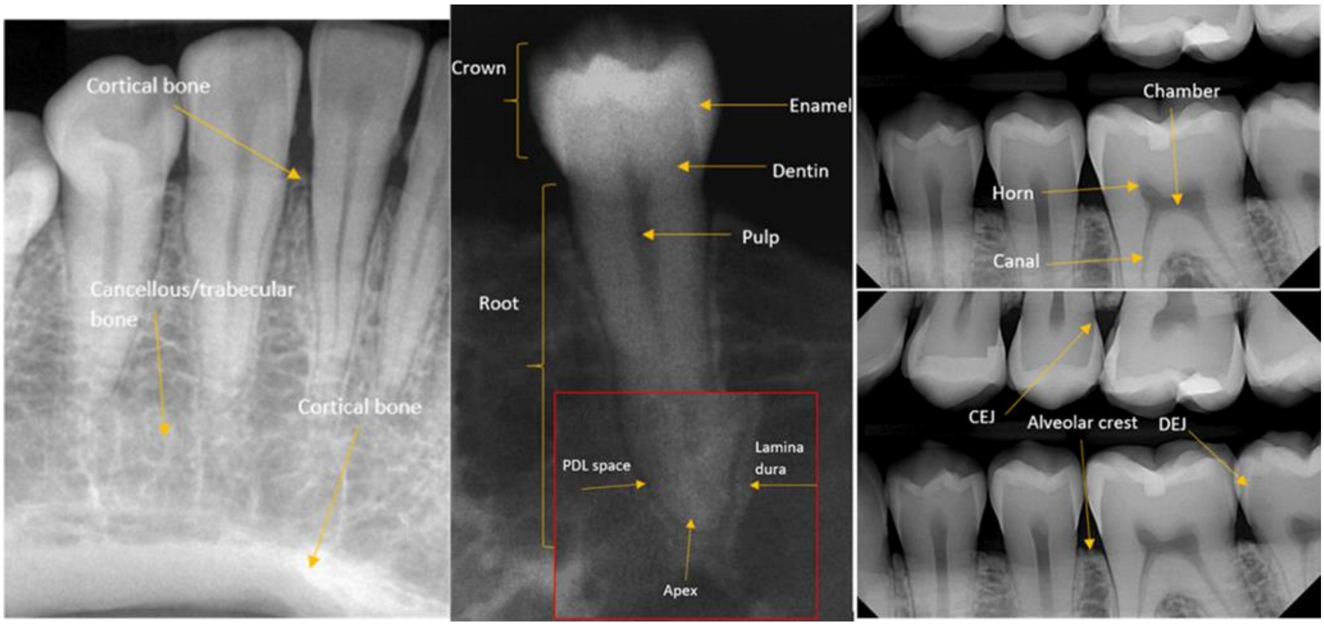


Figure 1. Radiographic appearance of normal anatomy of alveolar bone, teeth, and supporting structures.

Some terms of dental radiographs:

Prominences of bone: Prominences of bone are composed of dense cortical bone and appear radiopaque on dental images.

Process: A marked prominence or projection of bone; an example is the coronoid process of the mandible

Ridge: A linear prominence or projection of bone; an example is the external oblique ridge of the mandible.

Spine: A sharp, thorn-like projection of bone; an example is the anterior nasal spine.

Tuberosity: A rounded prominence of bone; an example is the maxillary tuberosity

Spaces and depressions in bone:

Spaces and depressions in bone do not resist the passage of the X-ray beam and appear radiolucent on dental images.

Four terms can be used to describe the spaces and depressions in bone viewed in maxillary and mandibular periapical images, as follows:

Canal: A tube like passageway through bone that contains nerves and blood vessels; an example is the mandibular canal

Foramen: An opening or hole in bone that permits the passage of nerves and blood vessels; an example is the mental foramen of the mandible.

Fossa: A broad, shallow, scooped-out or depressed area of bone; an example is the submandibular fossa of the mandible.

Sinus: A hollow space, cavity, or recess in bone; an example is the maxillary sinus.

Miscellaneous terms:

Two other general terms can be used to describe normal landmarks viewed on a dental image, as follows:

Septum: A bony wall or partition that divides two spaces or cavities. An example is the nasal septum.

Suture: An immovable joint that represents a line of union between adjoining bones of the skull. An example is the median palatine suture of the maxilla.

Normal anatomical landmarks:

Bony Landmarks of the Maxilla (fig. 2):

Incisive foramen: The incisive foramen (also known as the nasopalatine foramen) is a boney opening or hole located at the midline of the anterior portion of the hard palate. The nasopalatine nerve exits the maxilla through the incisive foramen.

Radiographically: On an anterior maxillary periapical image, the incisive foramen appears as a small, ovoid or round radiolucent area located between the roots of the maxillary central incisors.

Median palatal Suture: The median palatal suture is the immovable joint between the two palatine processes of the maxilla.

Radiographically: On an anterior maxillary periapical image, the median palatal suture appears as a thin radiolucent line between the maxillary central incisors.

Lateral fossa: The lateral fossa (also known as the canine fossa) is a smooth, depressed area of the maxilla located between maxillary canine and lateral incisors.

Radiographically: On an anterior maxillary periapical image, the lateral fossa appears as a radiolucent area between the maxillary canine and lateral incisor.

Nasal cavity: The nasal cavity (also known as the nasal fossa) is a pear-shaped compartment of bone located superior to the maxilla.

Radiographically: On an anterior maxillary periapical image, the nasal cavity appears as a large, radiolucent area superior to the maxillary incisors.

Nasal septum: The nasal septum is a vertical bony wall or partition that divides the nasal cavity into the right and left nasal fossae (fossae is the plural of fossa).

Radiographically: On an anterior maxillary periapical image, the nasal septum appears as a vertical radiopaque partition that divides the nasal cavity.

Floor of nasal cavity: The floor of the nasal cavity is a bony wall.

Radiographically: On an anterior maxillary periapical image, the floor of the nasal cavity appears as a dense radiopaque band of bone superior to the maxillary incisors.

Anterior nasal spine (ANS): The ANS is a bony sharp projection of the maxilla located at the base of the nasal septum in the maxillary midline.

Radiographically: The ANS appears as a V-shaped radiopaque area or triangular point radiopacity located at the intersection of the floor of the nasal cavity and the nasal septum. This structure is recorded on maxillary central incisor periapicals.

Maxillary sinus: A hollow space in the bones around the nose. There are two large maxillary sinuses, one in each of the maxillary bones, which are in the cheek area next to the nose.

Radiographically: On a posterior maxillary periapical image, the maxillary sinus appears as a radiolucent area located superior to the apices of maxillary premolars and molars.

Septa within maxillary sinus: Bony septa (septa is the plural of septum) may be seen within the maxillary sinus. Septa are bony walls or partitions that appear to divide the maxillary sinus into compartments.

Radiographically: On a posterior maxillary periapical image, the septa appear as radiopaque lines within the maxillary sinus.

Inverted Y: The term inverted Y refers to the intersection of the maxillary sinus and the nasal cavity as viewed on a dental image.

Radiographically: On a maxillary canine periapical image, the inverted Y appears as a radiopaque upside-down Y formed by the intersection of the lateral wall of the nasal **fossa** and the anterior border of the maxillary sinus.

Maxillary tuberosity: The maxillary tuberosity is a rounded prominence of bone that extends posterior to the third molar region.

Radiographically: On a posterior maxillary periapical image, the maxillary tuberosity appears as a radiopaque bulge distal to the third molar region.

Zygomatic process of maxilla: The zygomatic process of the maxilla is a bony projection of the maxilla that articulates with the zygoma, or malar bone. The zygomatic process of the maxilla is composed of dense cortical bone.

Radiographically: On a posterior maxillary periapical image, the zygomatic process of the maxilla appears as a J-shaped or U-shaped radiopacity located superior to the maxillary first molar region.

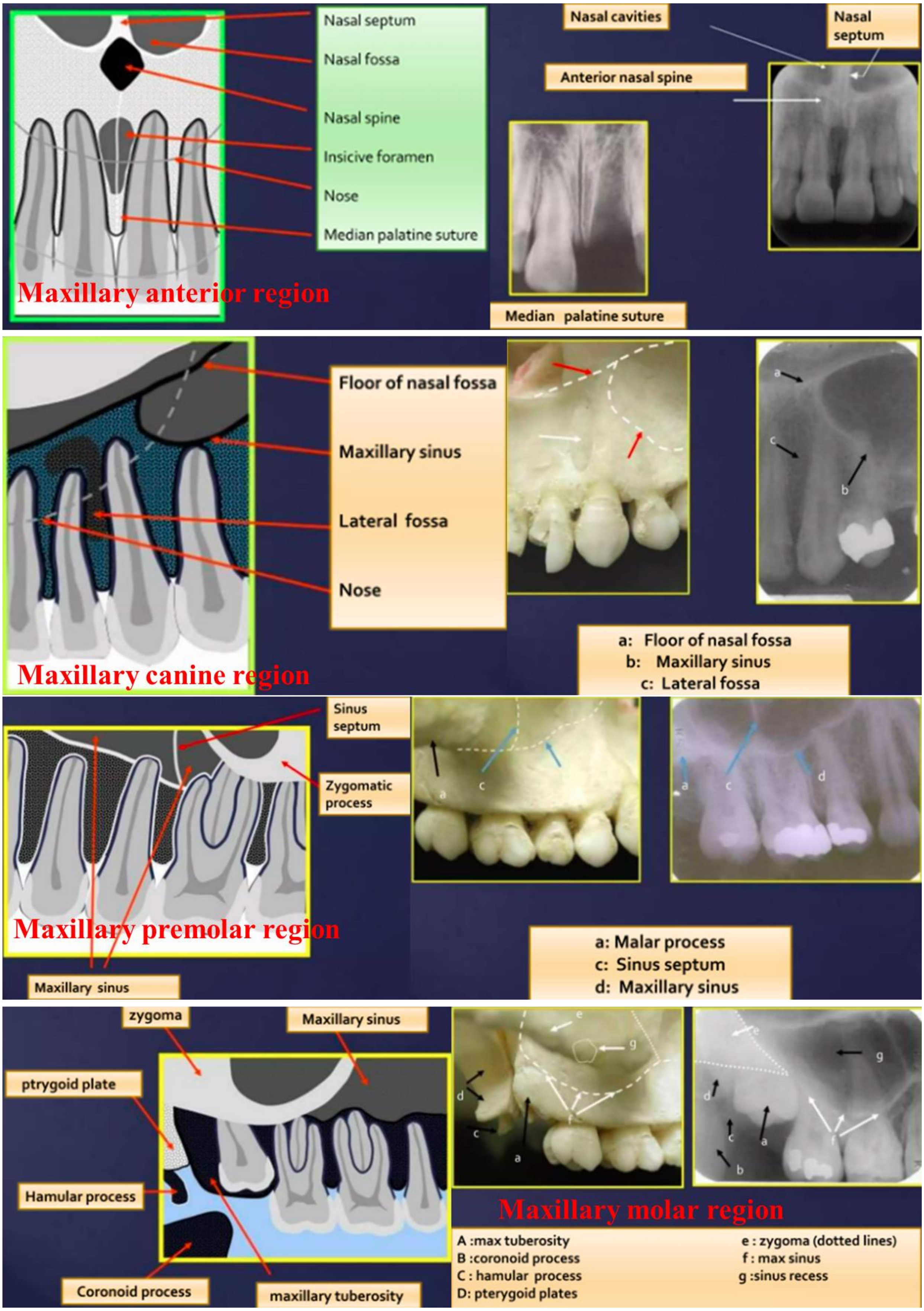


Figure 2. Diagrams and periapical radiographs demonstrating periapical radiographic

appearance of normal anatomy of; maxillary anterior region, maxillary canine region, maxillary premolar region, and maxillary molar region.

Bony Landmarks of the Mandible (fig. 3):

Genial tubercles: Genial tubercles are tiny bumps of bone that serve as attachment sites for the genioglossus and geniohyoid muscles.

Radiographically: On a mandibular periapical image, genial tubercles appear as a ring-shaped radiopacity inferior to the apices of the mandibular incisors.

Lingual foramen: The lingual foramen is a tiny opening or hole in bone located on the internal surface of the mandible. The lingual foramen is located near the midline and is surrounded by genial tubercles.

Radiographically: On a mandibular periapical image, the lingual foramen appears as a small, radiolucent dot located inferior to the apices of the mandibular incisors.

Mental ridge: The mental ridge is a linear prominence of cortical bone located on the external surface of the anterior portion of the mandible.

Radiographically: On a mandibular periapical image, the mental ridge appears as a thick radiopaque band that extends from the premolar region to the incisor region.

Mental fossa: The mental fossa is a scooped-out, depressed area of bone located on the external surface of the anterior mandible.

Radiographically: On a mandibular periapical image, the mental fossa appears as a radiolucent area above the mental ridge.

Mental foramen: The mental foramen is an opening or hole in bone located on the external surface of the mandible in the region of the mandibular premolars. Blood vessels and nerves that supply the lower lip exit through the mental foramen.

Radiographically: On a mandibular periapical image, the mental foramen appears as a small, ovoid or round radiolucent area located in the apical region of the mandibular premolars.

Mandibular canal: The mandibular canal is a tubelike passageway through bone that travels the length of the mandible. The mandibular canal extends from the mandibular foramen to the mental foramen and houses the inferior alveolar nerve and blood vessels.

Radiographically: On a mandibular periapical image, the mandibular canal appears as a radiolucent band. Two thin radiopaque lines that represent the cortical walls of the canal outline the mandibular canal. The mandibular canal appears below or superimposed over the apices of the mandibular molar teeth.

Mylohyoid ridge: The mylohyoid ridge (also known as the internal oblique ridge) is a linear prominence of bone located on the internal surface of the mandible. The mylohyoid ridge extends from the third molar region donward and forward to the second premolar area. The mylohyoid ridge serves as an attachment site for a muscle of the same name.

Radiographically: On a mandibular periapical image, the mylohyoid ridge appears as a dense radiopaque band that extends downward and forward from the third molar region at the level of the apices of the posterior teeth.

External oblique ridge: The external oblique ridge (also known as the external oblique line) is a linear prominence of bone located on the external surface of the body of the mandible. The anterior border of the ramus ends in the external oblique ridge

Radiographically: On a mandibular molar periapical image, the external oblique ridge appears as a radiopaque band extending downward and forward from the anterior border of the ramus of the mandible.

Submandibular fossa: The submandibular fossa (also known as the mandibular fossa or submaxillary fossa) is a scooped-out, depressed area of bone located on the internal surface of the mandible inferior to the mylohyoid ridge. The submandibular salivary gland is found in the submandibular fossa.

Radiographically: On a mandibular periapical image, the submandibular fossa appears as a radiolucent area in the molar region below the mylohyoid ridge.

Coronoid process: The coronoid process is a marked prominence of bone on the anterior ramus of the mandible. The coronoid process serves as an attachment site for one of the muscles of mastication.

Radiographically: The coronoid process is not seen on a mandibular periapical image but may appear on a maxillary molar periapical image. The coronoid process appears as a triangular radiopacity superimposed over, or inferior to, the maxillary tuberosity region.

Inferior border of mandible is the lower most part of the mandible. Appears as dense broad radiopaque band of bone.

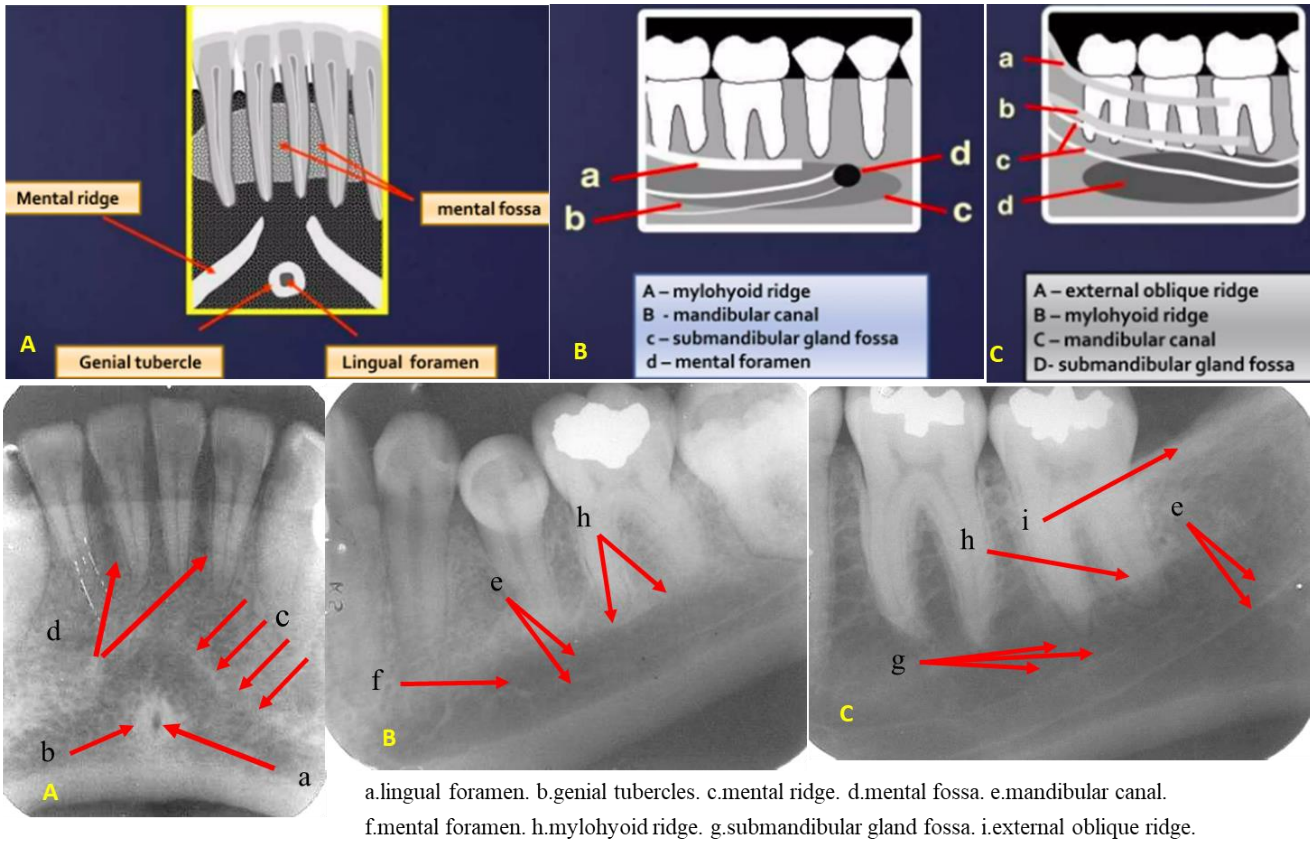


Figure 3. Diagrams and periapical radiographs demonstrating periapical radiographic appearance of normal anatomy of; (A) mandibular anterior region, (B) mandibular premolar region, (C) mandibular molar region.

Table 1. Summary of maxillary radiographic landmarks.

Landmark	Brief Description	Radiolucent / Radiopaque	Periapical	Bilateral / Unilateral	Alternate name
Anterior nasal spine	Triangular point	Radiopaque	Central incisor	midline	
Coronoid Process	Triangular	Radiopaque	Molar	Bilateral	
Hamular process	Finger-like	Radiopaque	Molar	Bilateral	Pterygoid Hamulus
Incisive foramen	Round/Oval	Radiolucent	Central incisor	Unilateral	Nasopalatine foramen
Inferior Nasal Concha	Round/Oval	Radiopaque	Central Incisor	Bilateral	Inferior nasal turbinate
Inverted Y	Upside-down Y	Radiopaque	Lateral incisor canine	Bilateral	
Lateral fossa	Diffuse	Radiolucent	Lateral incisor	Bilateral	Canine fossa

Maxillary Sinus	Horizontally Oblong	Radiolucent	Premolar / Molar	Bilateral	Maxillary antrum
Maxillary Tuberosity	Rounded	Radiopaque	Molar	Bilateral	
Mid-palatine suture	Vertical line	Radiolucent	Central Incisor	Unilateral	Median Palatal Suture
Nasal fossa	Vertically oblong	Radiolucent	Central incisor lateral incisor canine	Bilateral	Nasal cavity
Nasal septum	Vertical band	Radiopaque	Central incisor	Unilateral	
Pterygoid plates	Wing of bone	Radiopaque	Molar	Bilateral	
Zygomatic bone	Quadrangular-shaped	Radiopaque	Premolar / Molar	Bilateral	Malar bone
Zygomatic process	U-shaped	Radiopaque	Premolar / Molar	Bilateral	Malar process

Table 2. Summary of mandibular radiographic landmarks.

Landmark	Brief description	Radiolucent / Radiopaque	Periapical	Bilateral / Unilateral	Alternate name
External oblique ridge	Diagonal Line	Radiopaque	Molar	Bilateral	External oblique line
Genial tubercle	Doughnut-shaped	Radiopaque	Central incisor	Unilateral	Mental spine
Inferior border of mandible	Horizontal band	Radiopaque	Any mandibular	Bilateral	Lower border
Internal oblique ridge	Diagonal line	Radiopaque	Molar	Bilateral	Mylohyoid line
Lingual foramen	Pinpoint dot	Radiolucent	Central incisor	Bilateral	
Mandibular canal	Tubular	Radiolucent	Premolar Molar	Bilateral	Inferior alveolar nerve canal
Mental foramen	Circular	Radiolucent	Premolar canine	Bilateral	
Mental fossa	Diffuse	Radiolucent	Central incisor	Unilateral	
Mental ridge	Inverted V	Radiopaque	Central incisor lateral incisor canine	Bilateral	
Submandibular fossa	Diffuse	Radiolucent	Premolar Molar	Bilateral	Submandibular gland fossa mandibular fossa

Radiographic appearance of dental materials and foreign objects:

1. Recognize the appearance of dental materials in the radiographs.

2. Identify foreign objects in the radiographs.
3. Know the features as seen in intraoral radiographs.
4. Know the features as seen in panoramic radiographs.

Radiopaque restorative materials:

Gold, silver, amalgam, zinc oxide eugenol, zinc phosphate cement, gutta percha, silver points, metal bands and crowns , metal wires and dental implants.

Radiolucent restorative materials:

Acrylic, silicates, calcium hydroxide pastes, and porcelain.

Summary:

A dental assistant and dental hygienist should develop interpretation skills to recognize deviations from normal radiographic anatomy. The most common foreign objects recorded by dental radiographic images will most likely be dental restorative materials. Some restorations can be differentiated by relative degree of radiopacity or radiolucency; others are better identified by size and contour or by location on a tooth.

Restorative materials and foreign objects can include: amalgam; composite resin; glass ionomer; full metal, ceramic-porcelain, and (porcelain fused to metal) PFM crowns; fixed bridges; retention pins; dental liners, bases, and cements; amalgam fragments; and other objects from trauma.

Interpretation fundamentals:

Interpretation of radiographic findings is enhanced when a patient is present. Facilitates a comparison of radiographic findings with a clinical examination. Attempting to determine what a particular finding is from a radiograph alone may be difficult.

For example, a clinical examination may reveal the presence of a *composite resin restoration*, which can mimic decay radiographically.

Superimposition of tooth surfaces can make it difficult to definitively identify the type, size, number, and location of restorations. The appearance of a base material may be observed apical to a metallic or composite restoration, or the presence of metallic retention pins may be detected apical to a crown.

Evaluation of dental restorative materials is more likely to be conducted in conjunction with a clinical examination. These materials must be identified and assessed. It is important not to mistake foreign objects for pathology or other conditions requiring treatment intervention.

Table 3. Metallic and nonmetallic restorations:

Metallic dental materials	**Nonmetallic dental materials**
More radiopaque	**Less radiopaque**
Amalgam Gold alloy Stainless steel Fixed bridge clasp Retention pin Silver point Post and core Implant Orthodontic band , wire , bracket	Composite resin Glass ionomer Ceramic-porcelain Dental liner Dental base Dental cement Gutta-percha

Radiolucent restorative materials:

Acrylic, silicates, calcium hydroxide pastes, and porcelain.

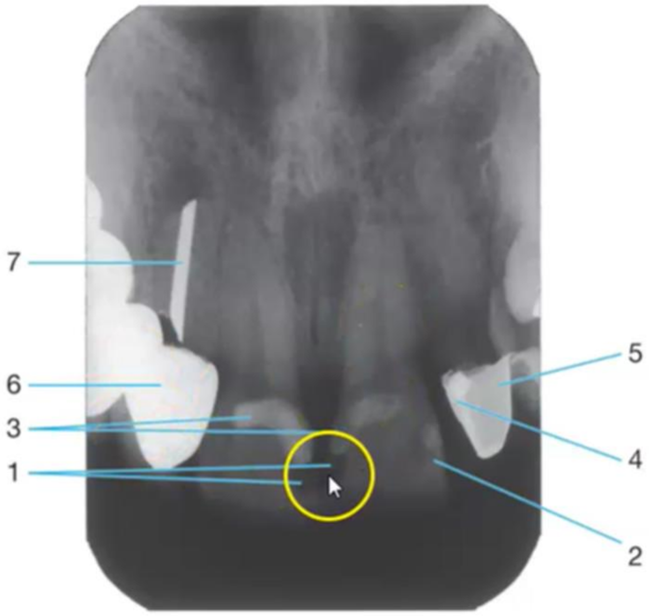


Figure 4 **Dental materials.** (**1**) Radiolucent composite resin. Do not mistake for caries. Note the prepared look. (**2**) Radiolucent dental base. Do not mistake for recurrent decay. (**3**) Radiopaque glass ionomer. Facial or lingual location cannot be definitively determined from two-dimensional image. (**4**) Radiopaque cement under crown. (**5**) Porcelain crown. (**6**) PFM crown. (**7**) Silver point endodontic filler.

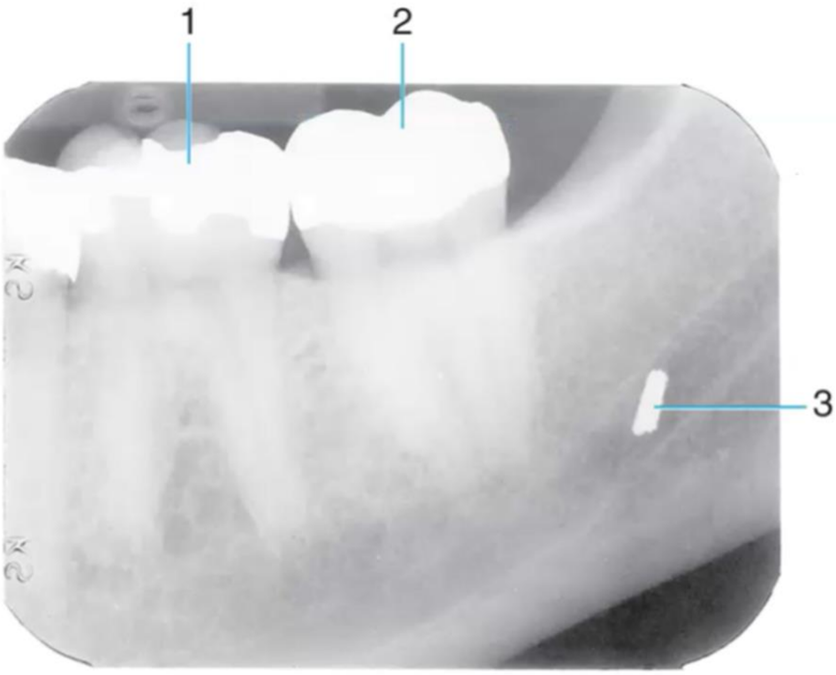


Figure 5 **Foreign objects.** (**1**) Irregular margins of amalgam, (**2**) smooth margins of full metal crown, (**3**) broken dental bur; accidentally lodged here during removal of third molar.

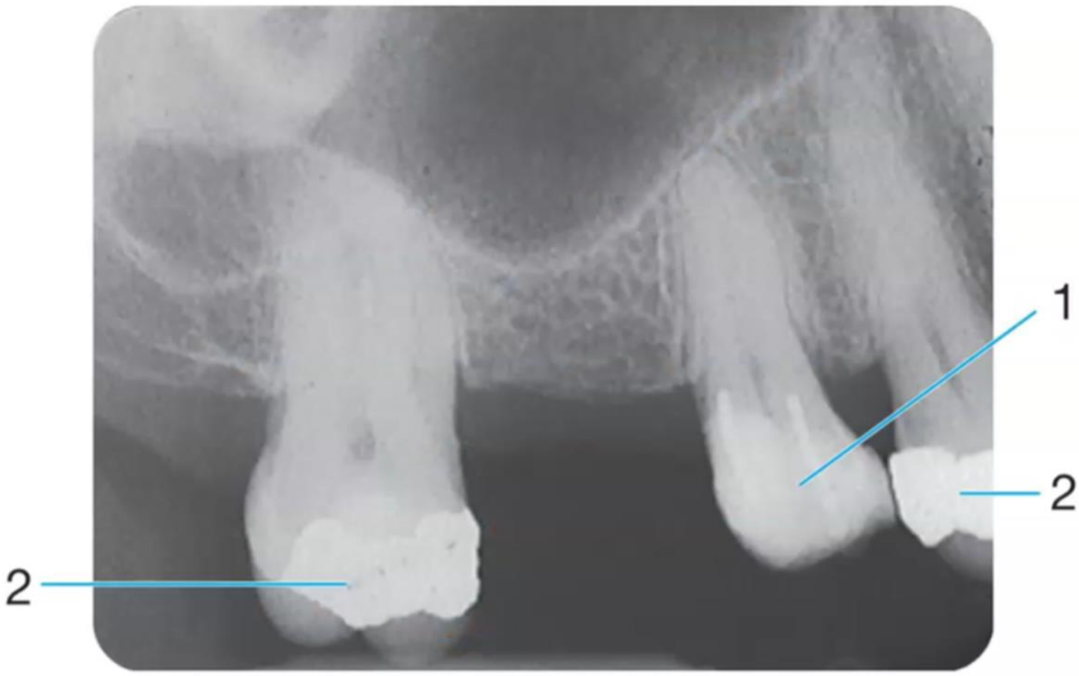


Figure 6 **Composite resin restoration.** (**1**) Appears slightly more radiopaque than dentin. Note the retention pins. (**2**) Amalgam restorations.

Figure 7 **Orthodontic appliance.** Note the root-end external resorption likely in response to orthodontic intervention.

Figure 8 **Surgical wire.** Used to treat a fractured mandible.

Figure 9 **Surgical wire.** Used to treat a fractured mandible.

Figure 10 Implant replaces missing tooth root structure.

Lecture 13 Radiographic appearance of common dental diseases

By

Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.

Oral Radiology Teacher, Anbar University

A Common dental diseases:

1. Dental caries.
2. Periodontal Diseases.
3. Pericoronitis.
4. Inflammatory lesions of the jaws.
5. Osteomyelitis.

Dental caries:

The most common disease in the mouth and also the most common disease of the entire body is the dental caries. It is the common infectious disease strongly influenced by diet, affecting 95% of population.

Radiography is useful for detecting dental caries because the carious process causes tooth demineralization. The demineralized area (carious lesion) of the tooth that allows greater infiltration of X-rays is darker (more radiolucent) than the unaffected portion and may be detected on radiographs.

Carious lesions are detectable radiographically when there has been enough demineralization to allow it to be differentiate from normal. 40% demineralization is required for definitive decision on caries. Meaning that caries is detected radiographically only in the advanced stages when there is sufficient decalcification of tooth structures. The radiographic appearance of caries is not representative of its actual size, that is, it is much larger clinically than seen on a radiograph.

A thorough clinical examination that includes imaging is needed to diagnose carious lesions. A clinical examination may be able to identify carious lesions on the occlusal and exposed smooth surfaces of the teeth. However, it is nearly impossible to clinically identify caries occurring on the proximal surfaces of teeth (interproximal caries) unless there has been cavitation.

When this occurs, it usually means that the carious lesion has become large enough to be identified clinically. An early carious lesion may not have yet caused sufficient demineralization to be detected radiographically. Intraoral radiography can reveal carious lesions that otherwise might go undetected during a thorough clinical examination.

A number of studies have shown the value of dental radiographs by repeatedly demonstrating that approximately half of all proximal surface lesions cannot be seen clinically and may be detected only with radiographs.

Radiographic techniques:

Bite-wing and parallel radiographs are more useful in caries detection more than bisecting technique because incorrect horizontal or vertical angulation of the x-ray beam can result in a number of illusions (fig. 1). They are valuable in detecting proximal caries which may go undetected during clinical examination.

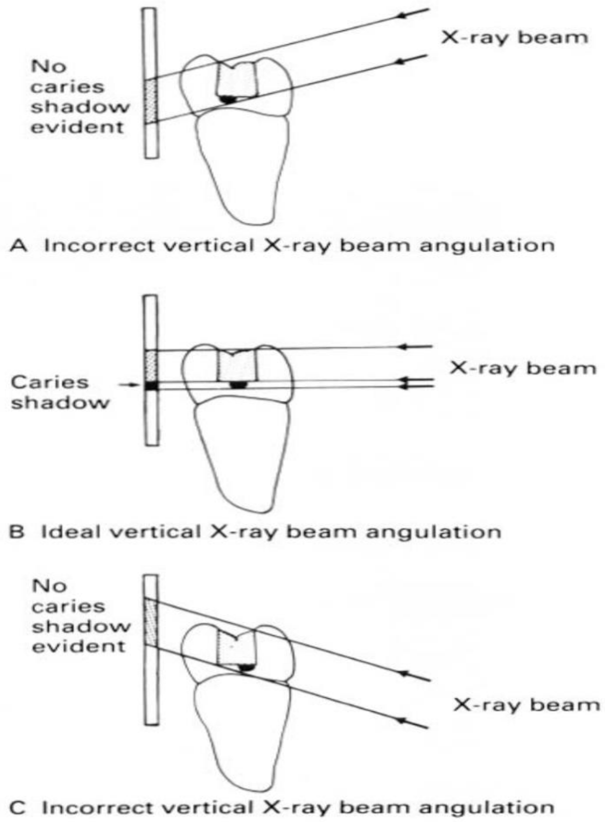


Figure 1: The effect of vertical beam angulation on caries detection in bite-wing and parallel technique. **(A)**, Incorrect vertical beam angulation. **(B)**, Ideal vertical beam angulation. **(C)**, Incorrect vertical beam angulation.

Also, errors in exposure factors and errors in processing can produce radiographic illusions of dental caries (fig. 2). A radiographic diagnosis of caries must always be supplemented with a careful clinical examination.

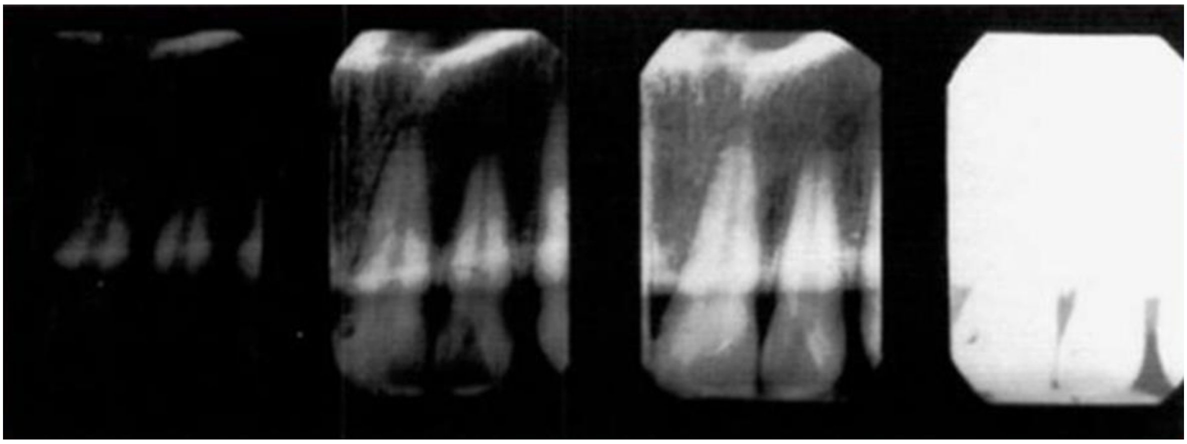


Figure 2: The errors in exposure factors and errors in processing can produce radiographic illusions of dental caries.

Radiolucent Cervical Burn Out:

It is an artefactual phenomenon created by the anatomy of the teeth and the variable penetration of the X-ray beam. This radiolucent shadow is often evident at the neck of the teeth, demarcated above by the enamel cap or restoration and below by the alveolar bone level. It is triangular in shape being less apparent at the center of tooth. Usually all the teeth on the radiograph are affected, especially the smaller premolars (fig. 3).

Figure 3: Cervical burnout is caused by overexposure of the lateral portion of roots between the enamel and the alveolar crest and results in an ill-defined radiolucent zone (arrows).

Interpretation of dental caries regarding to its location:

Interpretation of incipient occlusal dental caries: Radiographs are usually not effective for the detection of an occlusal carious lesion until it reaches the dentin.

Interpretation of moderate occlusal dental caries: The moderate occlusal lesion is usually the first to induce specific radiographic changes.

The classic radiographic change is a broad-based, thin radiolucent zone in the dentin with little or no changes apparent in the enamel.

Carious lesions occur in four general areas of the tooth:

1. Pit and fissure caries (fig. 4 A); includes class I occlusal surfaces of posterior teeth, lingual pits of maxillary incisors, and buccal surfaces of mandibular molars.
2. Smooth surface caries and interproximal surface caries (fig. 4 B); includes class v buccal, lingual surfaces of anterior and posterior teeth, and class II interproximal surfaces of all teeth below the interproximal contact points.
3. Root surface caries (fig. 4 C); cementum is exposed due to teeth traumatized by conditions such as malocclusion, consistent bruxing, or clenching. due to cementum being only 50% mineralized, root surface caries can occur if the patient receives multiple lactic-acid exposures.
4. Secondary or recurrent caries (fig. 4 D); includes caries seen adjacent to or beneath an existing restoration.

Figure 4: A. Pit and fissure caries. B. Smooth surface caries and interproximal surface caries. C. Root surface caries. D. Secondary or recurrent caries.

1. Occlusal Caries:

The spread of caries in the enamel follows the path of the enamel rods and produces a triangular appearance with the base of the triangle at the dentino-enamel junction and the apex of the triangle towards the occlusal surface of the tooth.

In the dentin, the occlusal caries follows the path of the dentinal tubules and forms another triangular radiolucency but with the base of the triangle at the dentino-enamel junction and the apex towards the dental pulp.

Occlusal caries progresses to form two triangular areas with a common base at the dentino-enamel junction. The caries follow the path of dentinal tubules (fig. 5).

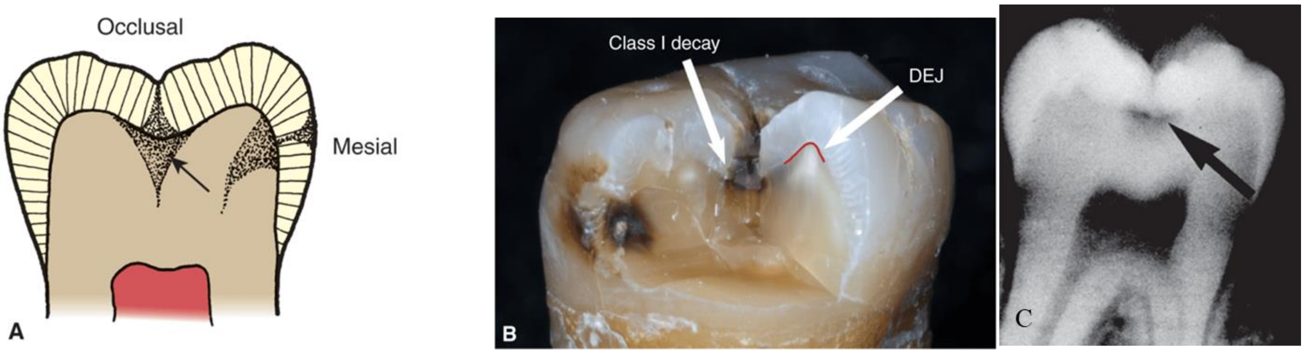


Figure 5: Spread pattern of class I decay. **A**. The occlusal lesion at the arrow (class I, pit and fissure) is small externally and widens within enamel toward the depth of the enamel as it approaches the DEJ. Once within dentin, the caries spreads out laterally, as it progresses toward the pulp. **B**. In this cross section of a tooth, class I decay spreads out as it approaches dentin, and once into dentin, it spreads out. **C**. Radiograph of a class I lesion (arrow) on tooth #31. By the time the lesion appeared this deep on the radiograph, the caries had destroyed dentin to such a depth that the preparation may end up being as large and deep and require a dental cement base. This decay caries should have been detected earlier with a good clinical examination.

2. Proximal Caries:

Interproximal carious lesions are most commonly found in a region that extends between the contact points of teeth apically to near the free gingival margin. Radiographic detection of carious lesions on the proximal surfaces of teeth depends on loss of enough mineral to result in a detectable change in radiographic density. Approximately 40% demineralization is required for radiographic detection of a lesion. Bitewing intraoral film used to detect the proximal caries.

Initially detected on a radiograph by a small notching on the enamel surface just below the proximal contact point.

It continues to demonstrate approximately a triangular pattern with its base towards the outer surface of the tooth and with a flattened apex towards the dentino-enamel junction.

After reaching the dentino-enamel junction, the carious lesion spreads along the junction and forms a second base.

From this second base, the caries proceeds towards the pulp along the path of the dentinal tubules and forms another triangular radiolucency with the apex towards the pulp (fig. 6).

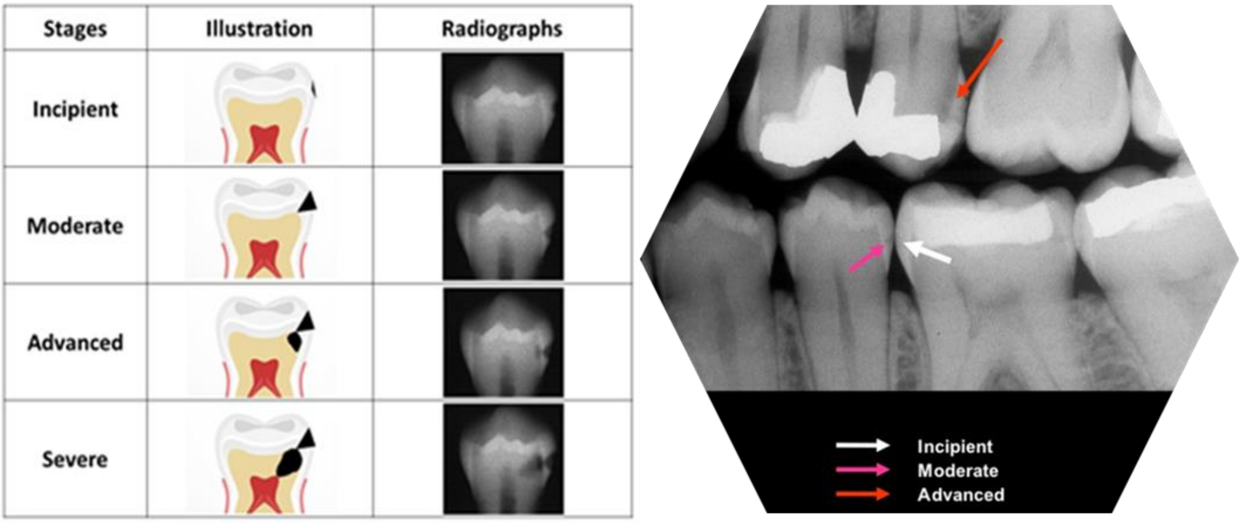


Figure 6: **Proximal caries.** According to the LEFT diagrams and images; the carious lesions on the distal of the premolar can be classified as: incipient, moderate, advanced, and severe carious lesions. The image on the RIGHT shows radiographic appearances of incipient, moderate, and advanced carious lesions.

3. Facial, buccal, and lingual caries:

Facial, buccal, and lingual caries; originate in enamel pits and fissures on the facial and lingual surfaces of gingival free margin.

The radiographic radiolucency is well demarcated from the surrounding sound tooth structure due to the presence of well-defined non-carious enamel around radiolucency (fig. 7). It is difficult to differentiate between buccal and lingual caries on a radiograph.

They start as round lesions and enlarge to become elliptical or semilunar. When superimposed on DEJ, they may mimic occlusal caries. Clinical examination helps in definitive diagnosis.

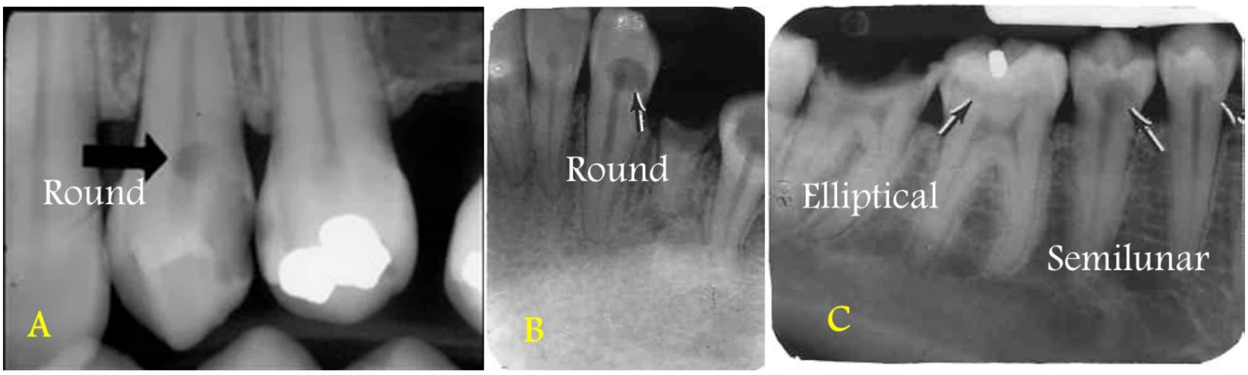


Figure 7: **A**, Buccal caries with sever interproximal caries on tooth #12. **B** and **C**, Facial, buccal, and lingual caries (smooth surface caries).

4. Root surface caries (cemental caries):

Root surface caries involves both cementum and dentin. Its prevalence is approximately 40% to 70% in an aged population. The tooth surfaces most frequently affected are (in order) buccal, lingual, and proximal.

On a radiograph, root caries produces a saucer shaped (scooped-out) appearance. It does not occur in areas covered by a well-attached gingiva.

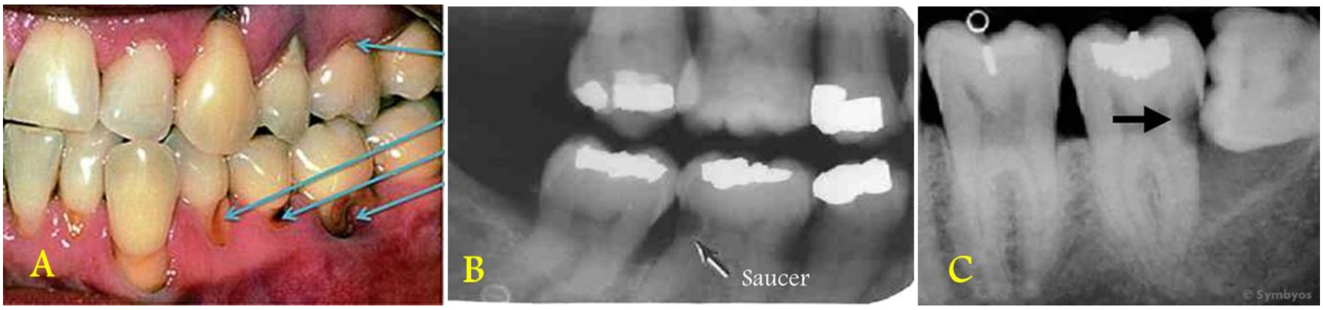


Figure 8: **A**, Root surface caries involves both cementum and dentin, the areas not covered by a well-attached gingiva. **B** and **C**, Root caries produces a saucer shaped (scooped-out) appearance.

5. Recurrent caries:

Recurrent caries is that which recurs in a previously treated and restored tooth. It may result from poor adaptation of a restoration, which allows for marginal leakage, or from inadequate extension of a restoration. In addition, caries may remain if the original lesion is not completely evacuated, which later may appear as residual or recurrent caries. The caries may occur under a restoration or along its margins.

The radiographic appearance of recurrent caries depends on the amount of decalcification present and whether a restoration is obscuring the lesion.

Recurrent caries may sometimes be misdiagnosed as (the non-commercial paste) of calcium hydroxide lining used underneath an amalgam and zinc phosphate base. On a radiograph, calcium hydroxide produces a thin radiolucent line whereas recurrent caries produces a diffuse radiolucency (fig. 9).

Figure 9: **A**, Diagram demonstrating lining and sublining underneath amalgam filling. B, On radiograph, recurrent caries produces a diffuse radiolucency. C, Recurrent caries occur under a restoration or along its margins

6. Rampant caries:

Rampant caries is the term used to describe rapid progression with severe and widespread involvement. This is most often seen in young children who have poor oral hygiene habits coupled with poor dietary habits (e.g., going to sleep with a bottle of milk or juice).

Imaging examinations of these patients can demonstrate advanced, generalized caries, involving smooth surfaces and teeth that usually do not present carious lesions (fig. 10).

Figure 10: Multiple rampant carious lesions.

7. Radiation caries:

Radiation caries resulting from xerostomia caused by serial head and neck radiation therapy.

Radiation induced caries:

1. Lack of production of saliva.
2. Increased acidity.
3. Decrease in secretory immunoglobulin A.
4. Loss of buffering capacity.
5. Shift towards cariogenic flora.
6. Reduced remineralizing potential.

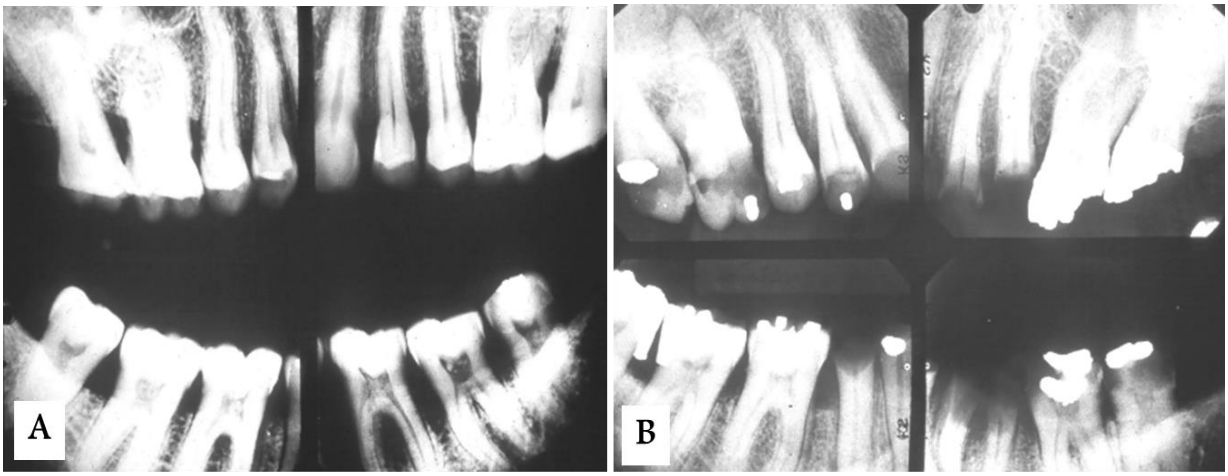


Figure 11: Radiation-Related Dental Caries; **A**, Before radiation therapy. **B**, One year after radiation therapy.

Periodontal Diseases:

The most common of periodontal disease are gingivitis and periodontitis. Assessment of periodontal disease, contributions of radiographs. Radiographs play an integral role in the assessment of periodontal disease. They provide unique information about the status of the periodontium and a permanent record of the condition of the bone throughout the course of the disease.

It is important to emphasize that the clinical and radiographic examinations are complementary. The clinical examination should include periodontal probing, a gingival index, mobility charting, and an evaluation of the amount of attached gingiva.

Features that are not well delineated by the radiograph are most apparent clinically, and those that the radiograph best demonstrates are difficult to identify and evaluate clinically.

Radiographic features of healthy periodontium:

A healthy periodontium can be regarded as periodontal tissue exhibiting no evidence of disease. However, to be able to interpret radiographs successfully clinicians need to know the usual radiographic features of healthy tissues where there has been no bone loss (fig. 12).

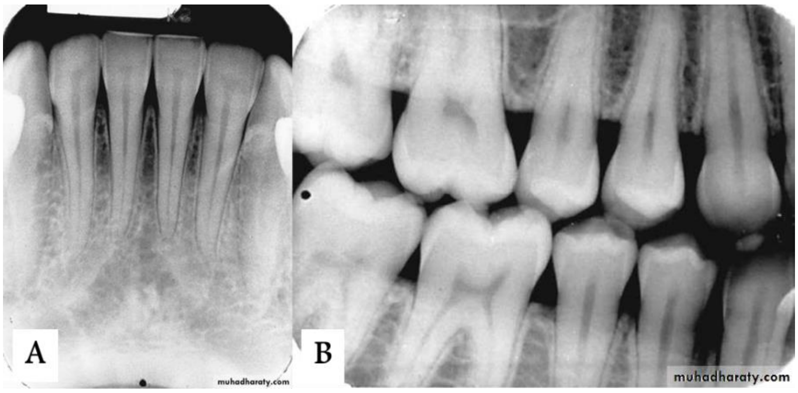


Figure 12: **A**, Healthy alveolar crest in the anterior region that appears pointed and highly radiopaque. **B**, Healthy alveolar crest in the posterior region that appears flat, smooth, and radiopaque.

The only reliable radiographic feature is the relationship between the crestal bone margin and the cemento-enamel junction (CEJ). If this distance is within normal limits (2-3 mm) and there are no clinical signs of loss of attachment., then it can be said that there has been no periodontitis.

Radiographic features of periodontal disease:

Acute and chronic gingivitis:

Radiographs provide no direct evidence of the soft tissue involvement in gingivitis.

Early radiographic changes in periodontitis: Radiograph is not sensitive enough to detect the earliest signs of periodontal disease. Glickman listed the sequence of early radiographic changes that occur in periodontitis as (fig. 13):

Crestal irregularities: The crest of the interdental bone becomes rough and irregular along with indistinctness and interruption in the continuity of the lamina dura seen along the mesial or distal aspect of the interdental alveolar crest.

Triangulation: Triangulation is the widening of periodontal membrane space along either mesial or distal aspect of the interdental crestal bone.

The sides of the triangle are formed by lamina dura and the root and the base is toward the crown.

Interseptal bone changes: One of the earliest radiographic signs of periodontitis is the finger-like radiolucent projections extending from the crestal bone into the interdental alveolar bone.

These projections are result of a deeper extension of the inflammation from the connective tissue of the gingiva.

They represent widened blood vessel channels within the alveolar bone that allow for the passage of inflammatory fluid and cells into the bone.

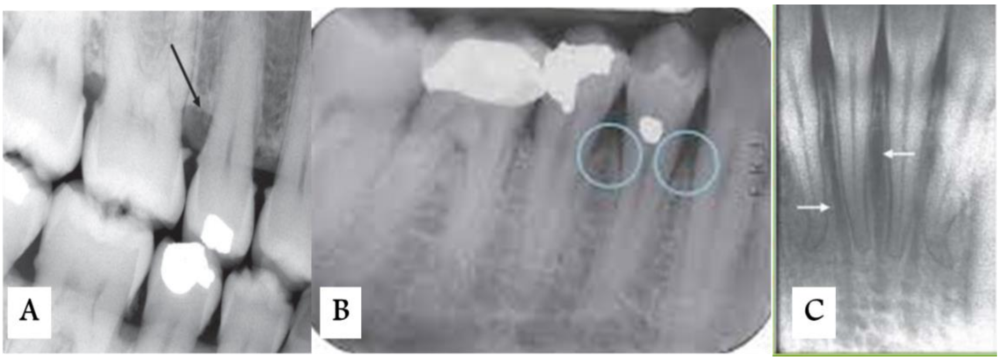


Figure 13: **A**, Crystal irregularities. **B**, Triangulation. **C**, Interseptal bone changes.

Periodontitis:

Periodontitis is the name given to periodontal disease when the superficial inflammation in the gingival tissues extends into the underlying alveolar bone and there has been loss of attachment. The destruction of the bone can be either localized affecting a few areas of the mouth, or generalized affecting all areas. The radiographic features of the different forms of periodontitis are similar; it is the distribution and the rate of bone destruction that varies.

Evaluation of bone loss:

The radiograph actually indicates the amount of bone remaining and the amount of bone loss attributed to periodontal disease can be estimated indirectly as the difference between the physiologic bone level and the height of remaining bone.

The terms used to describe the various appearances of bone destruction include:

1) Horizontal bone loss.
2) Vertical bone loss.
3) Furcation involvements.

Bone loss can be determined in terms of:

Distribution: When the bone loss occurs in isolated areas, with less than 30% of the sites involved, it is described as **localized bone loss**. When the bone loss is evenly distributed throughout the dental arches, with more than 30% of the sites involved, it is called **generalized bone loss** (fig. 14).

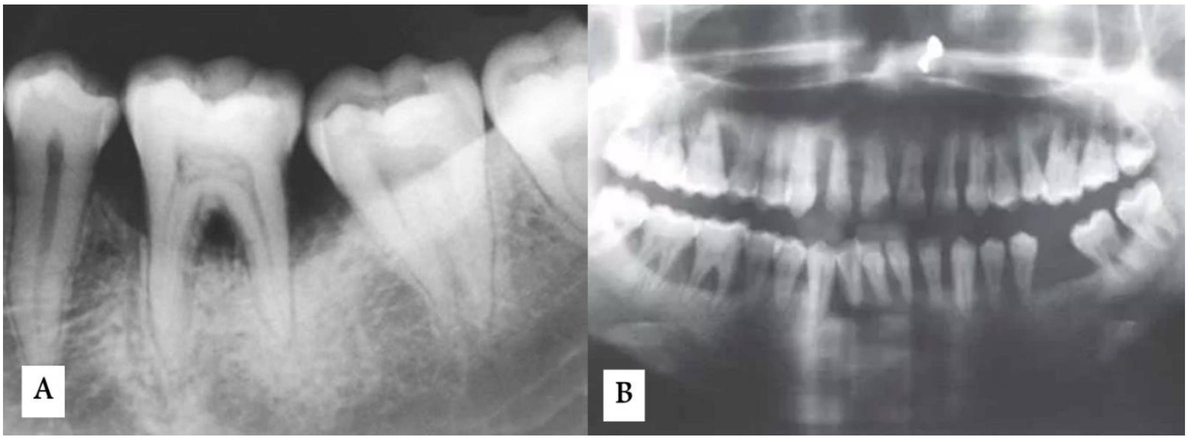


Figure 14: **A**, Localized bone loss. **B**, Generalized bone loss.

The direction or pattern of bone loss: The terms horizontal and vertical have been used traditionally to describe the direction or pattern of bone loss using the line joining two adjacent teeth at their cemento-enamel junctions as a line of reference. When the bone loss occurs on a plane that is parallel to a line drawn from CEJ of a tooth to that of an adjacent tooth, it is called **horizontal bone loss**. When the bone loss occurs on a plane that is at an angle to a line drawn from CEJ of a tooth to that of an adjacent tooth, it is called **vertical or angular bone loss** (fig. 15).

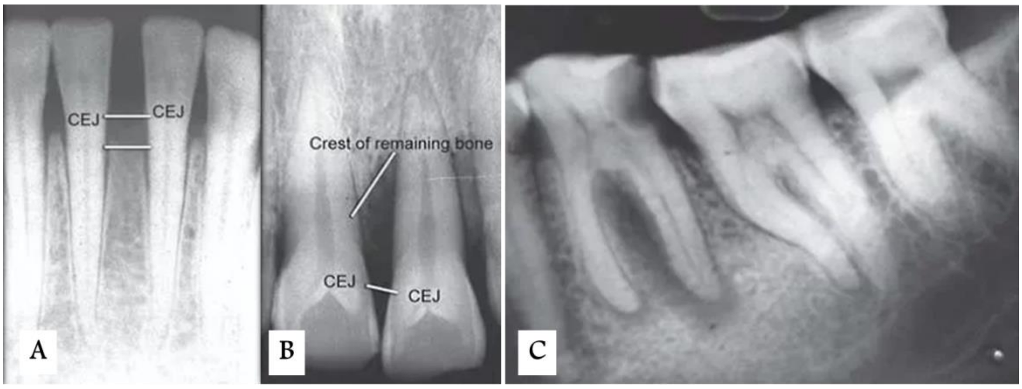


Figure 15: **A**, horizontal bone loss. **B**, vertical or angular bone loss. **C**, Perio-endo lesion refers to teeth (typically molars) that have concurrent clinical and radiological signs of disease of periodontal and pulpal origin.

Severity: The amount of bone loss is then assessed as mild, moderate or severe. Bone loss viewed on a dental radiograph can be defined as mild bone loss (1 to 2 mm), moderate bone loss (3 or 4 mm) and severe bone loss (5 mm or greater).

Figure 16: **A**, Slightly bone loss. B, Moderate bone loss. **C**, Severe bone loss.

Furcation involvement: The term furcation involvement describes the radiographic appearance of bone loss in the furcation area of the roots which is evidence of advanced disease in this zone.

Radiographs can be helpful in locating furcation involvement; however, the furcation involvement will not be seen unless the bone resorption extends apically beyond the furcation.

Although central furcation involvements are seen more readily in mandibular molars, they can also be seen in maxillary molars, mandibular molar furcation is much more sharply defined than the maxillary molar furcation where the palatal root is superimposed over the furcation, Widening of the PDL space at the apex of the interradicular bony crest of the furcation is strong evidence that the periodontal disease process involves the furcation.

If sufficient bone loss has occurred on the lingual and buccal aspects of a mandibular molar furcation, the radiolucent image of the lesion becomes prominent (fig. 17).

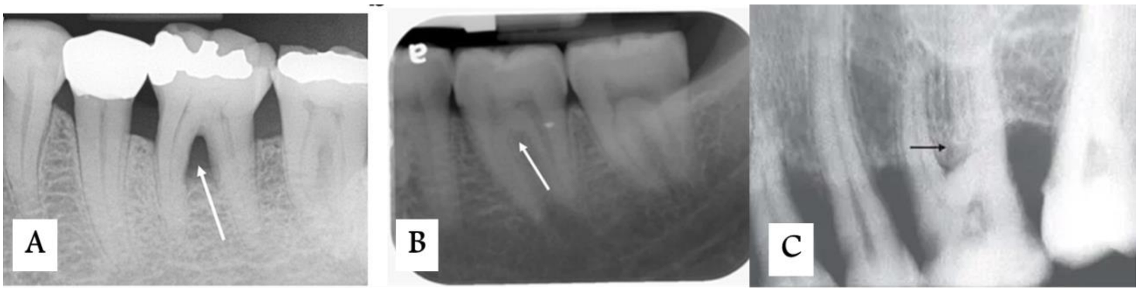


Figure 17: Intraoral radiographs demonstrate molar furcation status. **A**, Presence of furcation involvement. **B**, Absence of furcation involvement.. **C**, Furcation in maxillary molar superimposed by a palatal root.

Predisposing factors of periodontal disease:

Dental radiographs play a major role in the detection of local irritants, such as calculus and defective restorations:

- Calculus appears radiopaque on a dental radiograph often appearing as pointed or irregular radiopaque projections extending from the proximal root surfaces.
- Calculus may also appear as ring like radiopacity encircling the cervical portion of a tooth, or may appear as a nodular projection or a smooth radiopacity on a root surface.

The diagnosis of absence or presence of calculus deposits should not be based on radiographic interpretation, since small deposits are not visible in radiographs.

Gross proximal caries and root surface caries may be seen in conjunction with periodontal bone loss.

Defective restorations act as contributing factors to periodontal disease. Radiographs are useful in detecting defective margins of restorations.

However, if there is excessive vertical or horizontal angulation of the central X-ray beam, there is a risk of underestimating, but not overestimating the size of the defective margin.

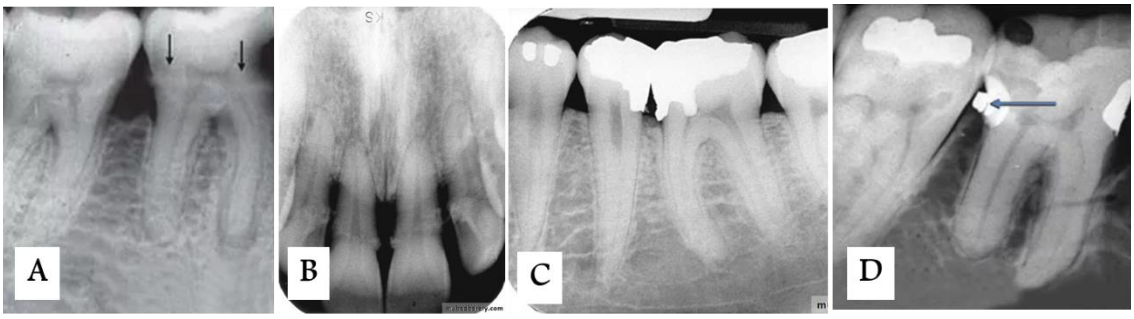


Figure 18: **A**, Calculus appears as ring-like radiopacity. **B**, Subgingival calculus that appears as irregular radiopaque projections in the maxillary anterior region. **C**, Defective restoration causing triangulation. **D**, Amalgam overhang on the mesial surface of the mandibular first molar.

Pericoronitis:

Clinical features:

As mandibular third molar is the most commonly impacted tooth and its position is in such a way that its pericoronal flap gets frequently traumatised, it is the most commonly affected region. Patient usually presents with swelling in affected area and inability to open the mouth completely. Patient may be having severe pain.

Radiographic Features:

The most common radiographic feature of pericoronitis of mandibular third molar is that there is presence of distal bone loss. This distal bone loss is semilunar or circumferential in shape (fig. 19). In the case of mesially tilted impaction, bone loss is present on the mesial side.

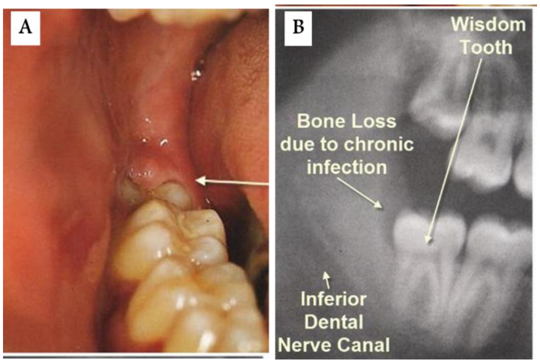


Figure 19: **A**, Partly erupted, inflamed and swollen operculum. **B**, X-ray showing an "arcuate" zone of radiolucency behind the wisdom tooth, indicating chronic infection. The soft tissue covering a partially erupted tooth is known as an operculum.

Inflammatory lesions of the jaws:

Inflammation is the most common disease process that the dentist encounters in practice. Whether acute or chronic, localized or generalized, dentists are responsible for identifying the important radiologic features of inflammation and for determining the extensiveness of bone involvement. Imaging plays a key role in this process, and is an important first step in patient diagnosis and management.

Periapical lesions:

Inflammatory lesions are by far the most common pathologic condition of the jaws. When the initial source of inflammation is a necrotic pulp and the bony lesion is restricted to the region of the tooth, the condition is called a **periapical inflammatory lesion.**

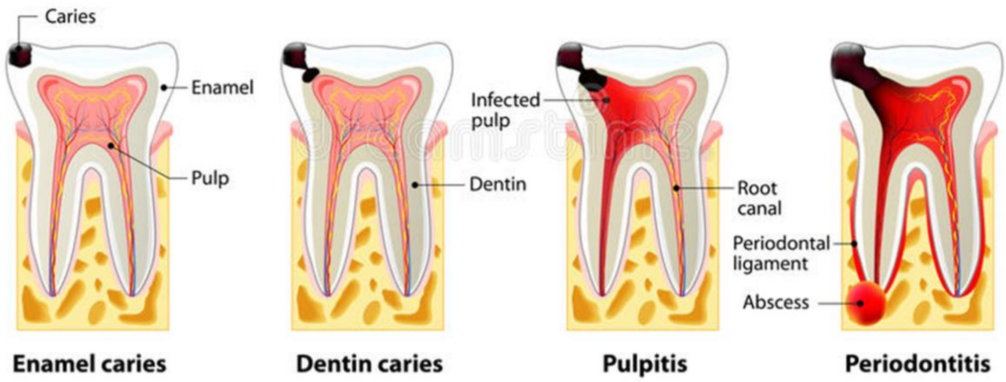


Figure 20: The stages of caries development. Dental disease: caries, pulpitis and periodontitis.

When the infection spreads in the bone marrow and is no longer contained, it is called **osteomyelitis**. It must be emphasized that the names of the various inflammatory lesions tend to describe their clinical and radiologic presentations and behavior.

Terminology:

acute or chronic apical periodontitis.

Periapical, radicular, or periradicular abscess.

Periapical, radicular, or periradicular granuloma.

Periapical, radicular, or periradicular) cyst.

Normal radiographic appearances:

The appearances of normal, healthy, periapical tissues vary from one patient to another, from one area of the mouth to another and at different stages in the development of the dentition (fig. 21).

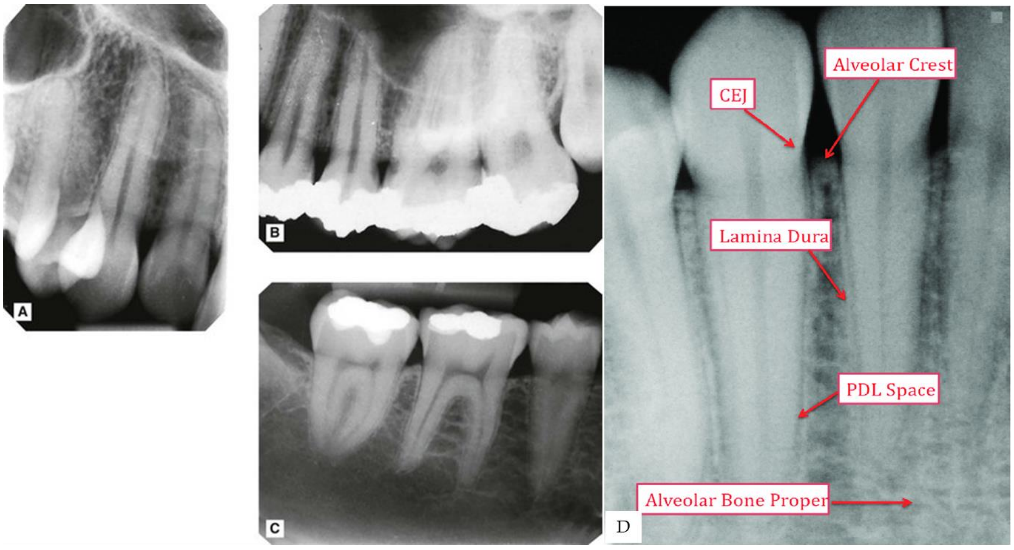


Figure 21. Periapical radiographs; **A** image, **B**, and **C** images showing the normal radiographic anatomy of the periapical tissues in different parts of the jaws. **D** image showing a pointed writing of appearance and location of periodontal components on a periapical radiograph. Note the continuous radiolucent line of the periodontal ligament shadow and the radiopaque line of the lamina dura outlining the roots.

Radiographic Features of periapical lesion:

The radiographic features of periapical inflammatory lesions vary depending on the time course of the lesion

1. Early lesion; Early periapical inflammatory lesions:

May show no radiographic change in the normal bone pattern. The earliest detectable change is loss of bone density, which usually results in widening of the periodontal ligament space at the apex of the tooth and later involves a larger diameter of surrounding bone. At this early stage no evidence may be seen of a sclerotic bone reaction (fig. 22, A).

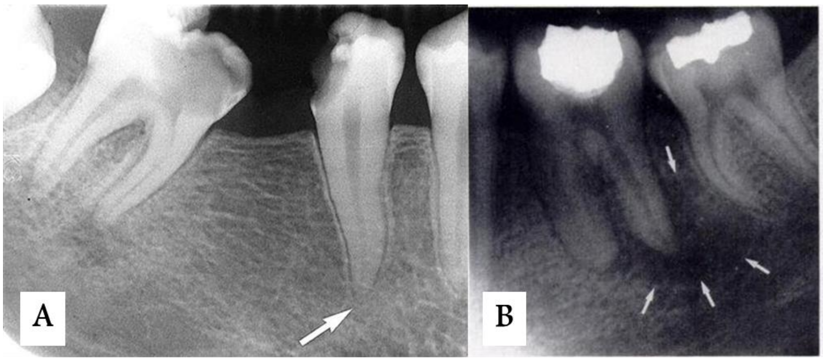


Figure 22. Intraoral radiographs show: A, **Very early lesion** involving the pulp of the second bicuspid without significant change in the periapical bone (arrow). In contrast, note the loss of the lamina dura and periapical bone at the apex of the mesial root of the second molar. Also note the subtle halo of sclerotic bone reaction around this apical radiolucency. **B**, Mandibular molar with diffuse radiolucency associated with distal root. Bone destruction was caused by an acute dental abscess (arrows).

2. Periapical granuloma:

Clinical features:

Patient is usually asymptomatic. In some cases, pain occurs which is mild in intensity. Vitality test of the tooth is negative. Due to periapical lesion, tooth may feel elongated in the socket. Swelling is usually not present.

Radiographicly; **periapical granulomas** are the most common periapical radiolucencies encountered in dental practice. The lesion is not fully dark but it has greyish appearance with well-defined borders, there is a loss of lamina dura in relation with the affected tooth, the size of radiolucency is less than 1.5 cm in diameter (fig. 23, A and B), if the size larger so it consider periapical cyst.

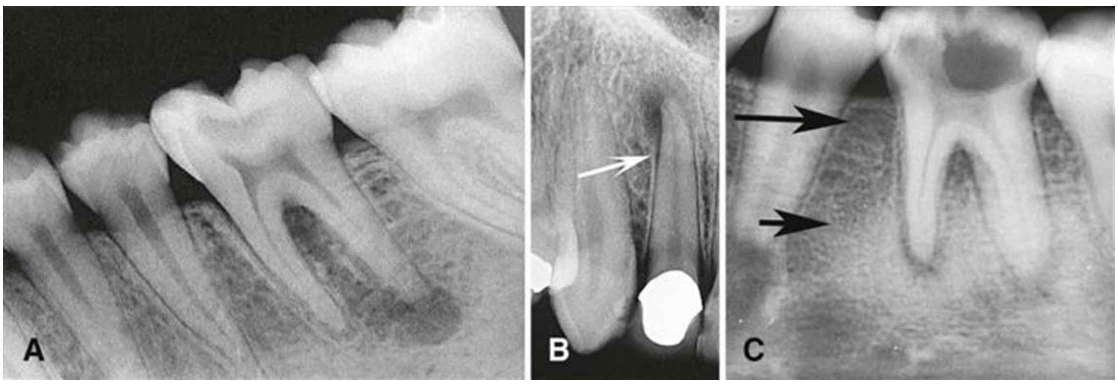


Figure 23: A **and B**, Periapical inflammatory lesions associated with a mandibular first molar and a maxillary lateral incisor. In both cases, the epicenter of bone

destruction is located at the apex of the root. Also, note gradual widening of the periodontal membrane space (white arrow) characteristic of an inflammatory lesion. **C**, Periapical image of sclerosing osteitis related to the first molar shows a gradual transition from thick and numerous trabeculae (short arrow) to a normal trabecular pattern (long arrow).

Differential Diagnosis:

Differences between cyst and granuloma: It is not easy to differentiate periapical granuloma from periapical cyst on the basis of radiographs. It is accepted that lesions having a diameter smaller than 1.5 cm are apical granulomas and lesions bigger than this are periapical cysts.

Difference between granuloma and apical abscess: Apical abscesses form large radiolucencies with diffuse irregular borders.

Periapical scar: Periapical scar is associated with endodontically treated tooth

3. Chronic periapical abscess:

Clinical features:

This creates minimal discomfort for the patients. Clinically, there will be a moderate-to-large carious lesion. The tooth may be slightly loose or tender to percussion.

Radiographic appearance of the lesion: the periapical tissue may appear normal radiographically, as it requires 10 days or more for an infection to erode cortical bone, may be quite variable, the lesion may have radiolucent appearance with ill-defined borders and in this time it impossible to differentiate it from granuloma or cyst (fig. 24).

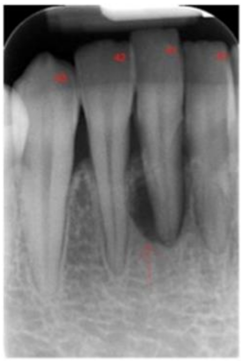


Figure 24: Large periapical radiolucency associated with tooth.

Differential Diagnosis:

There are many normal radiographic landmarks as well as pathological conditions which can be included in differential diagnosis. The normal radiographic anatomical landmarks include normal foramina, inferior dental canal and a large marrow space.

All these conditions can be diagnosed by looking at the lamina dura. Lamina dura in all three conditions is intact.

The pathological condition which can be confused with periapical abscess is periapical osteofibrosis (fig. 25), but in this condition tooth is vital.

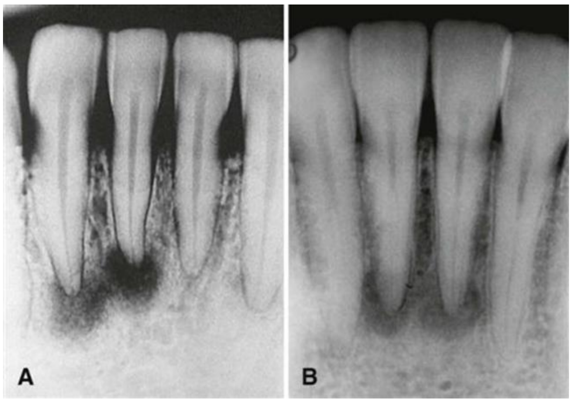


Figure 25: Radiolucent stage of periapical osteofibrosis. **A**, The lamina dura around the lower incisors has been lost. **B**, The periodontal membrane space can still be seen around lower central incisors. Periapical cemental dysplasia, periapical fibrous dysplasia, and periapical fibro-osteoma are synonyms for periapical osteofibrosis.

Condensing Osteitis:

It is an unusual reaction of bone to a mild bacterial infection entering the bone through a carious tooth in persons who have a high degree of tissue resistance. Instead of destruction, proliferation of bone takes place.

Radiographically:

1. This process appears as an irregularly-shaped sclerosis with a widened PDL space or periapical radiolucency between the root and the area of sclerosis (sclerosing bone is not attached to the tooth).
2. The key take away is that condensing osteitis is only associated with pulpal inflammation, while the other entities which may appear similar (idiopathic osteosclerosis, cemento-osseous dysplasia, hypercementosis, and cementoblastoma) are associated with vital teeth (fig. 26).

3. The sclerotic bone may remain after treatment of the inflammation (endodontic treatment or tooth extraction) and is termed as osteosclerosis or a bone scar (no surgical removal is needed).

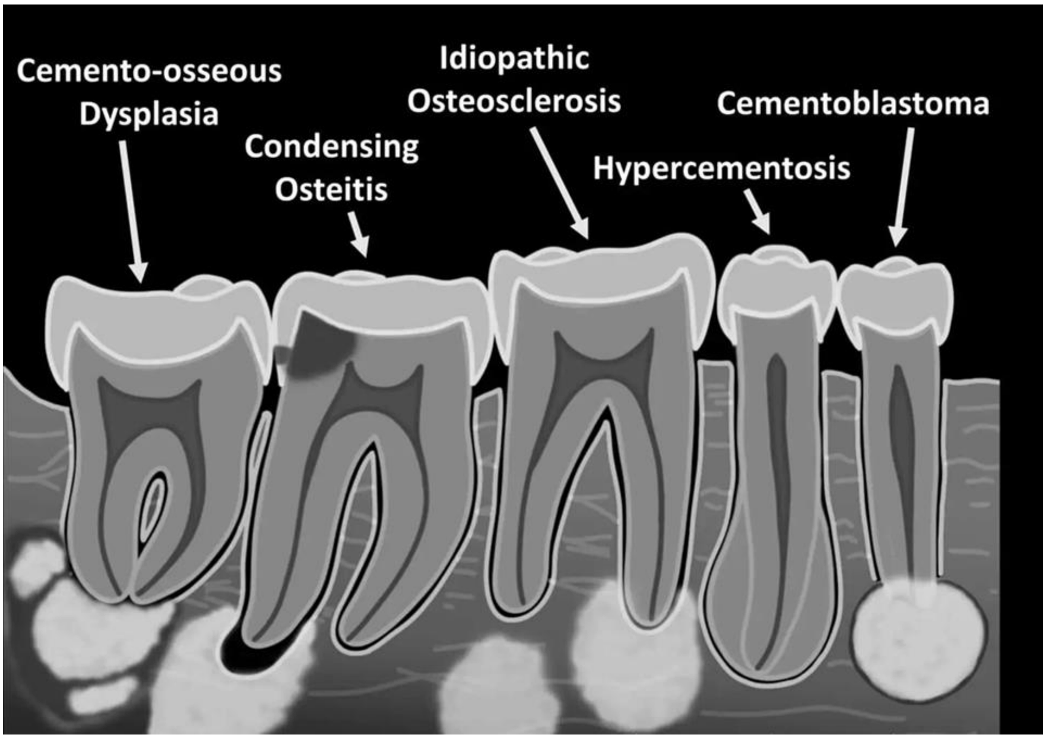


Figure 26: Diagram shows radiographic appearance of apical radiopacities.

Differential Diagnosis:

Condensing osteitis should be differentiated from:

Idiopathic osteosclerosis (radio-opacity is separated from the apex).

Other conditions that should be differentiated are hypercementosis (lamina dura is inside the lesion).

Osteomyelitis:

Osteomyelitis is an inflammation of bone. The inflammatory process may spread through the bone to involve the marrow, cortex, cancellous portion and periosteum.

Clinical features:

Osteomyelitis of the maxilla is much less frequent than that of the mandible because the maxillary blood supply is far more extensive.

Clinically, patients present with facial swelling, localized pain and tenderness, low grade fever, draining sinus tracts, suppuration, dental loss and sequestrum (**i.e. necrotic bone fragment**) formation

Radiographic Features of acute osteomyelitis:

1. Very early in the disease no radiographic changes are identified.
2. The first radiographic evidence of the acute form of osteomyelitis is slight decreased density of the involved bone.
3. There is loss of sharpness of the existing trabeculae.
4. In time bone destruction becomes more profound, resulting in an area of radiolucency in one focal area or in scattered regions throughout the involved bone.
5. Sequestra may be present but usually more clearly seen in chronic form of the disease.

Figure 27: A first panoramic radiograph of a patient taken at the age of 13 showing abnormal bone density of the mandible with small multiple lytic lesions in the left corpus and the area of the germ of the tooth 38. Histological examination predominantly showed chronic inflammatory infiltration and medullary fibrosis. Based on the findings, diagnosis of **primary chronic osteomyelitis** of the mandible had been made.

Differential Diagnosis:

Osteomyelitis should be differentiated from malignancy, Paget disease and eosinophilic granuloma. In the case of malignancy, there is no formation of sequestration which is very typical feature of osteomyelitis. Usually patient is aged below 40 years in case of osteomyelitis and in case of malignancy patient is above 40 years.

In Paget disease, bone involvement is multiple and in case of osteomyelitis bone involvement is single. Margins of eosinophilic granuloma are better defined if we compare it with osteomyelitis.

Summary of a case report with primary chronic osteomyelitis of the jaw: A 59-year-old woman was referred to the authors' oral and maxillofacial surgery practice with a chief complaint of intermittent pain around the decayed roots of the third molar on her right side for the previous 2 months, the radiographic features of this case are listed in fig. 28 .

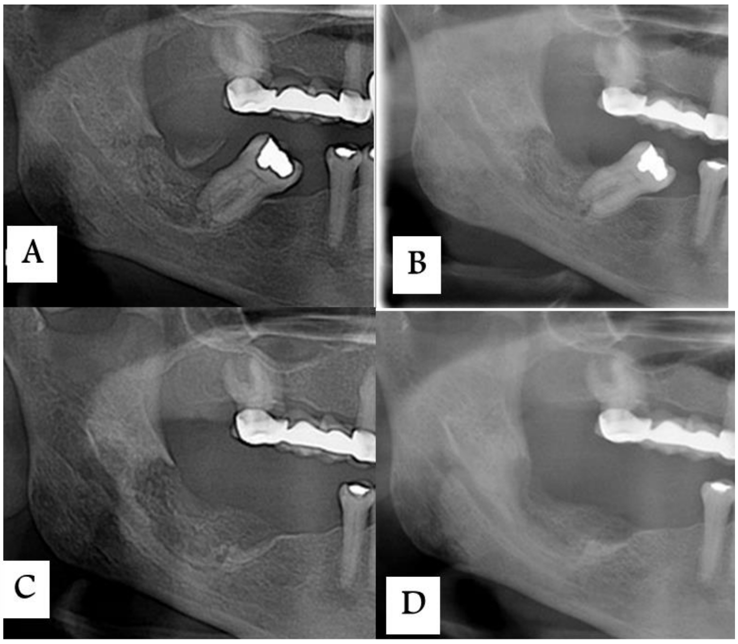


Figure 28; Cropped panoramic radiographs of primary chronic osteomyelitis of the jaw: **A**, an image on presentation showing a small portion of the third molar root mainly in the soft tissue above the alveolar bone level.

B, an image 1 month after extraction demonstrating mottled, mixed, irregular, radiolucent/radiopaque appearance of the posterior mandible around the extracted site, which extended anteriorly to include the adjacent second molar.

C, an image 2 months after the initial presentation showing persistent mottled, mixed, irregular radiolucent-radiopaque appearance, which was more extensive than seen on the previous panoramic image. Second lower right molar is removed.

D, The last image taken on this patient 5 months after the initial presentation and 3 months after the last debridement. It demonstrates partial fill of the mandibular defect and bone remodeling. No necrotic bone is seen.

Lecture 14 Extraoral radiography (techniques and anatomy)

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

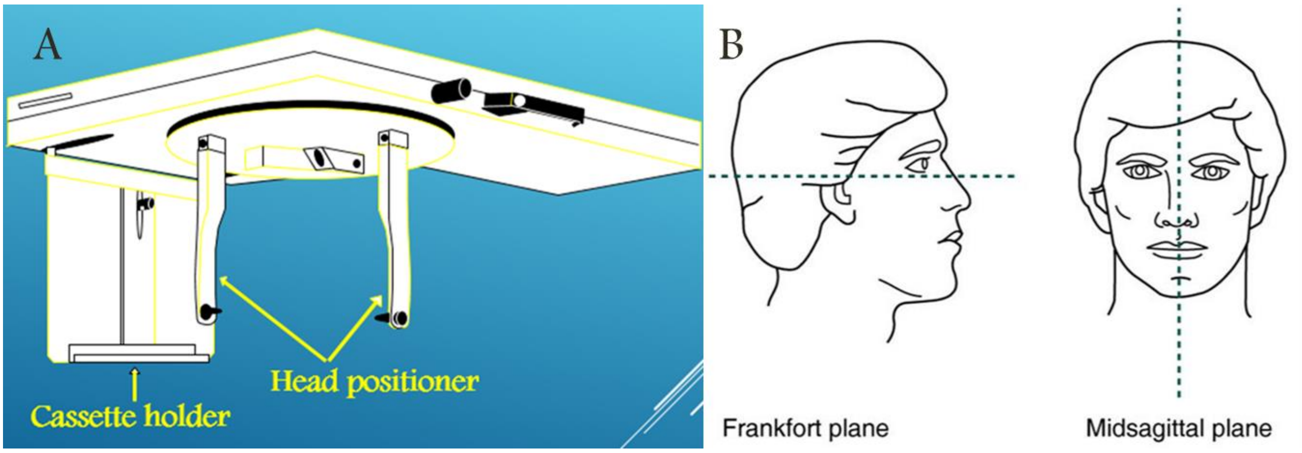


Figure 1. A, Head Positioner/Film Holder. B, Frankfort plane is a plane joining the inferior orbital margin and the external auditory meatus. The midsagittal plane divides the body in half into the left and right sides.

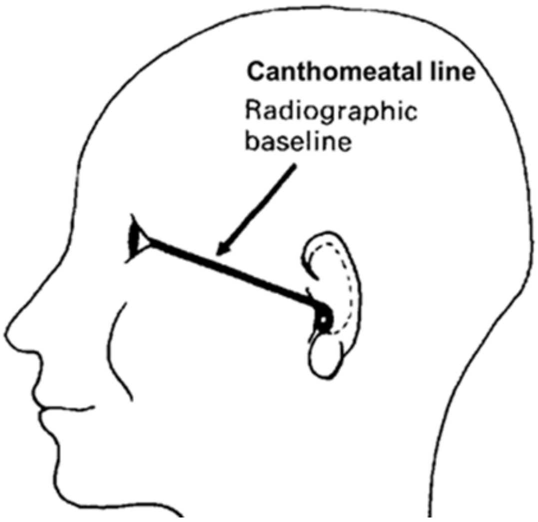


Figure 2. Radiographic baseline or canthomeatal line is a line extending from the outer canthus of the eye to the external auditory meatus.

Extraoral radiography: Extra-oral radiographic examinations include all views made of orofacial regions {craniofacial projections, cephalometric projections, and TMJ projections} with film positioned extraorally, in which both the X-ray source and the image receptor (film or digital sensor) are placed outside the patient's mouth.

The dentist used extraoral radiographs:

1. To examine areas not fully covered by intraoral radiographs.
2. Or to evaluate the cranium, face including the maxilla and mandible, or cervical spine for diseases, trauma, abnormalities, relationship between various orofacial and dental structures, growth and development of the face, or treatment progression.

To evaluate extraoral images: When film-based is used, the resulting radiograph should be first evaluated for overall quality, proper exposure, and processing which means an image with good contrast and density.

Proper patient positioning:

1. Prevents unwanted superimpositions and distortions.
2. And facilitates identification of anatomic landmarks.

Interpreting poor-quality images can lead to diagnostic errors and subsequent treatment errors.

Types of extra-oral radiographic examination according to X-ray beam direction:

Antero-posterior views	Postero-anterior views	Lateral views
1. Submentovertex view. 2. Transorbital view.	1. True Postero-anterior skull view. 2. Occipto-mental view. 3. Reverse Towne’s view.	1. Lateral oblique view. 2. True lateral skull view. 3. Transcranial view. 4. Transpharyngeal view.

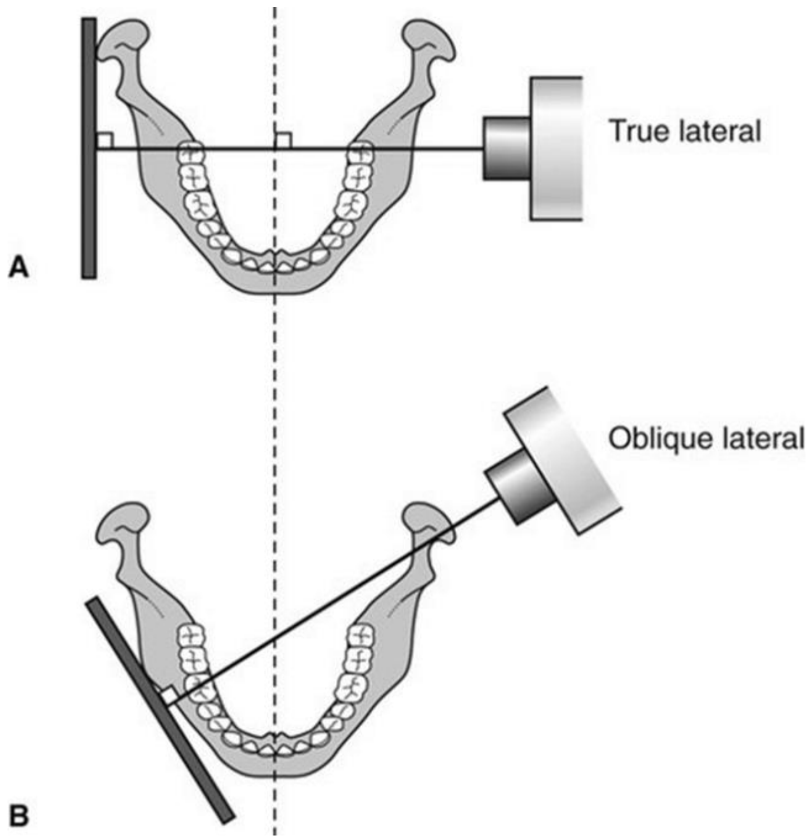


Figure 3. Diagrams showing what is meant by the terms true and oblique lateral.

Lateral oblique jaw projection: lateral oblique view:

Lateral jaw projection is useful to examine the posterior region of the mandible. It's very useful in the diagnosis of fracture or any pathology in patients with restricted mouth opening. There are three types of lateral jaw projections:

A. Body of mandible projection:

It's used in evaluation of impacted teeth, fracture of mandible and to demonstrates the premolar-molar region and the inferior border of the mandible. It provides much broader coverage than is possible with periapical projections.

Technique:

Film placement: Cassette is placed flat against the patient’s cheek and parallel with the body of the mandible, centered over the first molar. The lower border of the cassette should be parallel to the inferior border of the mandible and at least 2cm below it.

– The patient holds the cassette in position with the thumb placed under the edge of the cassette and the palm against the outer surface of the cassette.

Head position: The patients head is titled 15 degree to the side being imaged to avoid its superimposition on the area of interest. The chin is elevated upwards and extended slightly forward to avoid superimposition of hyoid bone on the mandible.

Beam alignment: Central ray is directed to a point just below the inferior border of the mandible on the side opposite the cassette.

The beam is directed upwards –15 to –20 degrees and centered on the body of the mandible (centered over the first molar). X-ray beam is directed posterioanteriorly from the opposite side perpendicular to the horizontal plane of the film (fig. 4).

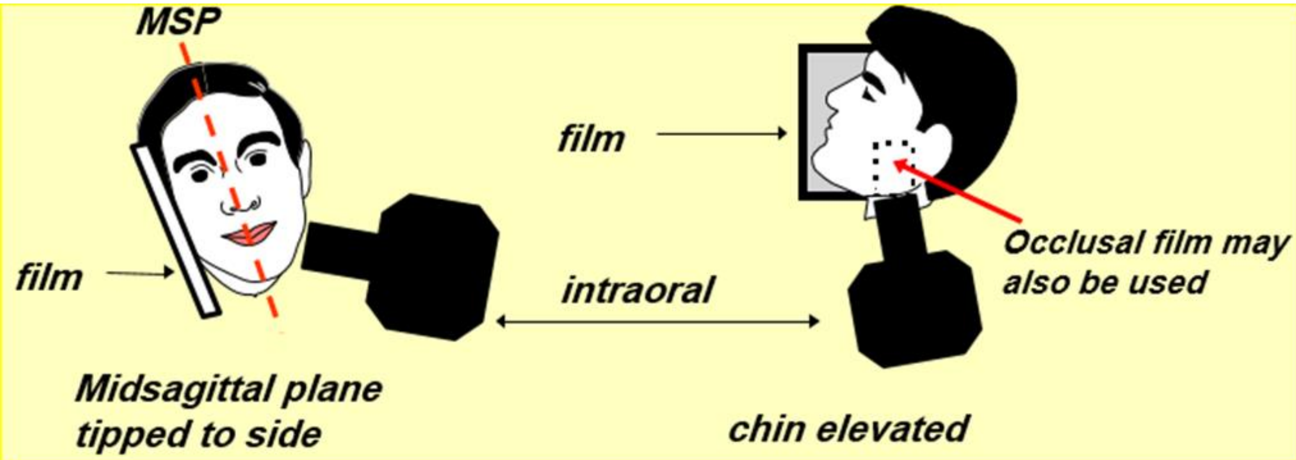


Figure 4. Lateral oblique projection (body of mandible projection). LEFT, Diagram showing the position of the image receptor, head position, and beam alignment from the front. RIGHT, Diagram showing the position of the image receptor, head position, and beam alignment from the side.

B. Ramus of mandible projection:

It gives a view of the ramus from the angle of the mandible to the condyle. It is very useful for examining the third molar regions of the maxilla and mandible.

Technique:

Film placement: The film is held flat on the cheek of the required side and centered over ramus of mandible. The lower border of the cassette should be parallel to the inferior border of the mandible and at least 2cm below it.

- The patient holds the cassette in position with the thumb placed under the edge of the cassette and the palm against the outer surface of the cassette.

Head position: The patients head is titled 15 degree to the side being imaged to avoid its superimposition on the area of interest. The chin is elevated upwards and extended slightly to avoid superimposition of hyoid bone on the mandible.

Beam alignment: The beam is directed upwards –15 to –20 degrees, 2cm below angle of the mandible and centered on the ramus of the mandible. X-ray beam is directed posterioanteriorly from the opposite side perpendicular to the horizontal plane of the film (fig. 5).

C. **Bimolar view:** In this view, both the right and left sides of mandible are taken in one film.

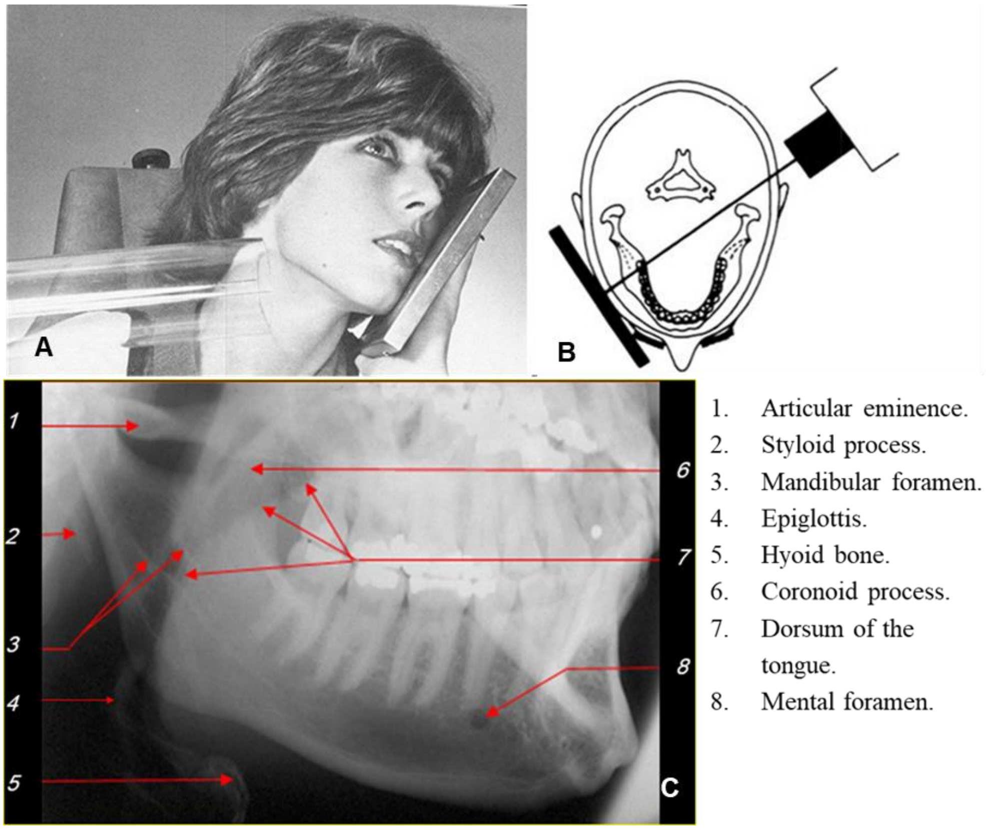
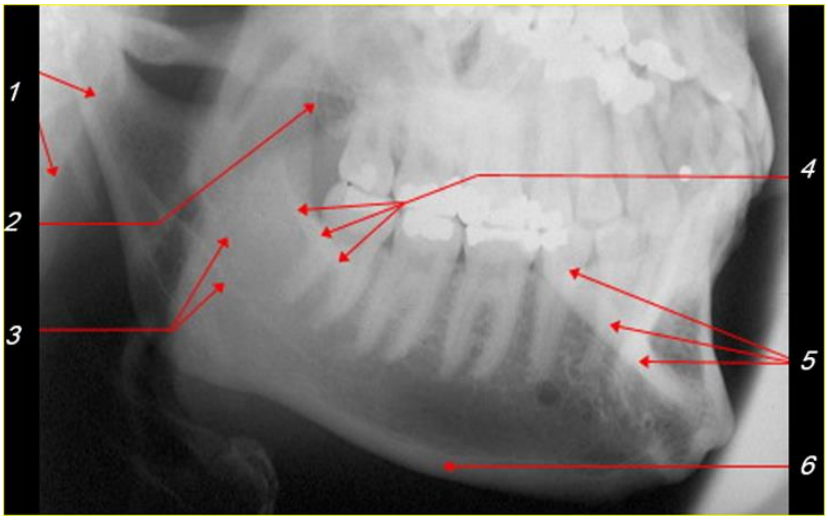
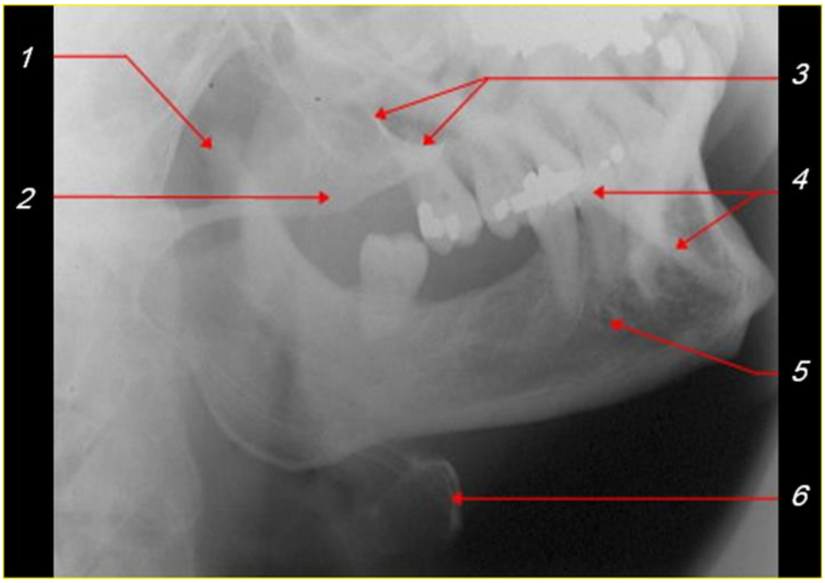


Figure 5. Lateral oblique projection. **A**, Positioning from the side. **B**, Diagram showing the position of the image receptor and beam alignment in relation to the lower arch in the axial view (ramus of mandible projection). **C**, Radiograph showing normal anatomy.



1. Posterior wall of pharynx.
2. Maxillary tuberosity.
3. Mandibular canal.
4. External oblique ridge.
5. Inferior border of mandible at tube side.
6. Inferior border of mandible at film side.

Figure 6. Lateral oblique image showing normal anatomy.



1. Coronoid process
2. Zygomatic arch
3. Zygomatic process of maxilla
4. Inferior border of mandible of tube side
5. Mental foramen
6. Hyoid bone

Figure 7. Lateral oblique radiograph showing normal anatomy.

Indications of lateral oblique jaw technique:

1. Assessment of the presence/absence of teeth and also the position of un-erupted teeth (especially third molars).
2. Detection and assessment of fractures of the mandible.
3. Assessment of large pathological lesions (e.g. cysts, tumours, osteodystrophies).
4. When intra-oral radiography is impossible (e.g. trismus, severe gagging).
5. Patients with physical and/or medical conditions in which large coverage and a rapid imaging technique is needed.

The most common craniofacial and skull projections projections:

Cephalometric projections:

They are standardized projections made with a **cephalostat**, which helps to maintain a constant relationship between the skull, the receptor, and the X-ray beam.

A cephalometric projection used a long source-to-object distance of 5 feet; to minimize image magnification. The object-to-receptor distance is typically 10 to 15 cm. These projections using film or digital sensors.

There are 2 main types of cephalometric projections:

A. Lateral cephalometric projection (lateral skull projection):

Indications:

1. A pretreatment record prior to the placement of orthodontic appliances.
2. Evaluate the relationships between the maxilla, mandible, and cranial base, in addition to soft-tissue relationships.
3. Monitor progress of orthodontic treatment and treatment outcomes.
4. Proceed with orthognathic surgical treatment planning.

Technique and positioning:

Film placement: The image receptor is positioned parallel to the patient's midsagittal plane.

Head position: The patient is placed with the left side toward the image receptor and asked to occlude in his normal intercuspation position.

Beam alignment: The central beam is perpendicular to the midsagittal plane and the image receptor centered over the external auditory meatus. Exact superimposition of right and left sides is impossible because the structures on the side near to the image receptor are magnified less than the same structures on the side far from the image receptor (fig. 8).

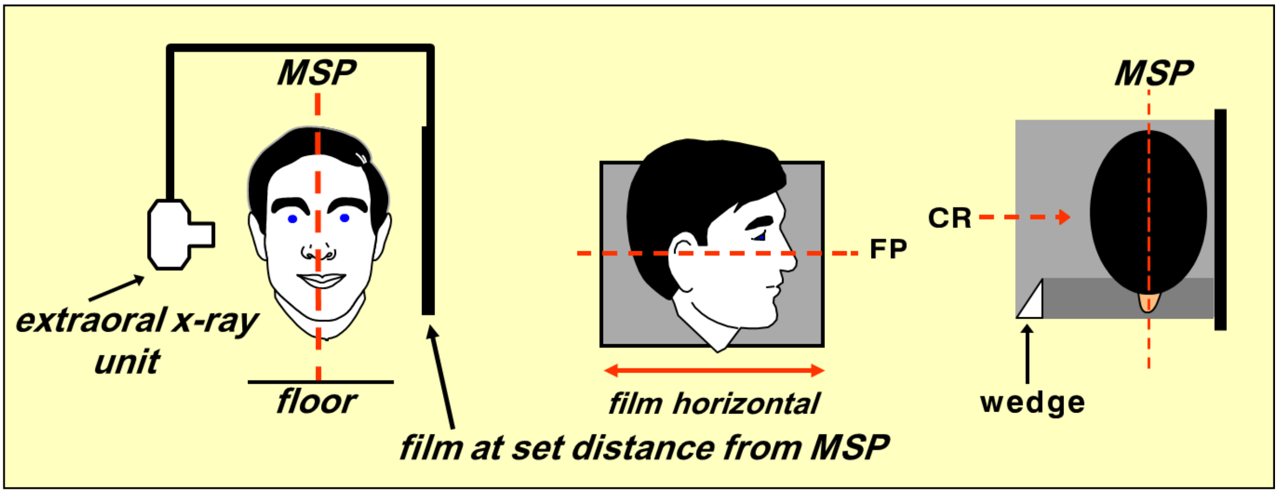


Figure 8. Lateral cephalometric projection. LEFT, Diagram showing the position of the image receptor, head position, and beam alignment from the front. MIDDLE, Diagram showing the position of the image receptor, head position, and beam alignment from the side. RIGHT, Diagram showing the position of the image receptor, head position, and beam alignment from the top.

B. Postero-anterior (PA) cephalometric projection:

Indications:

1. Evaluate craniofacial asymmetry.
2. Assess jaw skeletal relationships.
3. Monitor progress of treatment and treatment outcomes.
4. Proceed with orthognathic surgical treatment planning.

Technique and positioning:

Film placement: Cassette is placed in front of the patient, perpendicular to the floor and the midsagittal plane (parallel to the coronal plane).

Beam alignment: The central beam is directed perpendicular to the image receptor, directed from posterior to anterior (hence the name PA) at the level of the bridge of the nose (central ray is centered through the occiput). Zero horizontal angulation.

Head position: The patient faces the film, the head is tipped forewards so that the forehead and the tip of the nose touch the film (forehead-nose position). Radiographic baseline (canthomeatal line) parallel to the floor and perpendicular to the film. Midsagittal plane is perpendicular to the film and floor (fig. 9).

Another lateral skull and PA projection are made without **cephalostat** or standardization; used when a single lateral view of the skull is required like middle third facial fractures but not in orthodontics or growth studies.

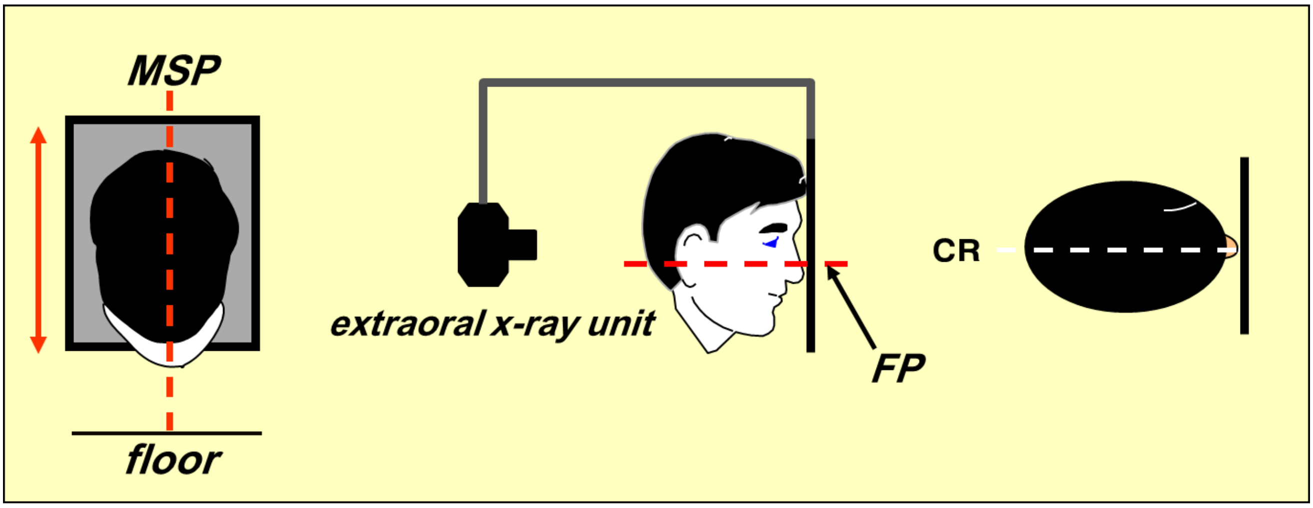


Figure 9. PA cephalometric projection. LEFT, Diagram showing the position of the image receptor and head position from the back. MIDDLE, Diagram showing the position of the image receptor, head position, and beam alignment from the side. RIGHT, Diagram showing the position of the image receptor, head position, and beam alignment from the top.

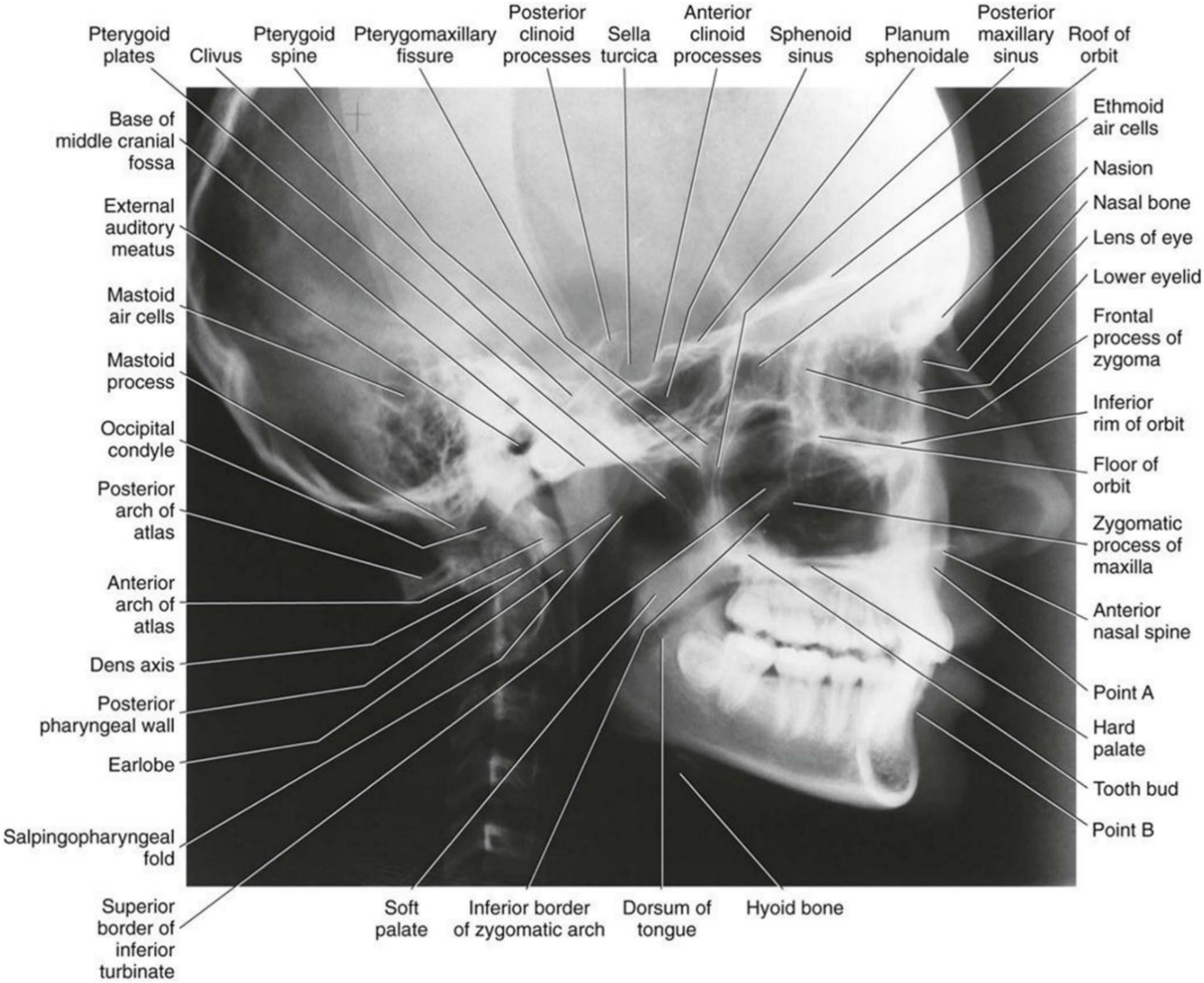


Figure 10. Anatomic landmarks identified in the lateral cephalometric projection.

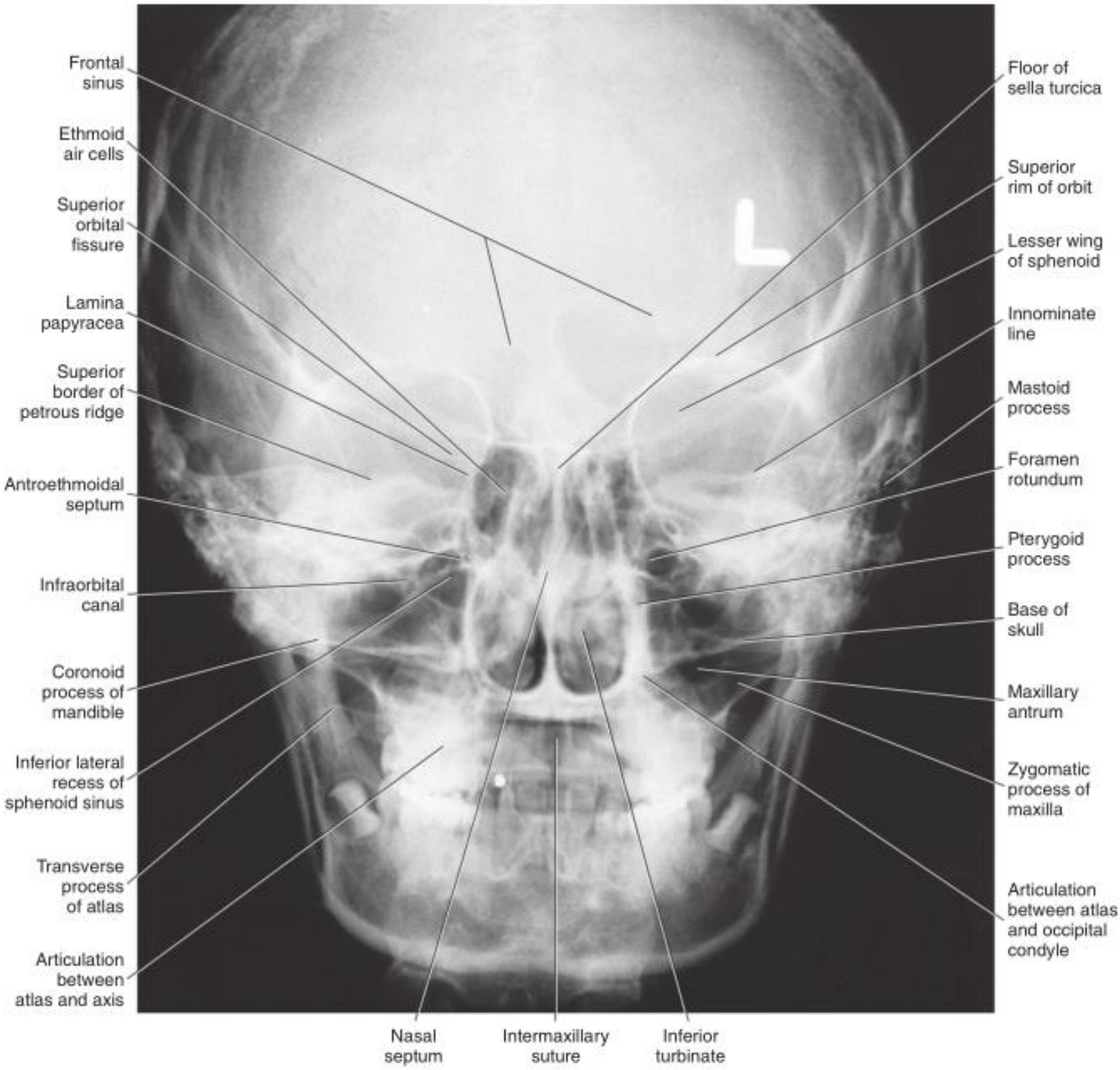


Figure 11. Anatomic landmarks identified in the PA cephalometric projection.

Most common cephalometric landmarks:

Cephalometric points:

Below is a list of the most relevant cephalometric points. When starting a tracing, it is important to understand these definitions, and to be able to identify them on a radiograph.

Skeletal landmarks:

1. Porion (P): Most superior point of the external auditory canal.
2. Sella (S): Center of the hypophyseal fossa.
3. Nasion (N): Frontonasal suture.
4. Orbitale (O): Most inferior point of the infraorbital rim.
5. PNS: Tip of the posterior nasal spine.
6. ANS: Tip of the anterior nasal spine.
7. A point (A): Deepest point of the anterior border of the maxillary alveolar ridge concavity.
8. B point (B): Deepest point in the concavity of anterior border of the mandible.
9. Pogonion (Po): Most anterior point of the symphysis.
10. Gnathion: Midpoint of the symphysis outline between pogonion and menton.
11. Menton (M): Most inferior point of the symphysis.
12. Gonion: Most convex point along the inferior border of the mandibular ramus.

Soft tissue landmarks:

1. **Soft tissue glabella:** Most anterior point of the soft tissue covering the frontal bone.
2. **Soft tissue nasion:** Most concave point of soft tissue outline at the bridge of the nose.
3. **Tip of nose:** Most anterior point of the nose.
4. **Subnasale:** Soft tissue point where the curvature of the upper lip connects to the floor of the nose.
5. **Soft tissue A point:** Most concave point of the upper lip between the subnasale and the upper lip point.
6. **Upper lip:** Most anterior point of the upper lip.
7. **Lower lip:** Most anterior point of the lower lip.
8. **Soft tissue B point:** Most concave point of the lower lip between the chin and lower lip point.
9. **Soft tissue pogonion:** Most anterior point of the soft tissue of the chin.
10. **Soft tissue gnathion:** Midpoint of the chin soft tissue outline between the soft tissue pogonion and soft tissue menton.
11. **Soft tissue menton:** Most inferior point of the soft tissue of the chin.

Submentovertex (SMV) or base projection:

Technique:

Film placement:

- Cassette is placed perpendicular to the floor and parallel with the radiographic baseline **in a cassette holding device**.
- Long axis of the cassette is placed vertically.

Head position:

- The patient faces away from the film, the head is tipped backwards (patient's neck is extended as far backward as possible).
- Radiographic baseline (canthomeatal line) parallel to the film and perpendicular to the floor.
- Midsagittal plane is perpendicular to the film and floor.

Beam alignment:

- Central ray is centered on an imaginary line joining the lower first molars.
- Central ray is directed upwards from below the chin -5 degrees and perpendicular to the image receptor, directed from below the mandible toward the vertex of the skull **(so named SMV)**, (fig. 12).

Area covered; it displays:

1) The base of the skull, including structures such as the foramen ovale, foramen spinosum, and sphenoid sinuses.
2) The zygomatic arches fracture, and the sphenoid sinuses, hard palate, and mandible.

Pathology shown: Some pathologies of the base of the skull and sphenoid sinuses.

Indications of submentovertex technique:

1. Fractures of zygomatic arches.
2. Lesions affecting palate, base of skull.
3. Sphenoidal air sinus investigation.
4. Medio-lateral assessment of posterior part of mandible.
   - Contraindicated in patients with suspected neck injuries and fractured odontoid peg.

Zygomatic arch projection:

It is also called as the **Jug-Handle** view. This radiograph is essentially similar to base of the skull projection (SMV) with the exception that the radiation exposure and development time are less.

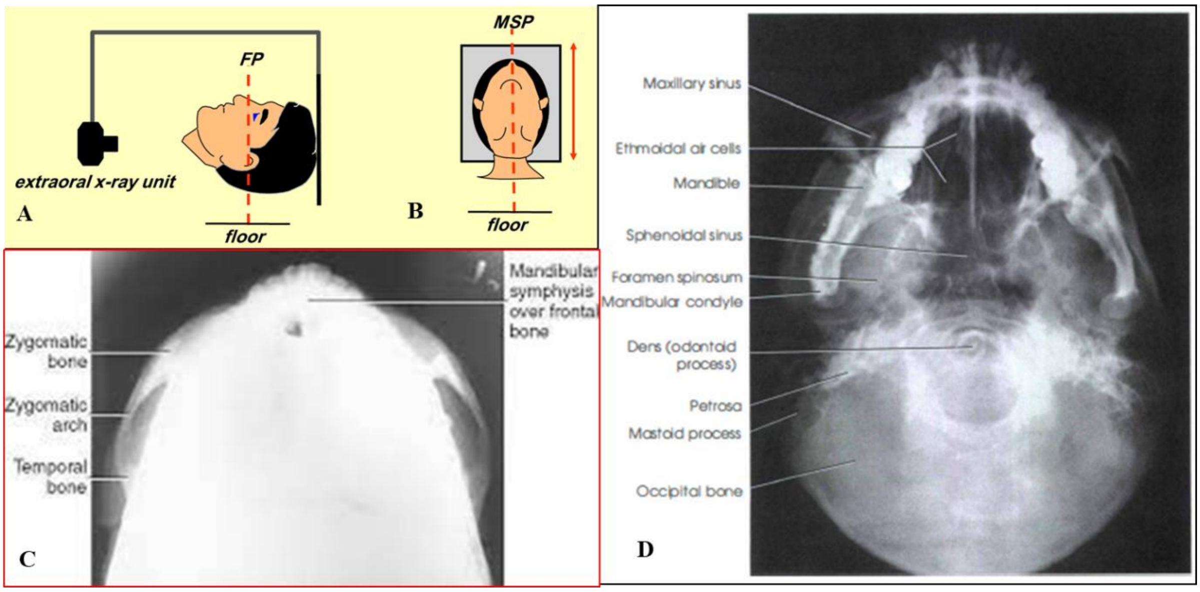


Figure 12. Submentovertex view. **A**, Diagram showing the position of the image receptor, head position, and beam alignment from the side. **B**, Diagram showing the position of the image receptor and head position from the front from below the mandible. **C**, Zygomatic arch view, Zygomatic arches are demonstrated laterally from each mandibular ramus be decreasing radiation dose. **D**, Submentovertex image.

Waters projection: **Sinus, or standard occipitomental projection:**

The Waters' projection is a variation of the PA view. It is the best projection to view 'sinuses'. It displays predominantly the maxillary sinuses. In addition, it demonstrates the frontal and ethmoid sinuses as well as the nasal cavity and midfacial fractures, the orbital ridges and floor, the zygomatico-frontal suture, and the nasal cavity.

Technique:

Film placement:

- The image receptor is placed in front of the patient.
- Cassette is placed perpendicular to the floor **in a cassette holding device**.

– Long axis of the cassette is placed vertically.

Head position:

– The patient faces the film, the head is tipped backwards so that the radiographic baseline (canthomeatal line) is at 45 degrees to the film.
– Nose and chin touch the film (nose-chin position).
– Midsagittal plane is perpendicular to the film and floor.
– ***Patient opens his mouth.***

Beam alignment: standard occipitomental projection:

– Central ray is centered through the occiput (centered in the area of the maxillary sinuses).
– Zero horizontal angulation (the central beam is perpendicular to the image receptor) (fig. 13).

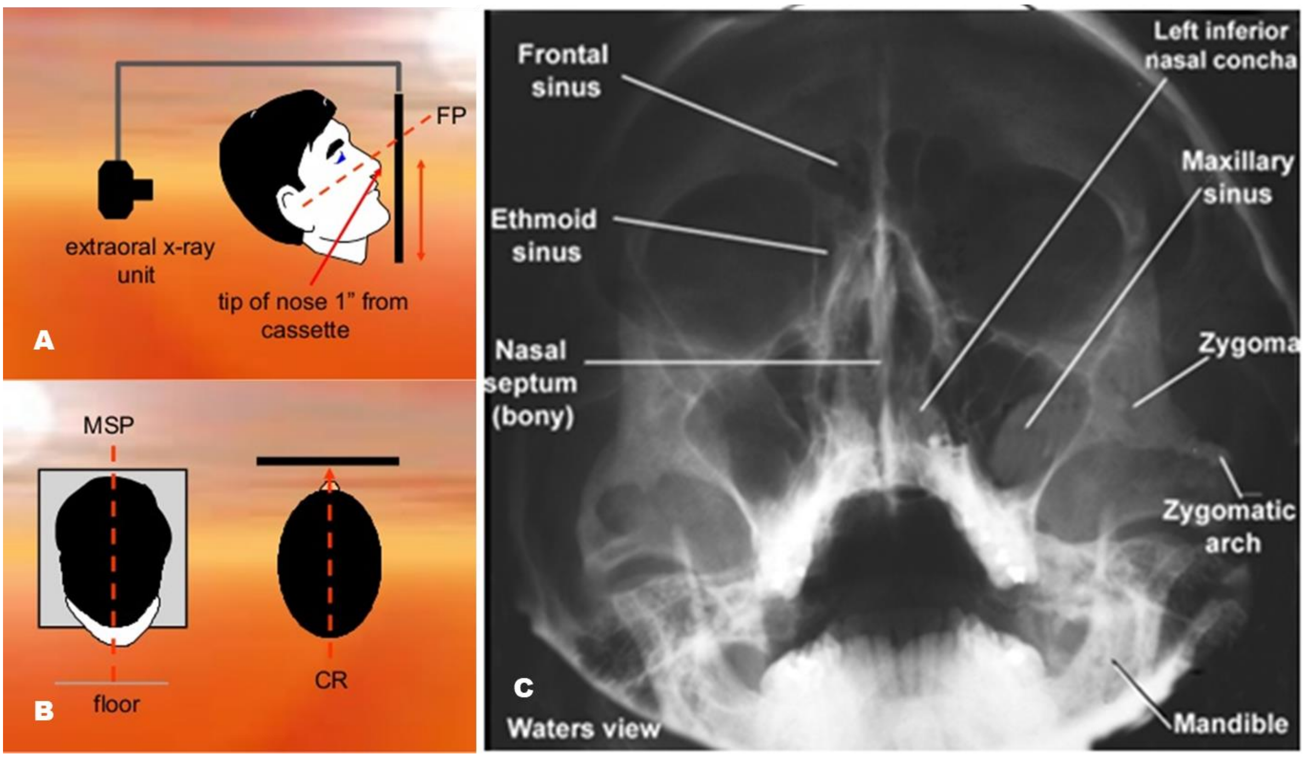


Figure 13. Waters view. A, Diagram showing the position of the image receptor and beam alignment from the side. B, Diagram showing the position of the image receptor from the back. C, Waters image showing normal anatomy.

Indications of sinus projection:

1. Maxillary, frontal, ethmoidal and sphenoidal sinuses investigations.

2. Coronoid process fractures.
3. Middle third facial fractures.

30° occipitomental projection: The patient is in the nose–chin position and the X-ray beam is aimed downwards at 30°, centered through the lower border of the orbit (fig. 14).

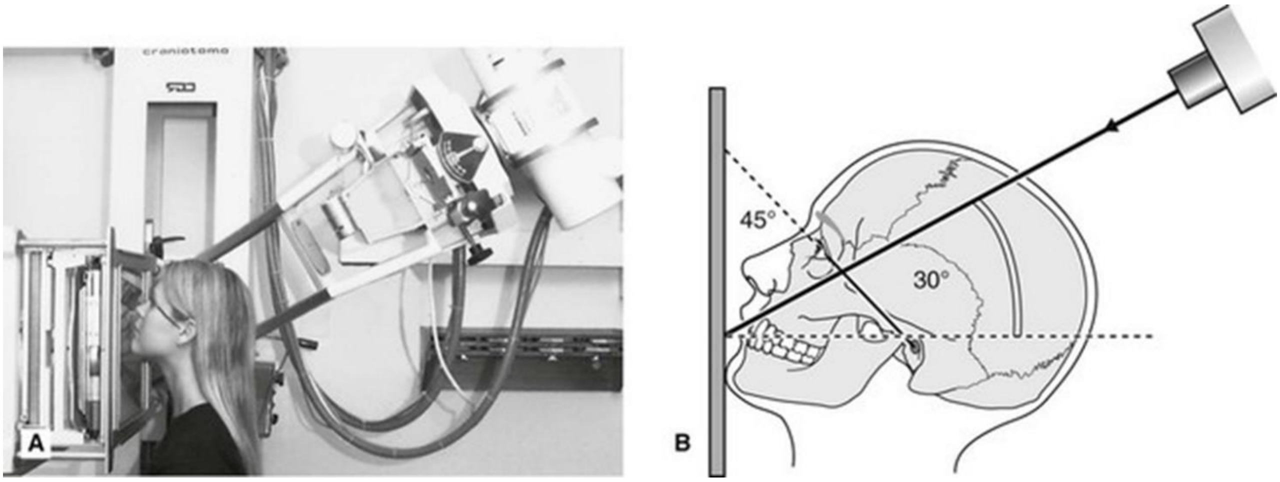


Figure 14. **A**, Positioning for the 30° OM projection – the patient is in the nose–chin position and the X-ray beam is aimed downwards at 30°. **B**, Diagram of the positioning – the radiographic baseline is at 45° to the image receptor, and the X-ray beam is aimed downwards at 30°.

Reverse Towne's projection:

A reverse Towne's view is simply the reverse with the face away from the emitter.

Film placement:

- The image receptor is placed in front of the patient, perpendicular to the midsagittal plane and parallel to the coronal plane (cassette is placed perpendicular to the floor in a cassette holding device).
- Long axis of the cassette is placed vertically.

Head position:

- The patient faces the film (the image receptor is placed in front of the patient). The patient's head is tilted downward so that the canthomeatal line forms a 25-degree to 30-degree angle with the image receptor.

- To improve the visualization of the condyles, the patient's mouth is opened so that the condylar heads are located inferior to the articular eminence (the condylar heads out of the glenoid fossa, open mouth technique).
- When requesting this image to evaluate the condyles, it is necessary to specify "open-mouth, reverse-Towne"; otherwise, a standard Towne view of the occiput may result.

Beam alignment:

- If the nose away from the film, the central beam is perpendicular to the image receptor at the level of the condyles (fig. 15, D).

Or, Head position and beam alignment:

- If the head is tipped forwards so that the forehead and the tip of the nose touch the film (forehead-nose position).
- Radiographic baseline (canthomeatal line) is parallel to the floor and perpendicular to the film.
- Midsagittal plane is perpendicular to the film and floor.
- Central ray is directed upwards from below the occiput at -30 degrees to the floor. Central ray is centered at the level of the condyles (fig. 15; A, B, and C).
- Zero horizontal angulation.

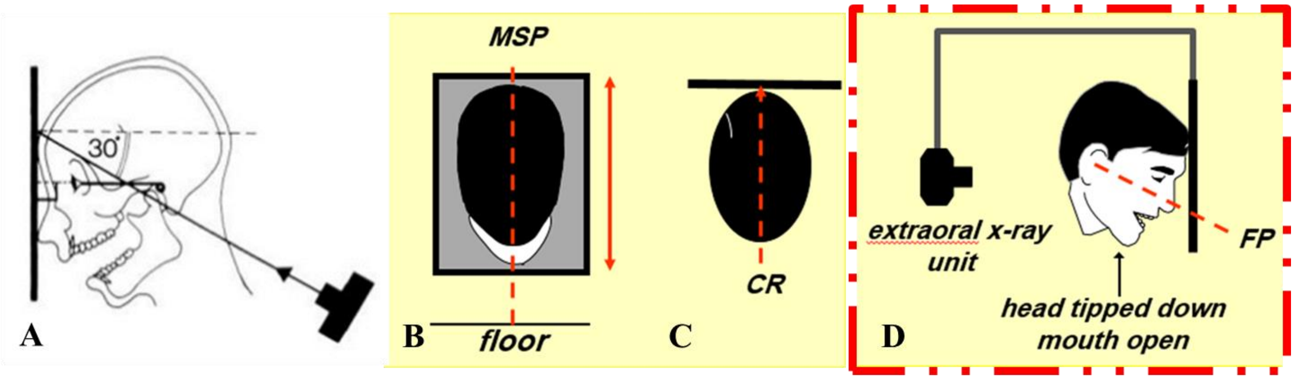


Figure 15. Diagram of the positioning for the reverse Towne's projection. (**A**) Positioning from the side, (**B**) positioning from the back, and (**C**) positioning from the top with -30 degrees to the floor. (**D**) Positioning from the side with 0 degree of the beam to the floor.

Indications of reverse Towne's radiograph:

1. Used to evaluate patients with suspected fractures of the condylar heads and condylar necks, also when displacement of the condyle is suspected

2. Condylar hypoplasia or hyperplasia.
3. Also show the posterolateral wall of the maxillary antrum.

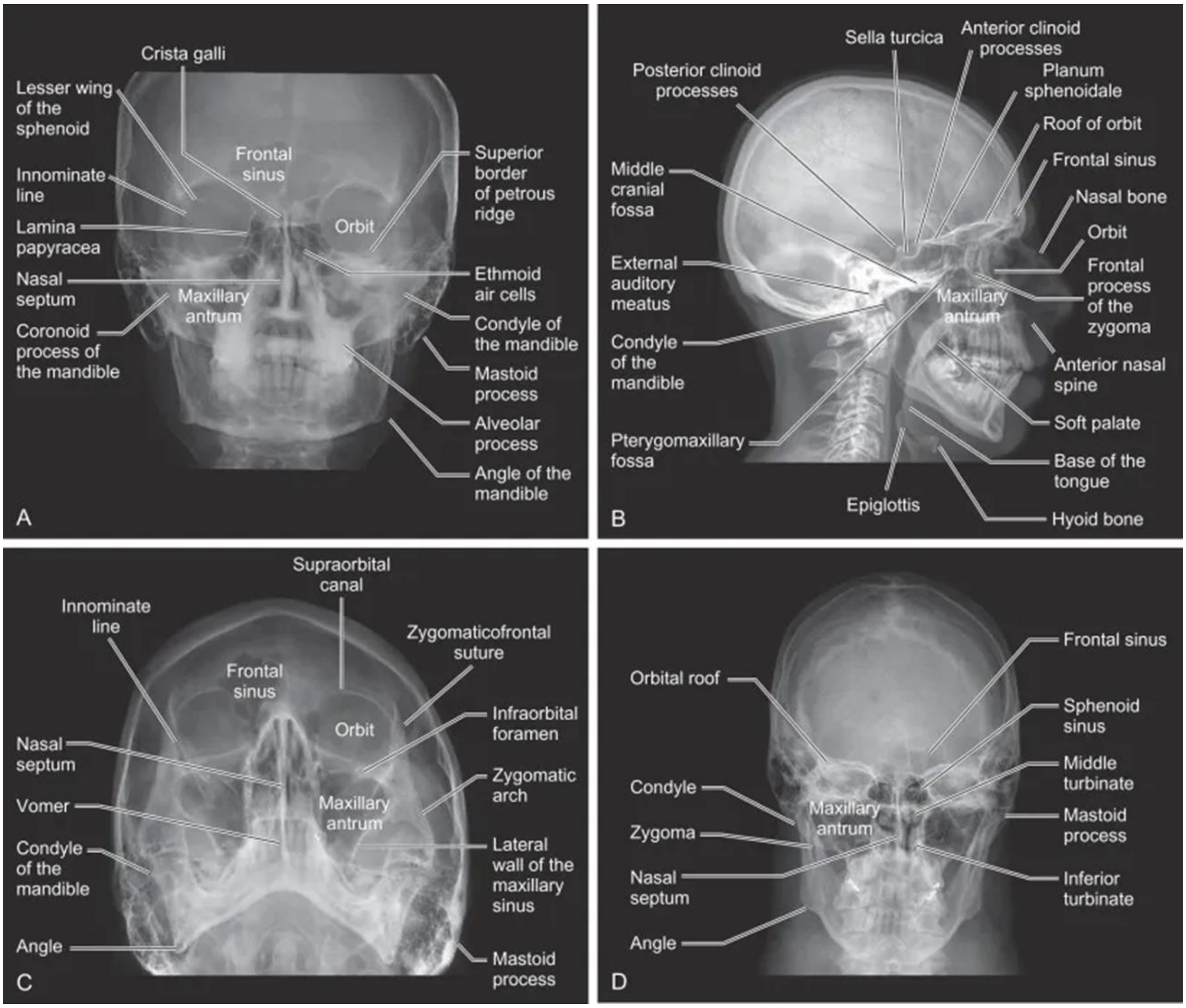


Figure 16. Plain radiographs of the face: (A) PA skull view. (B) True lateral skull view. (C) Occipitomental view. (D) Reverse Towne’s view.

Tempromandibular joint (TMJ) projections:

TMJ is the area where the mandible articulates with cranium. TMJ is consists of bones (mandibular condyle and temporal bone), articular disc, capsular ligament, and joint cavity (synovial membrane).

Bony components: The condyle is the mandibular component of the TMJ extends superiorly from the ramus by a narrow neck. Various condylar shapes noticed; may be flat, round, or convex.

The articular component of the temporal bone is formed by the inferior surface of the squamous process, and is composed of the glenoid fossa posteriorly and the articular eminence and tubercle anteriorly.

Articular disc (meniscus): It is composed of avascular fibrous connective tissue and it is positioned between the condylar and temporal components of the joint divides the joint cavity into inferior and superior joint spaces which are located below and above the disc, respectively.

Retrodiscal tissues (posterior disc attachment): It is consist of superior and inferior lamellae enclosing a region of loose vascular tissue, and this is often referred to as the bilaminar zone.

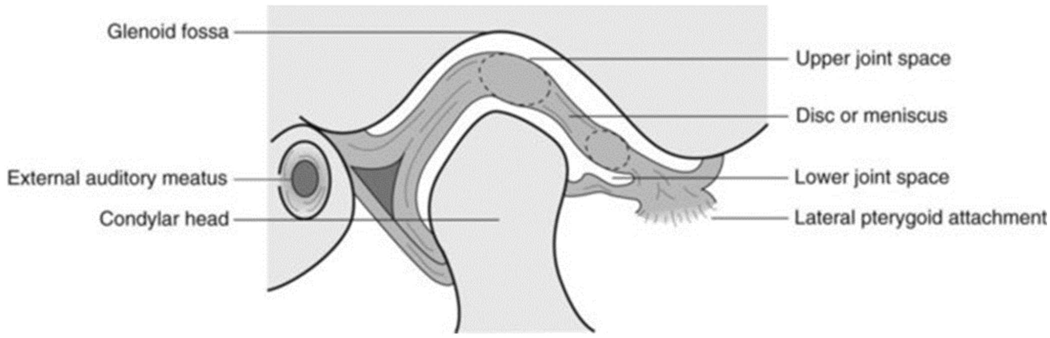


Figure 17. Diagram of a sagittal section through the right TMJ showing the various components.

Types of TMJ imaging techniques:

1. Plain radiographs; transcranial projection, transorbital projection, and transpharyngeal projection.
2. Panoramic radiography (OPG).
3. Cone beam computed tomography (CBCT) and Multidetector computed tomography (MDCT)
4. MRI and ultrasonography for soft tissue imaging.

Plain radiography:

Transcranial-view:

It is one of the most popular plain imaging techniques to study the TMJ.

- It used in visualization of changes in lateral aspect of the articulating surface, position and shape of condyle and fossa (joint space is visualized).

Film placement: The film cassette is positioned flat against the facial skin surface on the side of interest over the ear in such a way that it is centered over the TMJ.

Head position: The mid sagittal plane is perpendicular to the floor and parallel with the cassette.

Beam alignment: The central beam projected across the cranium either with closed-mouth or open mouth position. The central x-ray beam is directed to a point 2 inches superior to and 0.5 inches behind the external auditory meatus (fig. 18).

Figure 18. Transcranial projection. **A**, Teeth together. **B**, Maximal open position. **C**, The condyle can be visualized in the fossa with the articular eminence directly anterior. The relatively round (dark) area posterior to the condyle is the external auditory meatus. The condyle has translated out of the fossa during an opening movement.

Transorbital view:

This view is also called zimmer projection or transmaxillary projection. It is a frontal projection of the TMJ.

- It demonstrate the entire latero-medial articulating surface of the condyle and articulator eminence and the condylar neck.
- Transorbital view helps in the visualization of the joint with relatively less super imposition.

Head position: The head of the patient is tipped down 10 degrees in such a way that the canthomeatal line is horizontal. The midsagittal plane is kept at 30 degrees to the central X-ray beam by moving the head to the left for left side projection and to the right for right side projection.

Film placement: The cassette is positioned behind the patients head.

Beam alignment: The central X-ray beam is directed through the ipsilateral orbit and through the required TMJ, exiting from the skull behind the mastoid process. During the exposure, the patient is asked to open the mouth as widely as possible (fig. 19).

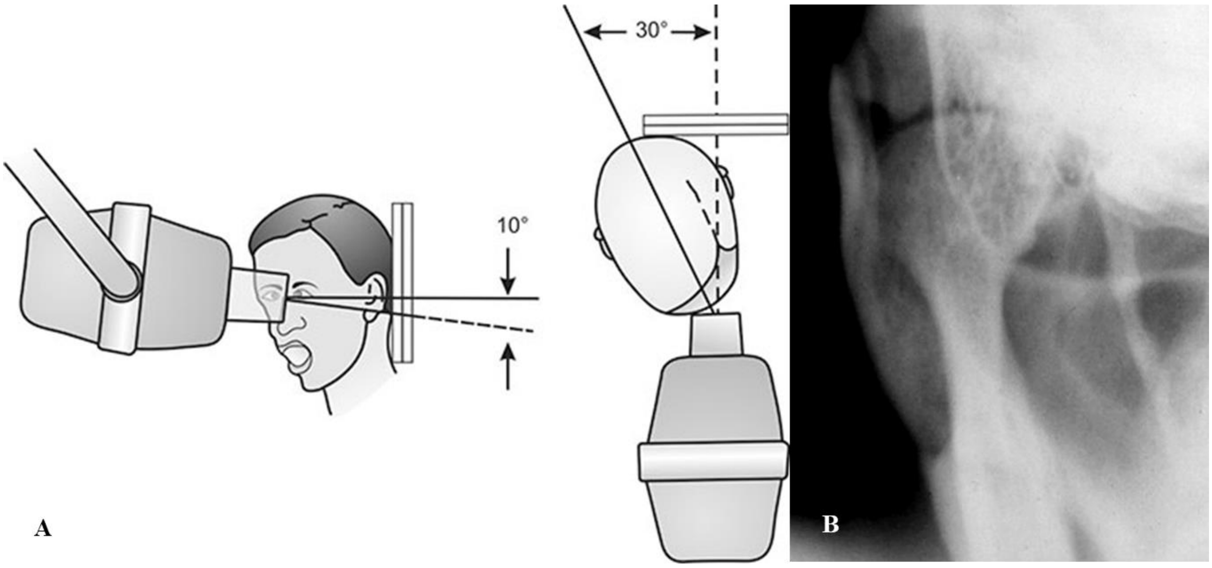


Figure 19. A, Diagram illustrating transmaxillary or transorbital projection. B, transorbital (coronal) view of the temporomandibular joints.

Transpharyngeal view:

It also called infracranial view.

- It demonstrate the angular process from the midmandibular ramus to the condyle.
- This technique helps in the diagnosis of fractures of the condyle and the condyle neck and in detecting alterations in condyle morphology.

Film placement: The cassette is positioned against the side of patient's head over the ear in such a way that the TMJ of interest is in the center of the cassette. The cassette is held parallel to the mid sagittal plane next to TMJ of interest.

Beam alignment: The X-ray tube is kept on the side of the skull opposite to the TMJ imaged. It is angled in such a way that the patient opens the mouth wide, so that the central X-ray beam enters through the tube side sigmoid notch, below the skull base through the oropharynx to TMJ (fig. 20).

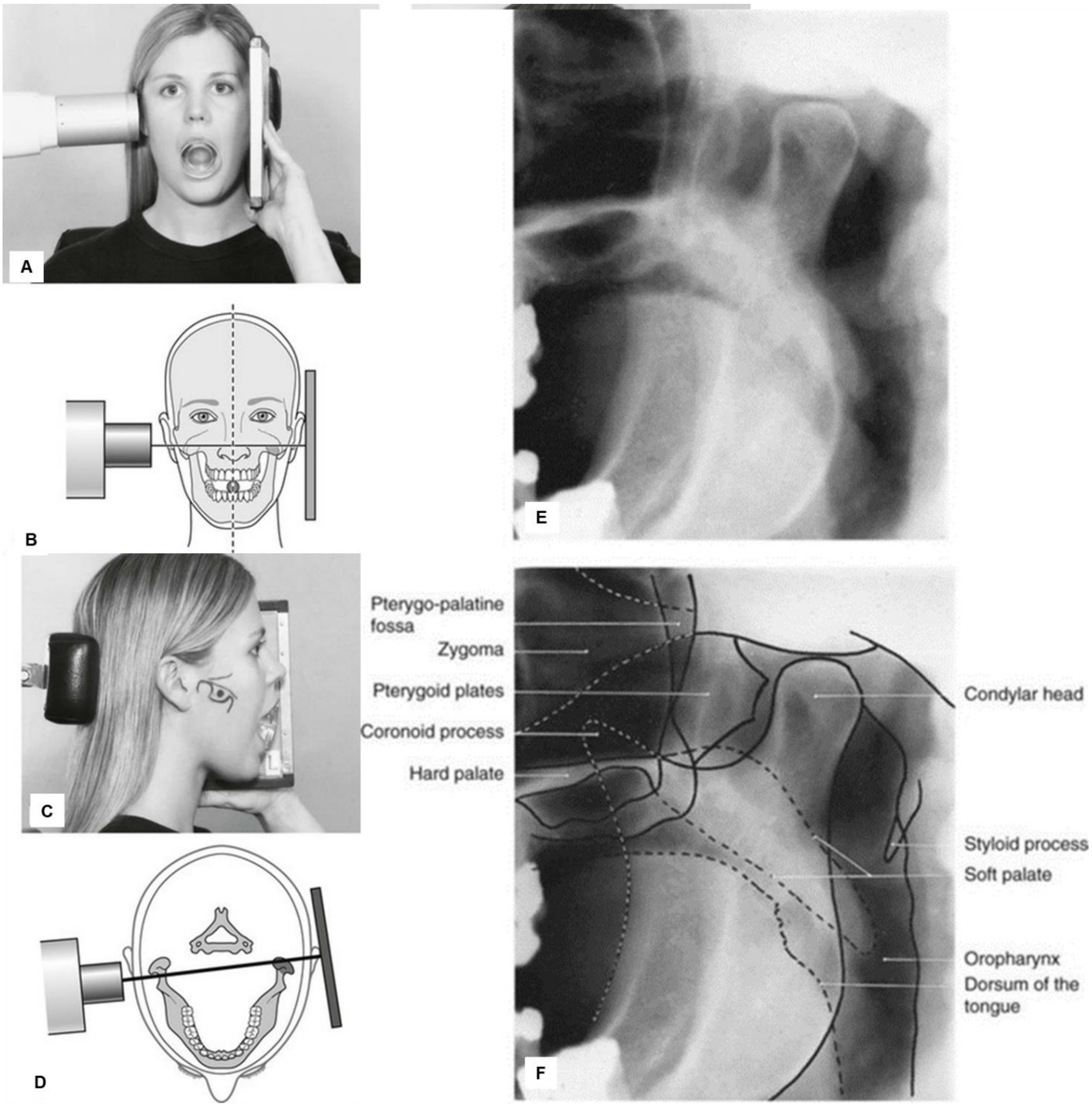


Figure 20. **A**, Positioning for the left transpharyngeal, the patient is holding the film against the left TMJ, the mouth is open and the X-ray beam is aimed across the pharynx. **B**, Diagram of the positioning from the front showing the film parallel to the mid-sagittal plane and the X-ray beam aimed across the pharynx. **C**, The side of the face with various anatomical structures; the zygomatic arch, condyle, sigmoid notch and coronoid process drawn in to clarify the centring point of the X-ray beam which is

marked. **D**, Diagram of the positioning from above, showing the X-ray beam aimed slightly posteriorly across the pharynx. **E**, Transpharyngeal radiograph. **F**, Same image (E) with the major anatomical features drawn in illustrating the shape of the head of the condyle and the condition of the articular surface from the lateral aspect.

Abnormalities of the TMJ:

1. Developmental abnormalities such as (condylar hypoplasia, condylar hyperplasia and coronoid hyperplasia, bifid condyle).
2. Soft tissue abnormalities such as disc displacement (with or without reduction).
3. Remodeling and arthritic conditions.
4. Trauma such as fracture, dislocation and effusion.
5. Ankylosis such as bony and soft tissue ankylosis.
6. Tumors (benign and malignant).

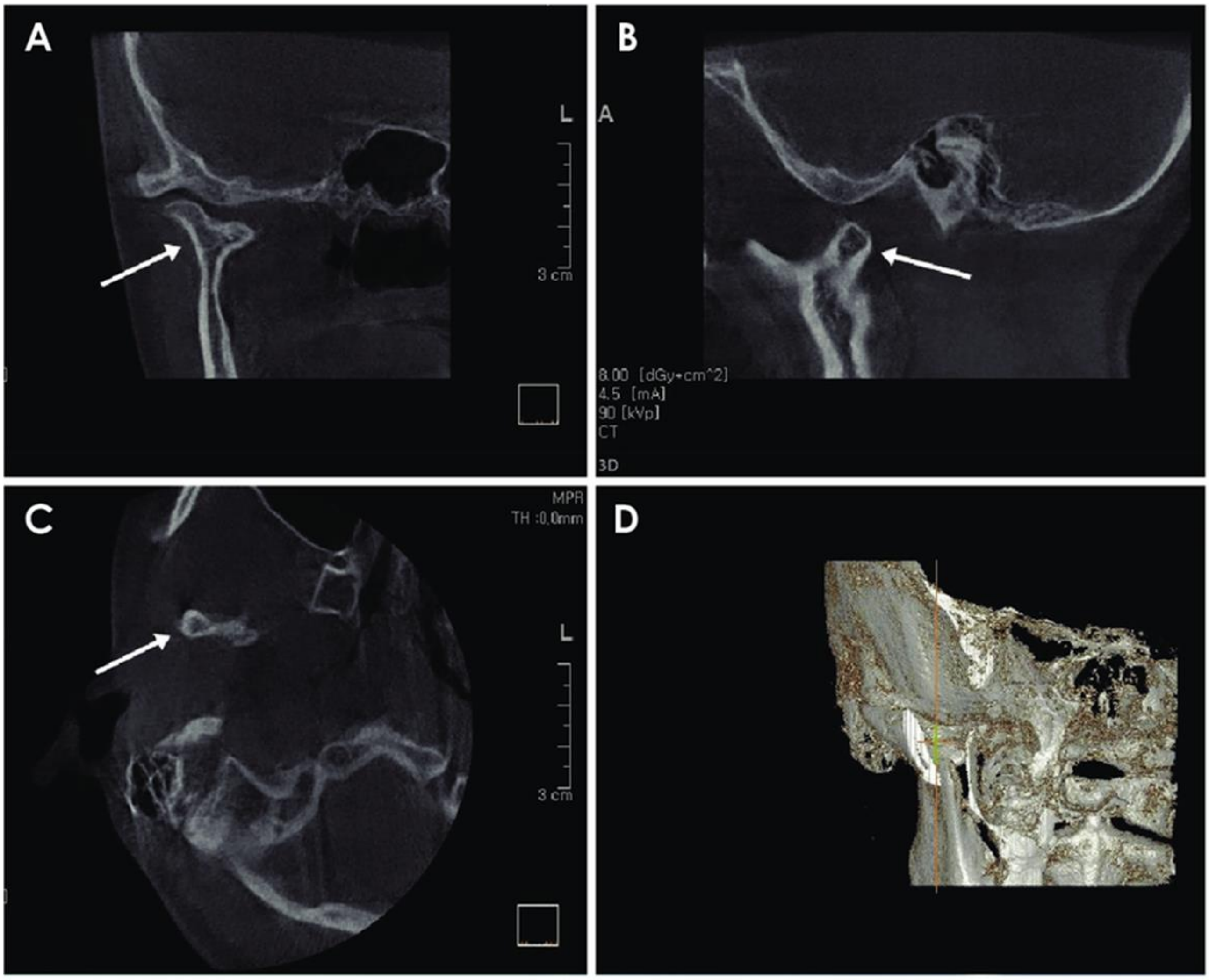


Figure 21. CBCT images demonstrate the appearance of the bifid mandibular

condyle. **A.** Coronal image. **B**. Sagittal image. **C**. Axial image. **D**. Three-dimensional reconstruction image.

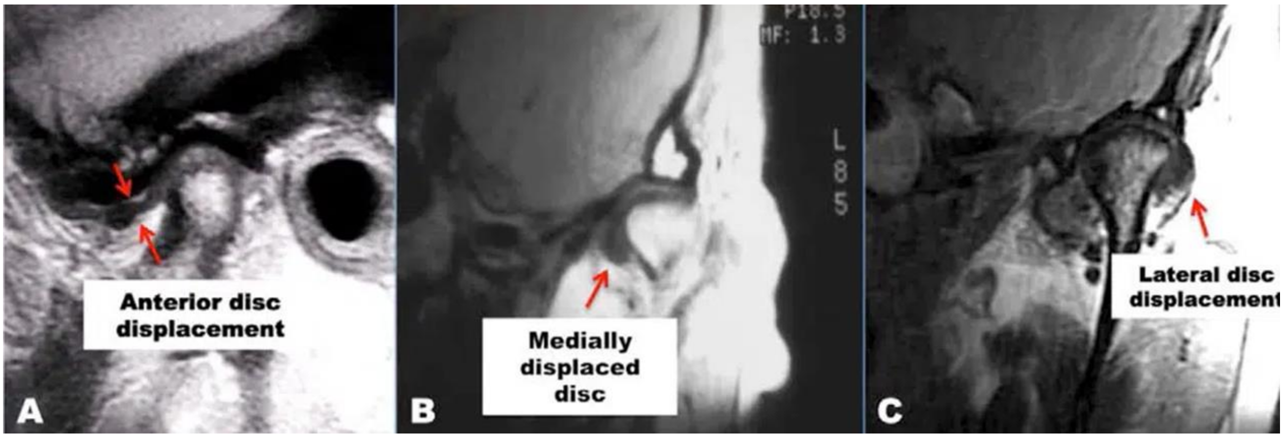
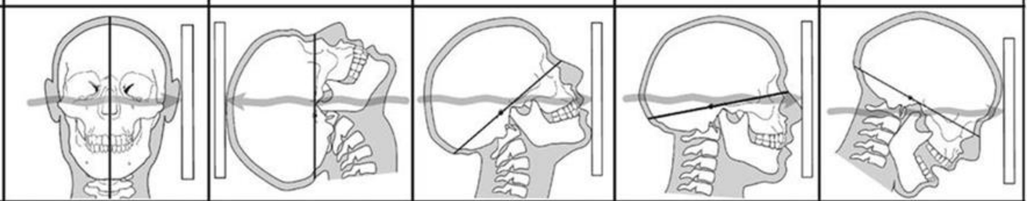
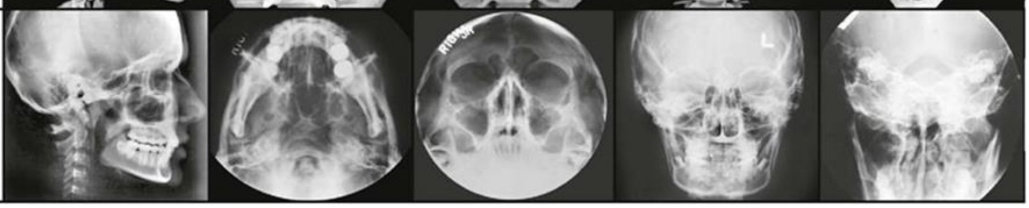


Figure 22. **A**. Sagittal view of anteriorly displaced disc. **B**. In this coronal view the articular disc is laterally displaced. **C**. In this coronal view the disc is medially displaced.

Table 1. Technical aspects of extraoral radiographic projections and resultant images.

	LATERAL CEPH	SMV	WATERS	PA CEPH	REVERSE TOWNE
Patient placement	Film parallel to midsagittal plane	Canthomeatal line parallel to film	Canthomeatal line at 37° with film	Canthomeatal line at 10° with film	Canthomeatal line at –30° with film
Central beam	Beam perpendicular to film	Beam perpendicular to film	Beam perpendicular to film	Beam perpendicular to film	Beam perpendicular to film
Diagram of patient placement					
Illustration of patient placement					
Skull view					
Resultant image					

Lecture 15 **Panoramic Radiography**

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

Panoramic imaging (also called pantomography, orthopantomogram, orthopantomograph, pantomogram, OPG or OPT) is a technique for producing a single tomographic image of the facial structures, where the maxilla, the mandible, and their supporting structures are in the focal trough and the structures that are superficial and deep to the trough are blurred. Images of multiple planes are taken to make up the composite panoramic image to show a two-dimensional view of a half-circle from ear to ear.

Principles of panoramic radiography:

Paatero and Numata were the first to describe the principles of panoramic radiography. X-ray source rotates around the patient's head and in opposite direction to the rotation of image receptor and collimator. Lead collimators in the shape of a slit, located at the x-ray source and at the image receptor, limit the central ray to a narrow vertical beam. Another collimator between the objects and the receptor reduces scattered radiation.

As the x-ray tube head moves around one side of the patient, the receptor assembly moves on the opposite side (fig. 1). The image receptor slides past the collimator sequentially producing a latent image. With a CCD image receptor, there is a vertical CCD linear array behind the collimator that continuously reads out the exposure to produce an image.

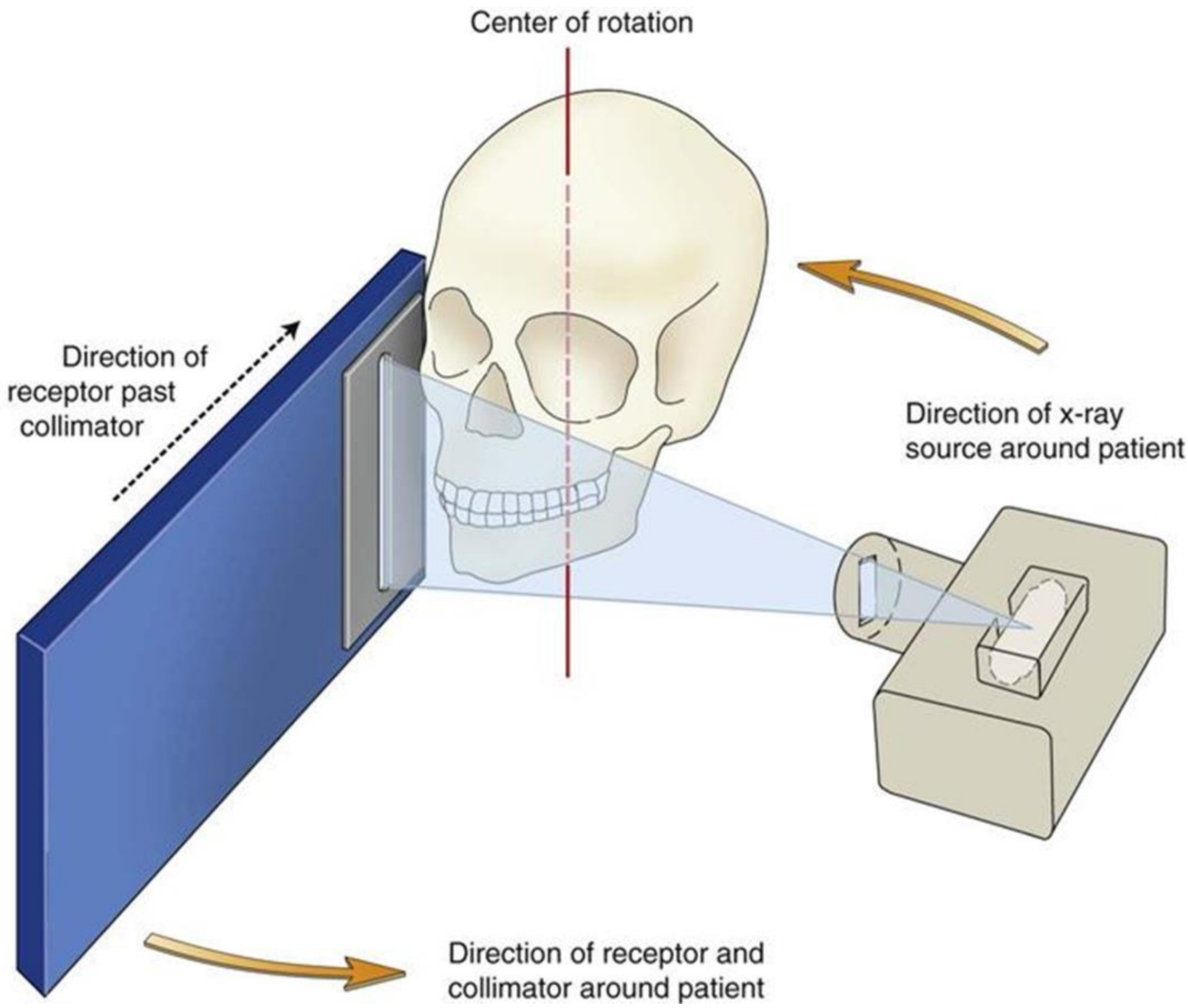


Figure 1. Schematic view of relationships between the x-ray source, the patient, the secondary collimator, and film or PSP image receptor.

Indications:

OPG is used by health care professionals to provide information on:

1. Overall evaluation of dentition.
2. Evaluation of intraosseous pathology such as cysts, tumors and infections.
3. Gross evaluation of of tempromandiular joints.
4. Evaluation of impacted teeth, dental implant, and orthodontic treatment.
5. Evaluation of permanent teeth eruption and mixed dentition.
6. Dentomaxillofacial trauma such as fracture.
7. Developmental disturbances of maxillofacial skeleton.

Advantages of panoramic examination:

1. Broad coverage of facial bones and teeth.
2. Exposes the patient to less radiation, one third the dose from an intraoral full mouth survey.
3. Field limitation techniques result in further dose reduction.
4. Ease of panoramic radiographic technique and requires less technical expertise.
5. Can be used in patients with trismus or in patients who cannot tolerate intraoral radiography.
6. Short time required for making the image (quick) and convenient radiographic technique where film placed outside the patient mouth
7. Patient's ready understandability of panoramic films, making them a useful visual aid in patient education and case presentation.
8. Patient movement distorts only that part of the image being produced at that instant.

Disadvantages:

1. Lower-resolution images that do not provide the fine details provided by intraoral radiographs.
2. Magnification across image is unequal, making linear measurements unreliable.
3. Image is superimposition of real, double, and ghost images and requires careful visualization to decipher anatomic and pathologic details.
4. Requires accurate patient positioning to avoid positioning errors and artifacts, so it is not suitable for children under 5 years or on some disabled patients.
5. Difficult to image both jaws when patient has severe maxillomandibular discrepancy. Some patients do not conform to the shape of the focal trough.

The main disadvantage of panoramic radiology is that the image does not display the fine anatomic detail available on intraoral periapical radiographs.

- The availability of a panoramic radiograph for an adult patient often does not preclude the need for intraoral films for the diagnoses of most commonly encountered dental diseases.

Why a periapical or bitewing film is preferred over a panoramic film for caries early periodontal disease, early or limited periapical pathology, and endo treatment?

1. Periapical radiography more useful for detecting small carious lesions, fine structure of the marginal periodontium, or periapical disease more than panoramic radiography.
2. The sharpness or detail seen on a periapical film is much better than that seen on a panoramic film. The images are "fuzzier" on a panoramic film and are not good for diagnosing early pathology.
3. On panoramic images the proximal surfaces of premolars also typically overlap.

Other problems associated with panoramic radiography include:

1. Unequal magnification and geometric distortion across the image.
2. Occasionally, the presence of overlapping structures, such as the cervical spine, can hide odontogenic lesions, particularly in the incisor regions.
3. Clinically important objects may be situated outside the focal trough and may appear distorted or not be seen at all.

When a full-mouth series of radiographs is available for a patient requiring only general dental care, typically little or no additional useful information is gained from a simultaneous panoramic examination.

Dental panoramic tomography has become a very popular radiographic technique in dentistry. The main reasons for this are as follows:

1. All the teeth and their supporting structures are shown on one film.
2. The technique is reasonably simple.
3. The radiation dose is relatively low approximately equal to that from four intraoral films.

Panoramic machines:

There are several manufacturers of panoramic equipment. Most of the units are designed for a patient to stand, but they will also accommodate a patient seated on a stool or in a wheelchair. For some machines, the tubehead always starts out on the same side of the patient (either left or right); for other machines, the tubehead can start from either side (varies from one patient to the next).

Focal trough (image layer):

The focal trough is a three-dimensional curved zone, or “image layer,” where the structures lying within this zone are reasonably well defined on the final panoramic image (fig. 2). Images are most clear in the middle and become less clear further from the central line. Objects outside the focal trough are blurred, magnified, or reduced in size and are sometimes distorted to the extent of not being recognizable.

Through the design of the panoramic machine, this zone corresponds to the shape of the upper and lower jaws.

The shape and width of the focal trough is determined by the path of the sliding rotation center. The closer the rotation center is to the teeth, the narrower the focal trough in that area. Because the rotation center is closer to the anterior teeth, the focal trough is narrower in this area.

Objects in the focal trough will be magnified in both the horizontal and vertical dimensions. The overall magnification will be 20-30%.

The shape of the focal trough varies with **the brand of equipment** used as well as with **the imaging protocol selected within each unit**.

The shape and width of the focal trough is determined by:

1. The path and velocity of the receptor and x-ray tube head (the path of the sliding rotation center).
2. Alignment of the x-ray beam.
3. Collimator width.

The location of the focal trough can change with extensive machine use, so recalibration may be necessary if consistently suboptimal images are being produced.

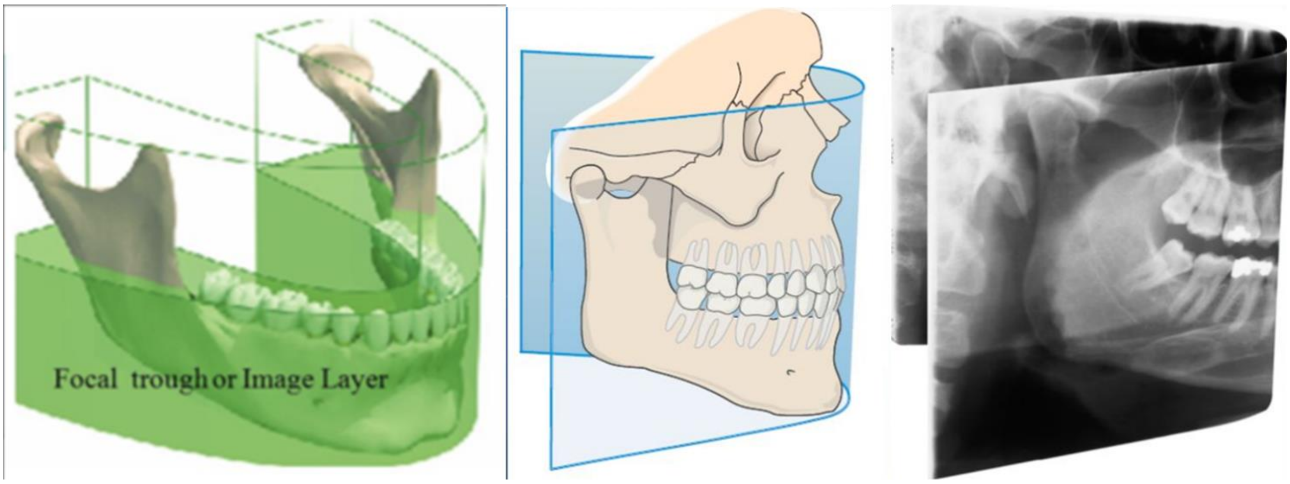


Figure 2. Focal trough. The moving source and receptor generate a zone of sharpness, known as the focal trough. The closer an anatomic structure is positioned to the center of the trough, the more clearly it is imaged on the resulting radiograph.

The tubehead rotates in an arc around the back of the patient's head. The film rotates in front of the patient. The center of this rotation varies as the tubehead rotates, producing a sliding rotation center (fig. 3). The vertical angulation cannot be varied. The X-ray beam is directed slightly upwards (fig. 4).

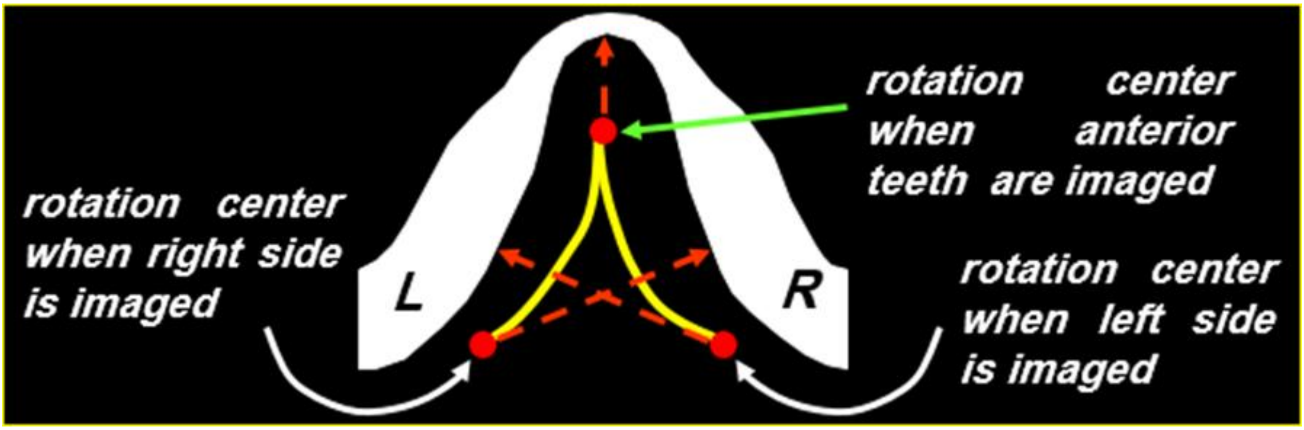


Figure 3. Sliding rotation centers.

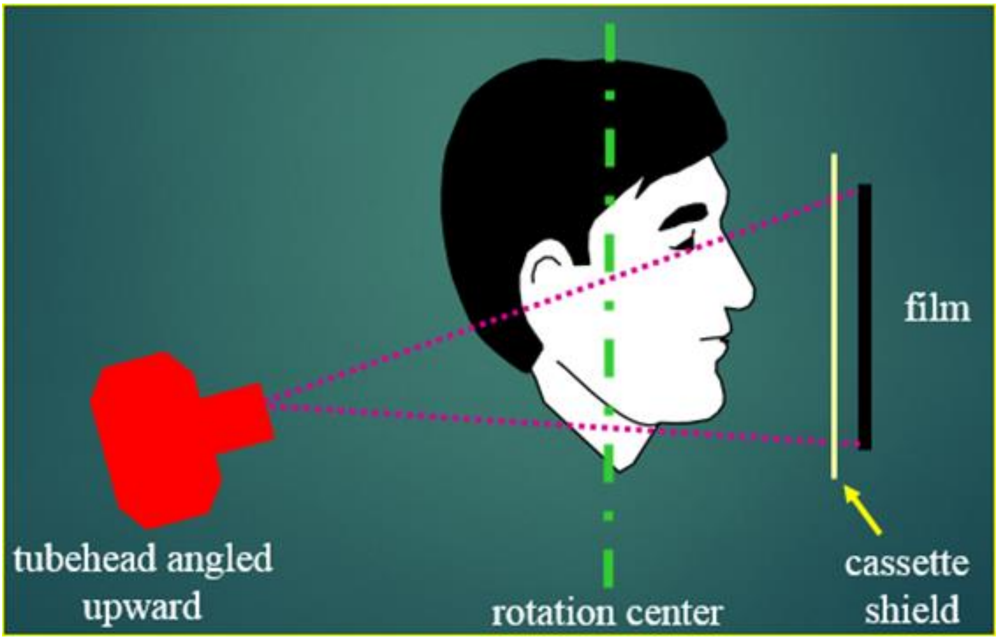


Figure 4. Diagram illustrating the upward vertical angulation in panoramic imaging.

In some panoramic machines, the shape of the focal trough can be adjusted by varying the shape of the moving center of rotation**:**

1. To conform better to the shape of the patients' maxillomandibular anatomy.
2. Or to show specific anatomic areas of interest better, such as the TMJ or the maxillary sinuses.
3. Allows better imaging of children.
4. Allows better imaging of unusually shaped patients.

– In some units, the rotational arc of the x-ray source-receptor movement is decreased to modify the focal trough size to pediatric jaws. The decreased rotational arc also results in reduced patient radiation exposure.

– In some modern panoramic units, the projection angle of the x-ray beam is modified to yield images with decreased overlap of adjacent teeth and with minimal superimposition of structures from the opposite side of the jaw.

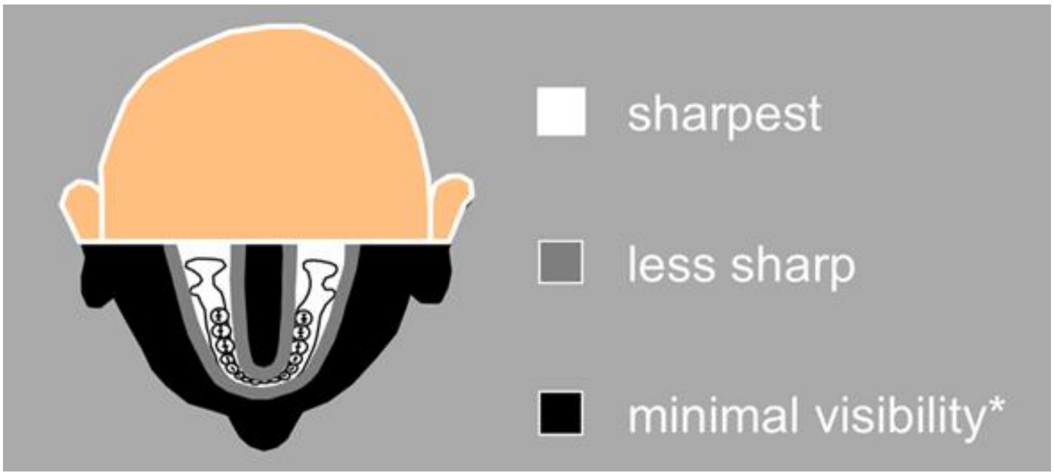


Figure 5. The sharpness of objects will vary depending on their location relative to the focal trough. * The images of objects with minimal tissue density are blurred and are not easily seen on the film. Dense objects, such as a bullet fragment, will still be seen.

Real, double, and ghost images:

Because of the rotational nature of X-ray source and receptor, the x-ray beam intercepts some anatomic structures twice. Depending on their location, objects may cast three different types of images:

A. **Real images:** object that lie between the center of rotation and the receptor form a real image (all the objects within focal trough cast relatively sharp images) (fig 6, D).
B. **Double images:** objects that lie posterior to the center of rotation and that intercepted twice by the x-ray beam form double images (fig 6, E).
C. **Ghost images:** objects that located between the X-ray source and center of rotation, can cast ghost images. The ghost image appear on the opposite side of it's true anatomic location and at higher level (fig 6, F).

A ghost image will be:

1. Located on the opposite side from the image of the actual object.
2. The same shape as the actual object.
3. Larger than the image of the actual object.
4. Projected higher on the film.
5. Blurred (less sharpness; "ghostlike") (fig. 7).

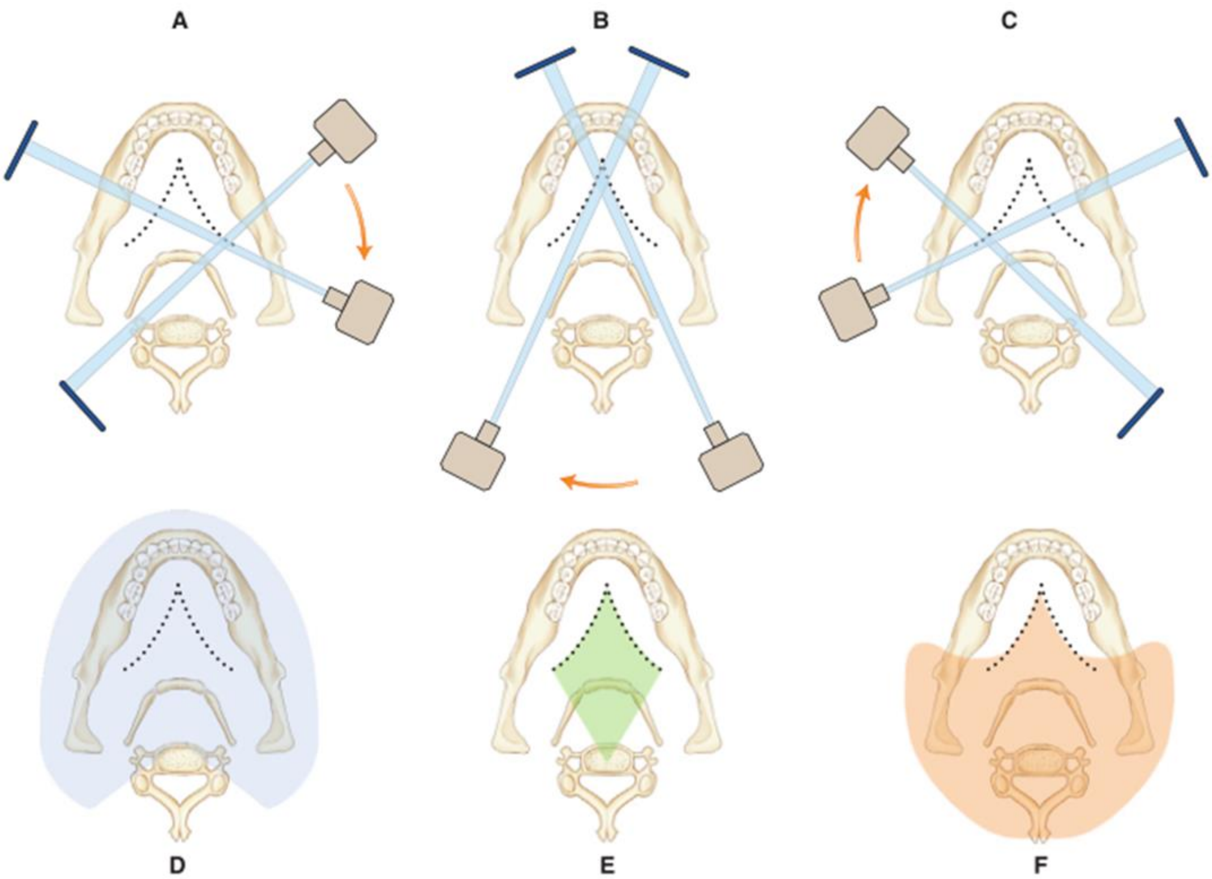


Figure 6. Formation of real, double, and ghost images.

A- C, The exposure begins with the x- ray tube head on the patient's right side and continues with the tube head moving behind the patient and ending on the left side. The dotted line represents the path of the moving center of rotation during the exposure cycle.

D, Structures between the moving center of rotation and the receptor for real images (blue zone).

E, Structures lying between the moving centers of rotation and the receptor that are imaged twice (green zone) cast double images.

F, Structures located between the x-ray source and moving center of rotation (orange zone) cast ghost mages.

A ghost image is the opaque shadow of a dense object (jewelry, anatomy) located on the opposite side of the patient. E.g., the ghost image of an earring in the patient's right ear will be seen in the maxillary left region on the film.

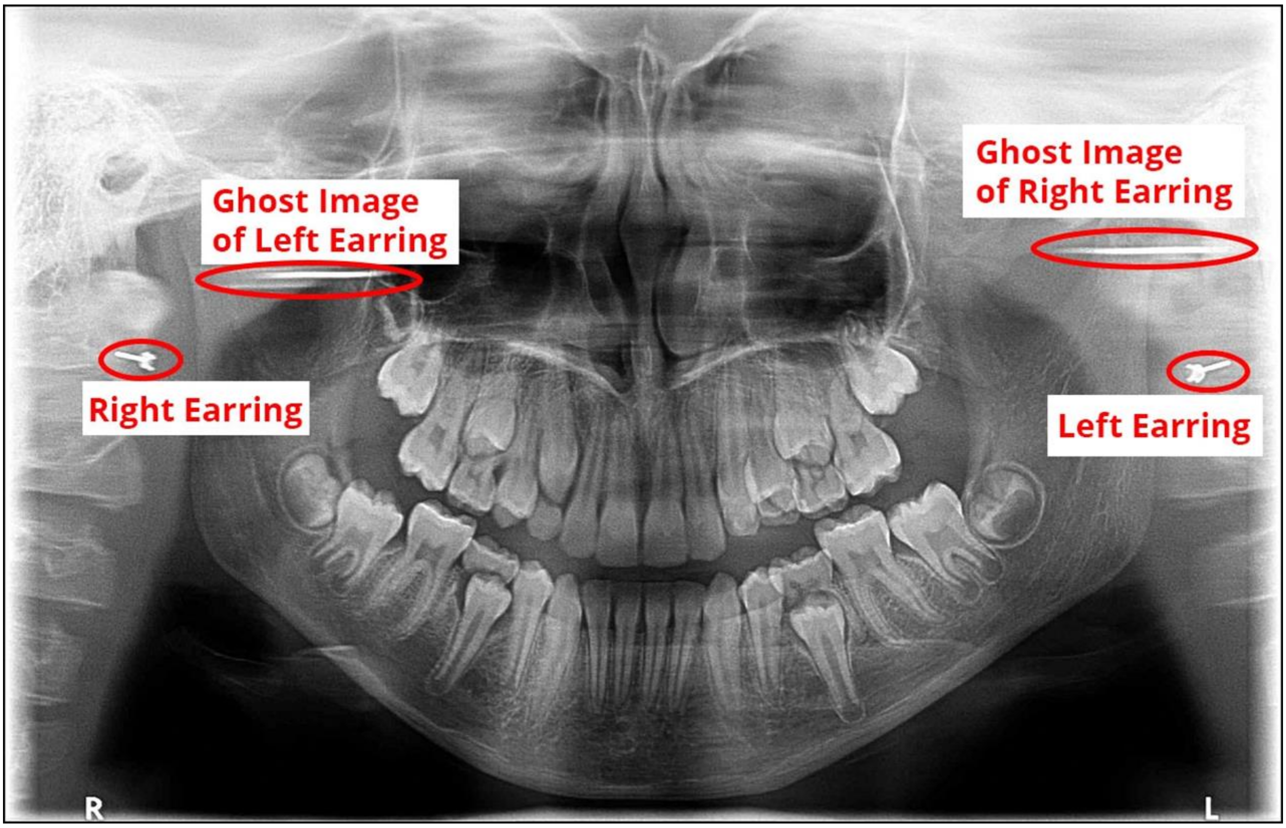


Figure 7. Radiographic appearance of ghost image.

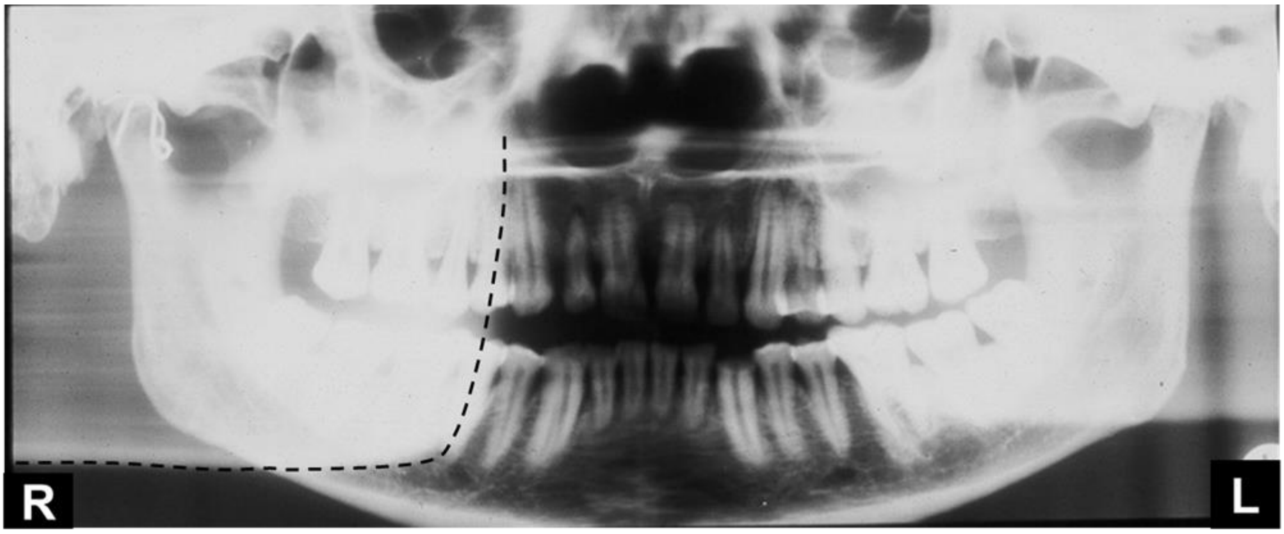


Figure 8. The dotted line below outlines the shape of the ghost image of the left side of the mandible. Because it is very dense bone, this normal anatomy can produce a ghost image.

Technique, patient positioning and head alignment:

This technique utilizes a narrow vertical negatively angled beam. The angle can be (−4 to −7°), so the beam exposes the patient just below the occipital bone. The beam is shaped by a lead collimator which is long, narrow slit located at the X-ray source and the image receptor (film or digital plate).

Equipment Preparation:

Receptor: Analog/PSP plate placed in cassette according to guidelines.

Select patient: Direct digital sensor – have the correct patient assigned in computer before setting up.

Infection control: The cover is placed on the bitestick before patient positioning or use a sterilized bite block made of impervious material between patients. After exposure, the cover is removed and discarded. Following this, the bitestick and all surfaces that contacted the patient's head should be wiped with a disinfectant.

Exposure Settings: Set according to the manufacturer's recommendations, which are pre-programmed according to the size of the patient. Most machines have a single setting for pediatric patients and two options for adult patients (according to their size). Newer machines do not require that the clinician selects specific exposure times and doses for each patient.

Height: Adjust entire machine to the correct height for the patient and any other moveable parts as necessary.

Exposure:

Complete the exposure by depressing the exposure button and holding it down until the x-ray tube has completed its arc and has come to a stop. Some machines have an audible signal that indicates the completion of the exposure.

Patient Preparation:

Patient preparation is extremely important for ensuring that a high-quality image is produced and that errors are avoided. For instance, incorrect patient preparation can lead to "ghost images" which can render the radiographic image undiagnostic. While ghost images often occur due to metallic objects, they can also occur due to anatomical structures located outside the image layer or focal trough. Ghost images always appear higher and distorted on the opposite side of the radiographic image. Some errors are unavoidable due to the patient's stature, facial asymmetry, or difficulty following instructions.

Proper patient preparation and positioning within the focal trough are essential for obtaining diagnostic panoramic radiographs.

Patient preparation:

Jewelry: All necklaces, piercings (earrings, tongue rings, etc.) and jewelry in the head and neck regions need to be removed prior to exposure.

Metal objects: Items such as headbands, bobby pins, hair clips, hearing aids, etc. must be removed prior to exposure. Removable partial dentures and orthodontic appliances should be taken out prior to imaging.

Basically, removing any metallic objects between the neck and the top of the ears. Berets, etc., above the top of the ears will not be seen on the film.

Lead Apron: Apron must not have a thyroid collar and should be placed properly so it does not block the x-ray beam.

Lead Apron: An important item to include when preparing the patient is the use of a lead apron, which is recommended for all radiographic procedures.

Lead aprons help provide protection for radiosensitive tissues in the neck, chest, reproductive areas, and blood forming tissue. In addition, lead aprons stop nearly 98% of scattered radiation from reaching reproductive organs.

There are lead-free aprons that use an alloy material instead of lead. They are 50% lighter and safer for patients and clinicians because they are lead-free.

While thyroid collars are not indicated for panoramic imaging, they are effective for use during intraoral imaging, because they have been shown to stop 92% of scatter radiation One study revealed that only 2% of the general dentists surveyed report using a lead apron with a thyroid shield prior to taking radiographs.

Table 1: Summary of patient positioning guidelines.

Standing/Sitting	If patient is able to stand, have them stand erect without the spine being slumped. If patient is seated, they should sit as upright as possible. It helps to do a test run with the panoramic machine to make sure it will not hit the patient's shoulders.
Mouth position	Patient needs to place maxillary/mandibular incisors correctly on bite block in order to achieve proper alignment of the teeth. Most units have a notch in the bite block indicating the proper location for the patient to bite.
Midsagittal Plane	The patient's head must be straight and not tilted. The midsagittal plane must be kept perpendicular to the floor.
Frankfort Plane	Keep the Frankfort plane parallel with the floor.
Tongue	Instruct the patient to place their entire tongue on the hard palate and leave it there for the duration of the exposure.
Lips	Instruct patient to keep their lips together for the duration of the exposure.
Eye	Have patient close their eyes so they do not follow the movement of the tube head.

Place the lead apron on the patient (no thyroid collar; it might block part of the x-ray beam). An apron with equal sides is usually used to protect the patient (fig. 9). Make sure the apron is positioned low on the back of the patient's neck (green arrow) so that it does not block the beam as the tubehead rotates behind the patient.

Figure 9. A poncho style lead apron protects the front and back of the patient.

Demonstrate the machine to the patient by cycling it while explaining the need to remain still during the procedure. This is particularly true for children, who may be anxious. Children should be instructed to look forward and to not follow the tube head with their eyes.

Patient positioning:

1. The anteroposterior position of the patient head is achieved typically by place the incisal edges of their maxillary and mandibular incisors into a notched positioning device (the biteblock).
2. The midsagittal plane must be centered within the focal trough without any lateral shift in the mandible.
3. The Frankfort plane should be parallel to the floor. The patient's chin and occlusal plane must be properly positioned to avoid distortion. The occlusal plane is aligned so that it is lower anteriorly.
4. Patients are positioned with their backs and spines as erect as possible and their necks extended. The vertebral column should be straight.
5. The midsagittal plane is perpendicular to the floor and centered on the bitestick.
6. Ask the patient to swallow and hold the tongue on the roof of the mouth. This raises the dorsum of the tongue to the hard palate, eliminating the air space and providing optimal visualization of the apices of the maxillary teeth.

Reference Lines:

- ***Frankfort Plane:*** represented by a line from the inferior border of the orbit to the top of the external auditory meatus.

- ***Midsagittal Plane:*** divides the head into right and left halves.

For edentulous patients, align the anterior edentulous ridges with the notches in the bitestick. Have the patient close gently.

For patients with severe Class II or Class III occlusion, align the front teeth as closely as possible with notches. Split the difference between the two if both arches cannot be aligned in the notches (fig. 10, A).

The patient is encouraged to stand straight. Since the x-ray beam is angled upward, it may pass through the vertebra if the patient is "slouched", creating a white shadow on the film (fig. 10, B).

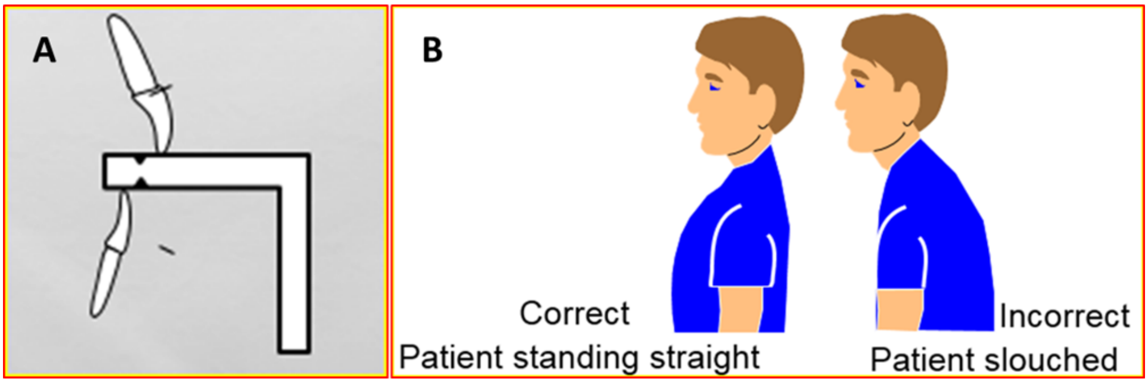


Figure 10. A, Patients with severe Class II malocclusion, the front teeth aligned as closely as possible with notches. B, Correct and incorrect patient standing.

Just before you are ready to begin the exposure sequence, advice the patient to swallow and feel the tongue contact the palate. Tell the patient to maintain this contact the entire time of the exposure (approximately 20 seconds). If they have a hard understanding this, just tell them to force as much of their tongue as possible against the roof of the mouth and hold it there. Advise the patient to keep the head still during the entire exposure.

Placement of the patient either too far anterior or too far posterior relative to the focal trough results in significant dimensional errors in the images (fig. 11):

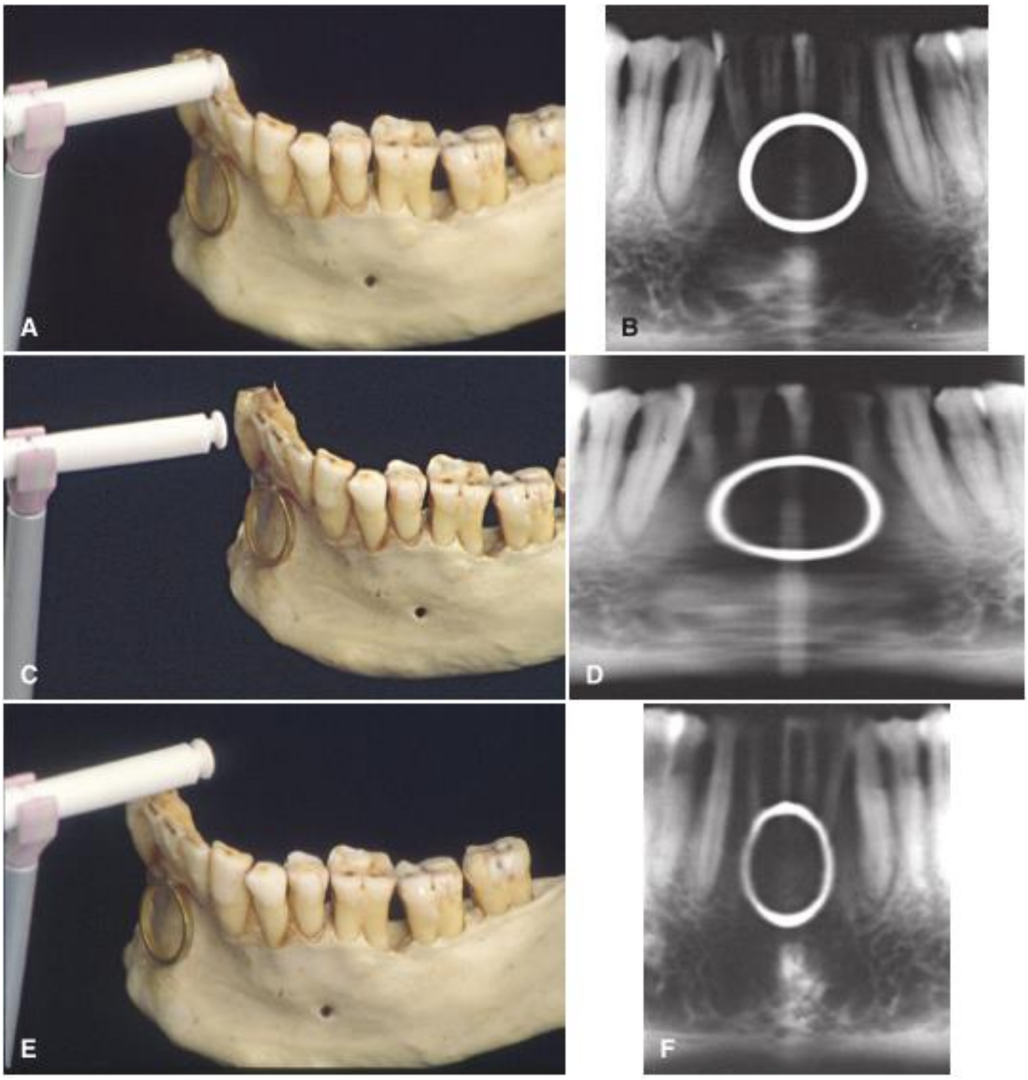


Figure 11. Influence of an object's position on its radiographic size.

A, A mandible is supporting a metal ring positioned at the center of the focal trough. The mandible is positioned at the center of the focal trough by placing the incisal edges of the central incisors in a notch at the end of a bite rod-positioning device. **B**, Resultant panoramic radiograph shows minimal distortion of the metal ring.

C, The mandible and ring are positioned 5 mm away from the focal trough. **D**, Resultant panoramic radiograph demonstrates horizontal magnification of both the ring and the mandibular teeth.

E, The mandible and ring are positioned 5 mm in front of the notch in bite-block. **F**, Resultant panoramic radiograph demonstrates the horizontal minification of both the ring and the mandibular teeth.

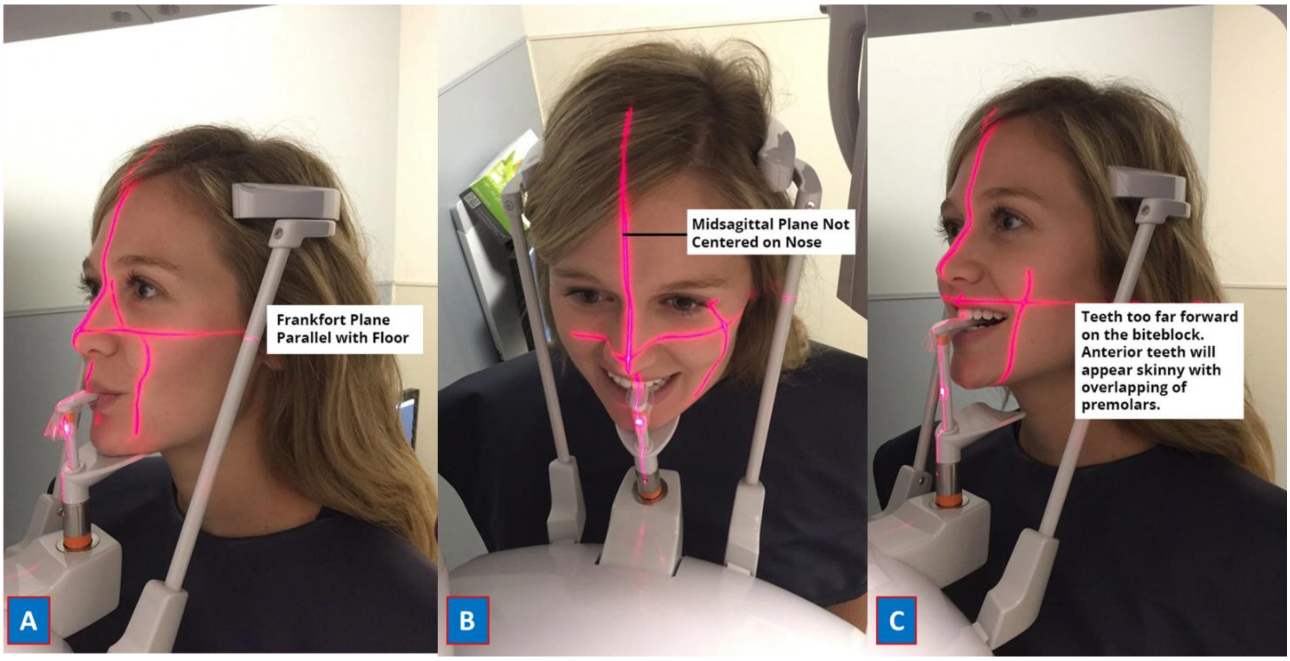


Figure 12. A, Correct patient positioning with the tongue pressed against the palate, teeth in the groove of the bite-block, and the indicator light for the midsagittal plane centered and perpendicular to the floor. B, Incorrect patient positioning, because the midsagittal plane is not centered along the midline of the face. C, Incorrect patient positioning, the patient is positioned too far forward, because the canine indicator light is posterior to the canine.

Table 2: Summary of common panoramic errors.

Error	Appearance on radiograph	Correction
Ghost images.	Ghost image resembles real image projected on opposite side of film and is higher.	Have patient remove all radiodense objects before exposure. May be produced by dense anatomical structures such as the mandible.
Failure to remove metallic objects.	Leaving metallic objects like partial dentures in the mouth for a panoramic film will usually cause radiopaque shadows that obscure important diagnostic information	Removing any metallic objects between the neck and the top of the ears. Removable partial dentures and orthodontic appliances should be taken out prior to imaging.
Positioning of the tongue.	Radiolucent artifact superimposed over the maxillary apices.	Instruct the patient to place their entire tongue on the hard palate and leave it there for the duration of the exposure.
Lead apron artifact.	Radiopaque, cone-shaped artifact in center of image.	Use lead apron without thyroid collar. Make sure the apron is positioned low on the

		back of the patient's neck.
Patient lips not closed.	Dark radiolucent shadow around anterior teeth.	Remind patient to close lips around bite block.
Patient chin is tipped too high	1. The occlusal plane on the radiograph appears flat or inverted (reverse smile line) 2. The image of the mandible is distorted. 3. A radiopaque shadow of the hard palate is superimposed on the roots of the maxillary teeth. 4. Condyles may not be visible Maxillary incisors appear blurred and magnified.	Keep Frankfort plane parallel with floor.
Patient chin is tipped too low.	1. The teeth become severely overlapped. 2. The symphyseal region of the mandible may be cut off the film. 3. Mandibular incisors appear blurred; roots appear short. 4. Both mandibular condyles may be projected off the superior edge of the film. 5. Exaggerated smile line (Joker).	Keep Frankfort plane parallel with floor.
Patient too far forward (anterior to focal trough).	1. Too far anterior results in reduced mesiodistal dimensions through the anterior sextants and resulting "thin" or narrowed teeth. 2. Spine is visible on film.	Make sure patient's teeth are in bite block notches.
Patient too far posterior (back to focal trough).	1. Magnified mesiodistal dimensions through the anterior sextants and resulting "fat" teeth. 2. Ramus isn't entirely visible.	Make sure patient's teeth are in bite block notches.
Failure to position the midsagittal plane. =Patient head not centered. =Rotational midline.	1. Right and left sides of Ramus and posterior teeth appear unequally magnified. 2. Side farthest from receptor appears magnified. 3. Side closest to receptor appears smaller. 4. Patient turned to right will produce image with magnification on left side and overlapping of contacts.	Ensure indicating light is located at center of patient's nose.
Patient head is tilted to one side.	One condyle appears higher than the other and the inferior border of the mandible is slanting.	Keep midsagittal plane perpendicular to floor.

=Poor midline positioning is a common error, causing horizontal distortion in the posterior regions, excessive tooth overlap in the premolar regions and, on occasion, nondiagnostic, clinically unacceptable images.		
Patients don't sit straight and align or don't stretch their back.	Large radiopaque region in the middle of the image (vertebral shadow).	Have patient stand as tall as possible. Seat patient if necessary.

Panoramic technique errors:

Patient preparation errors.

1. Ghost images.
2. Lead apron artifact.
3. Failure to remove metallic objects.

Patient positioning errors:

1. Patient lips not closed.
2. Positioning of the tongue.
3. Positioning of the Frankfurt plane.
    - Patient chin is tipped too high.
    - Patient chin is tipped too low.
4. Positioning of the teeth relative to the focal trough.
    - Teeth too anterior.
    - Teeth too posterior.
5. Positioning of the midsagittal plane.
    - Patient head not centered.
    - Patient head is tilted to one side.
6. Positioning of the spine.

Miscellaneous technique errors:

- Static electricity.
- Over-exposure or under-exposure.
- Reversed cassette.

The most common errors seen when taking panoramic radiographs:

Head Turned:

Turning the head moves the teeth closer to the film on one side and farther from the film on the other side. This results in an enlargement of the images of the teeth and ramus on one side and a reduction in the size of the images on the other side.

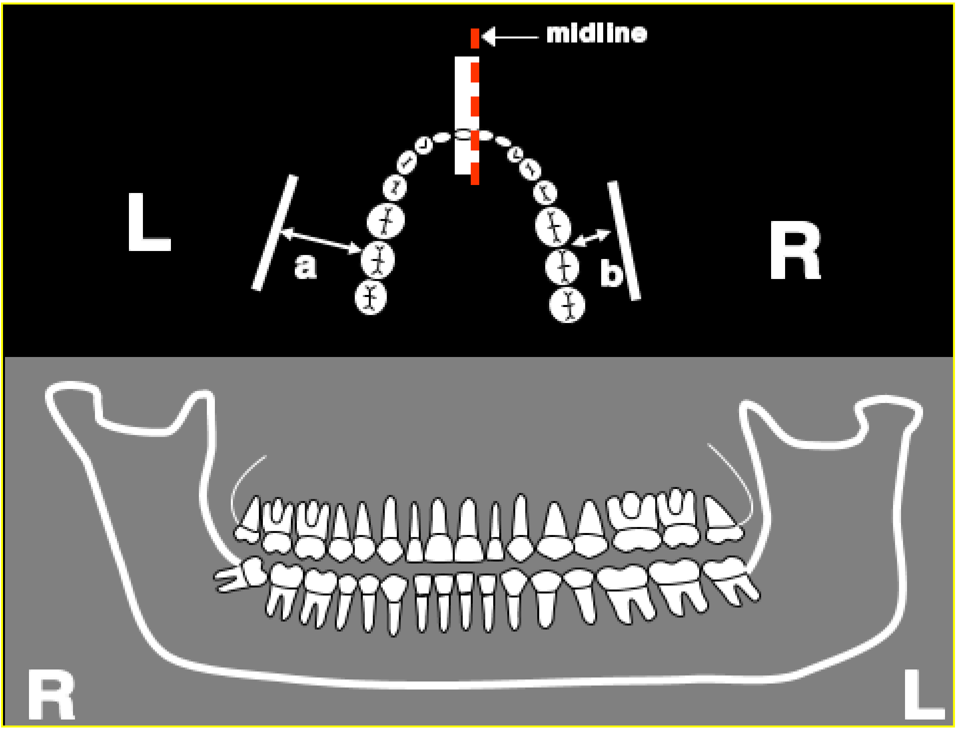


Figure 13. Patient head not centered. An enlargement of the images of the teeth and ramus on one side (point a) and a reduction in the size of the images on the other side (point b).

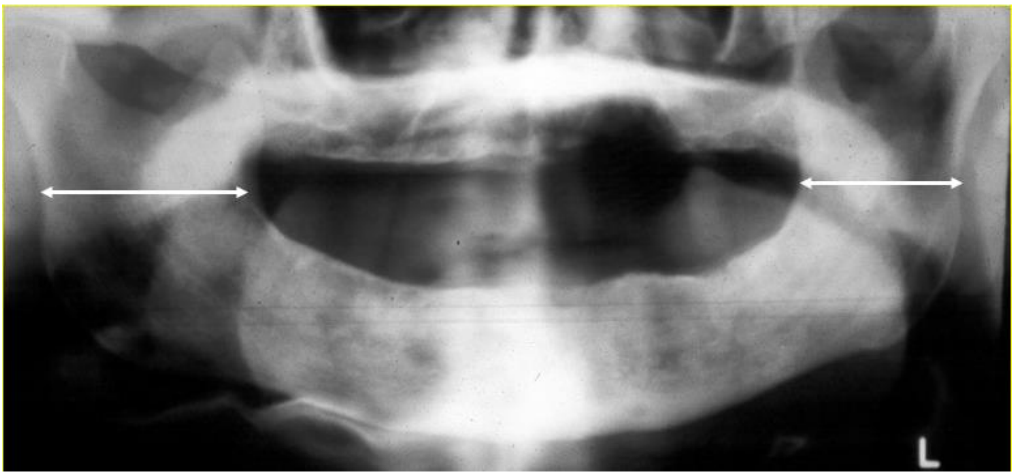


Figure 14. Head turned to the left. The ramus is wider on the right side.

Figure 15. Head turned to the right, moving the teeth closer to the film on that side. The teeth on the left side, being farther from the film, will be magnified more and appear larger.

Figure 16. The head is turned to left side, causing an asymmetry of the condyles, and wider teeth and ramus on the right side than the left side.

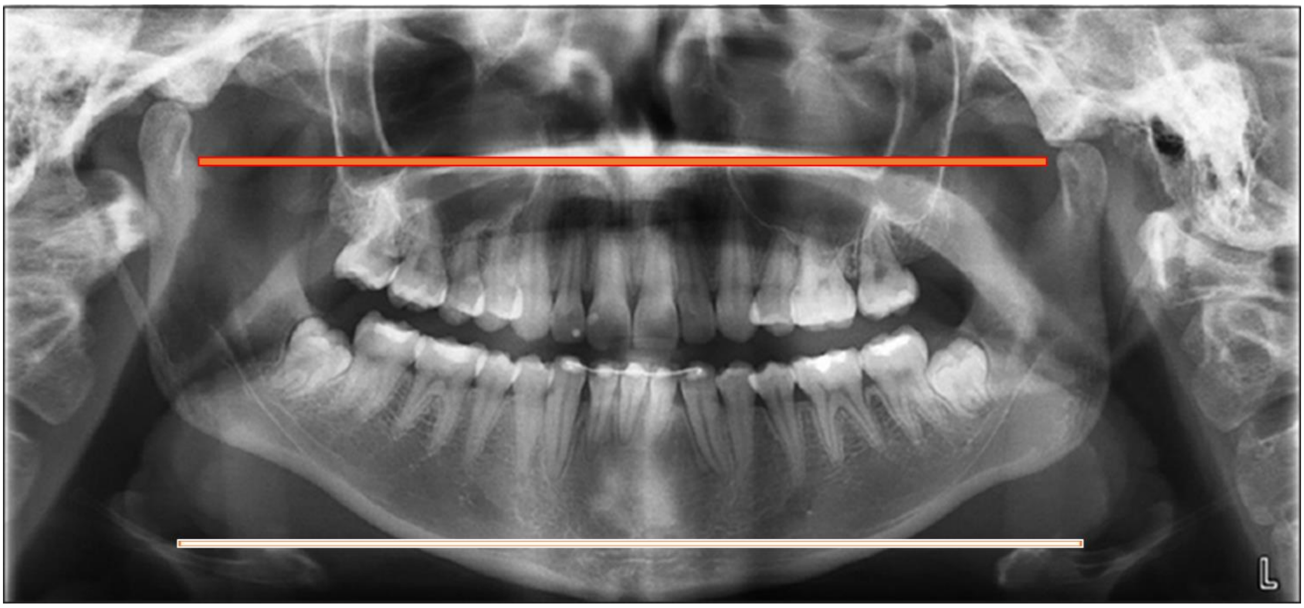


Figure 17. The head is tilted to one side (right side), causing one condyle to appear higher than the other (higher on the left side) and the inferior border of the mandible is slanting.

Figure 18. Panoramic radiograph caused by patient's midsagittal plane not positioned perpendicular to the floor. The left side of the radiograph is magnified due to the patient's head being tilted to the right.

Teeth too anterior: If the incisors are positioned anterior to the notch in the bitestick, they will end up closer to the film, which passes in front of the patient. This results in a reduction in the width of the images of the front teeth (less magnification) and, since they are now slightly outside the focal trough, the images of the teeth will be blurred.

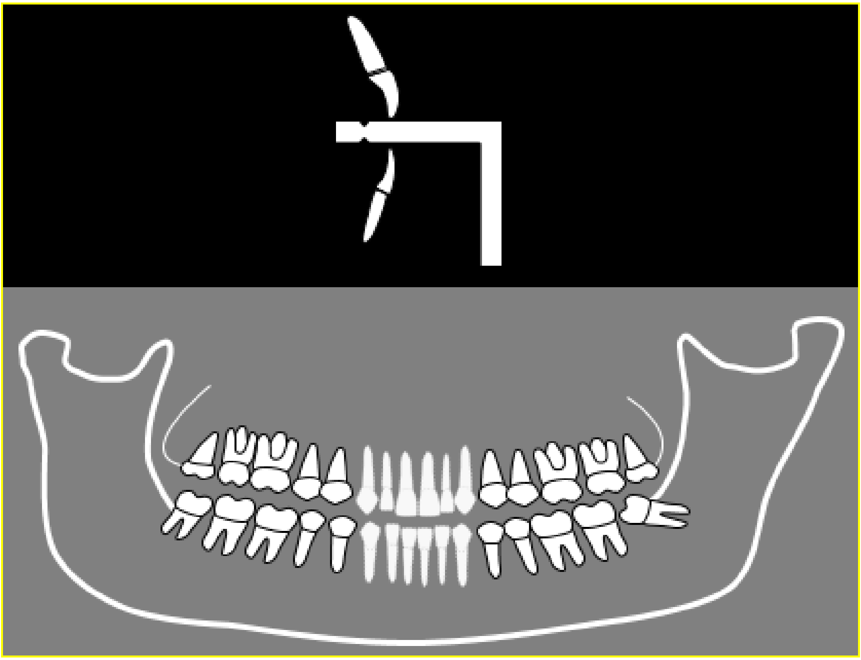


Figure 19. Diagram illustrating the teeth positioned too anterior to the notch on the bitestick.

Figure 20. The central incisors are in front of the bite groove, causing them to

appear thin and fuzzy. The cervical spine is in the focal zone, causing it to be superimposed on the mandible.

Teeth too posterior: If the incisors are positioned posterior to the notch in the bitestick, they will end up farther from the film, which passes in front of the patient. This results in an increase in the width of the images of the front teeth (more magnification) and, since they are now slightly outside the focal trough, the images of the teeth will be blurred.

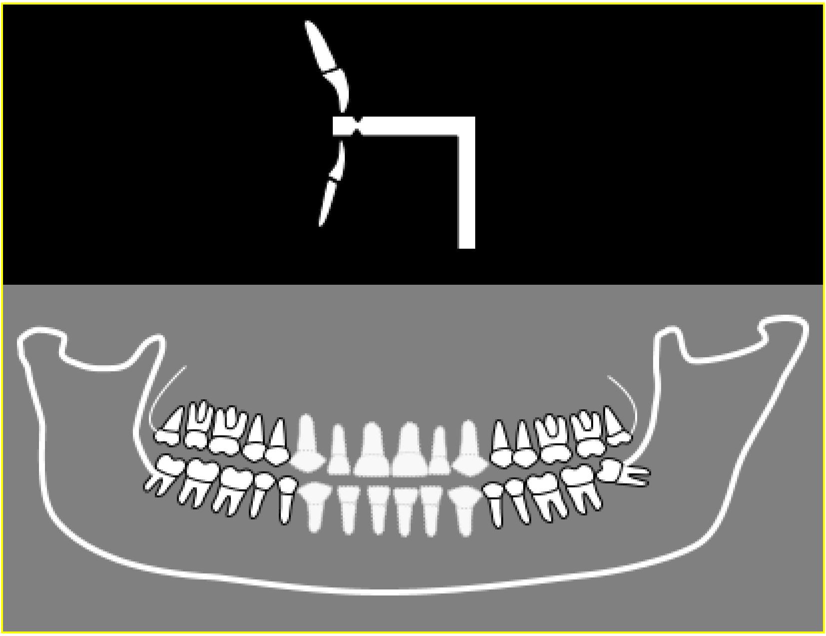


Figure 21. Diagram illustrating the teeth positioned too posterior to the notch on the bitestick.

Figure 22. Panoramic radiograph with wide and blurry anterior teeth due to the patient positioned posterior to the focal trough.

Head tipped down: If the head is tipped down too much, so that the Frankfort Plane is angled downward, the resulting film will show a V-shaped mandible and shortening of the mandibular incisors.

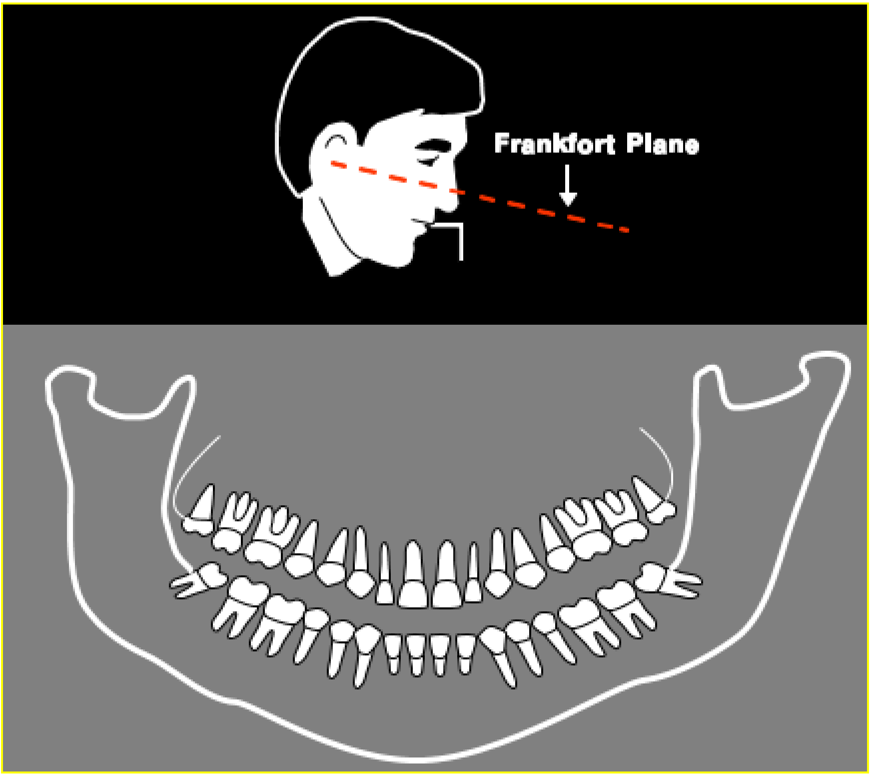


Figure 23. Diagram illustrating the head tipped down.

Figure 24. Chin tipped down too much. Roots of mandibular incisors shortened. V-shaped mandible.

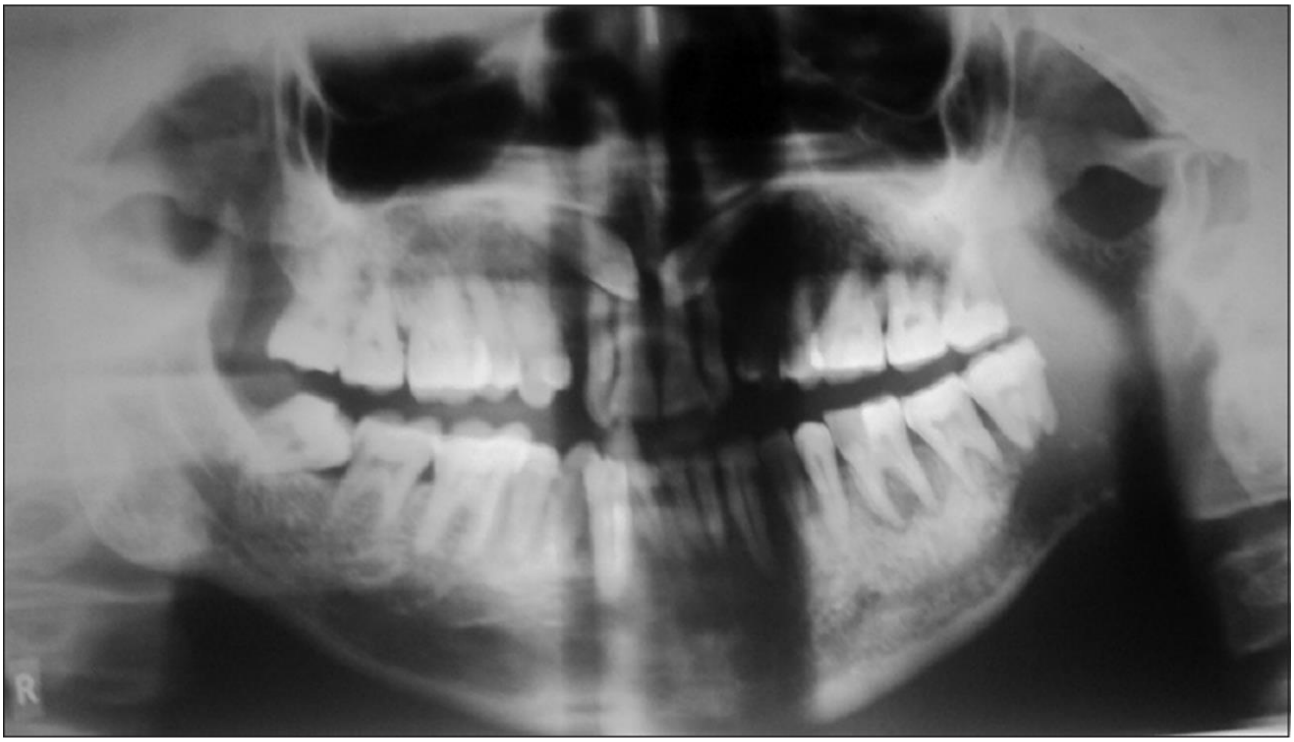


Figure 25. Patient's chin is tilted downward leading to appearance of a “Cheshire cat grin” due to the accentuated Curve of Spee.

Figure 26. The patient's chin is too low. The occlusal plane is "smiling" and the apices of the mandibular incisors are fuzzy.

Head tipped up: If the head is tipped up too much, so that the Frankfort Plane is angled upward, the resulting film will show a squared-off mandible and the hard palate will be superimposed over the roots of the maxillary teeth. A "reverse smile" may be seen.

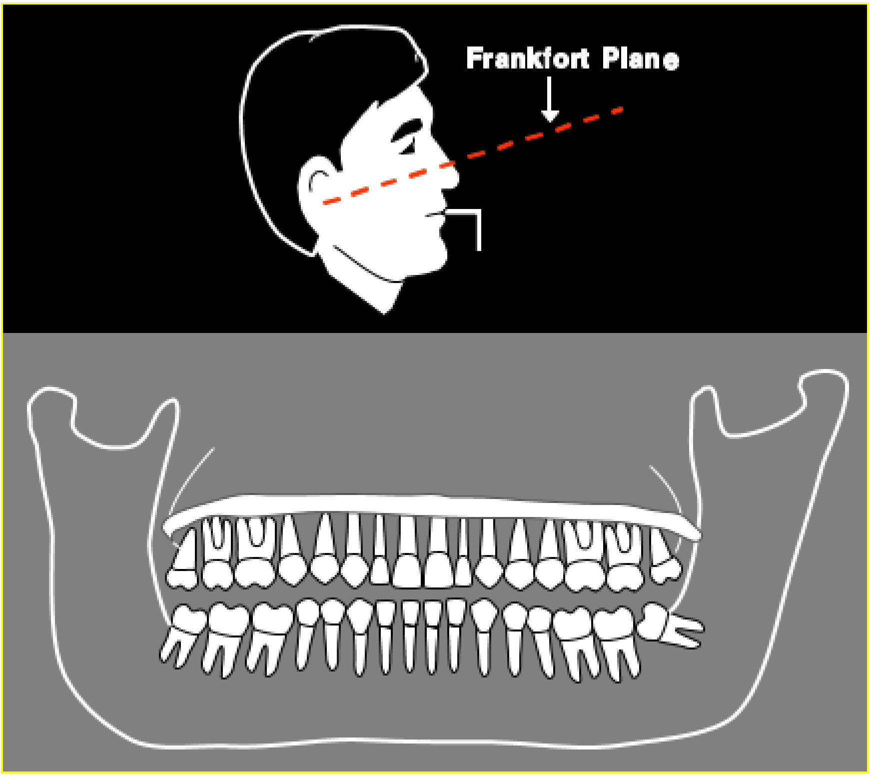


Figure 27. Diagram illustrating the head tipped up.

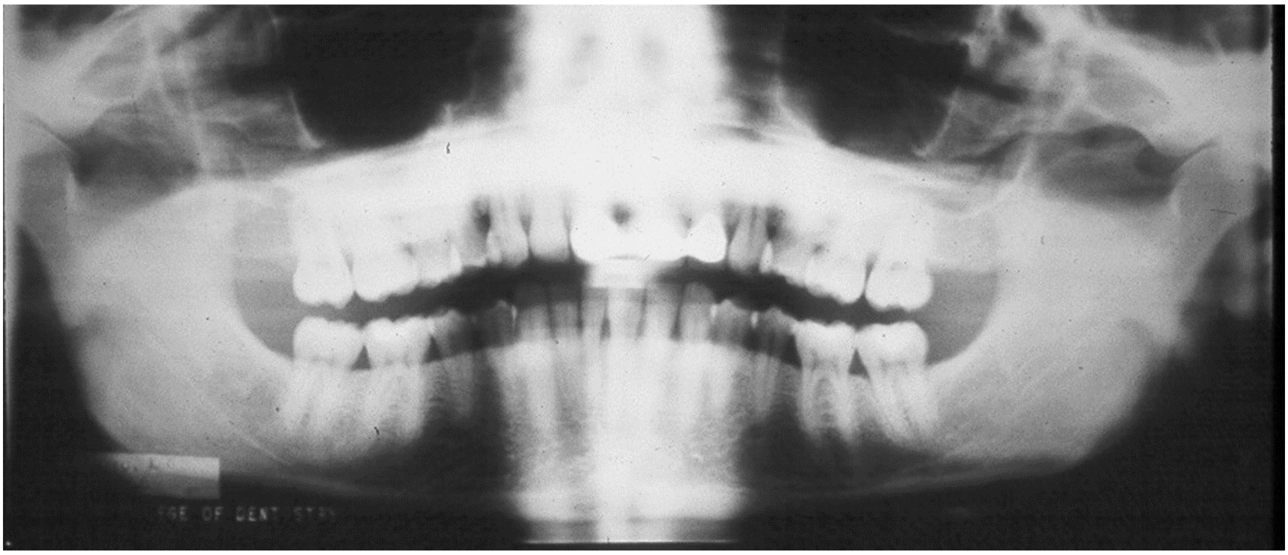


Figure 28. Chin tipped up too much. Hard palate superimposed over roots of maxillary teeth. Squared-off mandible. “Reverse Smile”.

Figure 29. Patient's chin is tilted upward leading to appearance as that of a wide “grimace” due to a flattened Curve of Spee.

Figure 30. The patient's chin is too high, causing a flat occlusal plane, splayed condyles, and loss of sharpness of the maxillary incisors.

Vertebral (spinal) shadow:

White area in the center of the film represents the shadow of the vertebral column due to patient slouching. Although faint, you will usually be able to see outlines of the teeth and bone in the area.

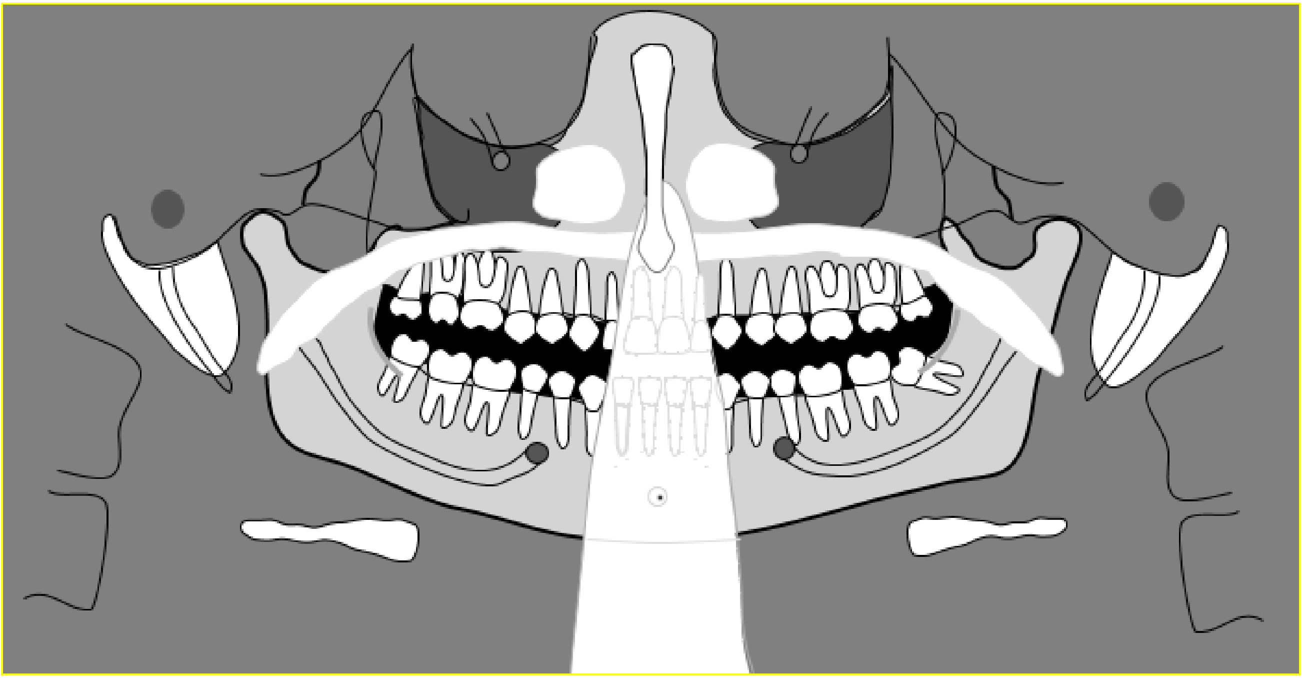


Figure 31. Diagram illustrating the radiopaque shadow of the vertebral column.

Figure 32. Shadow of the vertebral column due to patient slouching.

Figure 33. The cervical spine is slumped, appearing as a pyramid-shaped opacity, centered at the lower half of the film.

Lead apron shadow:

The lead apron should be placed low on the back of the patient's neck so that it does not block off the x-ray beam as the tubehead passes behind the patient. (A thyroid collar is never used for panoramic films). If the apron blocks the beam, a completely radiopaque shadow is produced on the film overlying a portion of the mandible; no evidence of teeth or bone is seen in this area.

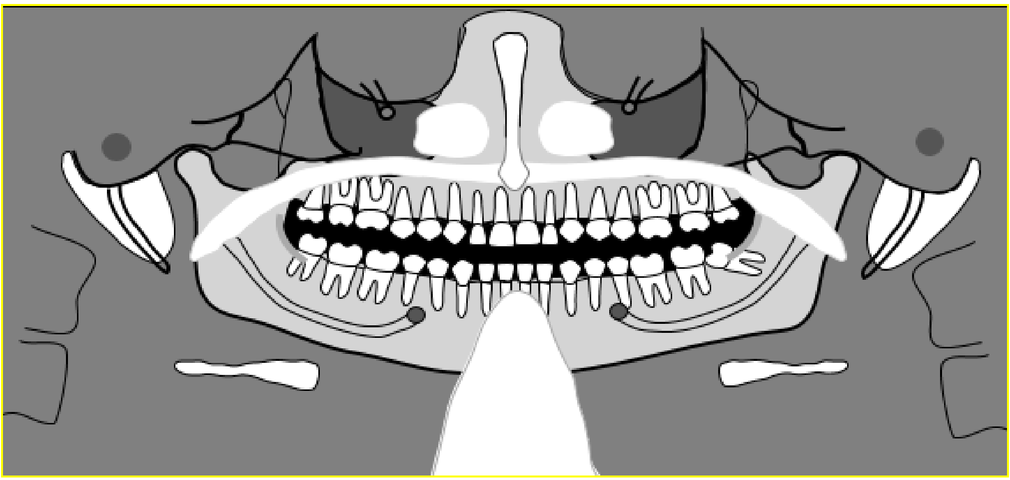


Figure 34. Diagram illustrating the lead apron shadow.

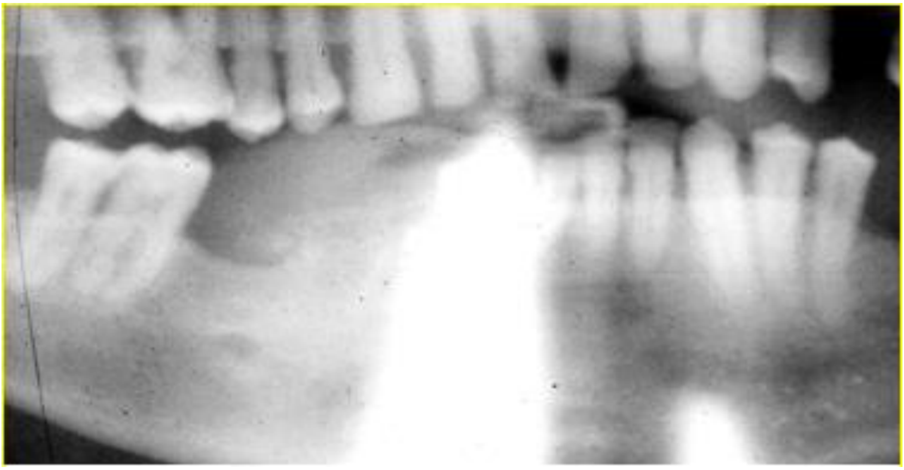


Figure 35. White areas on film represent lead apron being placed too high on back of neck.

Figure 36. Panoramic radiograph with radiopaque artifact due to a lead apron with a thyroid collar. A radiopaque band appears at the lower edge of the image with a triangular radiopacity in the center.

Ghost images:

As the x-ray beam passes around the patient, objects such as **jewelry or dense bone** will produce **a real image** on the side where the object is located and a **"ghost" image** on the opposite side.

This ghost image will have the same shape and orientation as the real image, but it will be larger and projected higher on the film and will be very blurred. It will be located and on the opposite side.

Usually caused by external objects such as earrings but may be produced by dense anatomical structures such as the mandible. Objects located between center of rotation and X-ray source.

Figure 37. Ghost images of earrings. The ghost image (see "a-ghost" above) has the same shape and orientation, but is higher, larger and on the opposite side when compared to the image of the actual object (see "a" above).

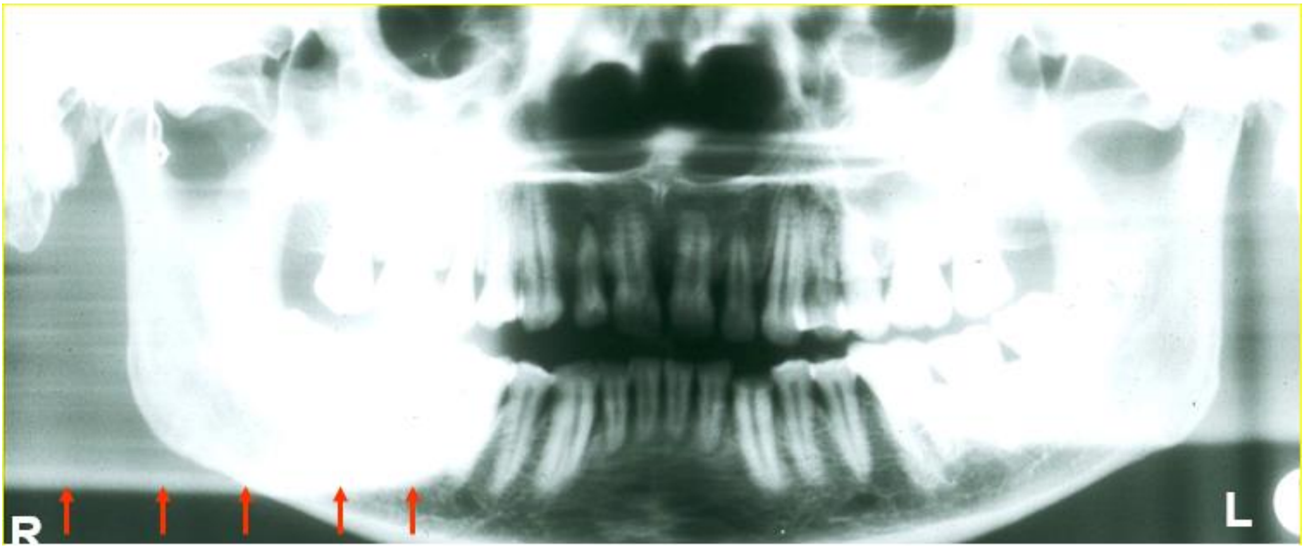


Figure 38. The red arrows above point to the ghost image of the left side of the patient's mandible.

Figure 39. Panoramic radiograph with red arrows identifying the ghost image of the inferior border of the mandible. The white arrows on the radiograph identify the cervical spine.

Palatoglossal air space:

Before exposing the film, the patient is asked to swallow (to feel the tongue elevate to contact the palate) and to keep the tongue against the palate during the entire exposure. This will help to eliminate the palatoglossal air space (see red arrows below). If this radiolucent band appears on the film, it may mask periapical radiolucencies that might be present.

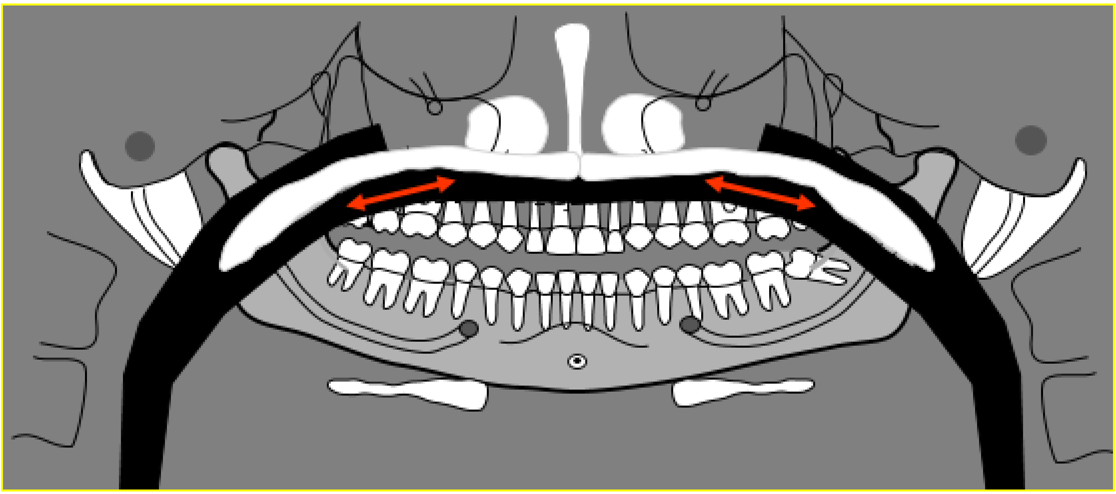


Figure 40. Diagram illustrating the radiolucent band of palatoglossal air space.

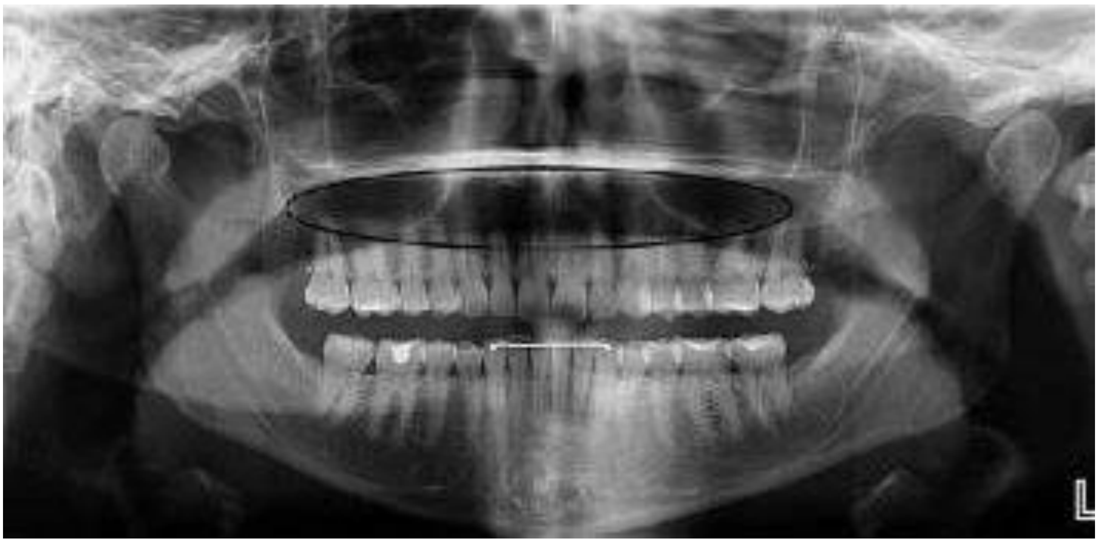


Figure 41. Panoramic radiograph with radiolucent artifact superimposed over the maxillary apices. The patient's tongue is not placed against the hard palate.

Lip space:

Before exposing the film, the patient is asked to close his lips on the bite block. This will help to eliminate the lip space. If this radiolucent shadow appears on the film, it masks the crowns of anterior teeth.

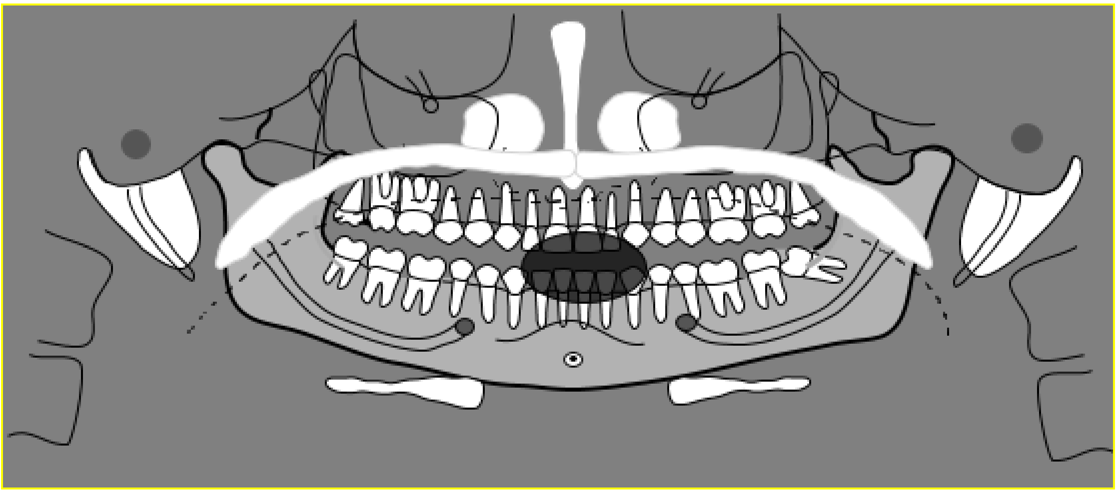


Figure 42. Diagram illustrating radiolucent shadow of lip space.

Figure 43. Panoramic radiograph with radiolucent artifact superimposed over anterior teeth. The patient's lips are not closed around the bite block.

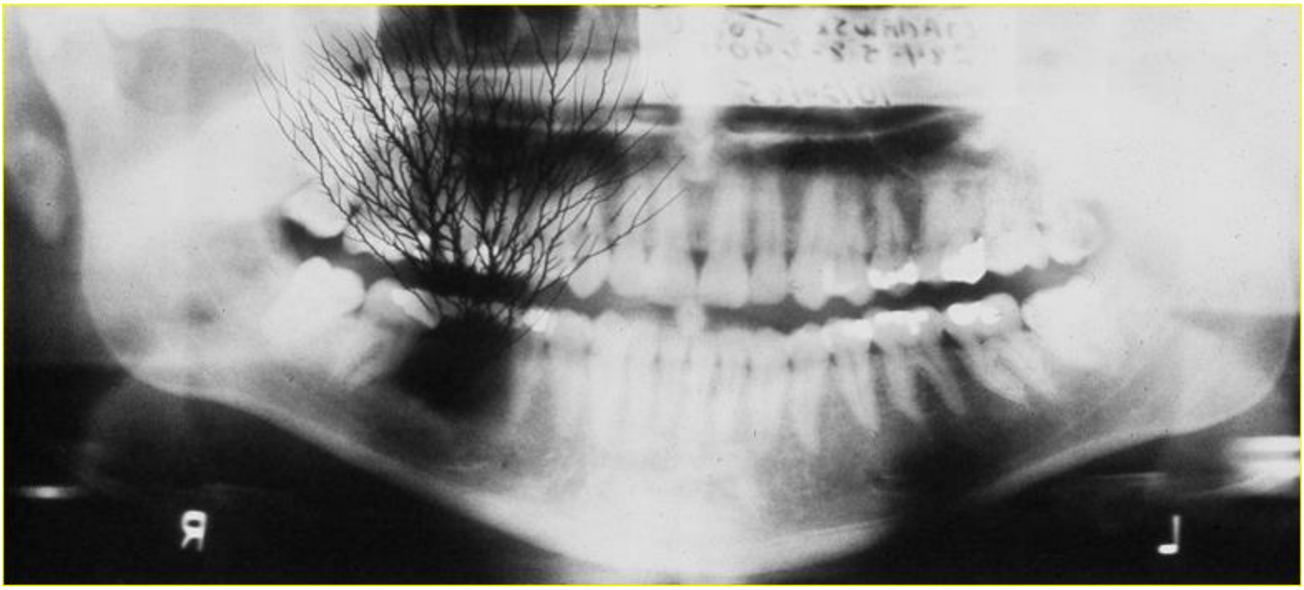


Figure 44. Static electricity caused by friction when removing film from box or cassette too rapidly.

Figure 45. Static electricity caused by friction when removing film from box or cassette too rapidly.

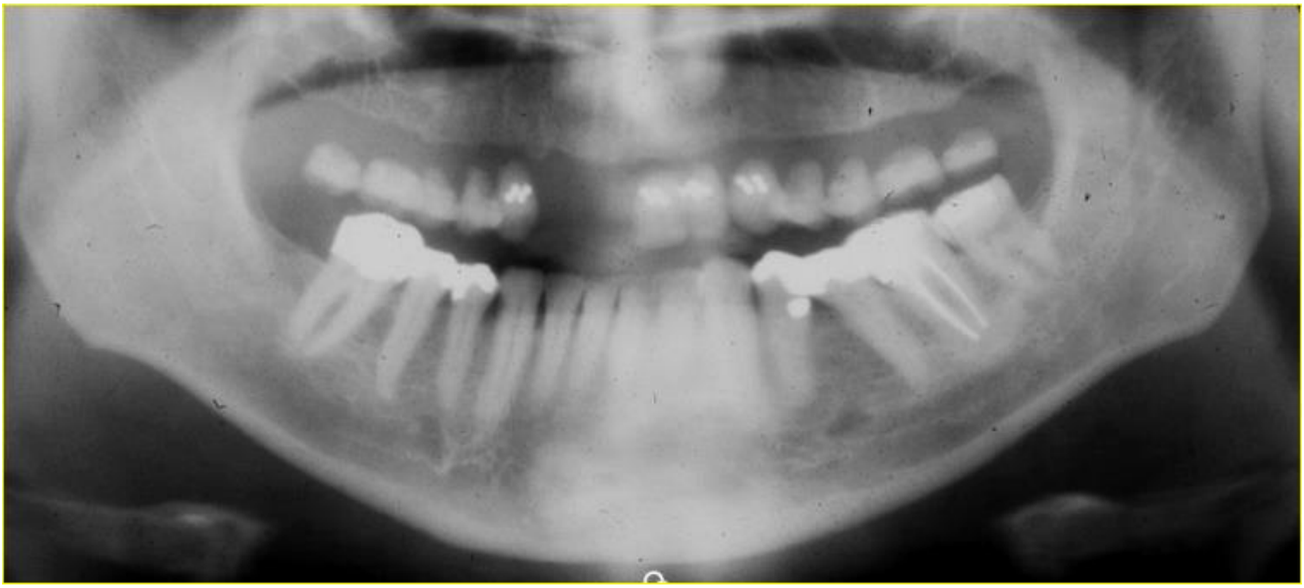


Figure 46. Failure to remove complete upper denture before exposure. This is usually not a problem since the denture acrylic is not dense enough to block the image of the maxillary bone.

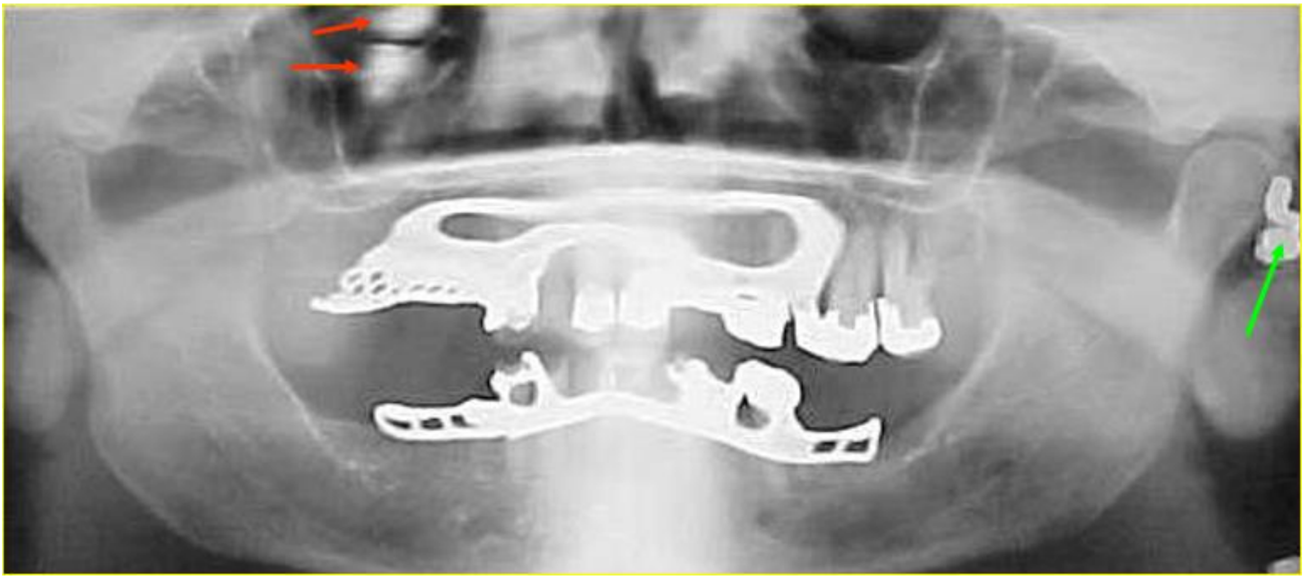


Figure 47. Leaving partial dentures in the mouth for a panoramic film will usually obscure important diagnostic information as seen in the above film. Note the hearing aid in the left ear (green arrow) and its ghost image overlying the right orbit (red arrows).

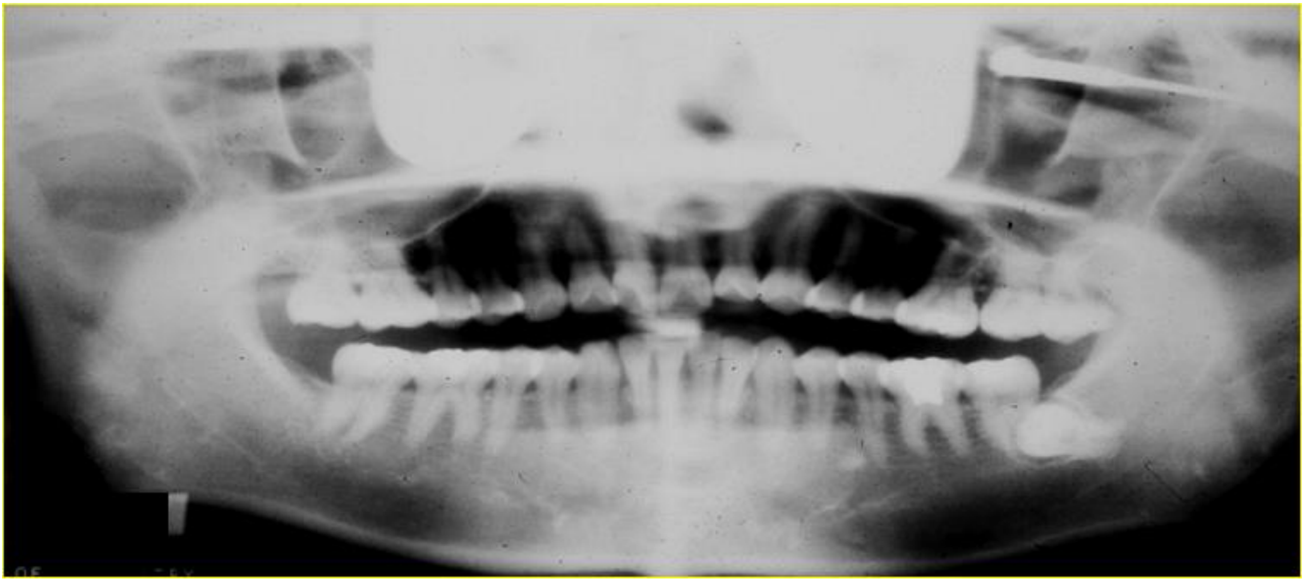


Figure 48. Failure to remove glasses. Also note squared-off mandible and reverse "smile", indicating chin tipped up too much.

Patient movement:

Figure 49. Radiograph shows image distortion due to patient movement during exposure.

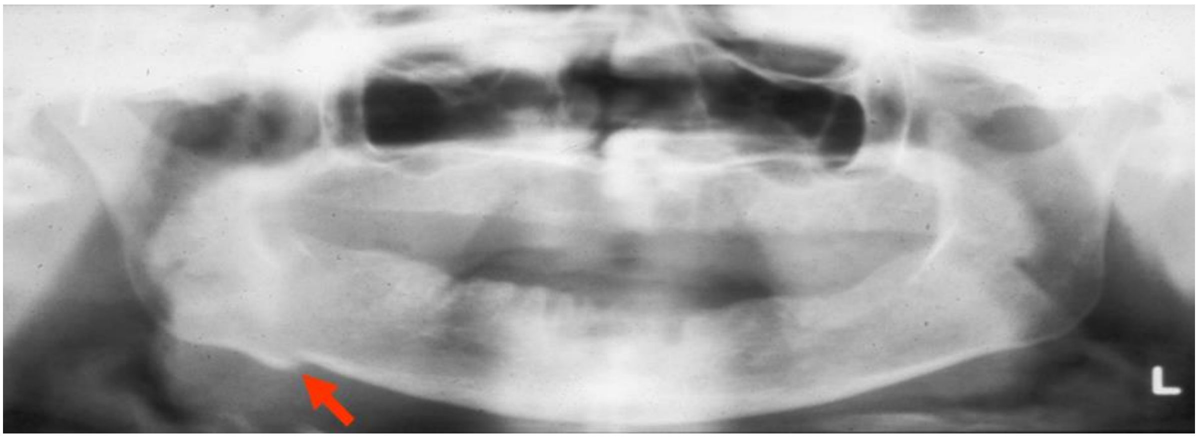


Figure 50. Slight patient movement indicated by notching of mandible at arrow.

Figure 51. Reversed Cassette

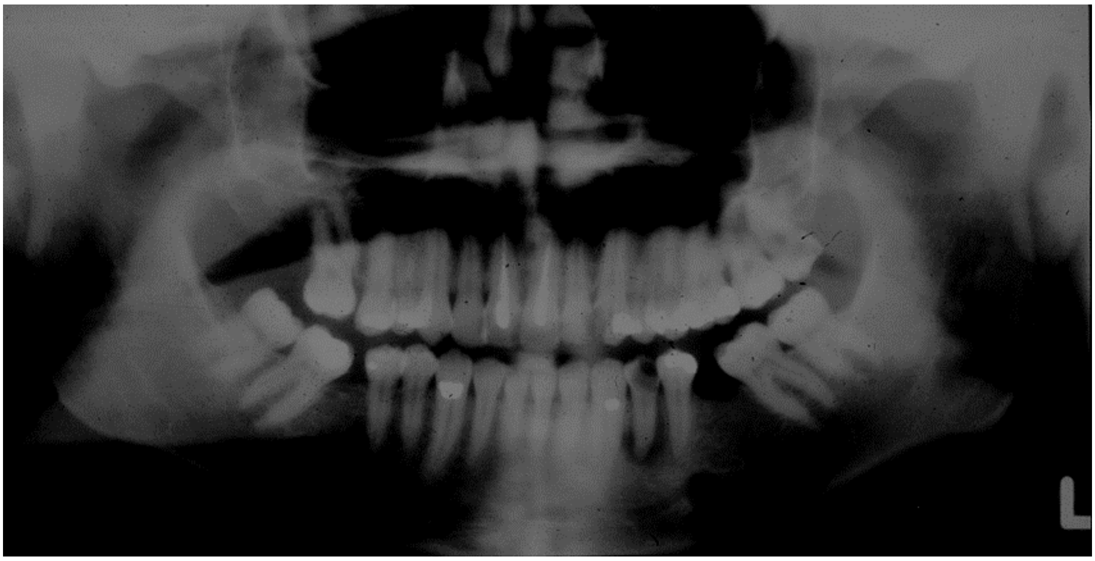


Figure 52. Dark image

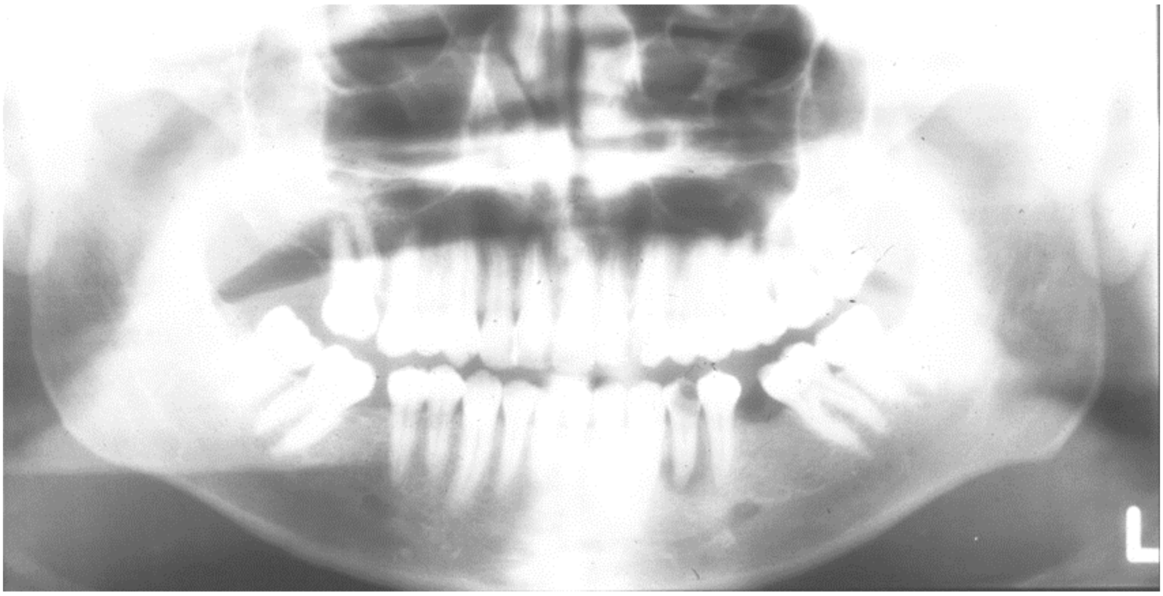


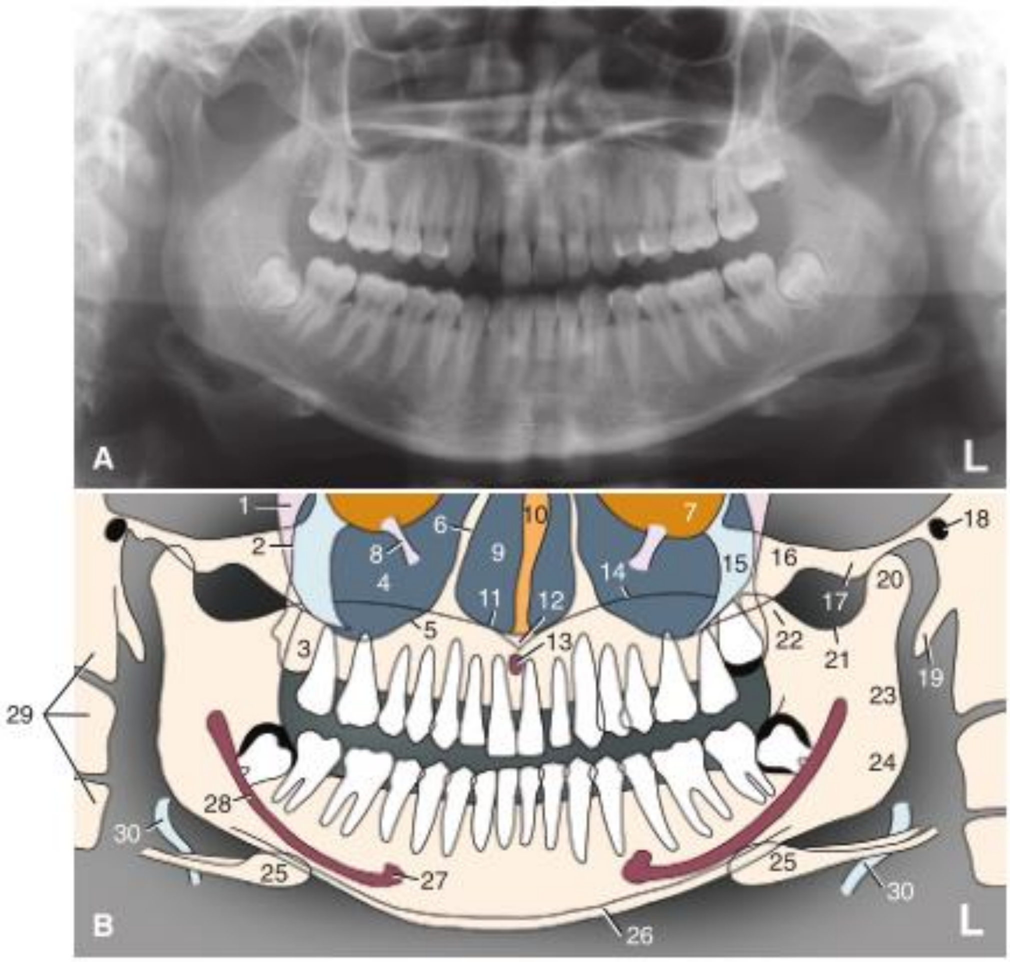
Figure 53. Light image

Figure 54. Panoramic radiograph shows the patient failure to position the tongue against the palate, leading to a dark shadow over the maxillary teeth between the palate and dorsum of the tongue**.**

Interpretation of panoramic images:

Interpretation of normal anatomical structures, ghost image and pathological conditions on a panoramic image can be complex. As a general rule, images should be viewed in dim light room using a viewer box or a computer monitor. An operator should always analyses a panoramic image for any possible technique or processing errors.

It is important to know a good panoramic radiograph the mandible is "U" shaped, the condyles are positioned about an inch inside the edge of the film and 1\3 of the way down from the top edge of the film. The occlusal plane exhibits a slight curve or "smile line", upwards. The roots of the maxillary & mandibular anterior teeth are readily visible.



1–10	11–20	21–30
1. Pterygomaxillary fissure	11.Floor of the nasal cavity	21. Sigmoid notch
2. Posterior border of maxilla	12. Anterior nasal spine	22. Coronoid process
3. Maxillary tuberosity	13. Incisive foramen	23. Posterior border of ramus
4. Maxillary sinus	14. Hard palate/floor of the nasal cavity	24. Angle of mandible
5. Floor of the maxillary sinus	15. Zygomatic process of the maxilla	25. Hyoid bone
6. Medial border of maxillary sinus lateral border of the nasal cavity	16. Zygomatic arch	26. Inferior border of mandible
7. Floor of the orbit	17. Articular eminence	27. Mental foramen
8. Infraorbital canal	18. External auditory meatus	28. Mandibular canal
9. Nasal cavity	19. Styloid process	29. Cervical vertebrae
10. Nasal septum	20. Mandibular condyle	30. Epiglottis

Figure 56. **A**. Properly acquired and displayed panoramic image of an adult patient. The patient's left side is indicated on the image, and the image is oriented as if the clinician were facing the patient. This is the same orientation used with a full-mouth series, making it easier for the clinician to orient himself or herself and to interpret the image.

B. Drawing of the same panoramic radiograph identifying midfacial and mandibular anatomic structures.

Panoramic Anatomy:

Panoramic radiographs are a common imaging modality used in primary and secondary dental care. Being able to interpret panoramic radiographs is an important skill for all dental practitioners using these images as part of their practice. Understanding the technique of panoramic radiography as well as a good knowledge of anatomy is important for accurate diagnosis.

Types of Panoramic Images:

1. Single Real Image:

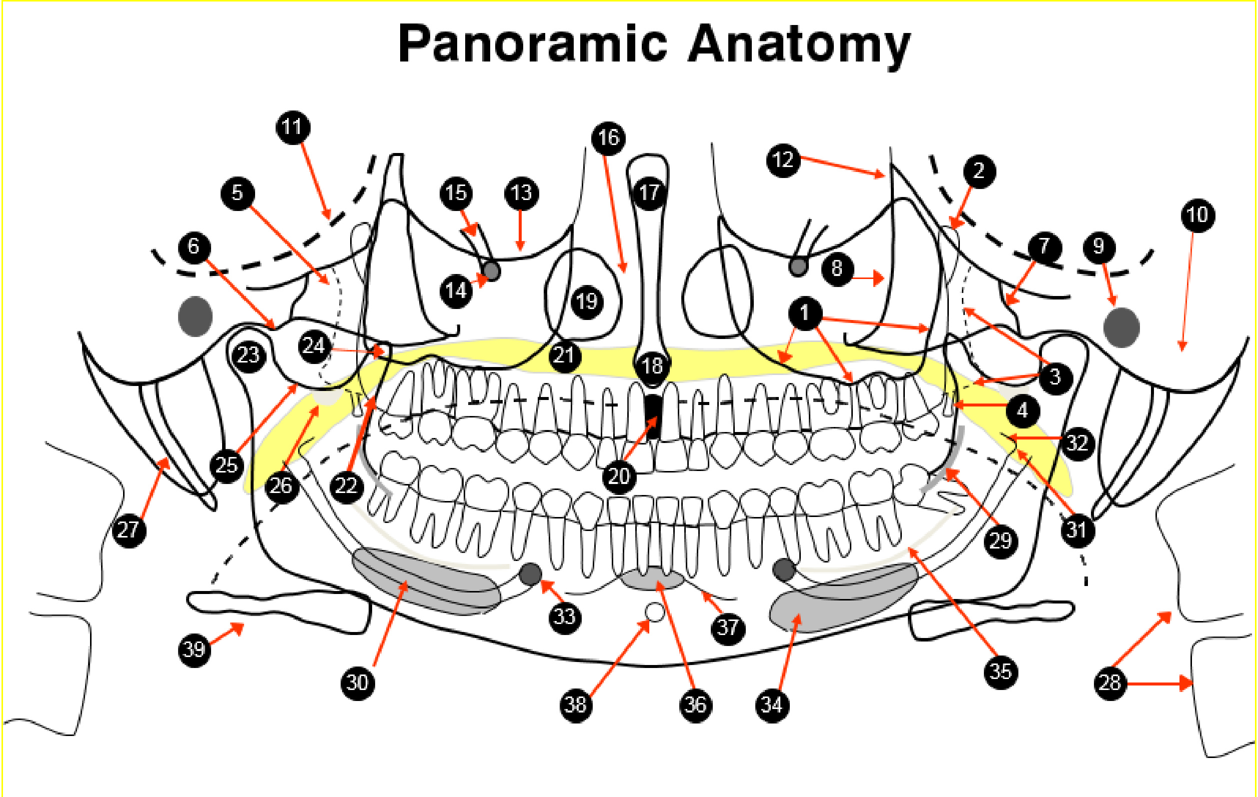
Only one image results from a given anatomical structure. Most images seen on a panoramic film are of this type. The object is between the center or rotation and the film

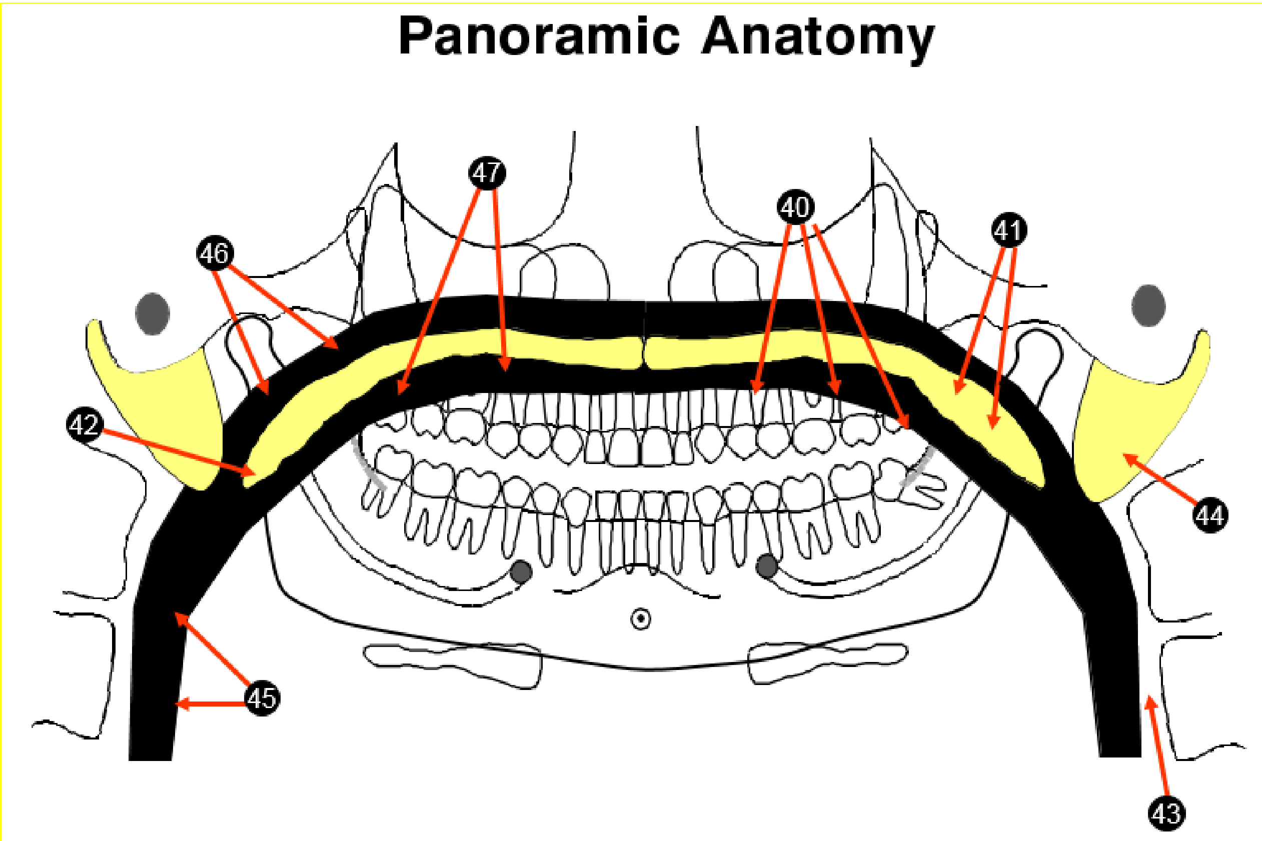
2. Double Real Image:

Two images of a single object which is located in the midline. Structures that produce these double real images include the hard and soft palate, hyoid bone and cervical spine. Object is between the center of rotation and the film.

3. Ghost Images:

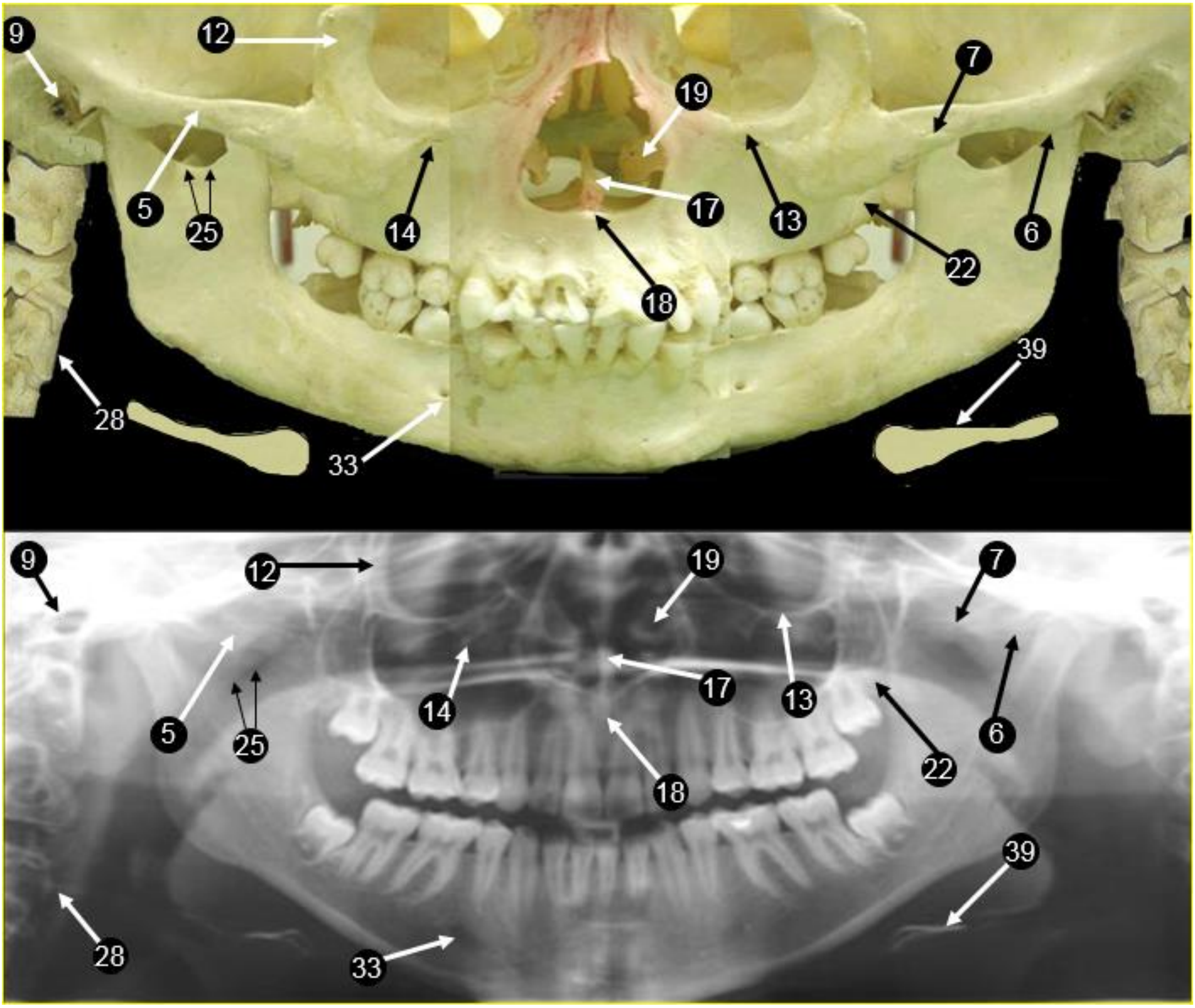
Usually caused by external objects such as earrings but may be produced by dense anatomical structures such as the mandible. Objects located between center of rotation and X-ray source.

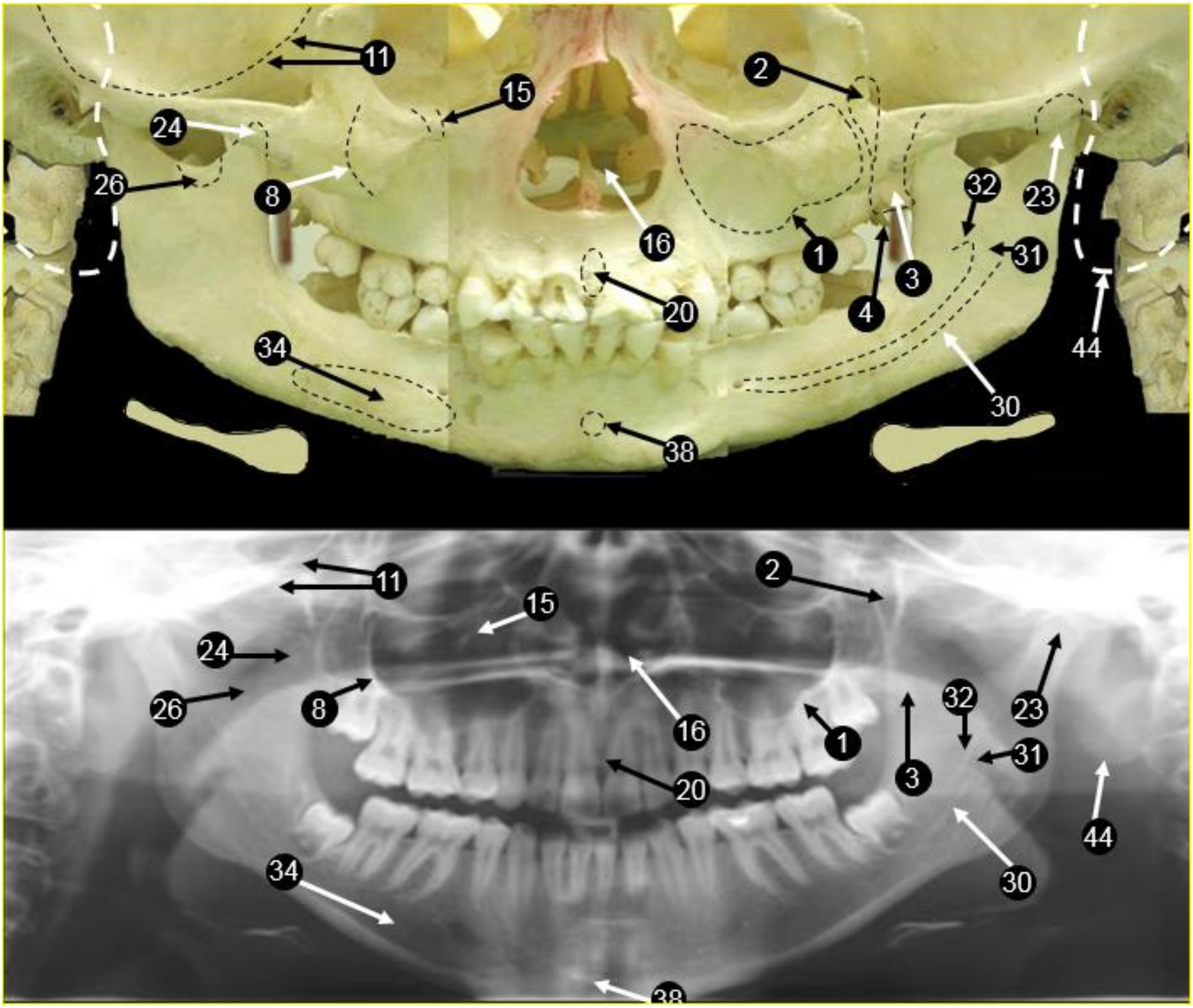


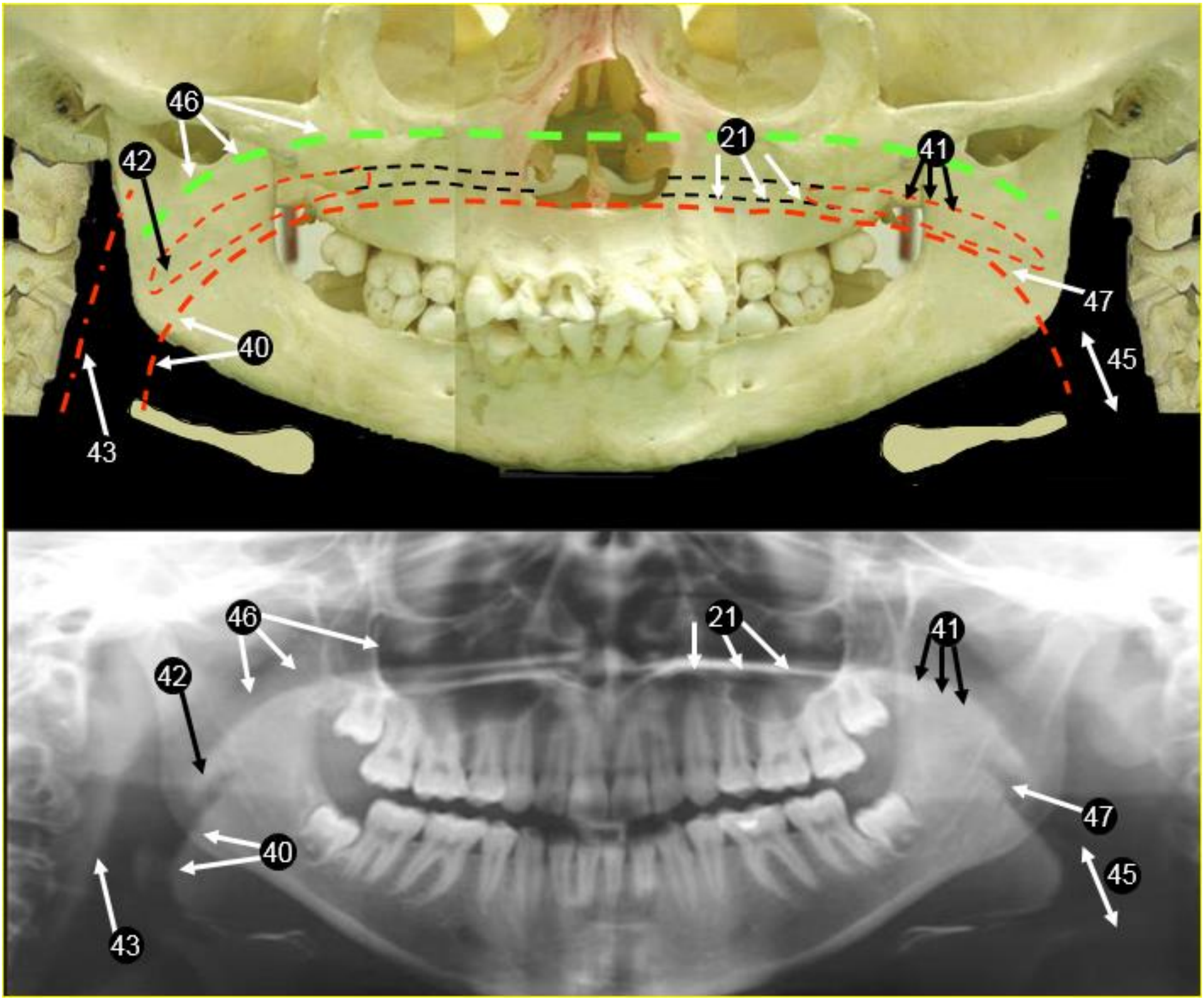


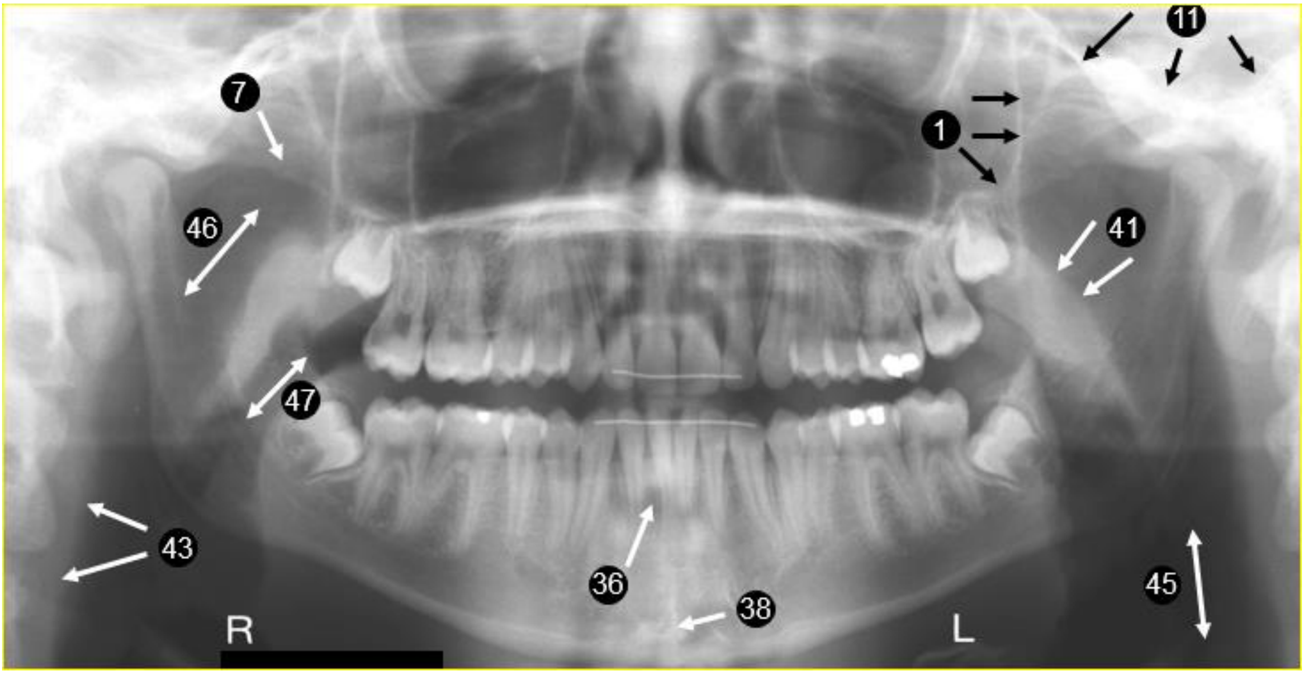
Panoramic Anatomy Key

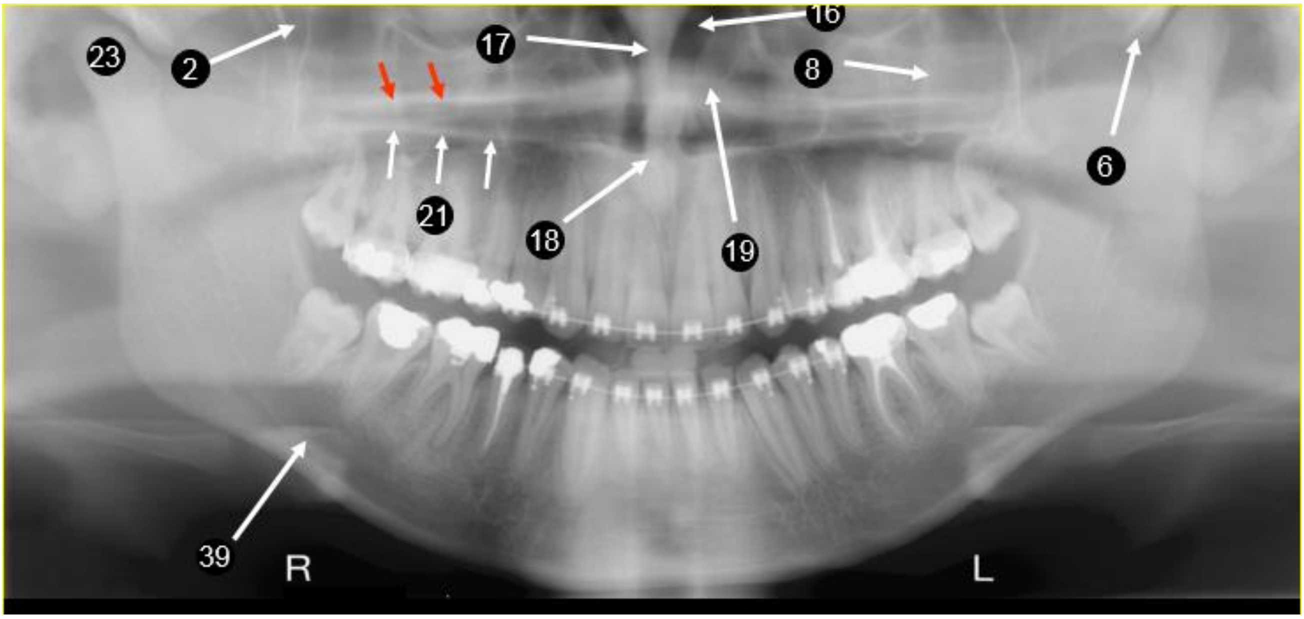
1. maxillary sinus
2. pterygomaxillary fissure
3. pterygoid plates
4. hamulus
5. zygomatic arch
6. articular eminence
7. zygomaticotemporal suture
8. zygomatic process of maxilla
9. external auditory meatus
10. mastoid process
11. middle cranial fossa
12. lateral border of the orbit
13. infraorbital ridge
14. infraorbital foramen
15. infraorbital canal
16. nasal fossa
17. nasal septum
18. anterior nasal spine
19. inferior concha
20. incisive foramen
21. hard palate
22. maxillary tuberosity
23. condyle
24. coronoid process
25. sigmoid notch
26. medial sigmoid depression
27. styloid process
28. cervical vertebrae
29. external oblique ridge
30. mandibular canal
31. mandibular foramen
32. lingula
33. mental foramen
34. submandibular gland fossa
35. internal oblique ridge
36. mental fossa
37. mental ridges
38. genial tubercles
39. hyoid bone
40. tongue
41. soft palate
42. uvula
43. posterior pharyngeal wall
44. ear lobe
45. glossopharyngeal air space
46. nasopharyngeal air space
47. palatoglossal air space


9
12
7
19
5
25
14
17
13
6
22
18
39
28
33
9
12
19
7
17
14
13
5
25
6
22
18
39
28
33

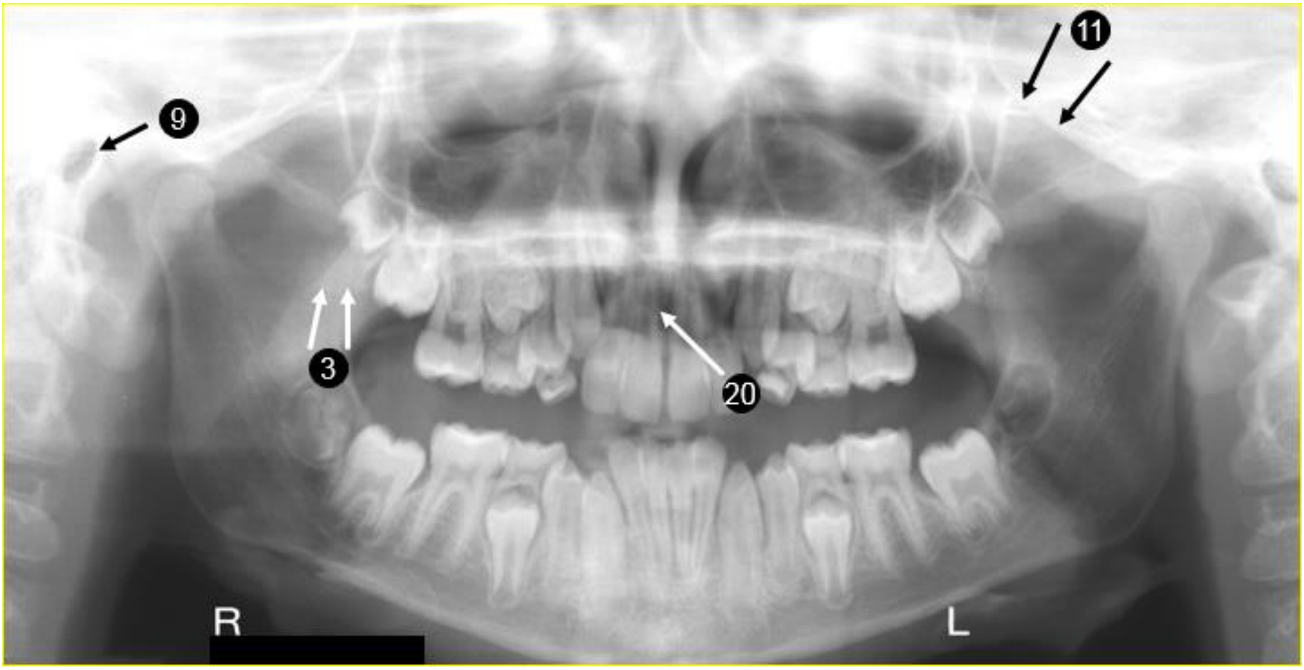

11
2
15
24
26
8
16
1
3
4
32
23
31
20
44
34
30
38

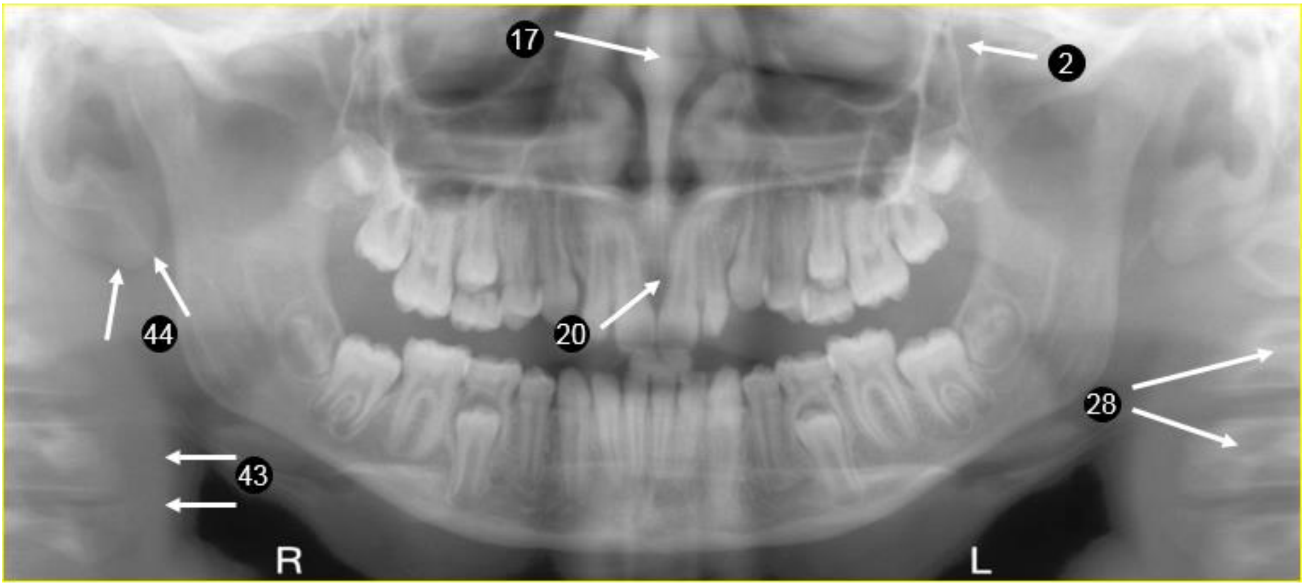

46
21
41
42
47
45
40
43
46
21
41
42
47
40
45
43

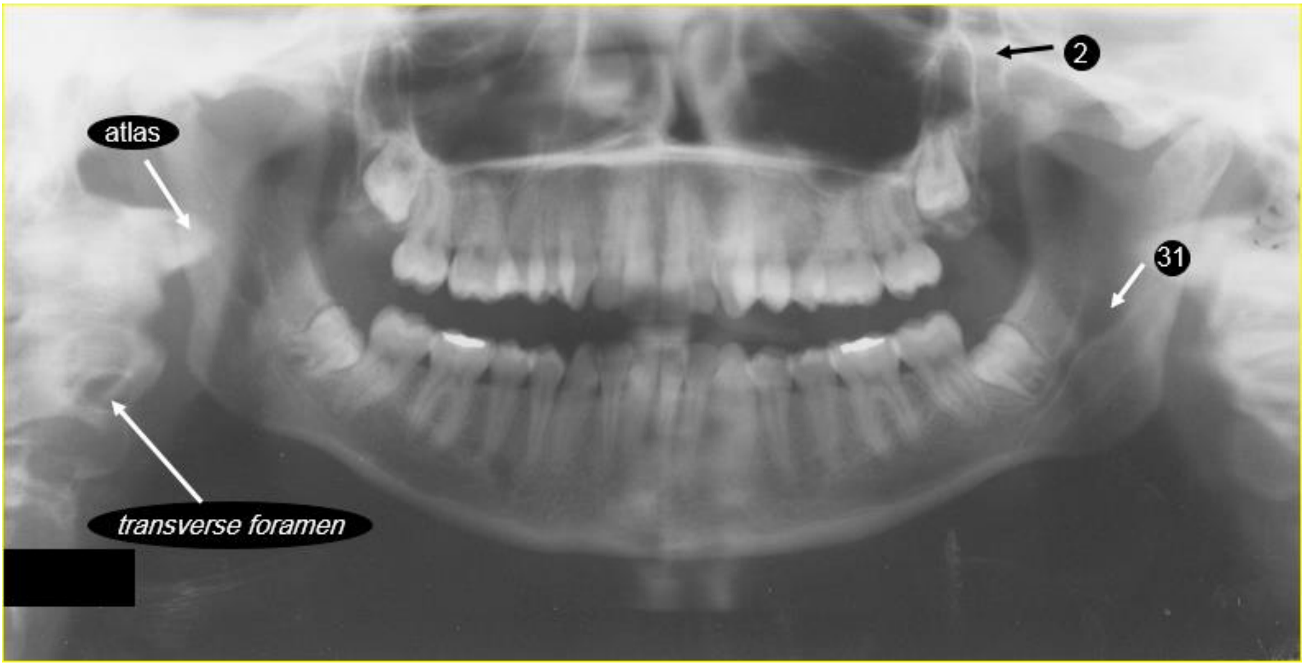

11
7
1
46
41
47
43
36
38
45
R
L

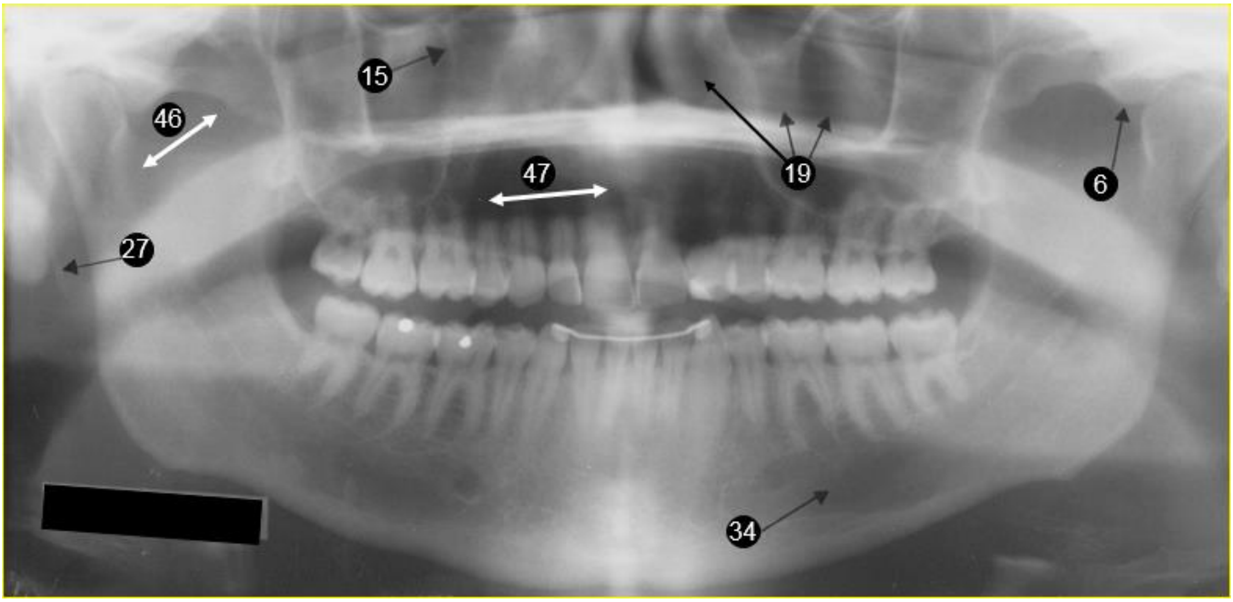


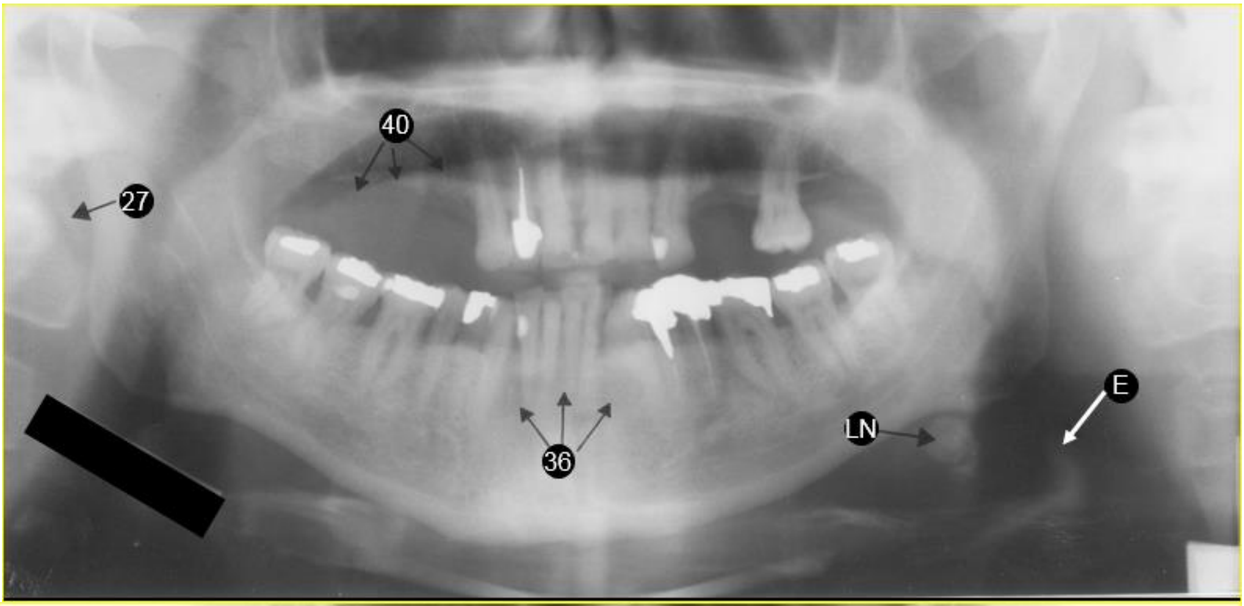
Red arrows point to ghost image of hard palate.

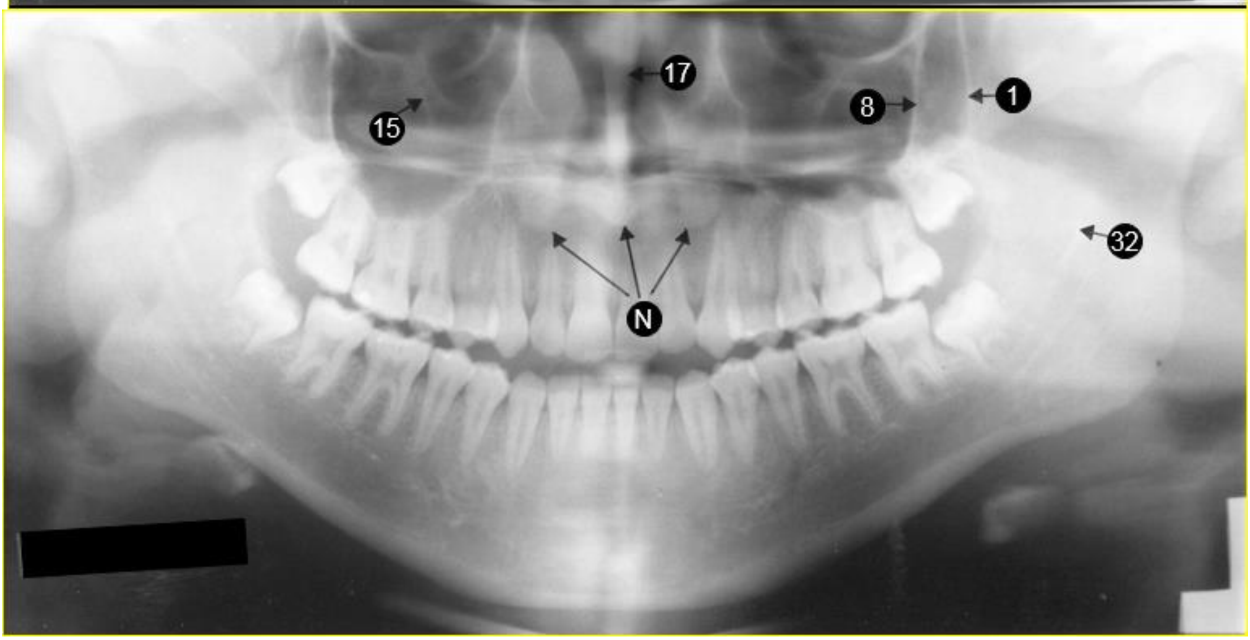



17
2
44
20
28
43
R
L


2
atlas
31
transverse foramen
[redacted]


15
46
47
19
6
27
34


40
27
E
LN
36


17
15
8
1
32
N

Lecture 16+17 Advanced imaging in dentistry

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

The advanced imaging modalities employ equipment and principles that are beyond the routine needs of most general dental practitioners which include:

1. Computed tomography (CT).
2. Cone beam computed tomography (CBCT).
3. Magnetic resonance imaging (MRI).
4. Ultrasonography (US).

Tomography:

Tomography is a specialized technique for producing radiographs showing only a section or slice of a patient. Tomographic image (or slice) shows the tissues within that section sharply defined and in focus. The section is thus referred to as the focal plane or focal trough. Structures outside the section are blurred and out of focus.

By taking multiple slices (fig. 1, A), three-dimensional information about the whole patient can be obtained. Production of each conventional tomographic slice requires controlled, accurate movement of both the X-ray tube head and the film during the exposure.

Computed Tomography (CT) is a well-accepted imaging modality for evaluation of the entire body. CT has undergone several evolutions and nowadays multi-detectors CT scanners have been evolved which have better application in clinical field.

CT scan machines uses X-rays, a powerful form of electromagnetic radiation, to produce sectional or slice images. In its simplest form a CT scanner consists of a radiographic tube that emits a finely collimated, fan-shaped X-ray beam that is directed to a series of scintillation detectors or ionization chambers (the radiographic film is replaced by very sensitive crystal or gas detectors).

The detectors measure the intensity of the X-ray beam emerging from the patient and convert this into digital data which are stored and can be manipulated by a computer (fig. 1, B).

This numerical information is converted into a grey scale representing different tissue densities, thus allowing a visual image to be generated. The image consists of a matrix of individual pixels representing the face of a volume called a voxel (fig. 2).

How does CT work?

During a CT scan, the patient lies on a bed that slowly moves through the **gantry** while the x-ray tube rotates around the patient, shooting narrow beams of x-rays through the body (fig. 3).

Instead of film, CT scanners use special digital x-ray detectors, which are located directly opposite the x-ray source. The computed tomography image is able to visualize abdominal organs and structures that are more similar in tissue density (fig. 4, RIGHT).

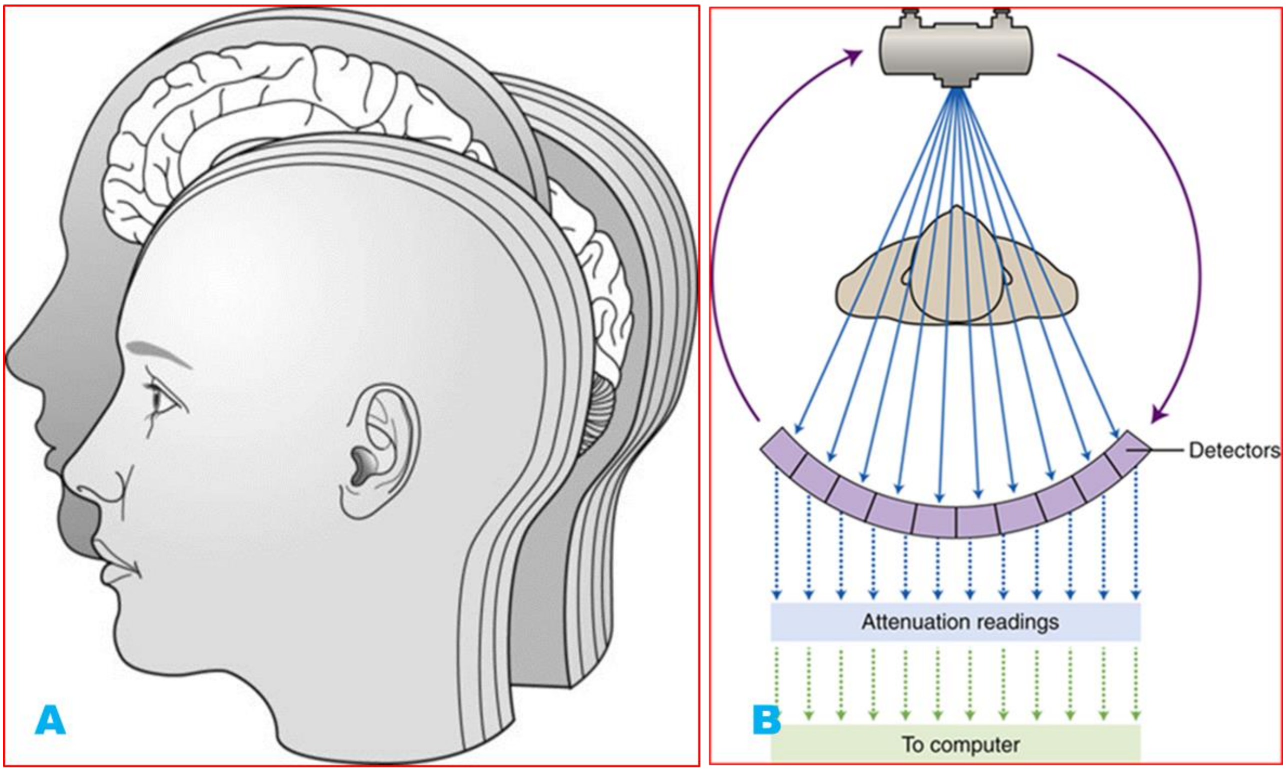


Figure 1. (A), Diagram illustrating the analogy of tomography. The patient is imaged and can be viewed in slices like a loaf of sliced bread. (B), Computed Tomography Process. As the x-ray tube and detectors rotate around the patient, the detectors measure the exit radiation multiple times and the digitized attenuation readings data are sent to the computer.

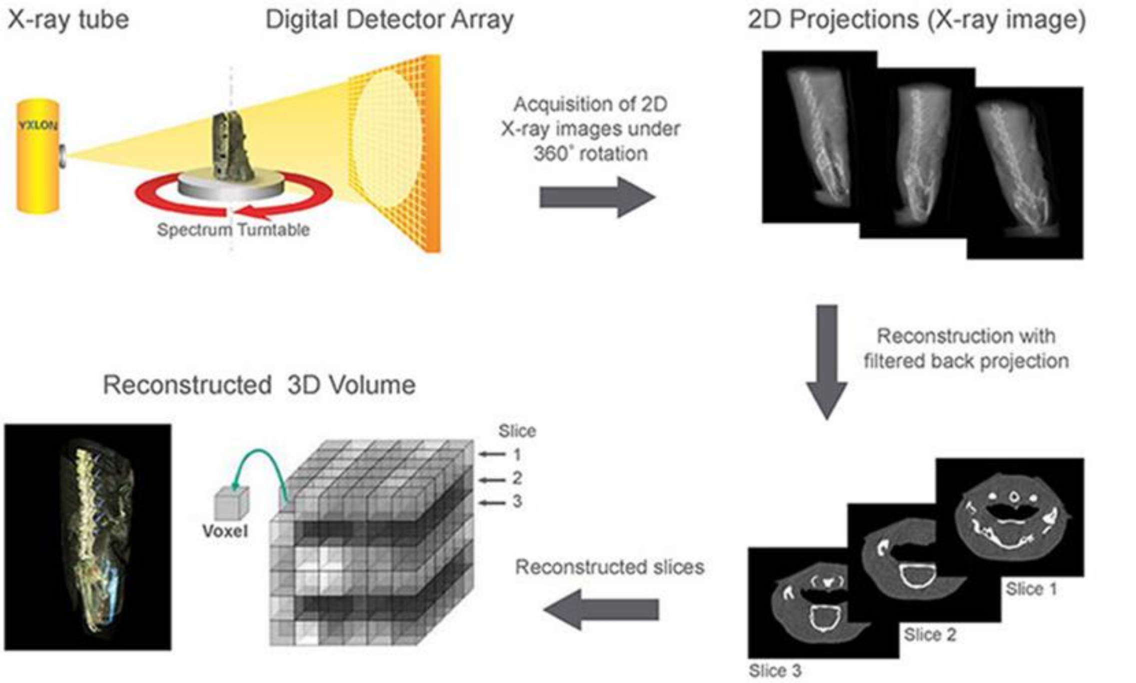


Figure 2. Computed tomography principles.

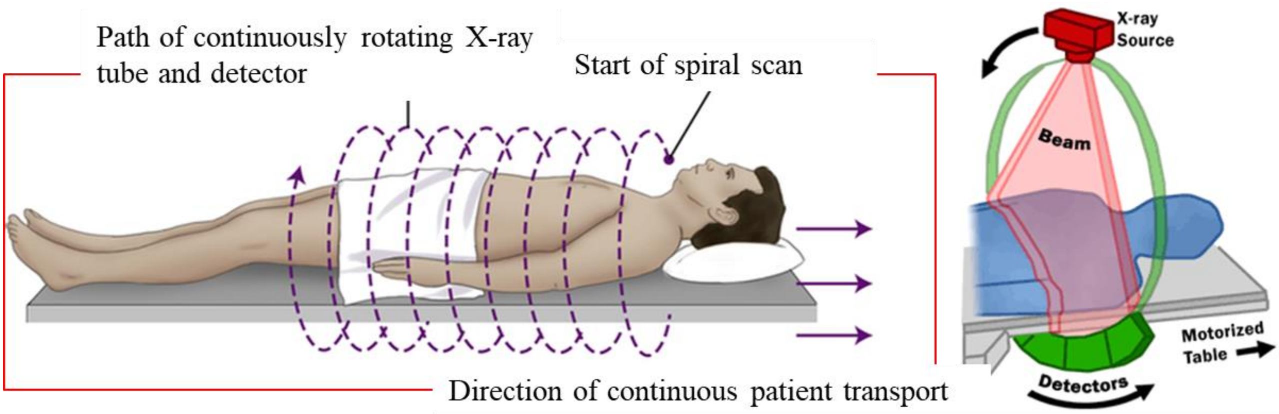


Figure 3. Spiral Computed Tomography. As the patient moves smoothly through the **gantry** aperture (along the Z axis), the tube and detectors continuously travel around the patient, creating a spiral path.

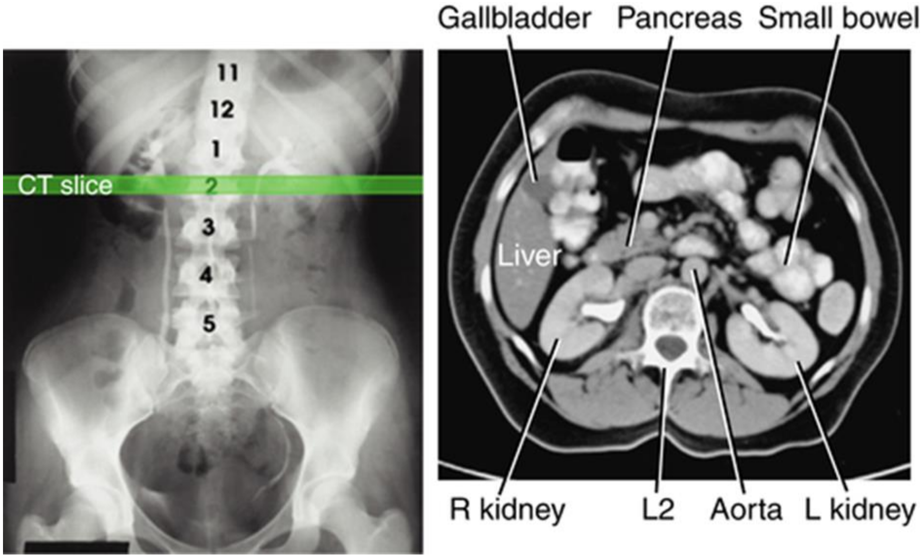


Figure 4. Cross-sectional slice (RIGHT) compared with the radiographic image (LEFT).

Applications of CT:

MDCT imaging has several applications in the diagnosis and treatment of dentomaxillofacial diseases:

1. Infections, including osteomyelitis and space infections.
2. Midfacial and mandibular trauma.
3. Developmental anomalies of the craniofacial skeleton.
4. Benign intraosseous cysts and neoplasms of the jaws.
5. Benign and malignant neoplasms that originate in, or extend into, the orofacial soft tissues.
6. Soft-tissue cysts.

Advantages of CT:

1. It provides axial, coronal and sagittal views of the tissue.
2. It shows anatomically precise location of the lesion and extent.
3. The structures of the soft tissues both normal and pathological are clearly displayed.
4. Because the image that is produced is formulated by the computer, areas of interest may be selectively viewed and enlarged by using computer programmers.
5. As the information is stored in the computer it can be viewed any time in the absence of patient.
6. Image can be manipulated.

Disadvantages of CT:

1. Is sophisticated, costly and expensive to maintain.
2. Very high-density materials such as metal bullets and dental restorations produce severe artefacts on CT scan, which makes the interpretation difficult.
3. There is an inherent risk associated with the contrast medium.

Cone-beam computed tomography (CBCT):

The first CBCT device (NewTom-9000; Quantitative Radiology, Verona, Italy) was described in 1998. Since then, a number of CBCT machines have been introduced into the market.

CBCT is a new medical imaging technique that generates 3D images. This imaging technique is based on a divergent pyramidal- or cone-shaped X-ray beam is directed through the middle of the area of interest and centered on a 2D detector on the opposite side that performs one rotation around the object, producing a series of 2D images. These recordings constitute "raw data" that is reconstructed by a computer algorithm to generate cross-sectional images.

Components of CBCT:

CBCT is composed of:

1. X-ray source with a rotating gantry.
2. A divergent pyramidal or cone-shaped source of ionizing radiation is directed through the middle of the region of interest.
3. CBCT scanner utilizes a 2D X-ray detector on the opposite side, which allows for a single rotation of the gantry to generate a scan.
4. Computer to display the images.

A three-dimensional **cone** (this example in fig. 5) or **pyramidal** (if collimation is rectangular) divergent x-ray beam is directed through the patient onto a detector (either solid-state flat panel detector or II/charge-coupled device). After a single two-dimensional projection is acquired by the detector, the x-ray source and detector rotate a small distance around a trajectory arc. At this second angular position, another basis projection image or frame is captured. This sequence continues around the object for the entire 360 degrees (full trajectory) capturing hundreds of individual images or along a reduced or partial trajectory (fig. 6, showing the basic 3-stage concept of a large CBCT scan).

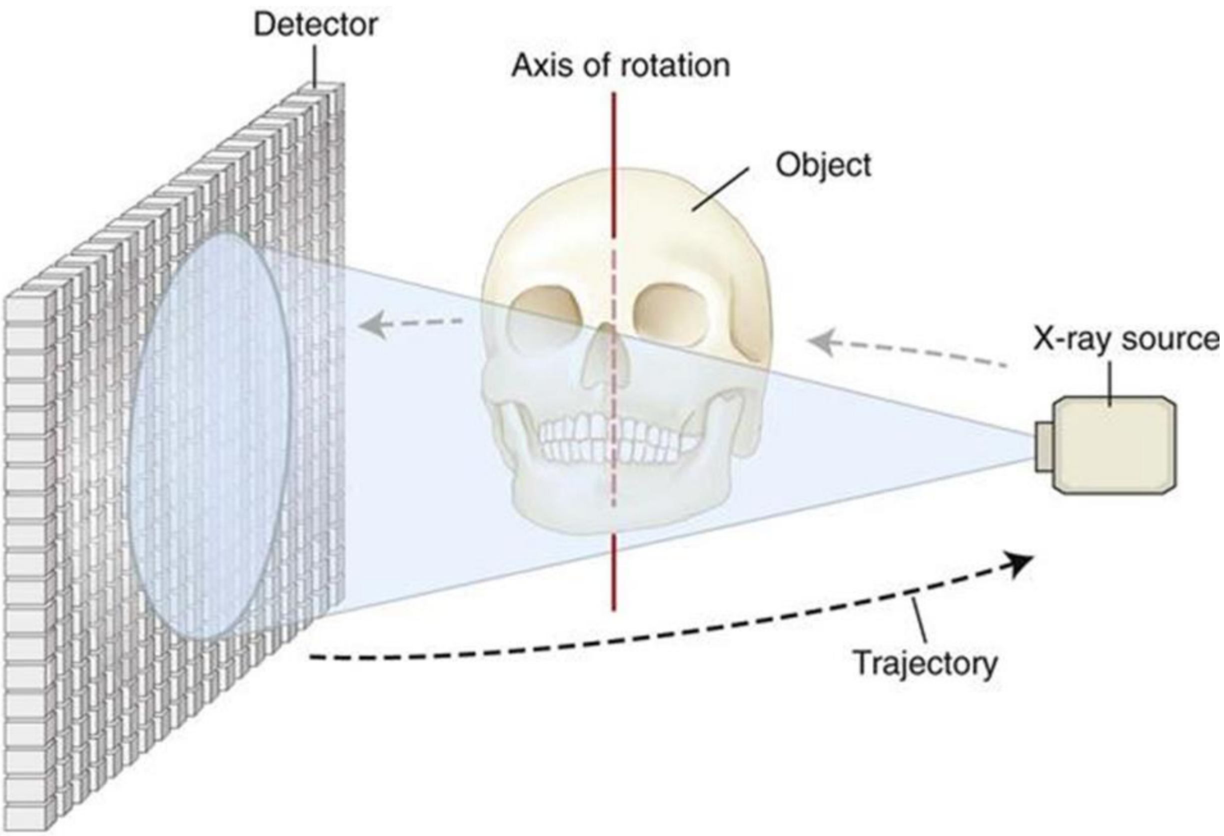


Figure 5. Cone-beam imaging geometry.

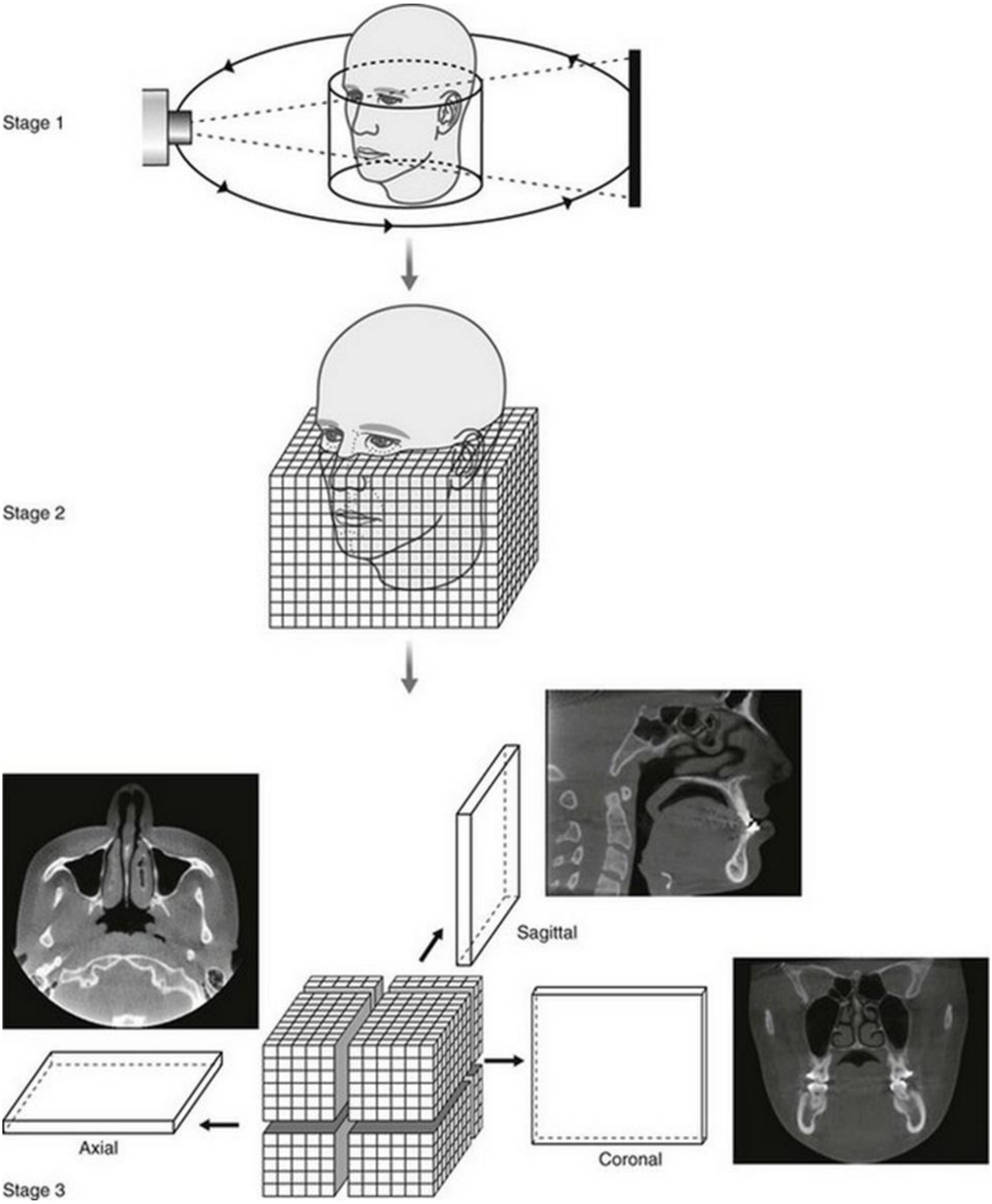


Figure 6. Diagram showing the basic 3-stage concept of a large CBCT scan. Stage 1- Data acquisition: a cone-shaped X-ray beam is used which orbits around the patient obtaining information/data in a cylindrical volume. The patient's maxillofacial skeleton is positioned within the cylinder. Stage 2- Primary reconstruction: the computer divides the cylinder into tiny cubes or voxels. Stage 3- Secondary or

multiplanar reconstruction: the computer creates separate images in the sagittal, coronal and axial anatomical planes.

Advantages:

1. Rapid scan time: Depending upon manufacturers, the single rotation, which is used in CBCT technology to acquire basis images for 3D imaging usually requires scan time ranging from 5 to 40 seconds comparable to panoramic radiography.
2. Beam limitation. The CBCT machines come with capability to collimate (*select the Field of View (FOV), fig. 7*) the primary X-ray beam to the area of interest, reducing the size of irradiation. This procedure fulfils the individual needs, reduces unnecessary exposure to the patient and minimizes scattered radiation that would degrade image quality.
3. Image accuracy. CBCT machines provide isotropic voxels i.e. equal in all three proportions as compared to anisotropic voxels found in conventional CT (fig. 8).
4. Reduced patient radiation dose. CBCT offers significant dose reductions of between 98.5% and 76.2% in contrast with patient dose reported for oral and maxillofacial imaging by conventional CT
5. Interactive display modes such as mutiplanar reconstruction that are applicable to maxillofacial imaging (fig. 9).

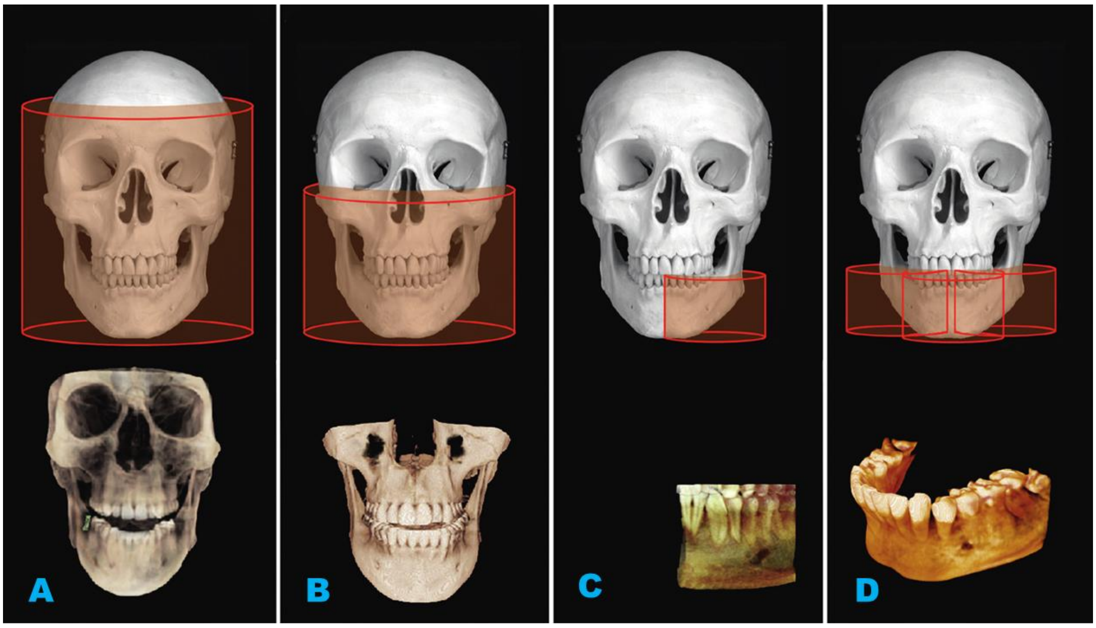


Figure 7. Showing the capability of CBCT machines to collimate (select FOV's) the X-ray beam to suit the needs of individual clinical situations. **Classification of CBCT units according to the FOV**. **A**, Large FOV scans provide images of the entire craniofacial skeleton, enabling cephalometric analysis. **B**, Medium FOV scans image

the maxilla or mandible or both. **C**, Focused or restricted FOV scans provide high-resolution images of limited regions. **D**, Stitched scans from multiple focused FOV scans provide larger regions of interest to be imaged from superimposition of multiple scans.

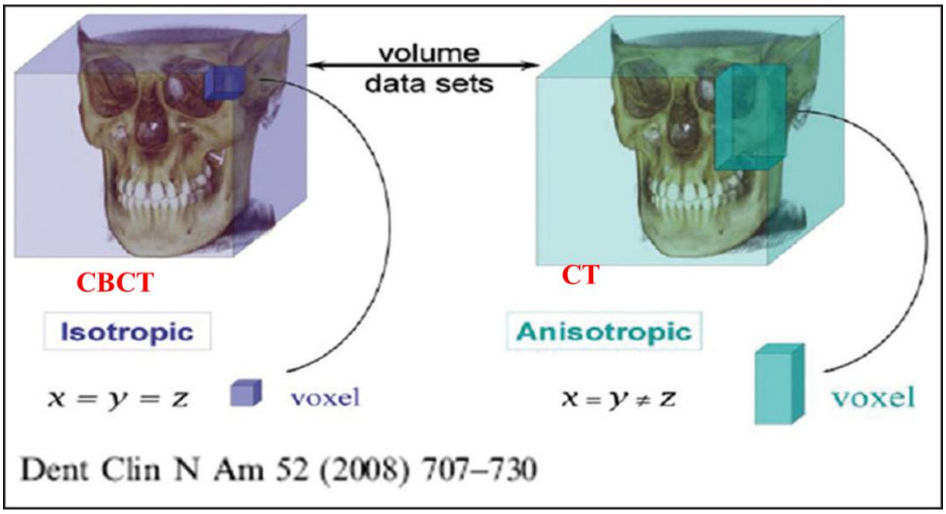


Figure 8. Isotropic nature of CBCT volumetric elements (voxels) and anisotropic (cuboidal) voxels of conventional or spiral CT. Recent advances in multidetector CT technology have made the acquisition of isotropic data feasible, with a trade-off in the form of increased radiation dose to the patient and prolonged scanning time.

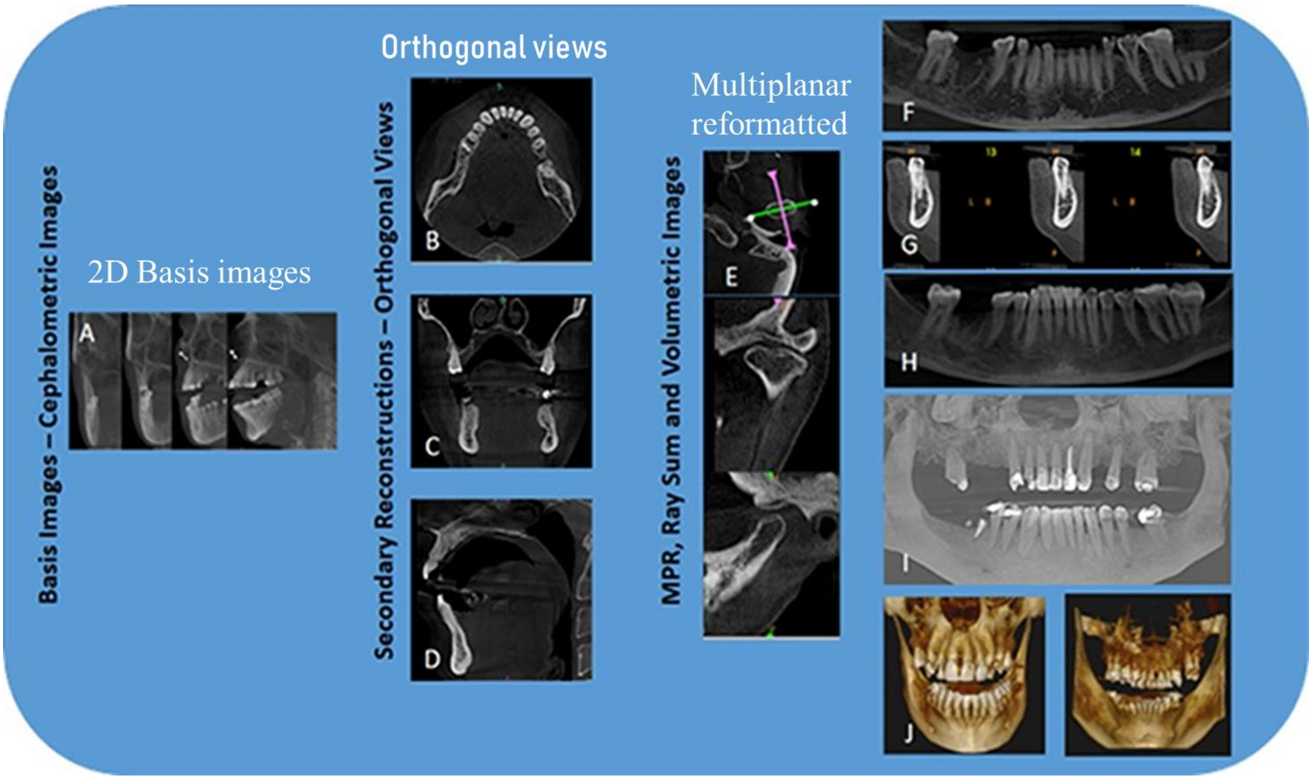


Figure 9. CBCT: **Image acquisition and display modes**.

(A), Acquired 2D Basis images are used for Secondary reconstruction of (B), axial (C), coronal and (D), sagittal views (orthogonal views).

Other display modes available in CBCT include (i) multiplanar reformatted (MPR) consisting of (E), Oblique slices (F), Curved slice and (G), Cross sectional views; (ii) **Ray sum** comprising (H), images of increased section thickness; and (iii) **volumetric images** consisting of Direct volume rendering (DVR), the most common of which being (I), maximum intensity projection (MIP) and (J), Indirect volume rendering (IVR) (3D).

IMAGE ARTIFACTS:

1. Extinction artefacts.
2. Beam hardening artefacts.

As an x-ray beam passes through an object, lower energy photons are absorbed in preference to higher energy photons. This phenomenon, called beam hardening, results in two types of artifact: (1) distortion of metallic structures as a result of differential absorption, known as a cupping artifact, and (2) streaks and dark bands, which, when present between two dense objects, create extinction or missing value artifacts.

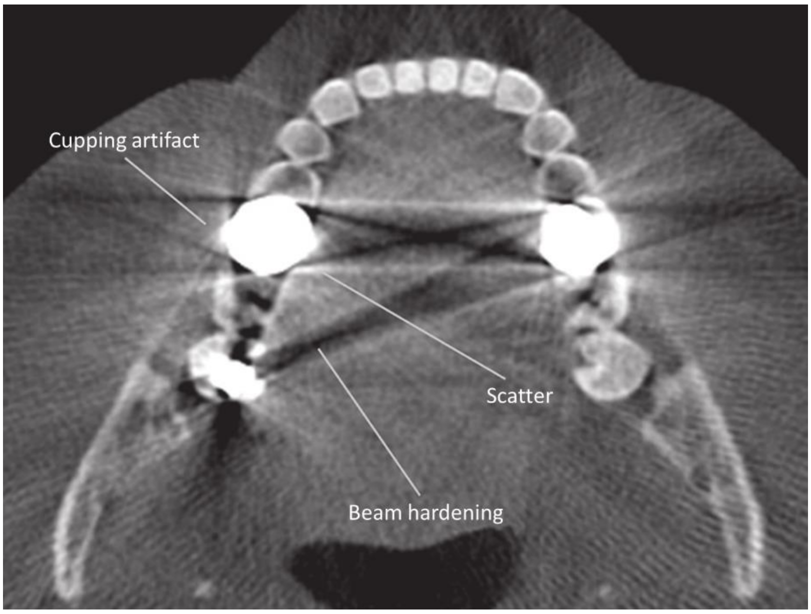


Figure 10. Introduced artifacts. Axial view demonstrating beam hardening (dark bands), scatter (white streaks), and cupping (image distortion) artifacts.

3. Ring artefacts.

Typically, scanner-related artifacts appear as circular or ring streaks resulting from imperfections in scanner detection or poor calibration.

Either of these problems results in a consistently repetitive reading at each angular position of the detector, resulting in a circular artifact.

Misalignment of the x-ray source to the detector creates a double contour artifact, similar to that created by patient motion.

Repeated use of CBCT equipment over time may result in slight configuration changes, and components may need to be periodically realigned.

Figure 11. Circular or ring artifacts. Visual appearance of scanner related artifacts as circular rings on an axial image suggests imperfections in scanner detection as a result of poor calibration.

4. Motion artefacts (misalignment artefacts).

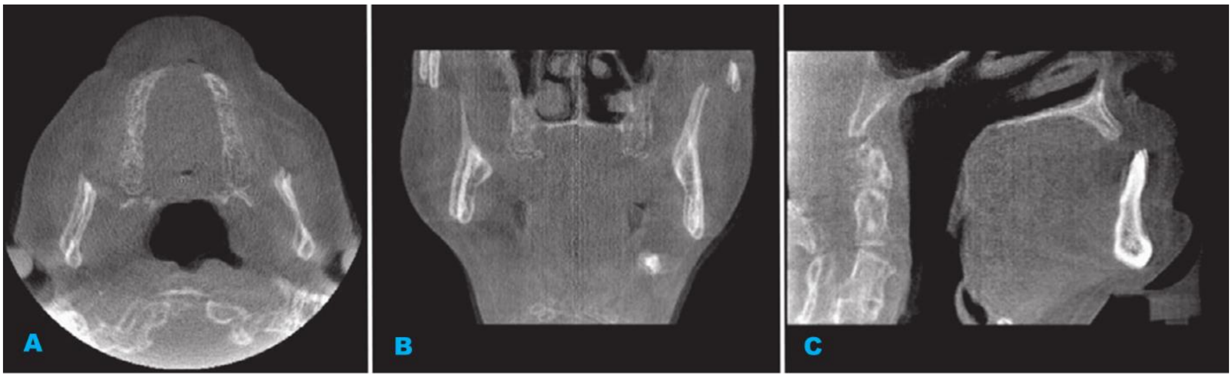


Figure 12. Motion artifacts. Patient motion during the scanning exposure can result in misregistration artifacts, which appear as double contours in the

reconstructed image as demonstrated in the axial (**A**), coronal (**B**), and sagittal (**C**) planes.

Limitations of cone-beam CT imaging:

1. Patient-related artifacts: Patient motion can cause misregistration of data, which appears as unsharpness in the reconstructed image.
2. Poor soft tissue contrast: scattered radiation contributes to increased image noise.
3. X-ray beam artifacts: Because the CBCT x-ray beam has lower mean kilovolt (peak) energy.

Application of CBCT:

1. Investigation of jaw pathology including cysts, tumors and fibro-osseous lesions.
2. Pre- and post-implant assessment =Implant imaging.
3. Orthodontic and orthognathic surgeries.
4. Endodontics.
5. Periodontics.
6. Investigation of the bony components of the TMJ (TMG diagnosis).
7. Investigation of the paranasal sinuses. e.g. Maxillary sinus assessment.
8. Assessment of wisdom teeth, in particular their relationship to the inferior dental canal. Assessment of impacted teeth (third molar and canine).
9. Orthodontic assessment, both dental development and skeletal base relationship.
10. Evaluation of facial trauma.

Views interpretations and Anatomy

There are three 2D views sagittal, coronal and axial, all these 2D views will reconstructed to form 3D view (fig. 9).

Magnetic Resonance Imaging (MRI):

Magnetic resonance imaging (MRI) is an imaging technique with a revolutionary impact in diagnostic imaging. It is noninvasive and uses nonionizing radiation. Instead, it depends on the magnet and radiofrequency waves (RF).

MRI principle and technique:

The essential principle of MRI involves the behavior of protons (positively charged nuclear particles) in the simplest atom which is hydrogen that consisting of one proton in the nucleus so it used to create the MRI image

To make an MR image, the patient is first placed inside a large magnet. This magnetic field causes the nuclei of many atoms in the body, particularly hydrogen, to align with the magnetic field (fig. 13)

The scanner directs a radiofrequency (RF) pulse into the patient, causing some hydrogen nuclei to absorb energy (resonate).

When the RF pulse is turned off, the hydrogen nuclei release the stored energy, which is detected as a signal in the scanner. The magnetic field in MRI scanner is provided by external powerful permanent magnet with strength range from (0.1 to 7 Tesla), 1.5 Tesla is the most commonly used (which is about 30,000 times the strength of the earth's magnetic field).

The strength of the MRI signal depends on the degree to which hydrogen is bound within a molecule. Tightly bound hydrogen atoms (in bone) produce weak signal.

While loosely bound or mobile hydrogen atoms (in soft tissues and liquids) produce strong signal. It makes images with excellent soft-tissue resolution.

Relaxation at the end of the RF pulse results in recovery of the longitudinal magnetization (T1 relaxation time required for 63% of the longitudinal magnetization return to equilibrium, while T2 relaxation time is time constant required to loss transverse magnetization).

The MRI images either T1-weighted images are more commonly used to demonstrate anatomy or T2 weighting are used to depict pathologic changes, such as inflammation and neoplasia.

In MRI the most common contrast agents used is Gadolinium (a paramagnetic substance) that shortens the T1 relaxation times of tissues and making them appear brighter.

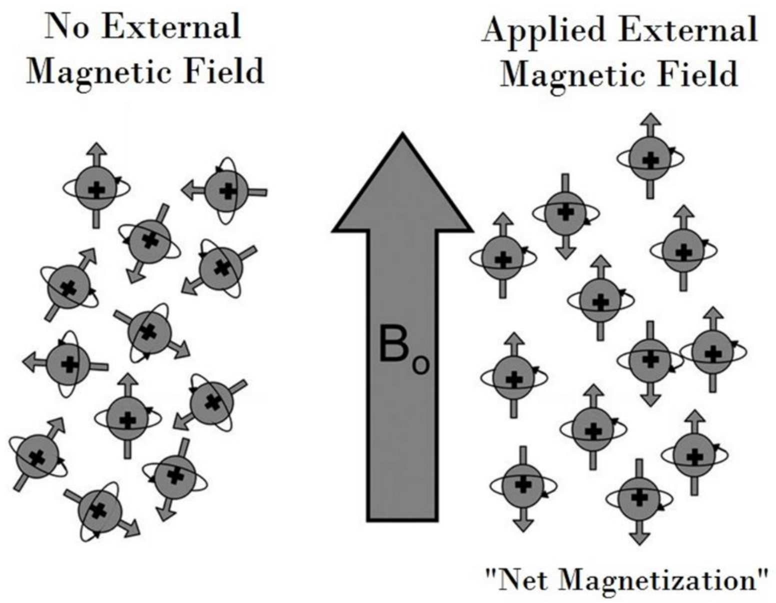


Figure 13. In the absence of a strong magnetic field, hydrogen nuclei are randomly aligned (oriented) as in (LEFT). When the strong magnetic field, is applied, the hydrogen nuclei precess about the direction of the field as in (RIGHT).

Advantages of MRI:

1. High-resolution images can be reconstructed in all planes (using 3D volume techniques). It offers best contrast resolution of soft tissues.
2. No ionizing radiation is involved, with no adverse effects have yet been demonstrated.
3. Direct multi planar imaging is possible without patient re-orientation.
4. Image manipulation available.

Disadvantages of MRI:

1. Relatively scanning time can be long and is thus demanding on the patient.
2. Patients with claustrophobia may not be able to tolerate the narrow space within the MRI scanner this can be managed by using open MRI, chemical sedation, general anesthesia, or listening to music on headphones.
3. Hazard associated with the presence of ferromagnetic (metal) substances in the patient's body, the strong magnetic fields can move these objects, cause excessive heating, or induce strong electrical currents, which may harm the patient, so MRI is contraindicated in patients with cardiac pacemakers, some cerebral aneurysm clips, vagus nerve stimulators, insulin pumps, cochlear implants, and in patients with embedded ferrous foreign bodies, such as shrapnel or bullets.

4. Metals dental restorations do not move but distort the image, Removable dental appliances must be removed prior to MRI scanning. Special considerations to patients with Steel orthodontic arch wires treatment.
5. There is medical evidence that a tattoo can cause a reaction (burning sensation) during MR imaging because some tattoo inks containing iron oxide.
6. Contraindicated In first trimester of pregnancy (especially with using Gadolinium contrast agent).
7. Metallic objects, e.g. endotracheal tubes need to be replaced by non-ferromagnetic alternatives.
8. Equipment is very expensive.
9. Bone, teeth, air and metallic objects all appear black, making differentiation difficult.

Applications of MRI in maxillofacial diagnosis:

Because of its excellent soft-tissue contrast resolution, MR imaging is useful in evaluating soft tissue conditions (Bone does not give an MR signal, a signal is only obtainable from bone marrow). Applications of MRI in dentistry include:

1. Evaluation of TMJ.
2. Evaluation of neoplasms. Tumor staging (salivary glands, tongue and floor of mouth).
3. Evaluation of salivary gland diseases.
4. Evaluation of vascular lesions in the orofacial region.
5. Evaluation of early jaws osteomyelitis.
6. Evaluation of maxillary sinus, nasal cavities, the tongue, and floor of mouth.
7. Functional MRI (fMRI) which is identification of motor and sensory areas of the brain in relation to pain, occlusion, fear, love, smell.
8. Assessment of intracranial lesions.

CT versus MRI:

	CT	MRI
1	Uses X-rays (ionizing radiation) it a good tool for examining hard tissue such as bone.	Uses non-ionizing radio frequency (RF) signals is best suited for soft tissue.
2	Contrast in CT images is generated from X-ray attenuation.	Variety of properties may be used to generate contrast in MR images.
3	Contrast agents is iodine or barium.	Contrast agents is gadolinium.
4	Limited to axial plane images from	Generate cross-sectional images in any

	which images reconstructed in any plane.	plane.
5	Best for solid tumors of the abdomen and chest.	Best For brain tumor detection.
6	More widely available, faster, and less expensive.	Long time, expensive.

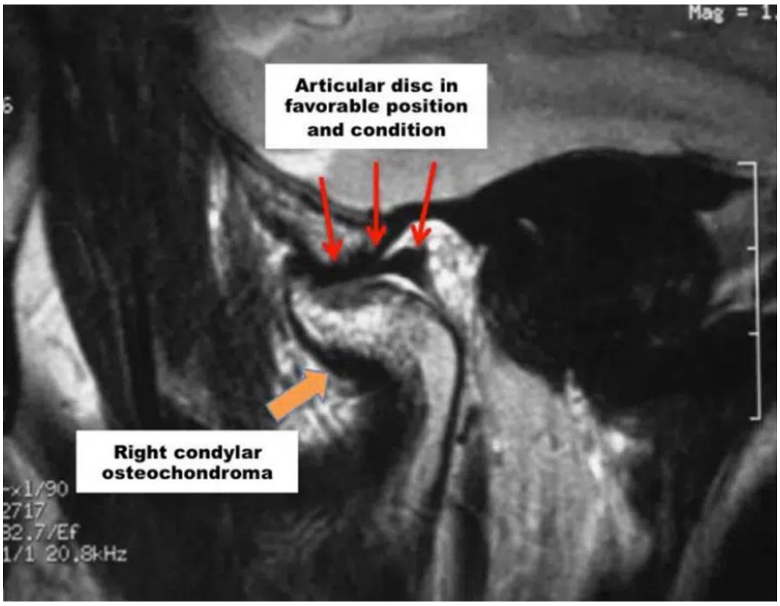


Figure 14. MRI of right TMJ shows osteochondroma with large exophytic growth of the anterior aspect of the condyle (CH Type 2Ah). The articular disc is in favorable position and salvageable.

Figure 15. MRI device.

Ultrasonography (US):

US is an advanced modality in oral and maxillofacial imaging, this technique based on sound waves that acquires images in real time without the use of ionizing radiation.

US principle and technique:

The US unit consists of a transducer and the monitor on which sonogram can be seen.

A transducer is a device that can convert electrical energy into sonic energy with frequencies range (1 to 20 MHz). The transducer emitting ultrasound is held against the body part being examined (fig. 16). The ultrasonic beam passes through or interacts with tissues of different acoustic impedance.

Some sonic waves are reflected and the rest are absorbed. The sound waves travel fast through the first tissue layer until they meet a different tissue, that reflect (echo) toward the transducer are detected by the transducer, amplified, processed, and displayed on monitor as a digital image (fig. 16).

Interpretation of sonograms relies on the tissues signals. Tissues that do **not produce signals**, such as fluid-filled cysts, are said to be **anechoic and appear black**.

Tissues that produce a weak signal are hypoechoic, whereas tissues that produce intense signals, such as ligaments, skin, or needles or catheters, are hyperechoic and appear bright.

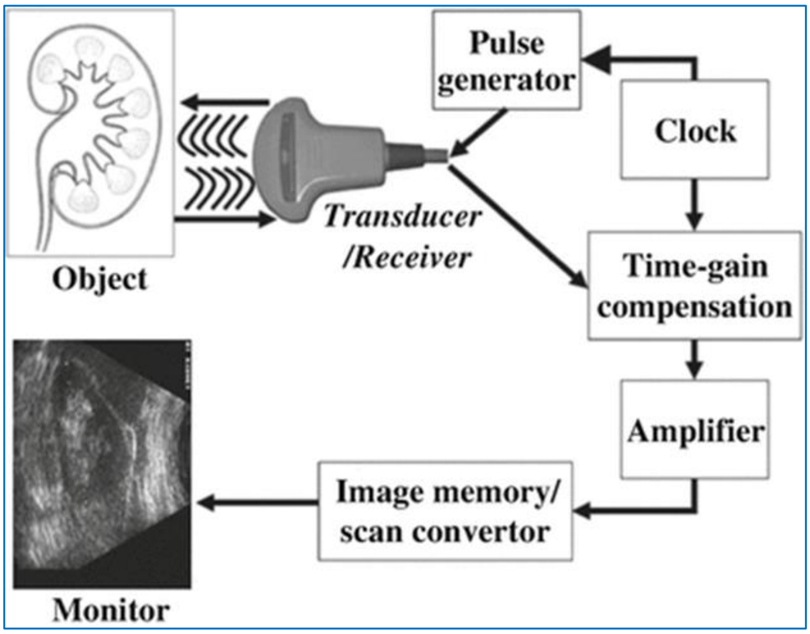


Figure 16. Schematic depiction of the sequence of image production by an ultrasound device.

Applications of ultrasonography in oral and maxillofacial imaging:

1. Evaluation of benign and malignant masses of neoplasms in head and neck region (the thyroid, parathyroid, lymph nodes, sinuses).
2. Salivary glands pathologies (neoplasm, stones, inflammation, and Sjögren's syndrome).
3. Evaluation of vessels of the neck, including the carotid artery for atherosclerotic plaques.
4. Ultrasonography is also used to guide fine-needle aspiration.
5. More recent advances include 3D imaging of a fetal face.
6. Color doppler sonography for evaluation of blood flow.
7. Detection of orofacial fracture.
8. Detection of facial muscles thickness.

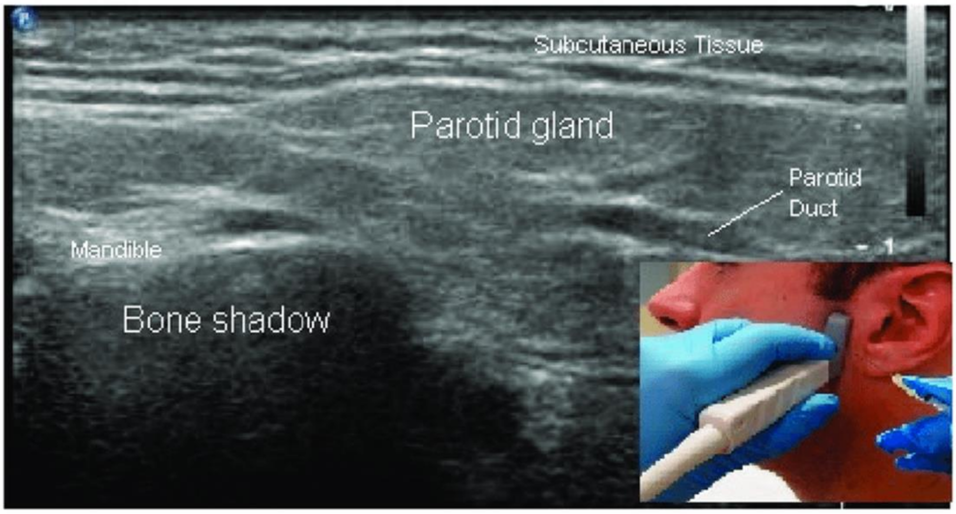


Figure 17. B-mode ultrasound image, parotid salivary gland.

Figure 18. Transverse ultrasound of right submandibular gland. Hypo to isoechogenic tumor inside the gland well delineated: pleomorphic adenoma.

Figure 19. Ultrasound Machine. A new era of ACUSON ultrasound system from Siemens Healthineers.

Lecture 18 Biological effects of radiation

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

Types of radiation:

1. Non-Ionizing Radiation: Radiation that does not have sufficient energy to dislodge orbital electrons. ex.: microwaves, ultraviolet light, lasers, radio waves, infrared light, and radar.
2. Ionizing Radiation: Radiation that has sufficient energy to dislodge orbital electrons. ex.: alpha particles, beta particles, neutrons, gamma rays, and x-rays.

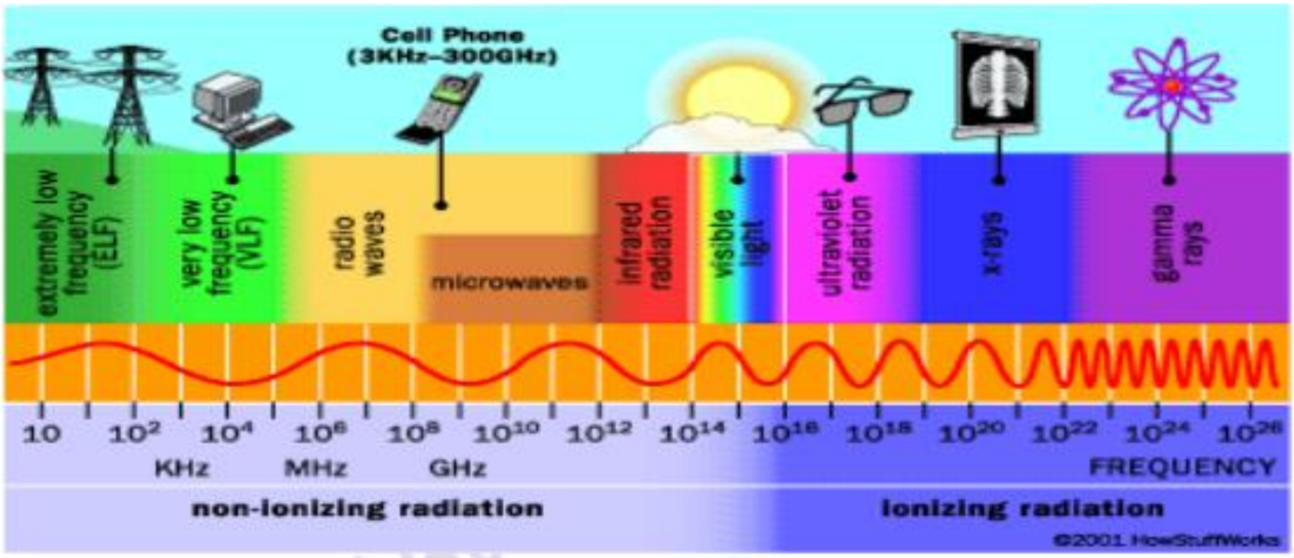


Fig. 1: types of radiation

All the atoms in human body has electrical stability when x- ray photon strikes a -ve electron in the atom of living subjects (tissues) it displace the electron leaving the atom electrically unbalance so the atom ionized such process called (ionization), this ionized atom has a strong tendency to seek its stability by accepting a –ve electron from somewhere else and by doing so a new chemical is form and the cell of which the atoms and molecules are parts can be altered. So that the basic effects of ionization are Molecular alteration and creation of new chemicals.

Radiation biology is the study of the effects of ionizing radiation on living systems. The initial interaction between ionizing radiation and matter occurs at the level of the electron within the first 10-13 second after exposure. These changes result in modification of biologic molecules within seconds to hours. In turn, the molecular changes may lead to alterations in cells and organisms that persist for hours, decades, and possibly even generations. They may result in injury or death of the cell or organism.

Effects of ionizing radiation:

Radiation acts on living systems through direct and indirect effects:

Direct effect:

When the energy of a photon or secondary electron ionizes biologic macromolecules, the effect is termed direct. Those effects occurred in specific area of the body where all exposed cells in this area are altered directly by ionization process and death occurred at the time of mitotic cell division.

When DNA molecule is struck by radiation, ionized, resulting in damage. Radiation hit cell, lead to direct ionization of DNA; if enzymatic repair occurs there is no effect, and if not permanent damage in DNA lead to biological effects; somatic effects and genetic effects: cancer – sterility.

Indirect effect:

It happened in several ways where new chemicals result from process of ionization are in compatible with body tissues, ex: when photon absorbed by water in an organism, ionizing the water molecules. The resulting ions form free radicals (radiolysis of water) that in turn interact with and produce changes in the biologic molecules.

Because intermediate changes involving water molecules are required, so conversion of water to H_2O_2 which cause cellular dysfunction also x-radiation can alter the chemical composition of hormones enzymes and other body secretions make them partially or totally ineffective such indirect effects depend on the amount of exposure to X- ray. This series of events is termed indirect.

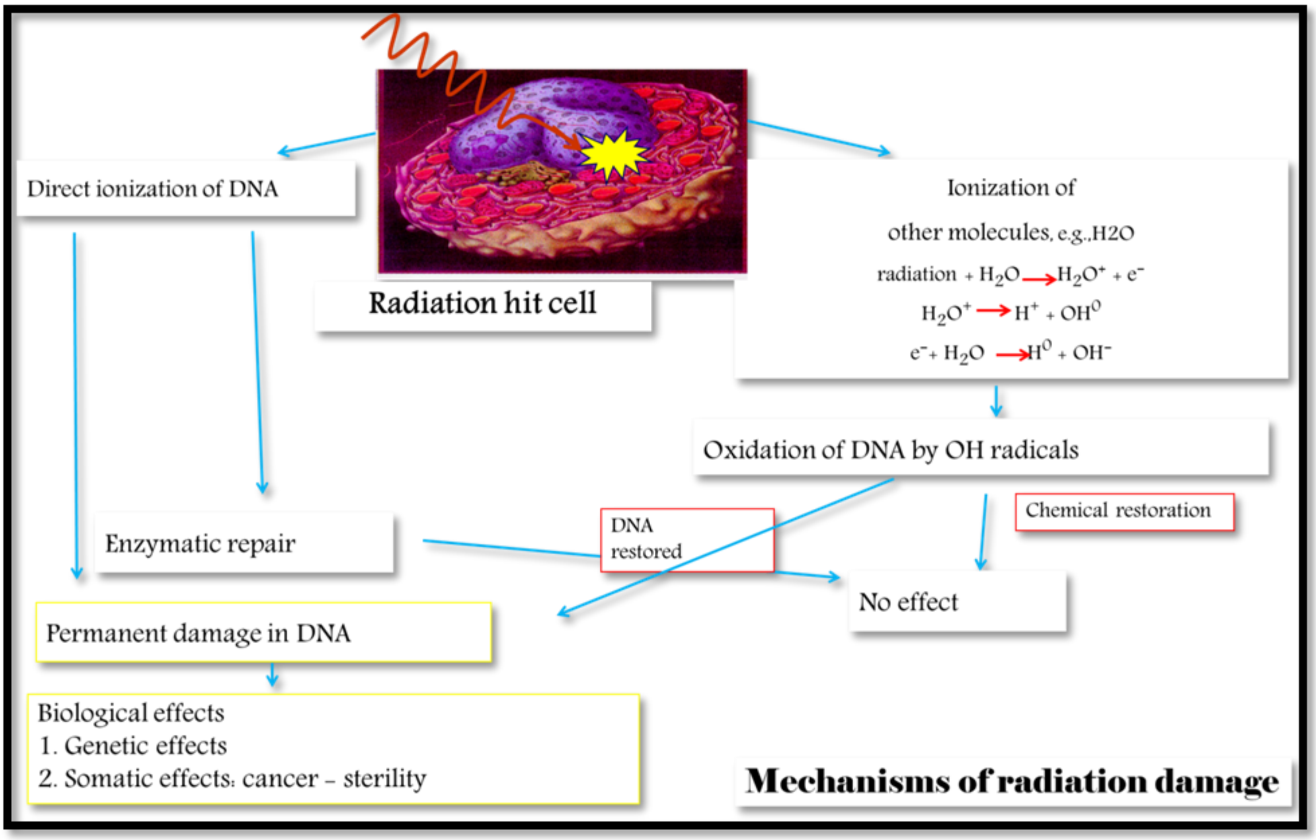
When water molecule is ionized. The ions, H_2O^+ and H_2O^-, are very unstable and break up into OH free radicals. OH free radical contains an unpaired electron in the outer shell and is highly reactive: reacts with DNA.

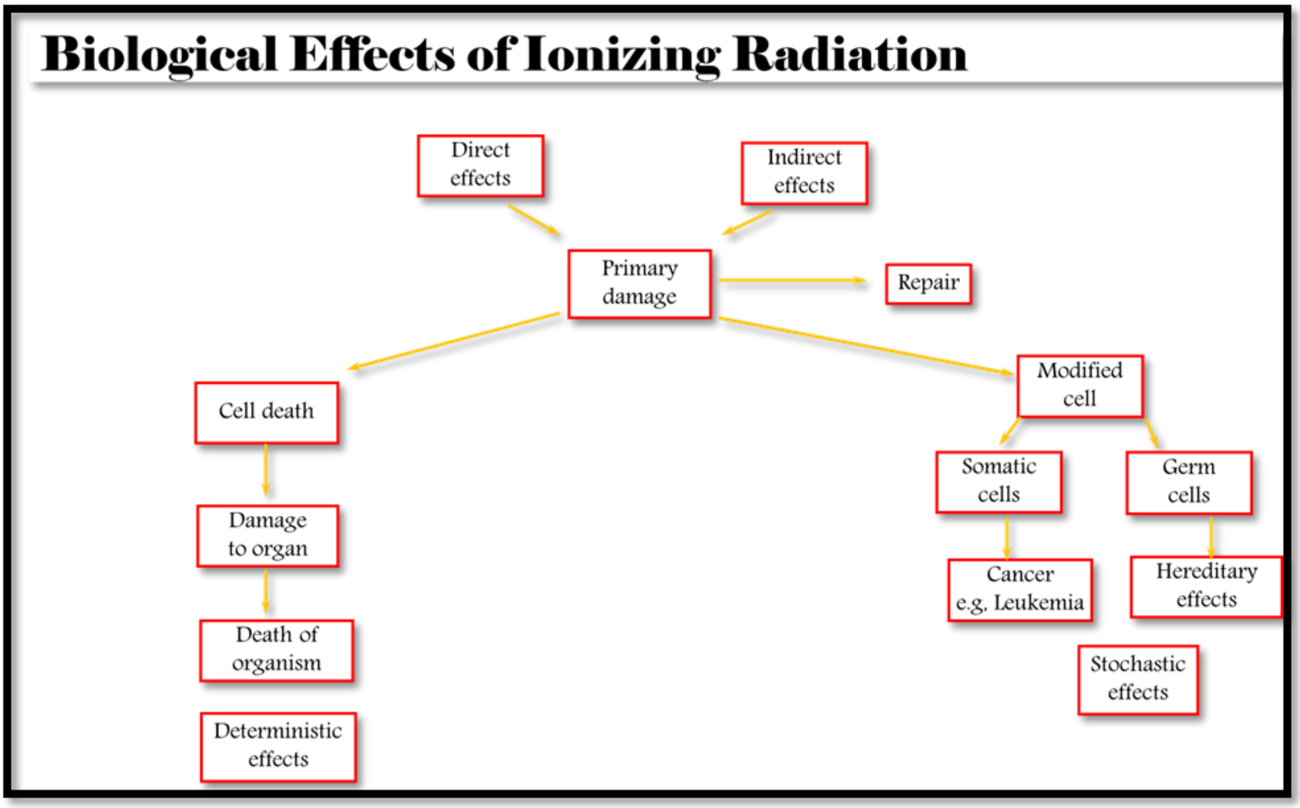
Free radicals may also combine with each other to produce hydrogen peroxide

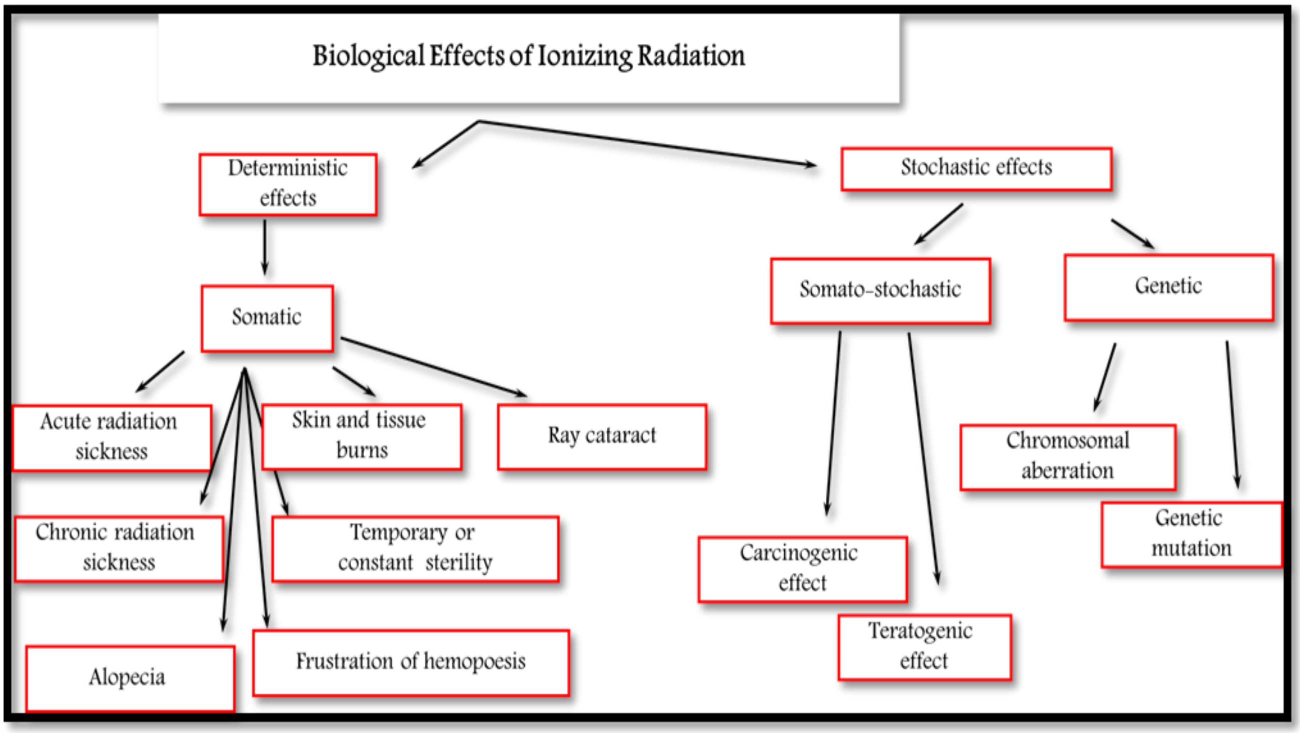
$OH\bullet + OH\bullet$ -------> H_2O_2

Hydrogen peroxide is a cell poison that may contribute to biological damage. 75% of radiation-caused DNA damage is due to OH free radical.

These free radicals lead to oxidation of DNA by OH radicals, if chemical restoration occurs so no effect, if not permanent damage in DNA lead to biological effects; somatic effects and genetic effects: cancer – sterility.




Biological Effects of Ionizing Radiation
Direct effects
Indirect effects
Primary damage
Repair
Cell death
Modified cell
Damage to organ
Somatic cells
Germ cells
Cancer e.g. Leukemia
Hereditary effects
Death of organism
Stochastic effects
Deterministic effects


Biological Effects of Ionizing Radiation
Deterministic effects
Stochastic effects
Somatic
Somato-stochastic
Genetic
Acute radiation sickness
Skin and tissue burns
Ray cataract
Chromosomal aberration
Chronic radiation sickness
Temporary or constant sterility
Genetic mutation
Carcinogenic effect
Alopecia
Frustration of hemopoesis
Teratogenic effect

What are the stochastic and deterministic effects of radiation??

Comparison of Stochastic and Deterministic Effects of Radiation:

	Stochastic Effects	Deterministic Effects
Caused by	Sublethal DNA damage	Cell killing
Threshold dose.	No. There is no minimum threshold dose. Effect can be caused by any dose of radiation.	Yes. Effect occurs only when the threshold dose is exceeded.
Severity of clinical effects and dose.	Severity of clinical effects is independent of dose; all-or-none response. An individual either manifests effect or does not.	Severity of clinical effects is proportional to dose; the higher the dose, the more severe the effect.
Relationship between dose and effect.	Frequency of effect proportional to dose; the higher the dose, the higher the risk of manifesting the effect.	Probability of effect independent of dose; most individuals manifest effect when threshold dose is exceeded.
Caused by doses used in diagnostic radiology.	Yes.	No.
Examples:	Radiation-induced cancer.	Osteoradionecrosis.
	Heritable effects.	Radiation-induced cataract.
	Radiation-induced skin cancer.	Radiation-induced skin burns formation.

Fig. 2: ionizing radiation symbol

Radio sensitivity of tissues and organs:

Body tissues differ in their susceptibility to ionizing radiation. Cells are most sensitive to radiation when they are immature, undifferentiated, and rapidly dividing. As cells mature and become specialized they are less sensitive to radiation. Cumulative effects of X-radiation exposure (radiation injury) lead to health problems.

The following tissue and organs are listed in order to their susceptibility to x-ray:

1. **High radio sensitivity:** lymphoid organs, Blood forming tissues (bone marrow), intestines, stem cells, lymphocyte and reproductive cells.
2. **Intermediate radio sensitivity:** Young or growing bone, Growing cartilage, glandular tissue, salivary glands, kidney, liver, lungs and epithelium of alimentary canal.
3. **Low radio sensitivity:** Skin, muscle and optic lens.
4. **The least effect** seen in nerve tissue and adult bone.

Short term effects of radiation on tissue seen in the first days or weeks after exposure while long term effects seen months and years after exposure.

The response of cells, tissues and organs to irradiation depends on exposure conditions and the cell environment, this modifying factors include

1. **Dose:** The severity of deterministic damage seen in irradiated tissues or organs depends on the amount of radiation received. All individuals receiving doses above the threshold level show damage in proportion to the dose.
2. **Dose Rate:** The term dose rate indicates the rate of exposure. For example, a total dose of 5 Gy may be given at a high dose rate (5 Gy/min) or a low dose rate (5 mGy/min). Exposure of biologic systems to a given dose at a high dose rate causes more damage than exposure to the same total dose given at a lower dose rate.
3. **Oxygen:** The radio-resistance of many biologic systems increases by a factor of 2 or 3 when irradiation is conducted with reduced oxygen (hypoxia). The greater cell damage sustained in the presence of oxygen is related to the increased amounts of hydrogen peroxide and hydroperoxyl free radicals formed (Both peroxyl radicals and hydrogen peroxide are oxidizing agents that can significantly alter biologic molecules and cause cell destruction. They are considered to be major toxins produced in the tissues by ionizing radiation).

ALARA principle (The law of radiation protection) As Low As Reasonably Achievable: Radiographs should only be taken at the minimum dosage with reasonable information, so the benefit from radiograph should be weighed against the radiation dose and then decide to take radiograph or not.

Latent period: The time that elapses between exposure to ionizing radiation and the appearance of observable clinical sign is termed the **Latent period** (a period of time interposed between exposure and clinical symptoms) and such period varies with the dose. So the more is sever dose the shorter is the latent period. Sometimes the latent period is as long as 25 years for some minimum doses.

Protection of patients from X-ray:

The dentist is responsible for all aspects of safe radiation exposure in the dental office.

This done by several ways:

Using faster (film speed) because the faster the film the less is the amount of radiation required to produce a radiographic image so it need less exposure time.

Collimation: this done by collimating device to prevent the unnecessary beam divergence, especially rectangular collimator.

Filtration: in order to absorb the long wave length X-ray photons (soft radiation) which have no diagnostic value.

Exposure and developing techniques: in order to prevent exposure of patient to much more radiation, we should know the exposure time for each segment of the jaw. So for anterior teeth the exposure time is 0.36 seconds for premolars is 0.40 seconds while for molars is 0.50 seconds if higher Kv. technique is used, it’s possible to use a constant exposure time for whole dentition.

* exposure time required for child and old people may have be decreased as much as 50% while exposure time required for dense and thick objects may have to be doubled. Some time when we use excessive long exposure time we have to decrease the developing time to get acceptable quality of radiographic image

Distance and kV: the purpose of using cylinders and cones in the X-ray machine is to [limit the path for X-ray] so X-ray beam hit only the examined area we have

2 cone length (8 and 16 inches) the long cone mean increase tube film distance and when use higher kV With this cone we reduce the radiation dose absorbed by skin surface.

Film placement and angulations: this is important to prevent retakes and get a radiograph with best diagnostic information.

Lined cylinder: sometime lining the open cylinder by sheet of lead foil with 0.2 –

0.3 mm thickness result in elimination of scattered radiation.

Protective apron and thyroid collar: sheet of lead used to cover chest and reproductive areas of the patient so must be used in pregnant and young adult also thyroid collar used for protection of thyroid gland. (Lead apron used by operator also for protection).

Using intensifying screen in extraoral film to reduce radiation dose to patients.

Using digital radiography that provide dose reduction of up to 90 percent compared to E-speed film.

Protection of operator:

Operator received secondary radiation and generally workers in X-ray clinic should not receive more than 5 rem of whole body radiation each year. It is not acceptable (never permitted) for the radiographer to hold the film in place and to hold the tubehead during exposure. The radiographer should stand behind a lead barrier during exposure whenever possible.

Operator received 3 types of radiation:

1. Scattered radiation from the patient.
2. Primary beam if he stands in its path.
3. Leakage radiation from the tube head.

To minimize the exposure of operator:

1. Position: operator must stand behind the patient because the head of the patient will absorb scattered radiation operator must stand with an angle of 90-135° to the radiation beam because in this area we have less scattered radiation.

2. Barrier: it interpose between the source of radiation and the operator it is the most effective method of providing safety to the operator and barrier is made of lead or steel or concert or barium plaster of 1/16 inch.

3. Distance: the intensity of radiation inversely proportional to the distance (inverse square law) so it's recommended for him to stand 6 feet away from the source of X-ray radiation.

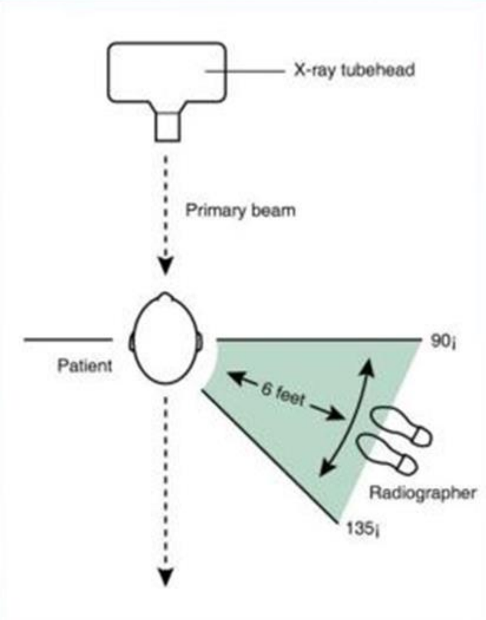


Fig 3: * position and distance rule: if no barrier is available, the operator should stand at least 6 feet from the patient, at an angle of 90 to 135 degrees to the central ray of the X-ray beam when the exposure is made.

Film badges:

Film badge is a blue plastic frame containing a variety of metal filters and a small radiographic film which exposed to X-ray. it provide a permanent record of the dose received by operators (radiographers and dentists) and it used for 1-3 months before being processed for monitoring of dose received by operator.

Each radiographer should have his or her own film badge. The film badge should be worn at waist level, should not be stored in the X-ray area when not being worn, and should not be worn when the radiographer is undergoing X-ray exposure.

Fig 4: film badge.

Typical Effective Dose From Radiographic Examinations

Examination	Median Effective Dose	Equivalent Background Exposure[a]
Intraoral[b]		
Rectangular collimation		
Posterior bite-wings: PSP or F-speed film	5 µSv	0.6 day
Full-mouth: PSP or F-speed film	40 µSv	5 days
Full-mouth: CCD sensor (estimated)	20 µSv	2.5 days
Round collimation		
Full-mouth: D-speed film	400 µSv	48 days
Full-mouth: PSP or F-speed film	200 µSv	24 days
Full-mouth: CCD sensor (estimated)	100 µSv	12 days
Extraoral		
Panoramic[b]	20 µSv	2.5 days
Cephalometric[b]	5 µSv	0.6 day
Chest[c]	100 µSv	12 days
Cone beam CT[b]		
Small field of view (<6 cm)	50 µSv	6 days
Medium field of view (dentoalveolar, full arch)	100 µSv	12 days
Large field of view (craniofacial)	120 µSv	15 days
Multidetector CT		
Maxillofacial[b]	650 µSv	2 months
Head[c]	2 mSv	8 months
Chest[c]	7 mSv	2 years
Abdomen and pelvis, with and without contrast[c]	20 mSv	7 years

Lecture 19 Infection Control

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

Dental personnel and patients are at increased risk for acquiring tuberculosis, HIV, herpes viruses, upper respiratory infections, and hepatitis strains A through E.

The primary goal of infection control procedures is to prevent cross-contamination and disease transmission from **patient to staff, from staff to patient, and from patient to patient.**

The potential for cross-contamination in dental radiography is great. Cross-contamination can be happened in different way:

1. An operator's hands become contaminated by contact with a patient's mouth and saliva-contaminated films and film holders. Then the operator also must adjust the x-ray tube head and x-ray machine control panel settings to make the exposure.
2. An operator handles digital sensors or opens film packets to process the films in the darkroom.

The dentist is responsible for minimizing or eliminating cross-contamination procedures. And responsible also to educates other members of the practice.

Key Steps in Radiographic Infection Control:

1. Apply standard precautions.
2. Wear personal protective equipment during all radiographic procedures.
3. Disinfect and cover x-ray machine, working surfaces, chair, and apron.
4. Sterilize nondisposable instruments.
5. Use barrier-protected film (sensor).
6. Prevent contamination of processing equipment.

1. Standard Precautions:

Standard precautions (also called universal precautions) are infection control practices designed to protect workers from exposure to diseases spread by blood and certain body fluids, including saliva.

Under standard precautions, all human blood and saliva are treated as infectious for human immunodeficiency virus (HIV) and hepatitis B virus.

2. Wear Personal Protective Equipment During All Radiographic Procedures:

Personal protective equipment is an effective means to shield the operator from exposure to potentially infectious material, including blood and saliva.

A. Hand hygiene is most important to prevent spread of infections. After the patient is seated, the hand should be washed using plain or antimicrobial soap. Alcohol-based hand rubs are also effective.
B. Disposable gloves should be worn in sight of the patient. The operator should always wear gloves when making radiographs or handling contaminated film or when removing barrier protections from surfaces and radiographic equipment.
C. Operators should wear protective clothing (e.g., disposable gown or laboratory coat) that covers clothes and skin to protect against potential contamination.

3. Disinfect and Cover Clinical Contact Surfaces:

Clinical contact surfaces are surfaces that might be touched by gloved hands or instruments that go into the mouth. These include the x-ray machine and control panel, chair-side computer, beam alignment device, dental chair and headrest, protective apron, thyroid collar, and surfaces on which the receptor is placed.

These are noncritical items. The goal of preventing cross-contamination is by disinfecting all such surfaces and by using barriers to isolate equipment from direct contact.

Barriers made of clear plastic wrap should cover working surfaces that were previously cleaned and disinfected, and should be changed when damaged and routinely after each patient.

Intermediate- and low level activity disinfectants recommended for use on clinical contact surfaces.

Fig. 1: The exposure control console should be covered with a clean barrier and changed after every patient.

Fig. 2: A new plastic bag is placed over the chair and headrest for each patient.

Fig. 3: A plastic bag is slipped over the x-ray tube head with a large rubber band just proximal to the swivel or tie ends, as shown here. The plastic is pulled tight over the PID and secured with a light rubber band slipped over the PID and placed next to the head.

Fig. 4: Hanging apron is sprayed with disinfectant and then dried and covered with a garment bag.

Panoramic chin rest and patient handgrips should be cleaned with a low-level disinfectant. Disposable biteblocks may be used. The head-positioning guides, control panel, and exposure switch should be carefully wiped with a paper towel that is well moistened with disinfectant.

Cephalostat ear posts, ear post brackets, and forehead support or nasion pointer should be cleaned and disinfected. These may then also be covered with a plastic barrier.

After patient exposures are completed, the barriers should be removed, and contaminated working surfaces (including surfaces in the darkroom) and the apron should be sprayed with disinfectant and wiped as described previously. The barriers should be replaced in preparation for the next patient.

4. Sterilize Non disposable Instruments:

Film -holding instruments are classified as semicritical items-instruments that are not used to penetrate soft tissue or bone but do come in contact with the oral mucous membrane. It can be sterilized by steam under pressure (autoclave).

5. Use Barriers with Digital Sensors:

Digital Sensors cannot be sterilized by heat, so a plastic barrier used to protect them from contamination when placed in the patient's mouth.

6. Prevent Contamination of Processing Equipment:

After all film exposures are made, the operator should remove his or her gloves and take the container of contaminated films to the darkroom.

The goal in the darkroom is to break the infection chain so that only clean films are placed into processing solutions. Two towels should be placed on the darkroom working surface. The container of contaminated films should be placed on one of these towels. After the exposed film is removed from its packet, it should be placed on the second towel. The film packaging is discarded on the first towel with the container.

Fig. 5: Film-holding instrument with barrier wrapping to protect sensor and cord from saliva.

Fig. 6: Dental film with a plastic barrier to protect film from contact with saliva. During opening, the plastic is removed and the clean film is allowed to drop into a container.

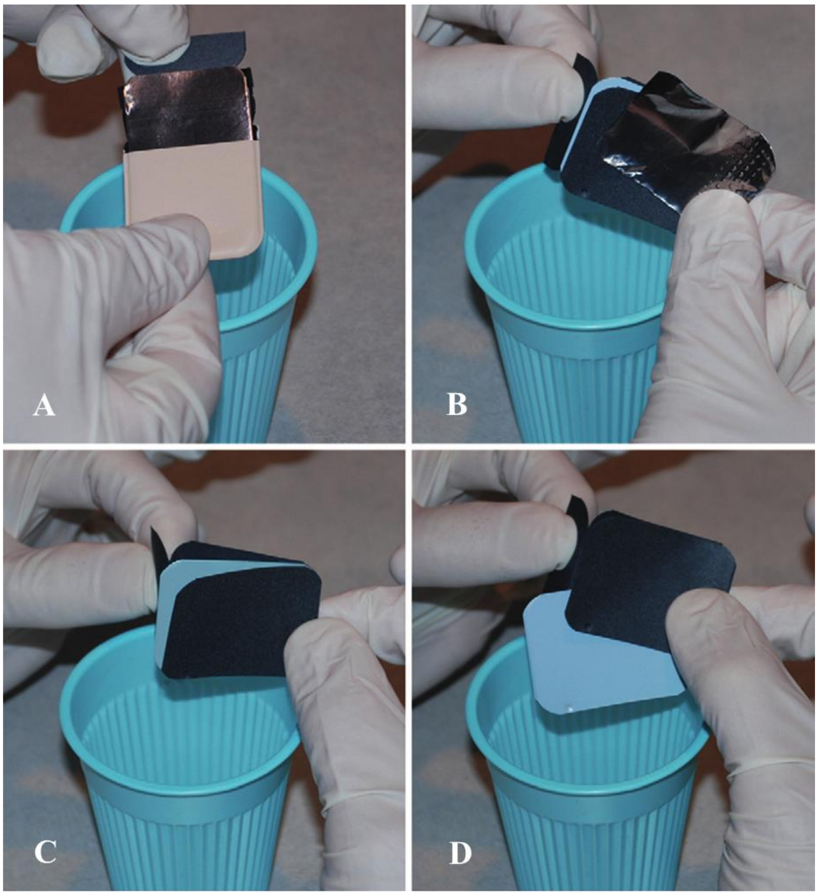


Fig. 7: Method for removing films from packet without touching them with contaminated gloves. **A,** Packet tab is opened, and lead foil and black interleaf paper are slid from wrapping. **B,** Foil is rotated away from black paper and discarded. **C,** Paper wrapping is opened. **D,** Film is allowed to fall into a clean cup.

Lecture 20

Cysts of the jaw

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

A cyst is a pathologic cavity filled with fluid, lined by epithelium, and surrounded by a definite connective tissue wall. Cysts occur more often in the jaws than in any other bone because most cysts originate from the numerous rests of odontogenic epithelium that remain after tooth formation. The cystic fluid either is secreted by the cells lining the cavity or is derived from the surrounding tissue fluid. The cyst has a spherical or round shape based on accumulation of fluid within the cavity. Without resistance, for example, within an air space such as the maxillary sinus, the cyst grows in a concentric fashion resulting in a spherical shape, but when growing within bone, its shape is influenced by the resistance of adjacent hard tissue. So when a cyst reaching a thick segment of cortical bone may develop a flat side.

The most common clinical features of jaw cysts:

1. The most common clinical features are swelling and lack of pain (unless the cyst becomes secondarily infected or is related to a nonvital tooth).
2. Cysts are often associated with unerupted teeth, especially third molars.

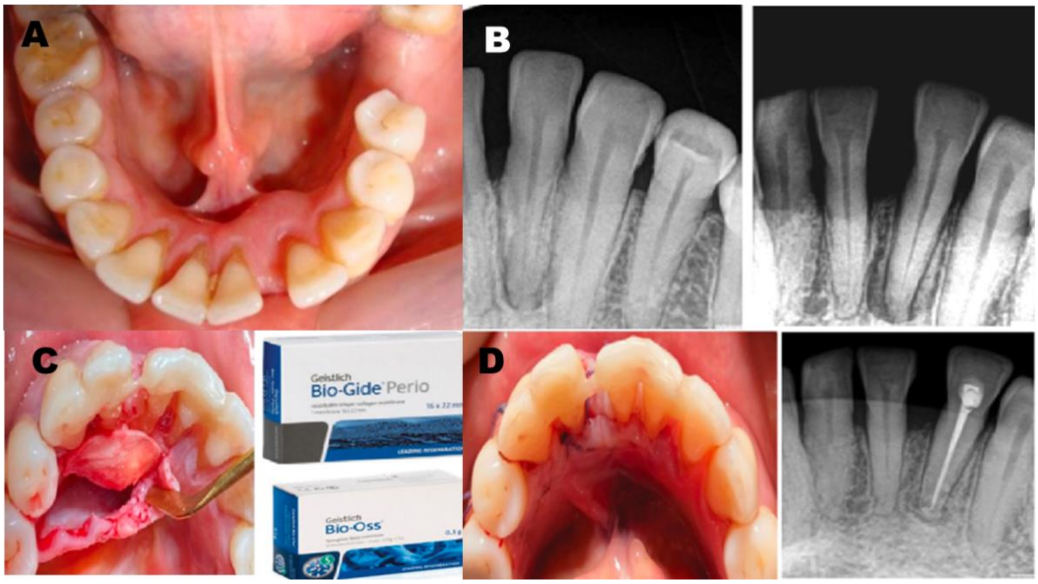


Figure 1. **A**, Clinical photograph showing the location of cystic lesion of the mandible. **B**, Periapical radiograph showing circumscribed radiolucent area confined to #32. **C**, Intraoral photograph showing cyst enucleated and cavity to be filled with bone

augmentation and membrane. **D**, Post-operative photograph and radiograph showing resolution of the lesion.

Odontogenic cysts (ODC):

Inflammatory ODC:

1. Radicular (dental) cyst.
2. Residual radicular cyst.

Developmental ODC:

1. Dentigerous cyst.
2. Odontogenic Keratocyst (OKCs).
3. Lateral periodontal cyst.
4. Glandular odontogenic cyst.
5. Adenomatoid odontogenic cyst.

Non odontogenic cyst:

1. Nasopalatine duct cyst (incisive canal cyst).
2. Traumatic bone cyst.

Inflamatory ODC:

1. **Radicular Cyst:**

Clinical features:

1. Radicular cyst is commonly seen in second to fifth decades of life.
2. Maxillary anterior region is most commonly affected as it is prone to more frequent trauma.
3. It is seen at apex of non-vital teeth.
4. It is asymptomatic unless it is secondarily infected.
5. Large cyst results in the swelling of the jaw and mobility of adjacent teeth.

Radiographic features:

1) Radicular cyst appears as radiolucent area at the apex of tooth with well-demarcated sclerotic margins unless secondarily infected.
2) The size of radiolucency is vary from small to large in diameter.
3) In case of secondary infection, margin of cyst can be destroyed.

4) Anatomical structures, such as maxillary antrum, nasal fossa and mandibular canal are frequently involved by teeth.

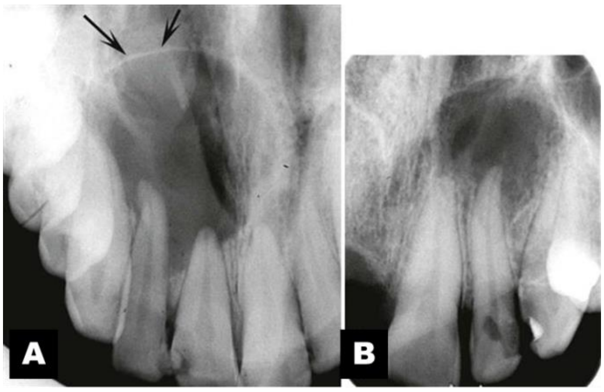


Figure 2. **A**, Note the epicenter is apical to the lateral incisor and the presence of a peripheral cortex (arrows). **B**, Note the lack of a well-defined peripheral cortex because this cyst was secondarily infected. Also note the root canal of the lateral incisor is abnormally wide and it is visible at the root apex.

Differential diagnosis:

It includes periapical granuloma (size of granuloma is less than 1.5 cm), periapical scar (history), traumatic bone cyst (not associated with teeth) and periapical cemental dysplasia (tooth is vital).

2. Residual Cyst:

Residual cysts most commonly are the retained periapical cysts from teeth that have been removed. They could also develop in a periapical granuloma that is possibly left after an extraction.

Clinical features:

Residual cyst can be found in any of the tooth-bearing area of the maxilla or mandible. Size may range from a few millimetres to several centimetres. Clinically, these cysts are usually found on routine radiographic examination of patients. Usually they are painless unless secondarily infected. They do not show expansion of cortical plates.

Radiographic features:

There is well-defined unilocular radiolucency in the periapical area of extracted tooth. If the cyst is secondarily infected, the hyperostotic border may be absent. Cyst may displace mandibular canal and adjacent teeth.

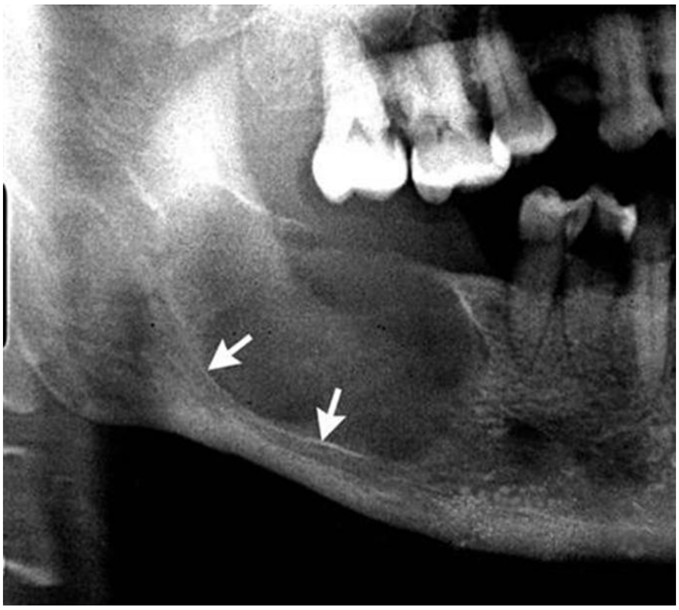


Figure 3. The epicenter of this infected residual cyst is above the inferior alveolar nerve canal and has displaced the canal in an inferior direction (arrows). The cortical boundary is not continuous around the whole cyst.

Differential diagnosis:

Differential diagnosis includes:

Keratocyst (mandibular posterior area), traumatic cyst (not associated with teeth).

Developmental odontogenic cysts;

1. Dentigerous Cyst:

Clinical features:

Dentigerous cysts develop around the crown of an impacted or embedded unerupted or supernumerary tooth or in association with odontomas. They are frequently associated with mandibular third molar followed by maxillary canines, maxillary third molar and mandibular second molar.

Radiographic features:

Dentigerous cyst appears as well-defined radiolucency with sclerotic borders seen at the cementoenamel (CE) junction of unerupted tooth. The sclerotic border is absent in case of infected cyst. The teeth are usually greatly displaced from their original position and are found lying on floor of cavity. Radiographically, dentigerous cyst can be central (cyst enclosing the crown of tooth symmetrically), lateral (cyst arising laterally from one side of crown) and circumferential (when whole tooth lies within the cystic cavity).

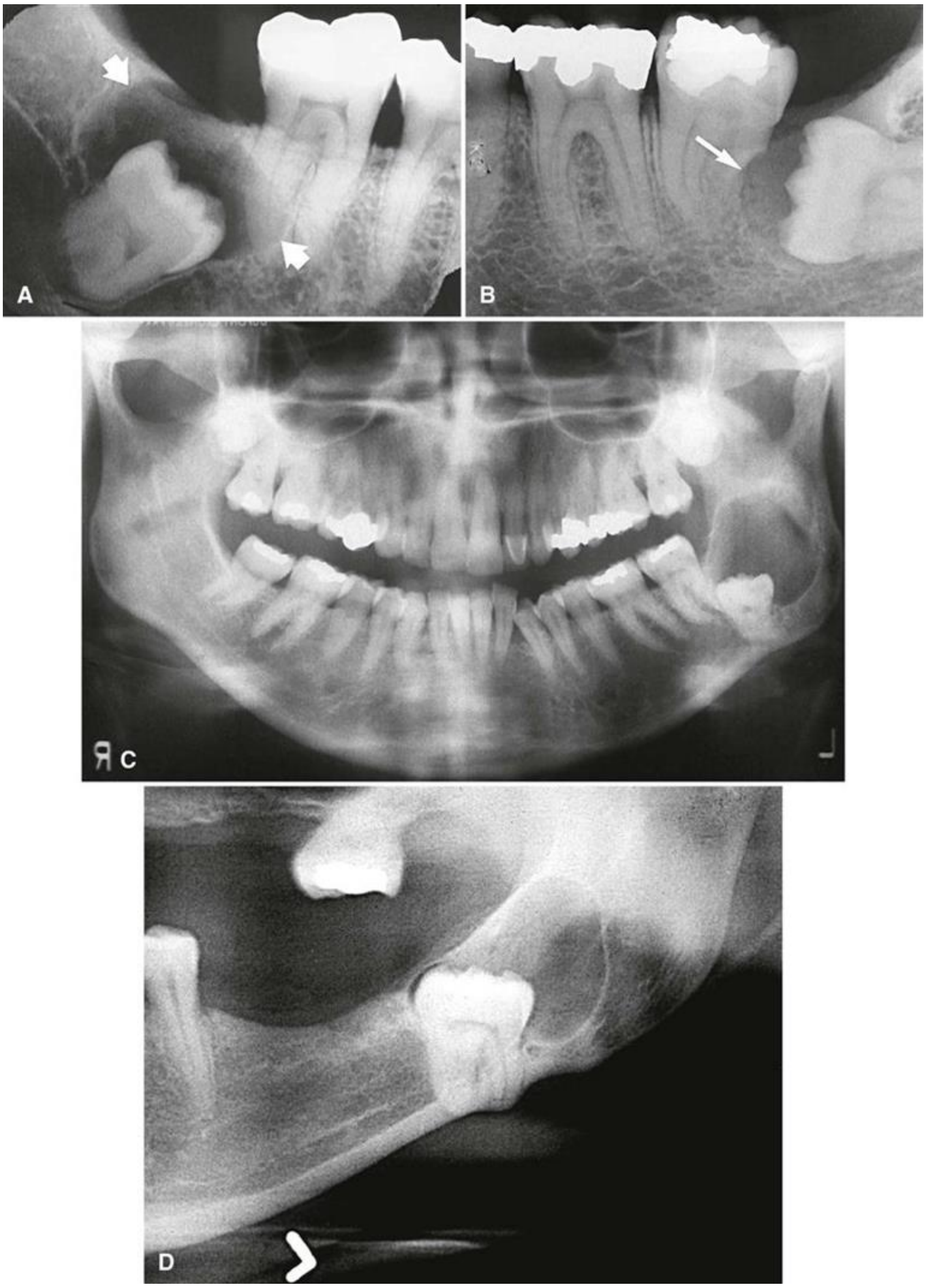


Figure 4. Dentigerous cysts. **A**, Cyst that surrounds the crown of a third molar (arrows). **B**, The cyst has caused resorption of the distal root of the second molar (arrow). **C**, Cyst that involves the ramus of the mandible. **D**, Dentigerous cyst that is expanding distally from the involved third molar.

Differential diagnosis:

Differential diagnosis includes:

Adenomatoid odontogenic cyst (AOT; maxillary anterior region).

Calcifying epithelial odontogenic tumour (evidence of calcification).

Radicular cyst (carious teeth).

2. Odontogenic Keratocyst (OKCs)

Clinical features:

- OKCs can develop in association with an unerupted tooth or as solitary entities in bone.
- OKCs usually cause no symptoms, although mild swelling may occur.
- It is most commonly located in molar ramus area of the mandible.

Radiographic features:

It has radiolucency radiographic appearance. Radiographically, it appears as round or oval unilocular or multilocular radiolucency; however, as compared to other cysts, it is less radiolucent due to the presence of keratin in it. The well defined and sclerotic borders may be visible around the radiolucency if the lesion is not infected

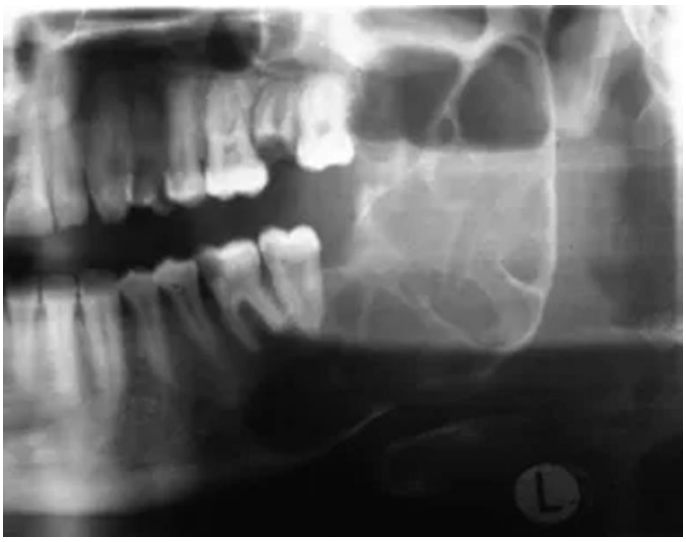


Figure 5. OKCs are characterized by well-defined unilocular or multilocular radiolucent areas with a clear peripheral radiopaque rim.

Differential diagnosis:

Includes:

Radicular cyst (nonvital teeth).

Dentigerous cyst (does not expand anteroposteriorly).

Residual cyst (history).

Traumatic bone cyst (no expansion).

3. Lateral periodontal cyst:

Clinical features:

It is usually asymptomatic and often discovered during normal radiographic examination. It is usually seen in fifth or sixth decade of life with slight male predilection. Eighty percent of the cases are reported in mandibular premolar–canine and lateral incisor areas.

Radiographic features:

As the name suggests this cyst appears as a radiolucent area situated laterally at middle third of the affected tooth between the apex and the alveolar crest of tooth. It is oval or round in shape with the size as small as less than 1 cm in diameter. The associated tooth is vital. The borders are sclerotic, well-defined surrounding the radiolucency, which is often missing in case of infected cyst.

Figure 6. A large tear-drop radiolucency located between the roots of the left canine and first premolar.

Differential diagnosis:

Differential diagnosis includes dentigerous cyst (associated with unerupted tooth), and radicular cyst (teeth are non-vital).

4. Glandular odontogenic cyst:

Clinical features:

It is relatively rare cystic lesion that occurs over a wide age range from the second to ninth decades, with a peak frequency in the sixth decade, more frequently in males than in females with a predilection for anterior mandible. The lesion shows slow, progressive, locally destructive, painless growth.

Radiographic features: The lesion appears as well-defined multilocular, occasionally unilocular radiolucency with sclerotic or scalloped borders. Root resorption of associated teeth and tooth displacement is noted.

Figure 7. The lesion appears as well-defined multilocular, occasionally unilocular radiolucency with sclerotic or scalloped borders. Root resorption of associated teeth and tooth displacement is noted.

Differential diagnosis:

All the lesions which are considered in the differential diagnosis of lateral periodontal cyst should be considered.

5. Adenomatoid odontogenic cyst:

Clinical features:

Adenomatoid odontogenic cyst is most commonly seen in individuals between 10 and 40 years of age with female predilection. The most common site of occurrence in the jaw is the anterior portion of maxilla than in the mandibular region. It may produce obvious swelling clinically, which is usually asymptomatic. It is painless.

Radiographic Features:

It appears commonly (75% of the tumor) as a unilocular radiolucency with smooth corticated border. Sometimes, it may be having sclerotic border. Generally, it presents as radiolucency adjacent to or involving crown of associated tooth. Occasionally, area of multilocular radiolucency with scalloped border may be seen. Sometimes, radio-opaque foci may be identified within the radiolucent region. Adjacent tooth displacement and divergence of associated root may be reported with slight erosion of underlying alveolar bone.

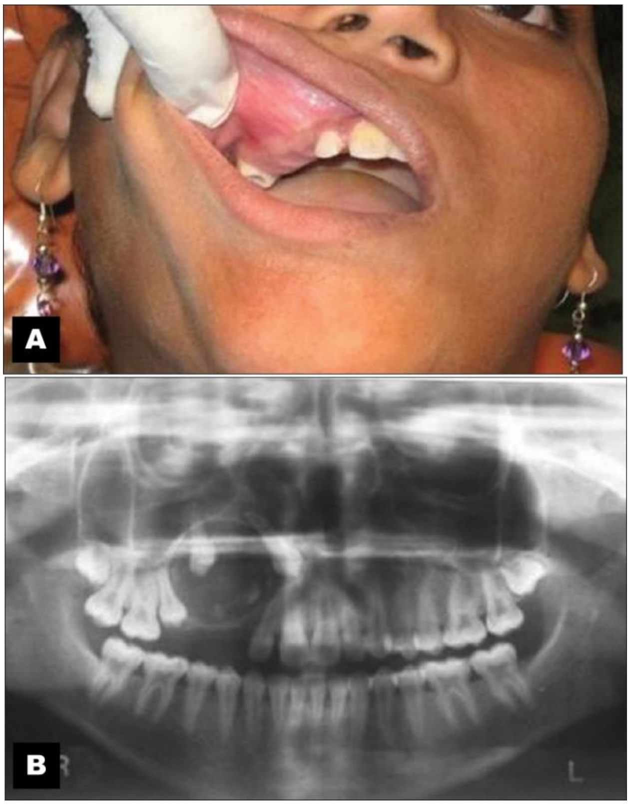


Figure 8. **A**, Clinically there is diffused swelling involving right anterior maxilla with moderate obliteration of nasolabial fold. **B**, OPG showing circumscribed radiolucent lesion with calcifications and impacted teeth.

Differential diagnosis:

It includes:

Odontogenic keratocyst tumour (more in posterior region).

Calcifying odontogenic cyst (common in old age).

Dentigerous cyst (posterior region).

Non Odontogenic Cyst:

1. Nasopalatine duct cyst:

Nasopalatine cyst is also called incisive canal cyst.

Clinical features:

Nasopalatine cyst is seen in fourth and fifth decades with male predilection. There is swelling in the anterior palate. Many lesions are asymptomatic and discovered only on routine radiographic examination.

Radiographic Features:

It appears as an area of midline radiolucency situated between roots of upper central incisor in nasopalatine canal. It can be round, oval or irregular in shape with curved margin. If the superimposition of anterior nasal spine occurs, cyst appears as heart shaped. It can cause resorption of root and displacement of teeth.

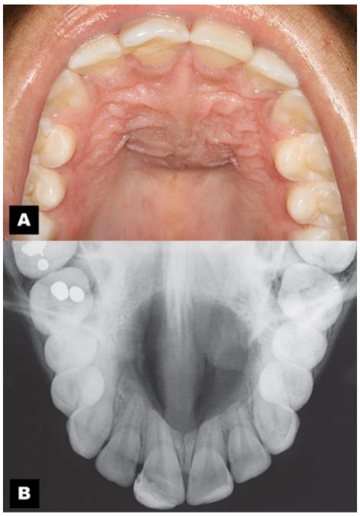


Figure 9. A, Intraoral examination showing swelling in the hard palate. B, Maxillary occlusal radiography showing well-defined unilocular radiolucent image in maxillary anterior region.

Differential diagnosis:

It includes incisive fossa (radiolucency less than 6 mm), radicular cyst (pulp is non-vital) and median palatine cyst (radiolucent lesion is behind the incisive canal).

2. Traumatic bone cyst:

Clinical features:

It is most frequently reported in older age group with male predominance. Mandible is affected more than maxilla in the jaws. It is seen in premolar-molar area. It presents as painless swelling. Teeth in the affected area are vital.

Radiographic features:

Area of radiolucency is situated in canine, bicuspid and molar regions of mandible. The radiolucent lesion is well demarcated from the adjacent bone. Margin is well defined or ill-defined with thin radio-opaque border. In some cases, as lesion extends between roots, the border becomes irregular and scalloped.

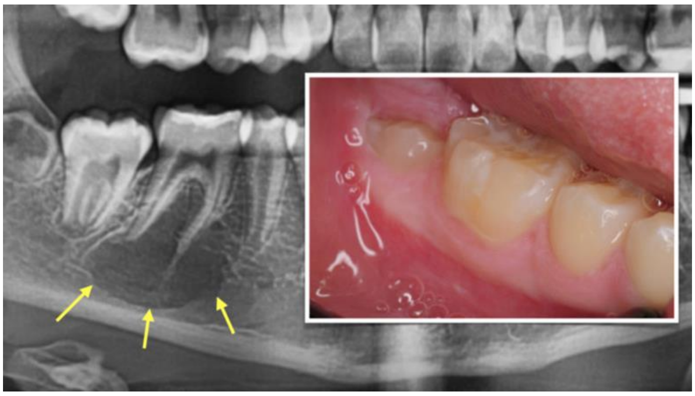


Figure 10. A Traumatic (simple) bone cyst of a ten year old.

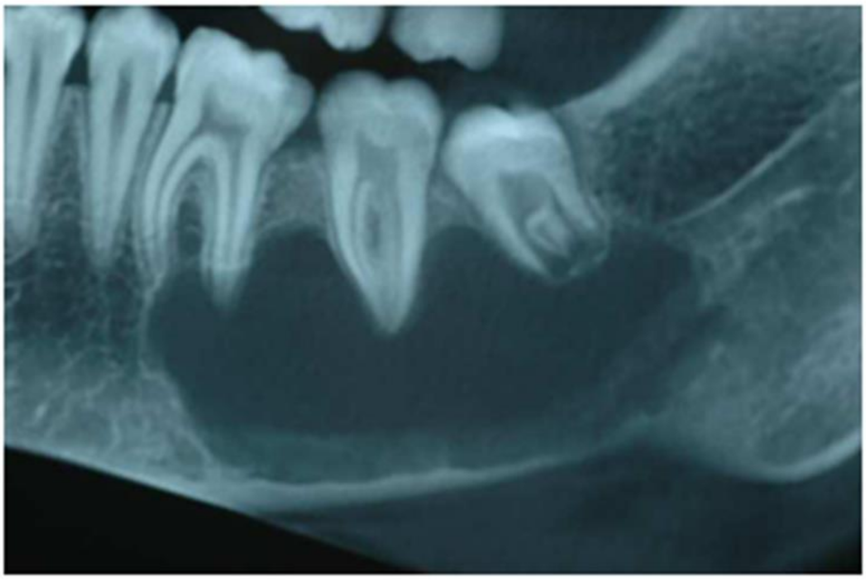


Figure 11. Panoramic radiograph revealed a unilocular radiolucency with clear margins extending within the molar area of the left mandible (Figure 1). The lesion was scalloping between the aforementioned teeth without any signs of root resorption, affecting the route of inferior alveolar nerve. The differential diagnosis included keratocystic odontogenic tumor, ameloblastoma and traumatic bone cyst.

Differential diagnosis:

It includes: radicular cyst, keratocyst (it expands along the bone).

Lecture 21 Dental and Craniofacial Anomalies

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

There are many developmental and acquired anomalies that can affect the teeth and facial skeleton so they classified into: Anomalies of the teeth and craniofacial anomalies. The diagnosis of them based on both the clinical and radiographic findings.

Table 1: Roadmap for this lecture.

Anomalies of the teeth		
Developmental teeth anomalies:		
Abnormalities in number:		
	1. Missing teeth (Hypodontia)	
	2. Hyperdontia	
Abnormalities in structure:		
	A. Genetic defect:	
		1. Amelogenesis imperfecta
		2. Dentinogenesis imperfecta
		3. Regional odontodysplasia (ghost teeth)
	B. Acquired defects:	
		1. Turner hypoplasia
		2. Congenital syphilis
Abnormalities in size:		
	1. Macrodontia (large teeth)	
	2. Microdontia (small teeth)	
Abnormalities in shape (morphology):		
	1. Fusion	
	2. Gemination	
	3. Concrescence	
	4. Dilaceration	
	5. Dens invaginatus and Dens evaginatus	
	6. Enamel pearl	
	7. Taurodontism	
	8. Talon cusp	
Abnormalities in eruption of teeth:		
	1. Transposition	
	2. Premature eruption (natal and neonatal teeth)	

	3. Delayed eruption (impacted teeth)	
Acquired teeth abnormalities:		
1. Attrition		
2. Abrasion		
3. Erosion		
4. Resorption		
5. Secondary dentin		
6. Pulp stones		
7. Hypercementosis		
Craniofacial anomalies:		
Cleft lip and palate is one of these anomalies.		

Anomalies of the teeth:

Developmental teeth anomalies:

These include abnormalities of the teeth in number, structure, size, shape (morphology), and eruption.

Abnormalities in number:

1. **Missing teeth (hypodontia):**

It's a condition at which the patient has missing one or few teeth as a result of their failure to develop. When numerous teeth are absent the condition called (oligodontia) and the failure of all teeth to develop called (anodontia). It could happen in Ectodermal Dysplasia. Imaging features of missing teeth may be recognized by identifying and counting the teeth present.

Figure 1. Developmental absence of maxillary and mandibular second premolars and maxillary canines. Note the apically positioned deciduous mandibular second molars. This appearance is suggestive of ankylosis of the teeth.

2. **Hyperdontia:**

It's a condition of having supernumerary teeth, or teeth which appear in addition to the regular number of teeth. The most common supernumerary tooth is a **mesiodens**, which is a mal-formed, peg-like tooth that occurs between the maxillary central incisors, **fourth and fifth molars** (paramolar, or distomolar) that form behind the third molars are another kind of supernumerary teeth. It could be associated with Cleidocranial Dysplasia. The imaging features of supernumerary teeth are variable.

They may appear entirely normal in both size and shape or they may be smaller and conical shape.

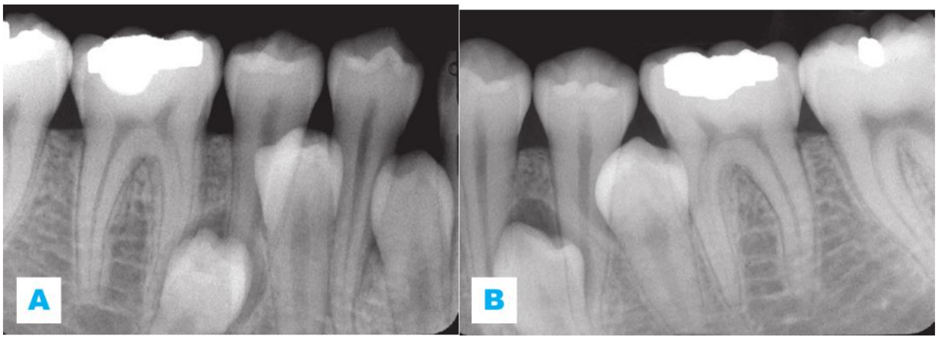


Figure 2. A and B, Periapical images show bilateral supplemental premolar teeth (peridens).

Abnormalities in structure:

The Abnormalities in teeth structures are subdivided into:

Genetic defect:

1. **Amelogenesis imperfecta:**

Genetic disturbances in enamel formation leading to altered morphology of enamel. There is normal dentin and pulp formation. Imaging features shows square-shaped crown, thin enamel and absence of cusps. The affected teeth appear undersized radiographically with thin enamel and abnormal contour.

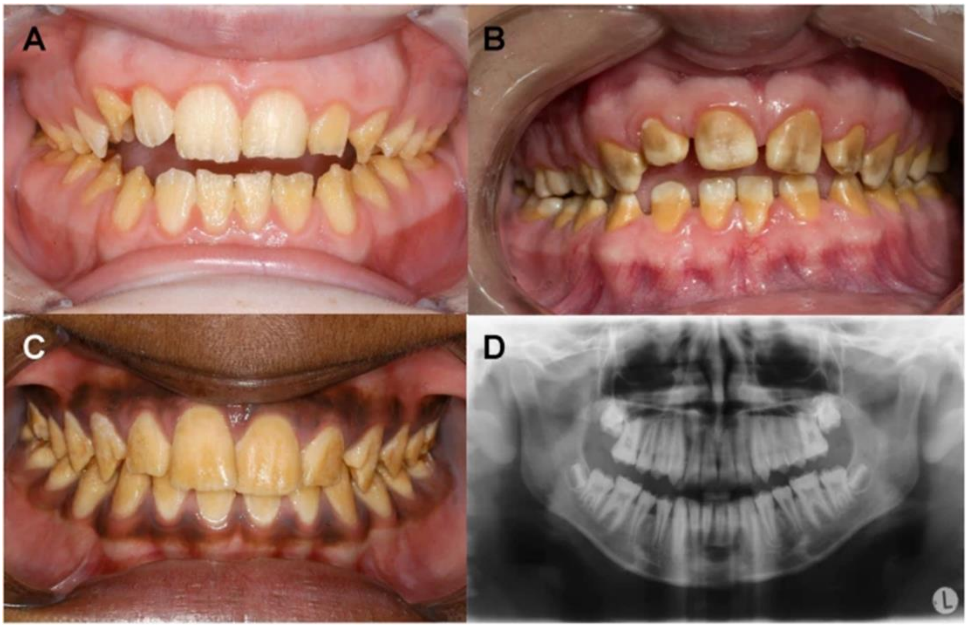


Figure 3. Types of amelogenesis imperfecta in the anterior aspect; hypoplastic type of AI = **A**, hypomaturated type of AI=**B**, hypocalcified type of AI=**C**; orthopantomogram shows hypomaturated-hypoplastic with taurodontism AI = **D**.

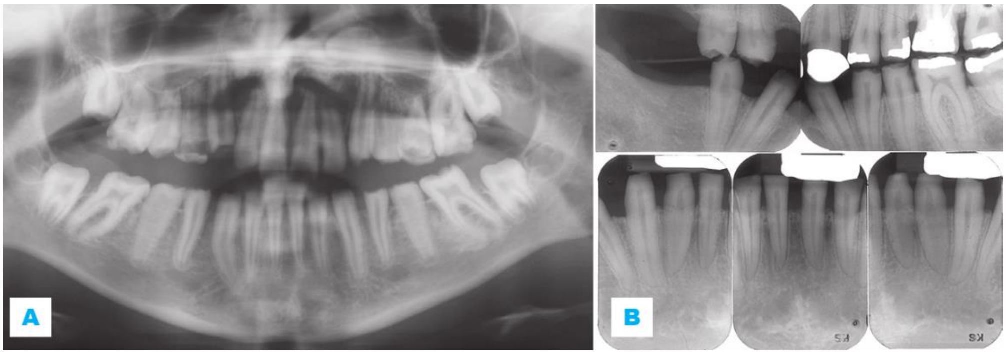


Figure 4. **A**, Cropped panoramic image of hypoplastic amelogenesis imperfecta. Note the absence of interproximal contacts and the "picket fence"-like appearance of the teeth. **B**, Intraoral images of another case of amelogenesis imperfecta. Note the very thin enamel layer.

2. Dentinogenesis imperfecta:

It is a genetic anomaly involving the dentin in both deciduous and permanent dentition. Imaging features show a marked constriction at cervical region of the tooth crown with pulp champer obliteration and short blunt roots. There is another genetically inherited abnormality that affects dentin called Dentin dysplasia.

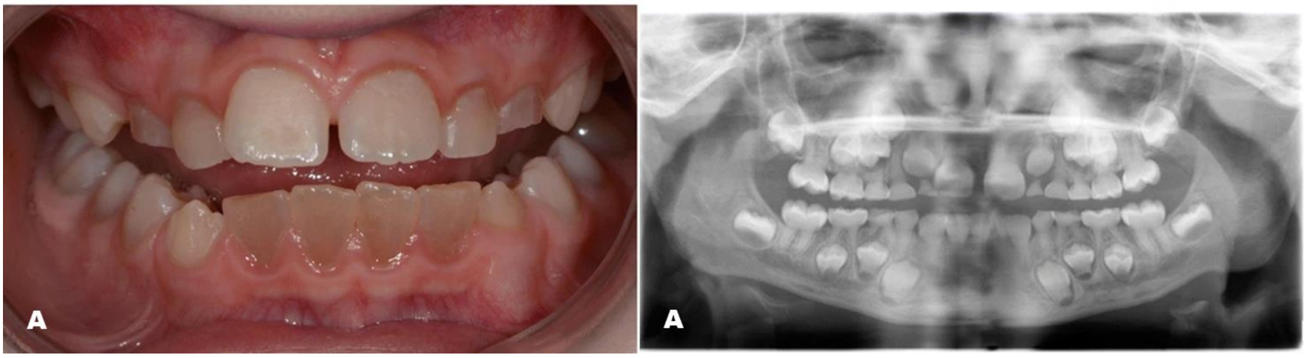


Figure 5. **A**, A 10-year-old boy presenting with dentinogenesis imperfecta (DGI) type II in the mixed dentition. In the permanent dentition, the mandibular incisors are most severely affected. **B**, Radiographic findings of DGI in the same boy at 6 years of age. Marked cervical constriction, varying degree of pulpal obliteration, and short roots are visible

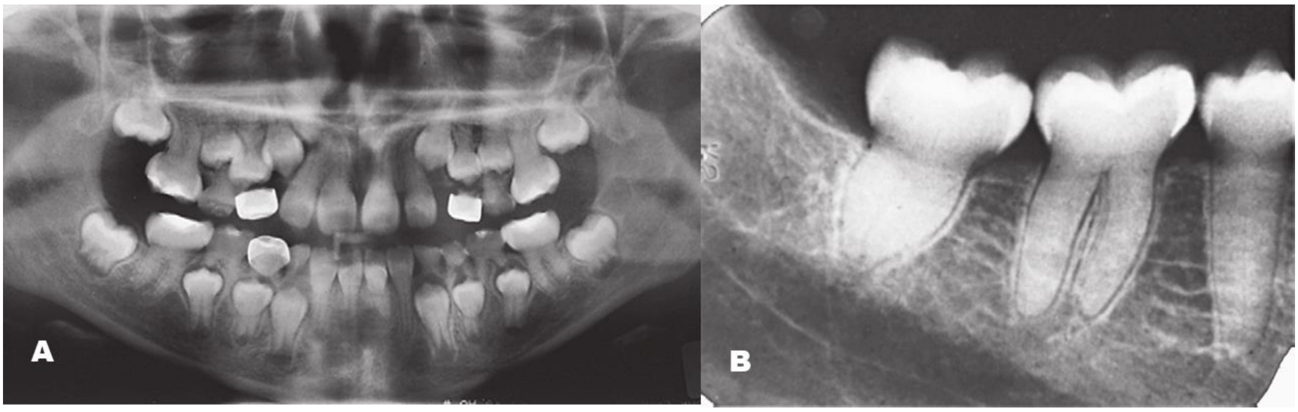


Figure 6. **A**, and **B**, Dentinogenesis imperfecta characteristically shows bulbous crowns, constriction of tooth at the cemen-toenamel junction, short roots, and a reduced size of the pulp chamber and root canals.

3. Regional Odontodysplasia (ghost teeth):

Ghost teeth is a rare condition in which both enamel and dentin are hypoplastic and hypocalcified. Imaging feature described as “ghost-like “appearance. The pulp chambers are large and the root canals are wide with very thin enamel and dentin.

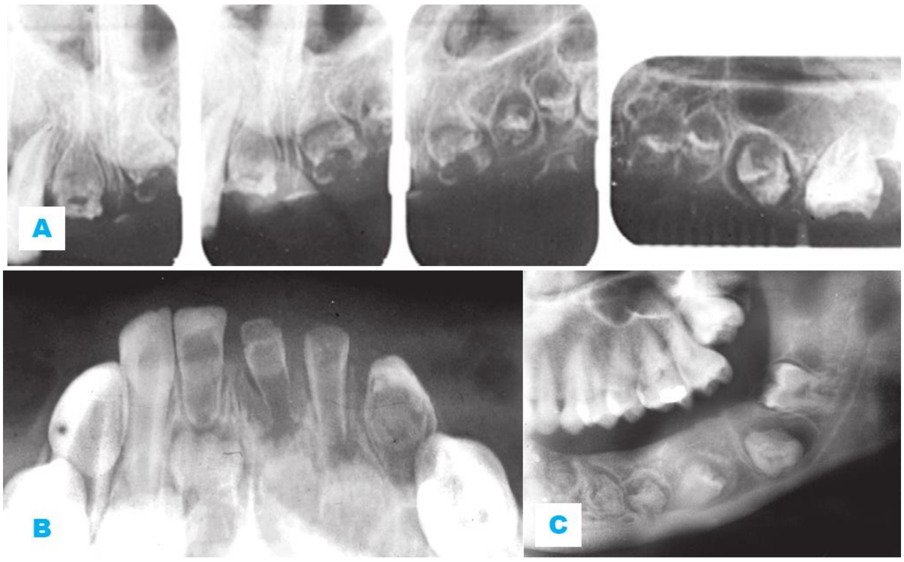


Figure 7. Periapical images reveal poor mineralization of all of the dental hard tissues in regional odontodysplasia. Note in the images how only one portion of the arch is involved. A, Involvement of the maxillary left dentition. B, Involvement of the primary incisors and canines. C, Involvement of the left mandibular premolars and first and second molars. Note the lack of eruption and hypoplasia of enamel and dentin expressed mainly as short roots.

Acquired defects:

1. Turner hypoplasia:

It's a frequent pattern of enamel defects seen in permanent teeth secondary to periapical inflammatory disease of the overlying deciduous tooth. The altered tooth is called (Turner's tooth). Imaging features of the involved region of the crown may appear as an ill-defined radiolucent region.

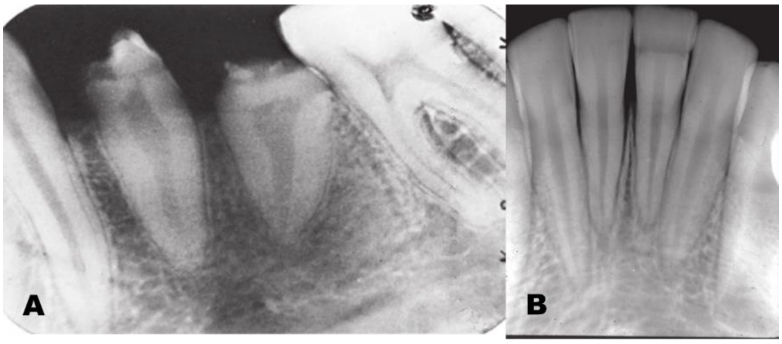


Figure 8. A, Turner's hypoplasia shown as an extensive malformation and hypomineralization of the crowns of both premolars. B, Band of hypoplasia extending across the crown of the mandibular left central incisor.

2. Congenital syphilis:

It's a dental hypoplasia that results from direct infection of the developing tooth by spirochete of syphilis, involves the permanent incisors that called (Hutchinson's teeth) and first molars that called (mulberry molars). Imaging features have a characteristic shapes of the affected incisor and molar crowns.

Figure 9. Congenital syphilis may induce a developmental malformation of the maxillary central incisors referred to as "Hutchinson's incisors." The abnormal morphology is characterized by tapering of the mesial and distal surfaces toward the incisal edge with notching of the incisal edge.

Figure 10. **A to C**: Mulberry molars in the (**A**) Maxillary arch; (**B**) mandibular arch; and (**C**) orthopantomogram.

Abnormalities in size:

1. Macrodontia (large teeth):

It's a condition in which the teeth are abnormally large, rarely affects the entire dentition. Often a single tooth or a group of teeth may be involved. Imaging features reveal the increased size of the teeth. The shape of the tooth is usually normal, but some cases may be distorted. It associated with crowding, malocclusion, or impaction.

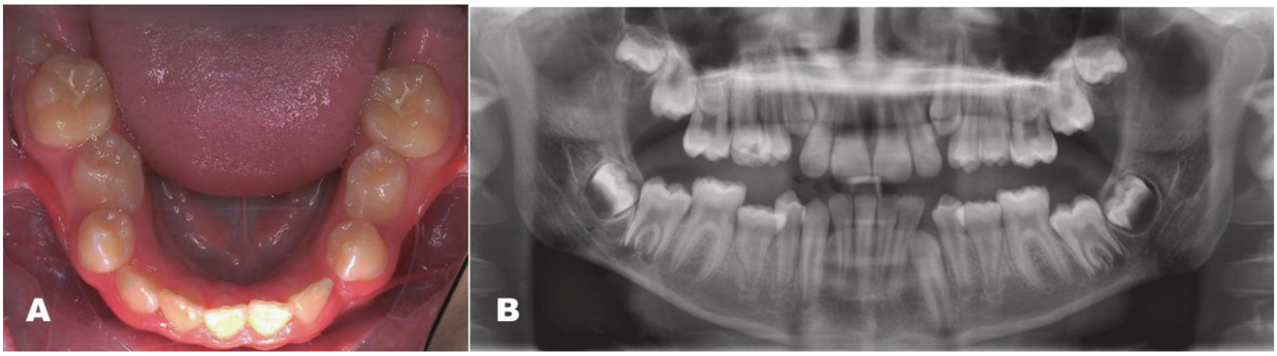


Figure 11. A, Clinical photograph of mandibular second premolar macrodontia. B, Panoramic image shows the greater mesial/distal widths of the tooth crowns compared with their respective first premolars.

2. Microdontia (small teeth)

It's a condition in which teeth appear smaller than normal. In the generalized form, all teeth are involved. In the localized form, only single or few teeth are involved. The most common teeth affected are the upper lateral incisors and third molars. Imaging features of the affected teeth are frequently small and malformed.

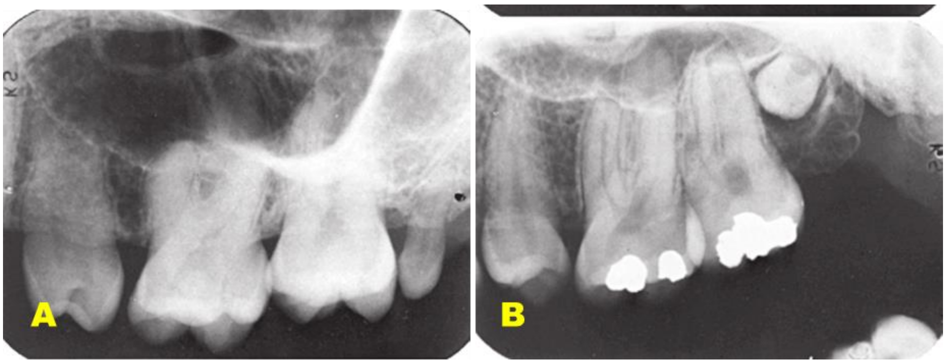


Figure 12. A, and B, Periapical images show a reduction in both the size and the number of cusps in microdontia of the maxillary third molars.

Abnormalities in shape (morphology):

1. Fusion:

Two teeth joined together into a single anatomic crown (union of two separated tooth germ). Fusion is more common in anterior teeth of both the deciduous and permanent dentitions. Imaging features of fused teeth show unusual shape, size, and pulp chamber or root canal.

Figure 13. Fusion of the central and lateral incisors in both the primary and the permanent dentitions. Note the reduction in number of teeth and the increased width of the fused tooth mass.

2. Gemination:

Single tooth germ divided into two teeth joined together (single root with one root canal with two or enlarged crowns). In Radiographic diagnosis the imaging features reveal the altered shape of the hard tissue and pulp chamber of the geminated tooth.

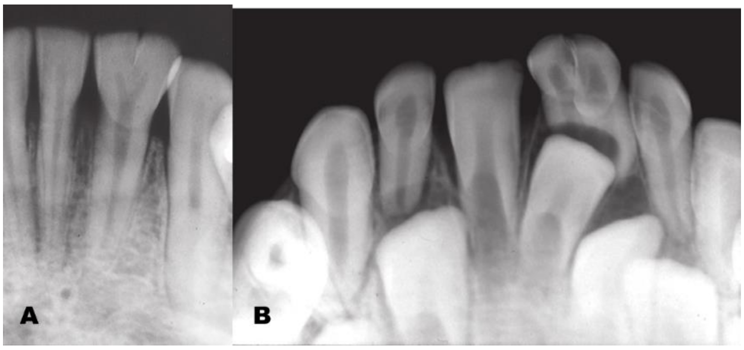


Figure 14. **A**, Gemination of a mandibular lateral incisor showing bifurcation of the crown and pulp chamber. **B**, Almost complete gemination of a deciduous lateral incisor.

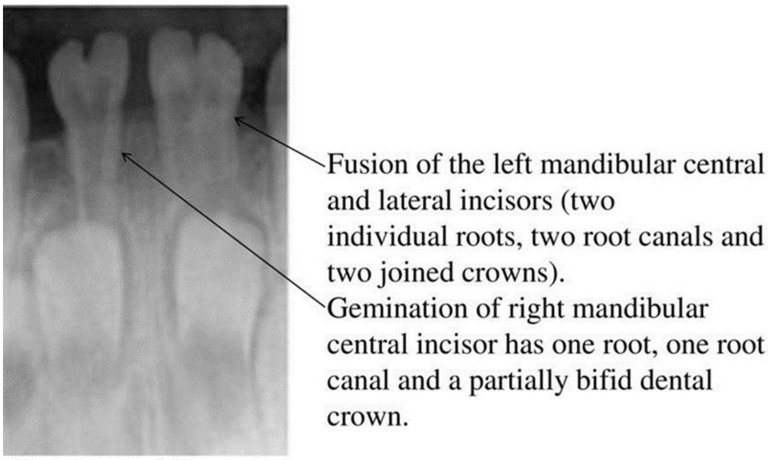


Figure 15. The differences between fusion and gemination.

3. Concrescence:

Concrescence is a union of two adjacent teeth by cementum only. Maxillary third molar frequently involved. Imaging features reveal concrescence teeth may be in close contact or are simply superimposed. Concrescence does not affect the clinical shape of the tooth.

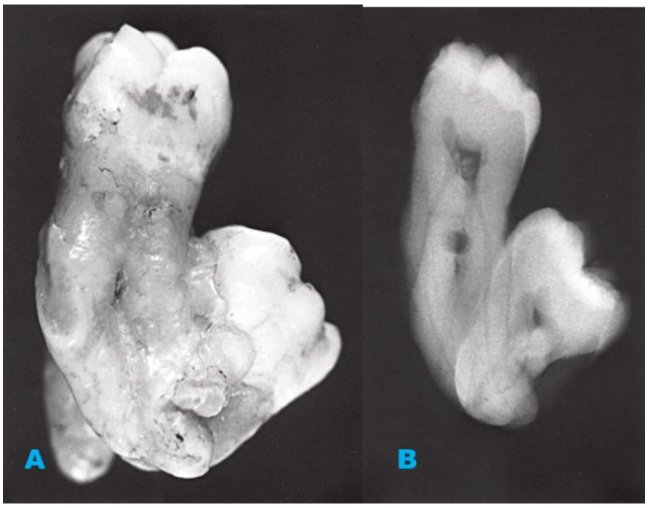


Figure 16. A, Concrescence occurs when two teeth are joined by cementum. B, Extraction of one tooth may result in theunintended removal of the second because the cementum bridge may not be well visualized.

4. Dilaceration:

Dilaceration is a deviation or sharp bend in the linear relationship of a tooth crown to its root; imaging features is readily apparent on an intraoral radiograph when the roots are bending mesially or distally, buccally or lingually.

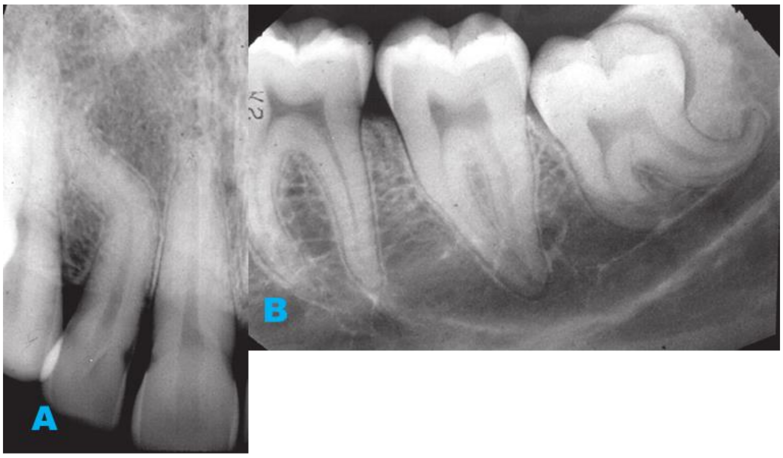


Figure 17. Dilaceration of the root of a maxillary lateral incisor (A) and mandibular third molar (B).

5. Dens invaginatus and dens evaginatus:

Dens invaginatus is infolding of the enamel surface into the interior of a tooth crown or the root. Imaging features show more radiopaque than the surrounding tooth structure, poorly defined root.

Dens evaginatus is the outpouching of the enamel on the occlusal surface. Imaging features shows an extension of a dentin tubercle on the occlusal surface covered with radiopaque enamel.

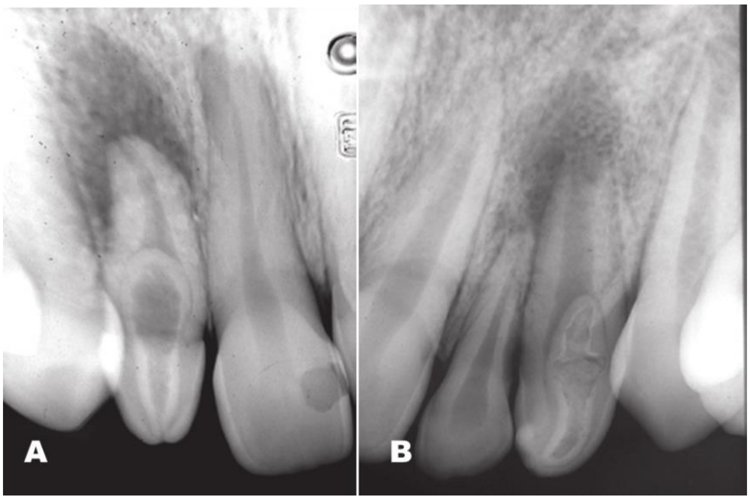


Figure 18. A, and B, Infolding of enamel is more severe in dens in dente as seen in these two periapical images. The invagination begins near the incisal edge of these abnormally peg-shaped lateral incisors.

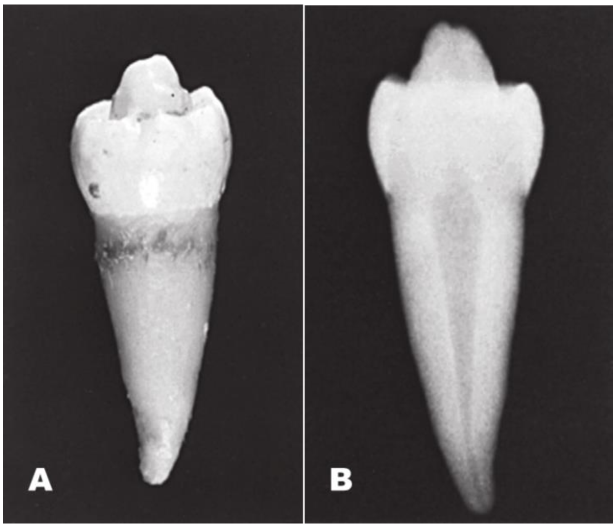


Figure 19. A, Occlusal tubercle of dens evaginatus as seen in a mandibular premolar. B, Periapical image of the specimen.

6. Enamel pearl

It's small spherical enamel masses (enameloma) located at the root of the molars and are found in 3% of the population. Imaging features of the enamel pearl appears smooth, round radiopaque structure.

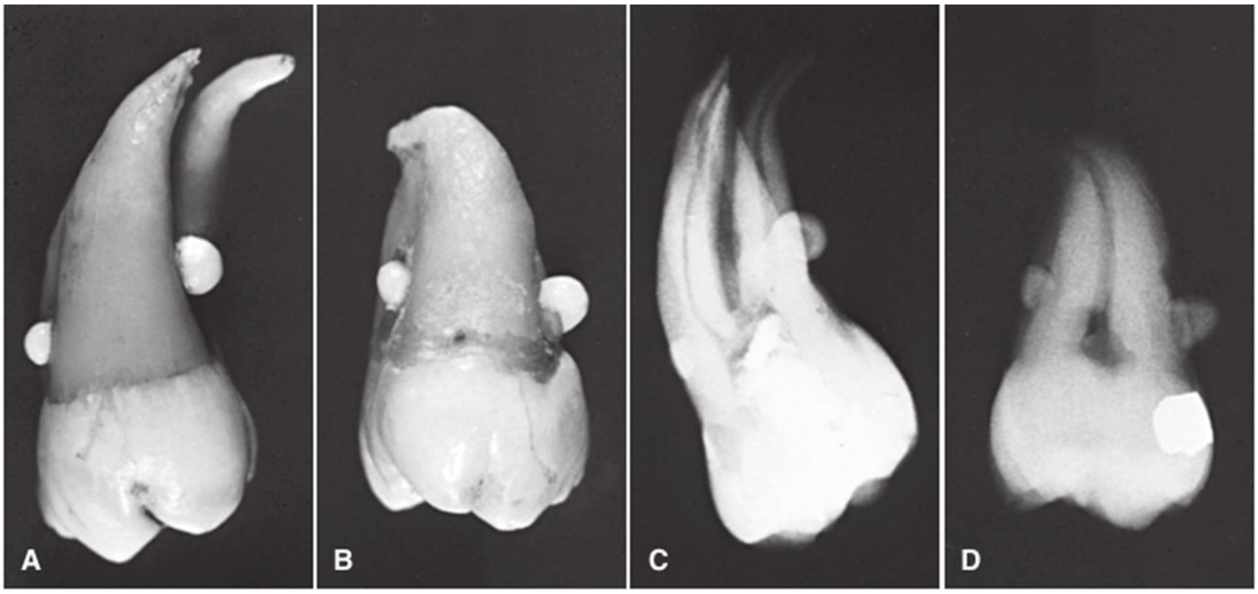


Figure 20. **A**, and **B**, Enamel pearls are small outgrowths of enamel and dentin in the furcation areas of teeth. **C** and **D**, Images of the teeth in **A** and **B**.

7. Taurodontism

It's a condition found in the molar teeth whereby the body of the tooth and pulp chamber is enlarged vertically with short roots, the floor of the pulp and the furcation of the tooth is moved apically. Imaging features is the elongated pulp chamber and the more apically positioned furcation, shortened roots with long crown.

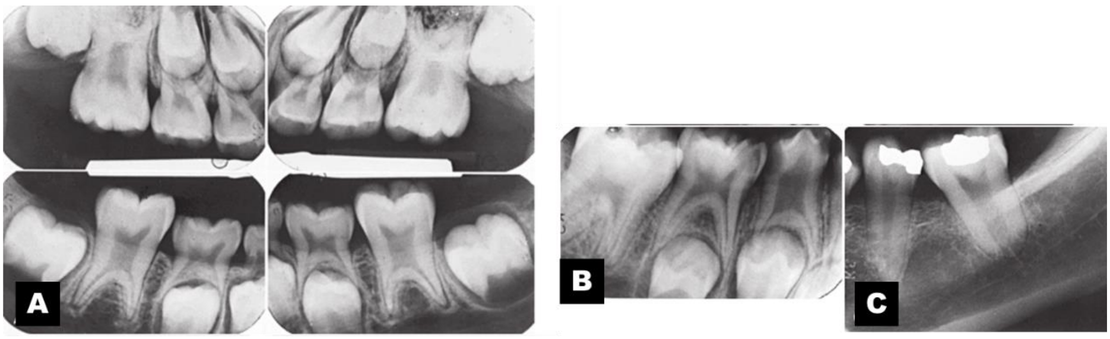


Figure 21. Periapical images reveal enlarged pulp chambers and apically positioned furcations in permanent first molars (**A**), a primary first molar (**B**), and a permanent molar (**C**).

8. Talon cusp:

It's an Accessory cusp like structure projecting from the cingulum area or cementenamel junction of the maxillary or mandibular anterior teeth. Imaging features show a distinct radiopaque image of talon cusp on the crown of the involved tooth.

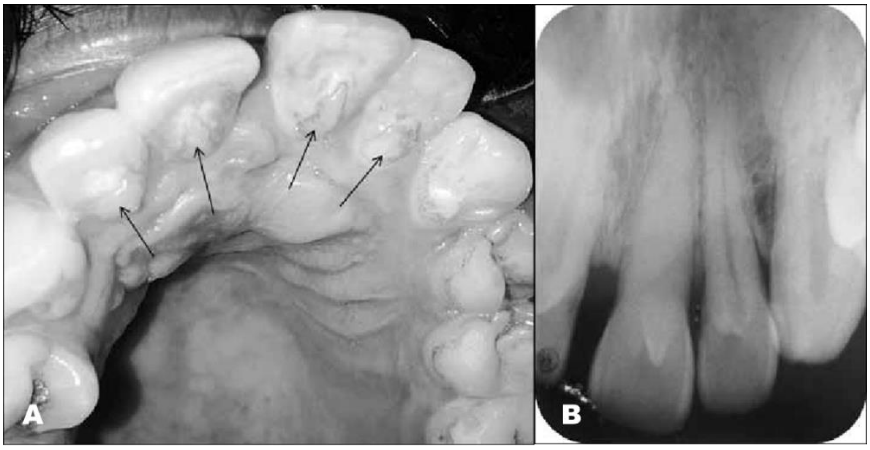


Figure 22. A, Talon cusps on the lingual surface of maxillary incisors bilaterally. B, Periapical radiograph showing the talon cusp as a "V" -shaped radioopaque structure on the left central incisor with calcification of the pulp canal and a "U" -shaped radioopaque structure on the left lateral incisor superimposing the crown.

Abnormalities in Eruption of Teeth:

1. **Transposition**:

It is the condition in which two adjacent teeth have exchanged positions in the dental arch. Imaging features reveal transposition when the teeth are not in their usual sequence in the dental arch.

Figure 23. Cropped panoramic image demonstrating bilateral transposition of the maxillary canines and first premolars.

2. Premature Eruption (natal and neonatal teeth):

The teeth erupted in the oral cavity **at the time of birth** are called as **'natal teeth'** and teeth erupting prematurely in first 30 days of life are called as 'neonatal teeth'. Imaging features the roots are not seen on the radiograph and the teeth are very small.

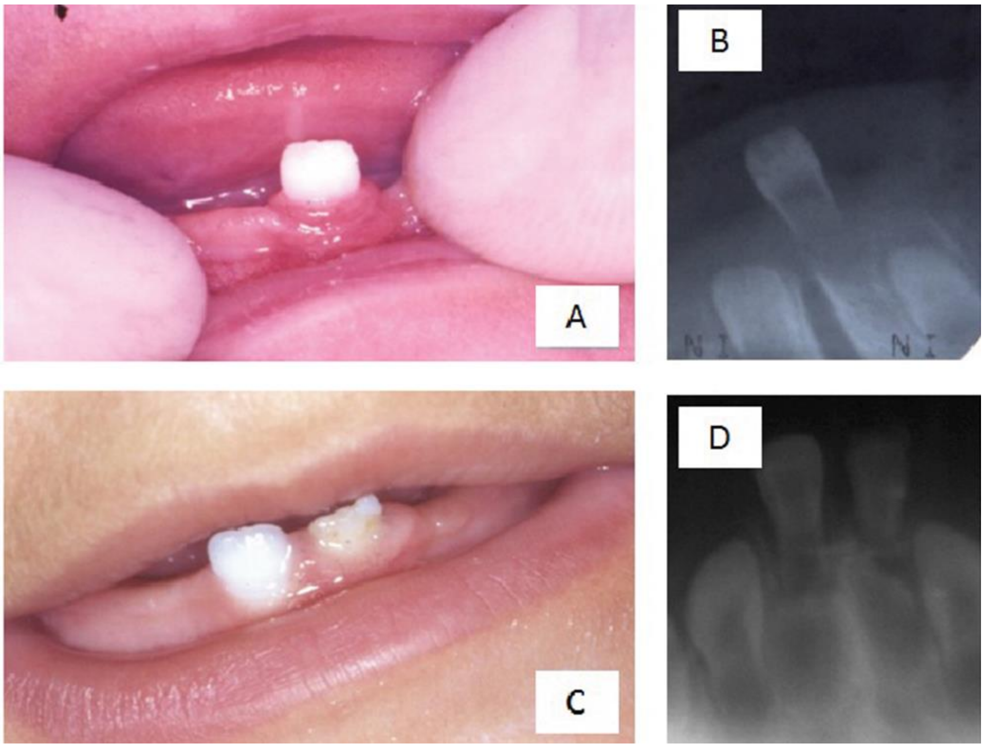


Figure 24. **A**, Photograph showing a 9-day-old infant with one neonatal tooth in the mandibular anterior region; **B**, Radiographic examination showing that the tooth was part of a primary series; **C**, Patient showing right mandibular central incisor erupted when she was 9 months; **D**, Radiographic evaluation showing good root implantation.

3. Delayed Eruption (Impacted Teeth):

Permanent teeth are observed to be delayed in eruption forming partially or completely impacted teeth, is more commonly in mandibular third molar, followed by maxillary canine and maxillary third molar. Imaging features of impacted mandibular third molar may show mesioangular, distoangular, vertical or horizontal impaction.

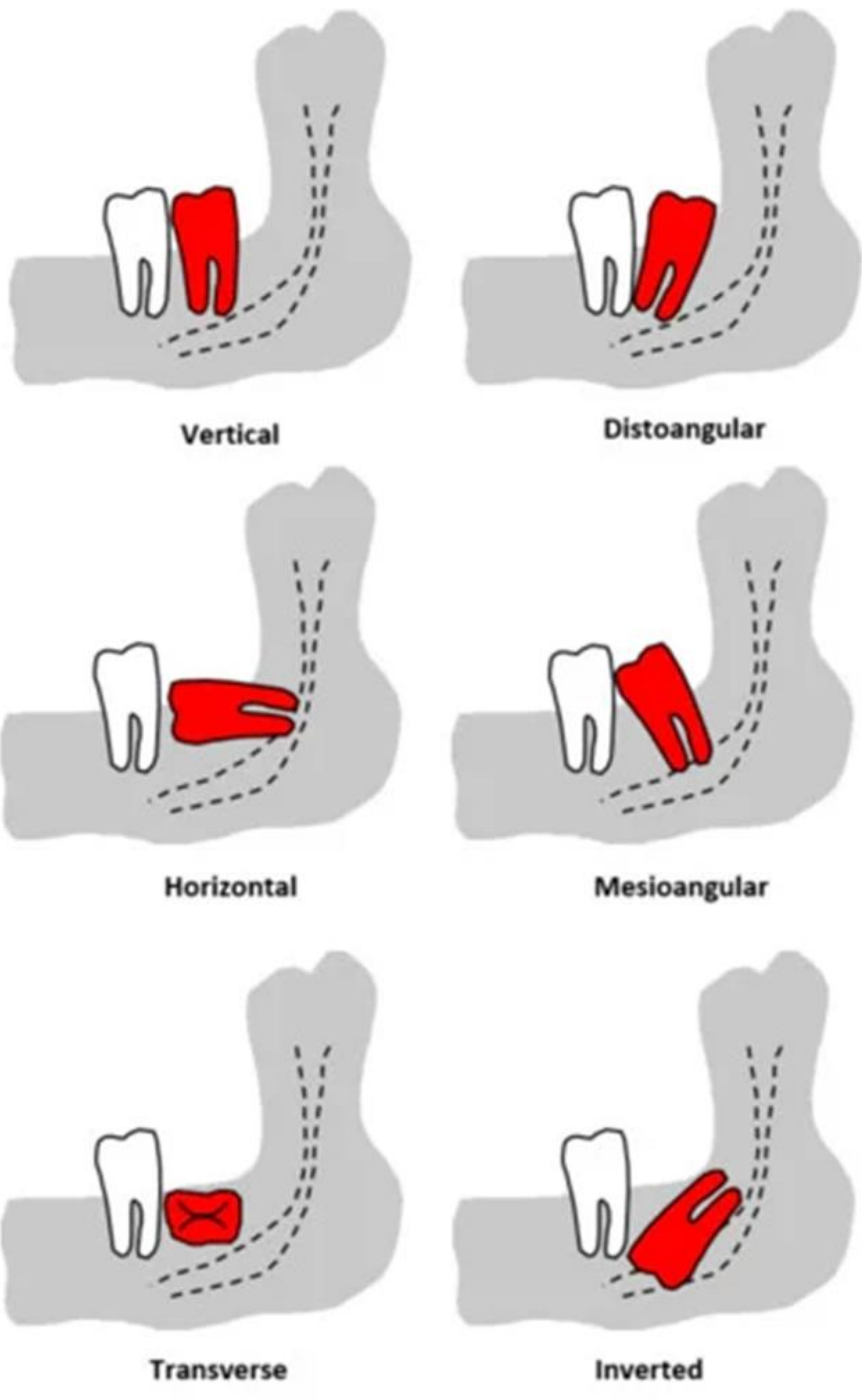


Figure 25. Winter's classification. The red teeth are the mandibular third molars. The figure expressed six types of impacted mandibular third molar according to winter's classification: vertical, mesioangular, horizontal, distoangular, transverse, and inverted.

Acquired teeth abnormalities:

Attrition: is physiologic wearing of teeth (occlusal contacts). The imaging appearance is flat incisal or occlusal surface.

Figure 26. Physiologic wear or attrition is demonstrated on this periapical image of the mandibular incisors.

Abrasion: is the nonphysiologic wearing of teeth (friction with a foreign toothbrush and dental floss, pipe…). Imaging appearance is defects at the cervical level of teeth.

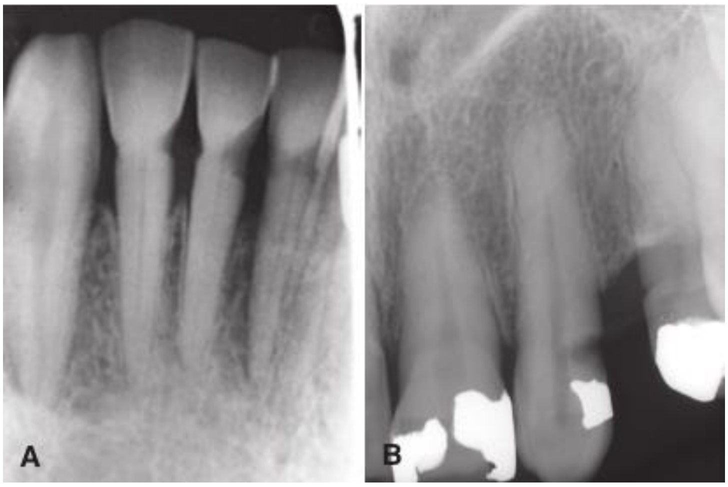


Figure 27. **A**, Abrasion of the cervical areas of these incisor teeth is evident from excessive (and improper) use of dental floss. Note the obliteration of the pulp chambers and reduction in size of the root canals. **B**, Abrasion on the distal aspect of the maxillary canine from a denture clasp.

Erosion: (chemical action). Imaging features appear as radiolucent defects on the crown.

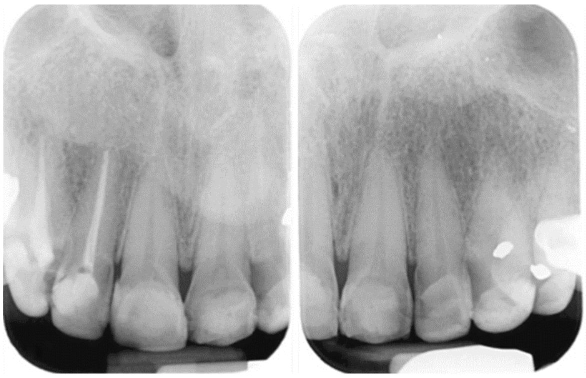


Figure 28. Radiographic image of erosion of the cervical areas of maxillary incisors.

Resorption: is the removal of tooth structure (internal or external). Imaging features for external root resorption are smooth loss apical and cervical regions with blunt root apex, while internal resorption round, oval radiolucent within the root or crown.

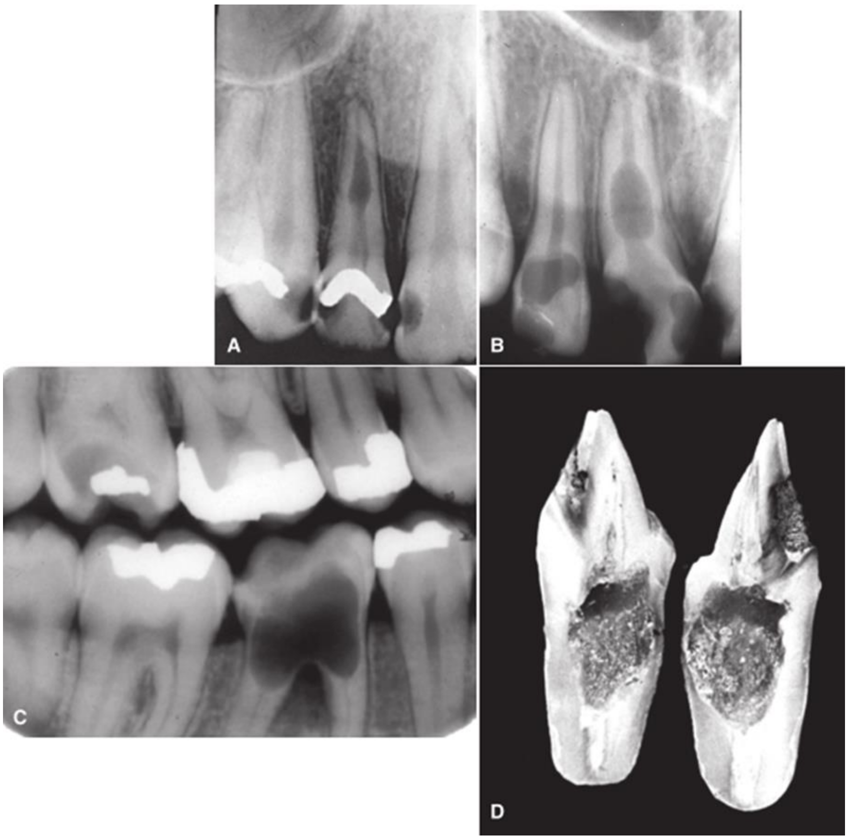


Figure 29. Internal root resorption may occur in either the crown or the root of teeth. Periapical images show internal resorption centered in the root canal system (**A** and **B**) and in both the crown and the roots (**C** and **D**) in a sectioned incisor (after crown reduction).

Figure 30. External root resorption results in a loss of tooth structure from the apex. Note the blunted root apices, the widened pulp root canals, and the intact lamina dura.

Secondary dentin: additional dentin deposited. Imaging features is a reduction in size of the normal pulp.

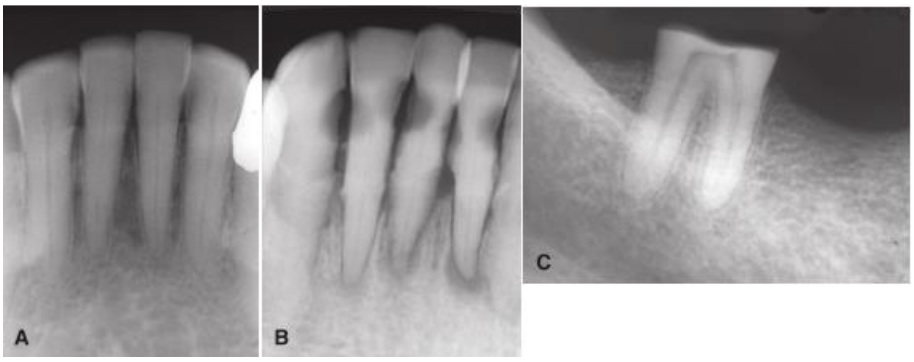


Figure 31. **A**, Normal formation of secondary dentin causes recession of the pulp chamber and narrowing of the root canals. **B**, Secondary dentin has obliterated the pulp chambers and narrowed the root canals. This is likely a result of the carious lesions. **C**, Secondary dentin formation has obliterated the pulp chamber stimulated by the severe attrition of the coronal aspect of this molar.

Pulp stones (foci of calcification in the dental pulp). The imaging appearance is radiopaque structures within pulp, Pulpal sclerosis is another form of pulp calcification, but it diffuse to larger area.

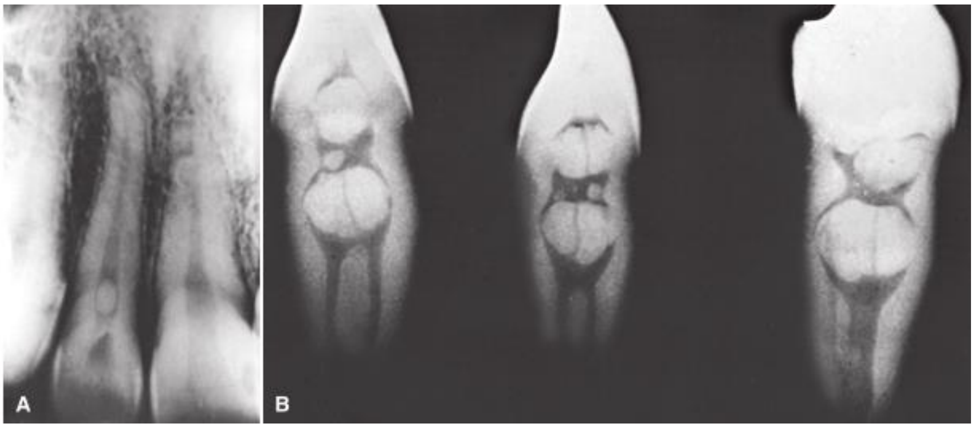


Figure 32. (**A**) Pulp stones may be found as isolated calcifications in the pulp. (**B**) When large, they may cause deformation of the pulp chamber and root canals.

Hypercementosis is excessive deposition of cementum on the tooth roots. Imaging is an excessive buildup of cementum around all or part of a root.

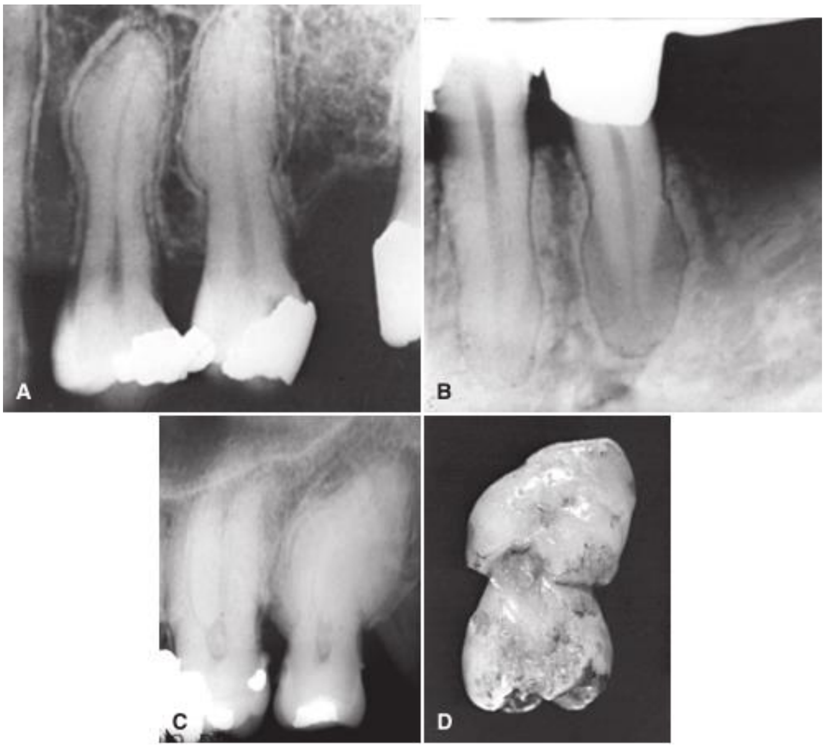


Figure 33. Hypercementosis of the roots. A-C: In all cases, note the continuity of the lamina dura and the PDL space that encompasses the extra cementum. D, An extracted molar exhibits extensive hypercementosis.

Craniofacial anomalies:

The craniofacial anomalies are usually first discovered in infancy or childhood. Some are caused by genetic mutations, others result from environmental factors, and a third group are multifactorial. Cleft lip and palate is one of these anomalies.

Cleft lip and palate:

Cleft lip occurs due to failure of union of medial and lateral maxillary processes. While, cleft palate (CP) develops from a failure of fusion of the lateral palatal shelves

Cleft lip and palate together (CL/P) is either unilateral or bilateral. In both CL/P and CP, the palatal defects interfere with speech and swallowing.

Multiple radiographic procedures are performed on patients with CL/P throughout childhood and adolescence. These may include panoramic, periapical, occlusal, and cephalometric radiographs, as well as multidetector computed tomography and, more recently, cone-beam imaging.

Imaging Features appear as well-defined vertical radiolucent defect in the alveolar process with numerous dental anomalies (absence of the maxillary lateral incisor, presence of supernumerary teeth, enamel hypoplasia, malformed teeth, and delayed eruption with hypodontia in both arches).

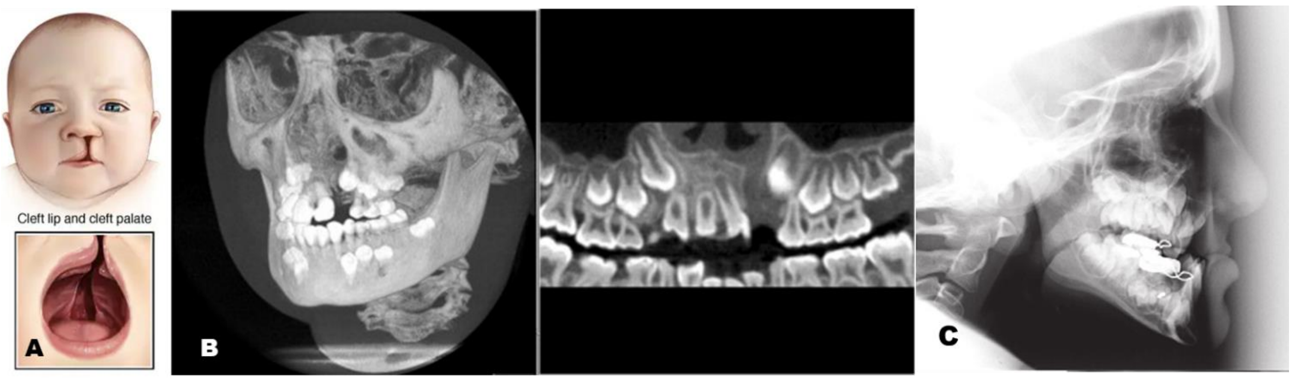


Figure 34. Cleft lip/palate results in defects in the alveolar ridge and abnormalities of the dentition. **A**, Unilateral cleft lip/palate. **B**, CBCT image of a patient with unilateral cleft lip/palate. **C**, Lateral cephalometric view shows underdevelopment of the maxilla.

Lecture 22

Traumatic Injuries

By

Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.

Oral Radiology Teacher, Anbar University

Oral and maxillofacial injuries refer to injuries of the orofacial soft tissues, facial skeleton, teeth and associated specialized soft tissues within the head and neck region as a result of wounding or external violence. These injuries can lead to orofacial deformity and malfunction, greatly diminishing quality of life and worker productivity.

Traumatic injuries of the teeth:

Fractures of the dental root may occur at any level and involve one or all the roots of multirooted teeth. Most of the fractures confined to the root occur in the middle third of the root. The ability of the dental film to reveal the presence of a root fracture depends on the degree of distraction of the fragments and depend on how the x-ray beam is in alignment with the plane of the fracture. When visible, the fracture appears as a sharply defined radiolucent line confined to the anatomic limits of the root.

Traumatic dental injuries of teeth occur frequently in children and young adults.

Enamel infraction: An incomplete fracture (crack) of the enamel without loss of tooth substance.

Enamel fracture (uncomplicated crown fracture): A fracture with loss of enamel only.

Enamel-dentine fracture (uncomplicated crown fracture): A fracture with loss of enamel and dentine, but not involving the pulp.

Complicated crown fracture: A fracture involving enamel and dentine, and exposing the pulp.

Crown-root fracture: A fracture involving enamel, coronal and radicular dentine, and cementum.

Root fracture: A fracture involving radicular dentine, cementum and the pulp.

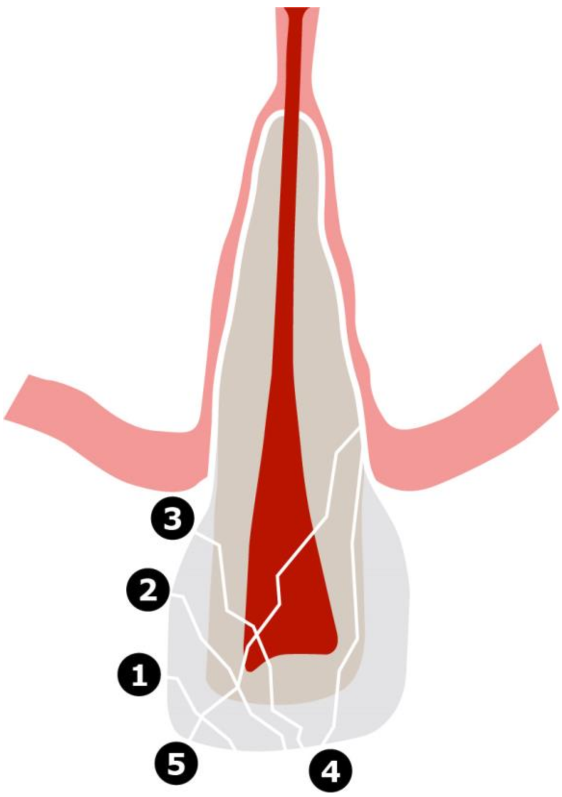


Figure 1. 0 = none. 1 = enamel fracture. 2 = enamel and dentin fracture = uncomplicated crown fracture. 3 = enamel and dentin fracture including the pulp = complicated crown fracture. 4 = enamel-dentin-cementum fracture = uncomplicated crown-froot fracture. 5 = Enamel-dentin-cementum fracture including the pulp = complicated crown-root fracture.

Radiographic evaluation:

Radiographic evaluation of dentoalveolar injuries should include a panoramic radiograph and periapical radiograph of involved teeth.

The radiographic examination reveals the stage of root formation and discloses injuries affecting root portion of the tooth and periodontal structures.

Multiple periapical radiographs taken at different angles are useful to demonstrate the root fractures that are minimally displaced.

Ideally three different radiographs from different angles should be obtained for each traumatized tooth.

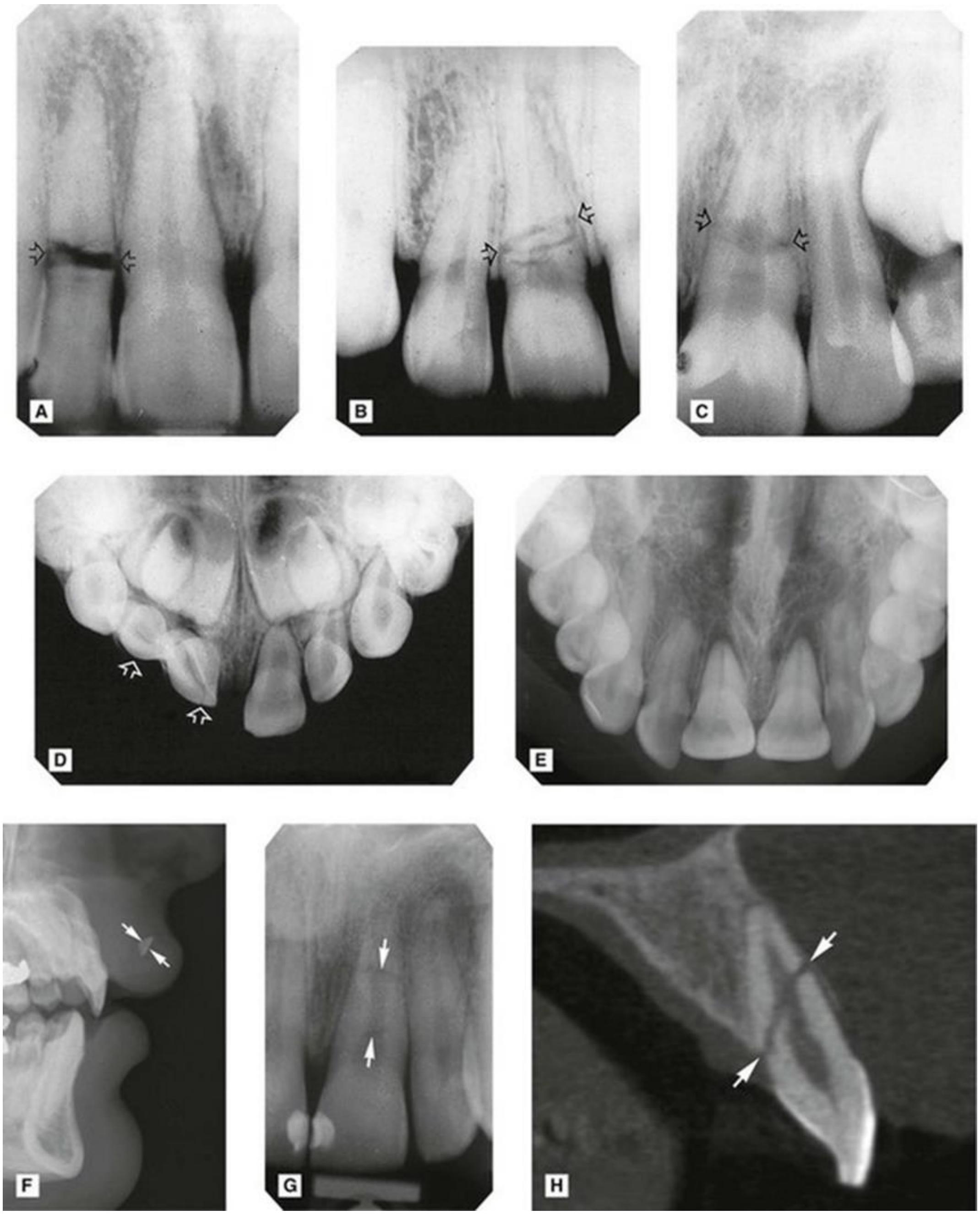


Figure 2. Examples of traumatized teeth and their surrounding structures. **A** Root fracture of right lateral incisor (arrowed) with wide separation of the fragments. **B** Root fracture of upper right central incisor (arrowed) with minimal separation of fragments. **C** Root fracture of left central incisor (arrowed) with marked discontinuity in root outline. **D** Intrusion and fracture of primary right central and lateral incisor (arrowed). **E** Palatal luxation of upper R & L central incisors – crowns displaced palatally, roots displaced buccally – hence they appear foreshortened. Note also the widening of the periodontal ligament space. **F** Tooth fragment in the upper lip (arrowed). **G** Periapical and **H** sagittal CBCT scan of a fractured upper left central incisor (arrowed).

Fractures of the Alveolar Process:

Fractures of the alveolar process are found predominantly in the anterior teeth and the premolar region. These injuries may be isolated or may be seen in conjunction with traumatic injuries to teeth.

Radiographic Features:

The fracture is readily identified in the intraoral periapical radiograph.

Lateral extraoral radiographs best demonstrate the location of the fracture if some bone displacement has occurred. More close the fracture to the alveolar crest, greater is the possibility of presence of root fractures. Usually two radiographs produced with different projecting angles are required for the accurate diagnosis.

Fracture of the Mandible:

Despite the fact that the mandible is the largest and strongest facial bone, by virtue of its position on the face and its prominence, it is commonly fractured when maxillofacial trauma has been sustained

According to the anatomical site:

The fractures can be classified according to the site of fracture and its incidence as follows:

1. Symphyseal fractures and parasymphyseal fractures.
2. Body fractures.
3. Gonial area or angle fractures.
4. Condylar fractures (intracapsular) and subcondylar fractures.
5. Coronoid process fracture.
6. Dentoalveolar fractures.

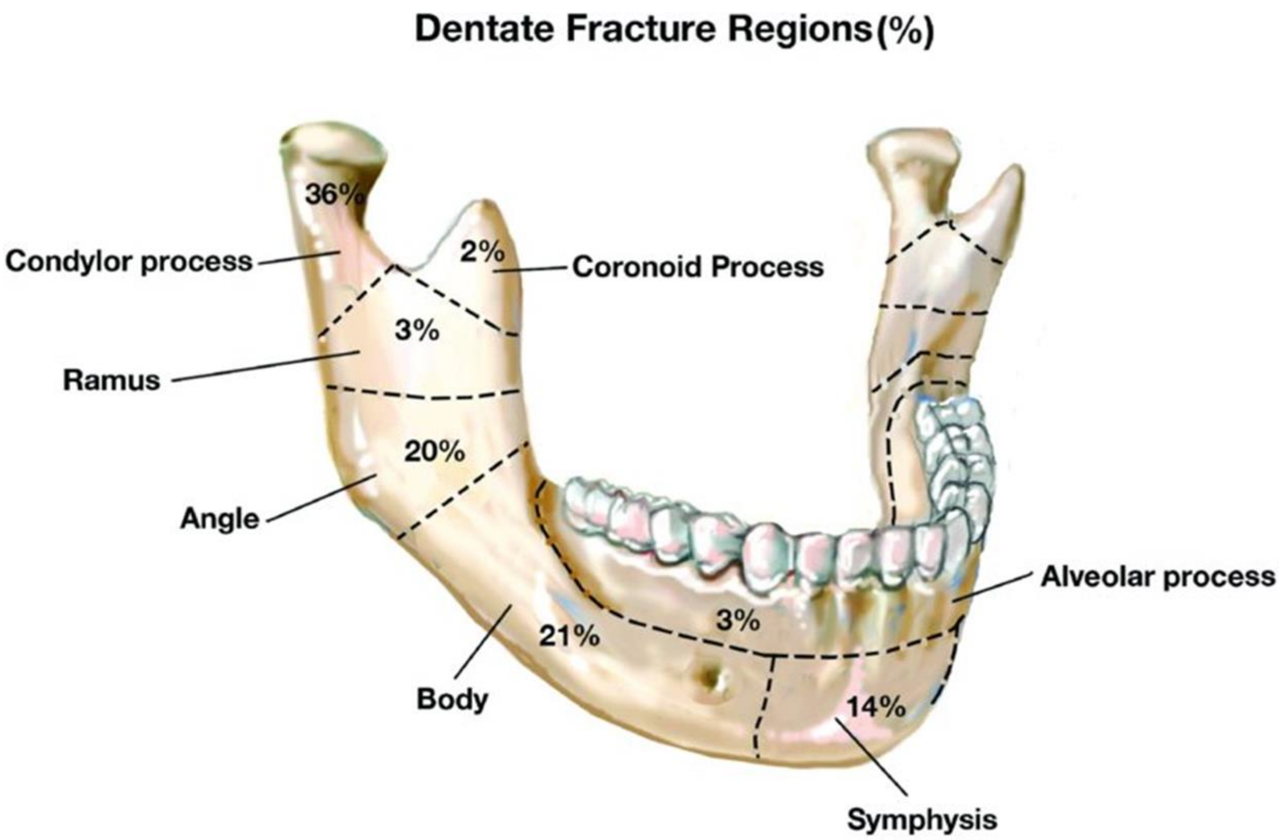


Figure 3. Percentage of dentate mandible fractures by region. Modified from Ochs, MW (2008).

Radiographic Features:

The radiographic examination of a suspected mandibular fracture may include intraoral or occlusal views, intraoral periapical radiograph, panoramic view, posteroinferior or submentovertex plain radiograph, reverse Towne's view, lateral oblique radiograph and CT.

The margins of the fractures usually appear as sharply defined radiolucent lines of separation that are confined to the structure of the mandible. The lateral oblique view of the mandible can be of help in the diagnosis of ramus, angle and posterior body fractures.

The posteroanterior (PA) view demonstrates any medial or lateral displacement of the fractures of ramus, angle, body or symphysis. The mandibular occlusal view demonstrates displacement in the lateral or medial direction of the body fractures and also shows the anterior or posterior displacement of the symphyseal fracture.

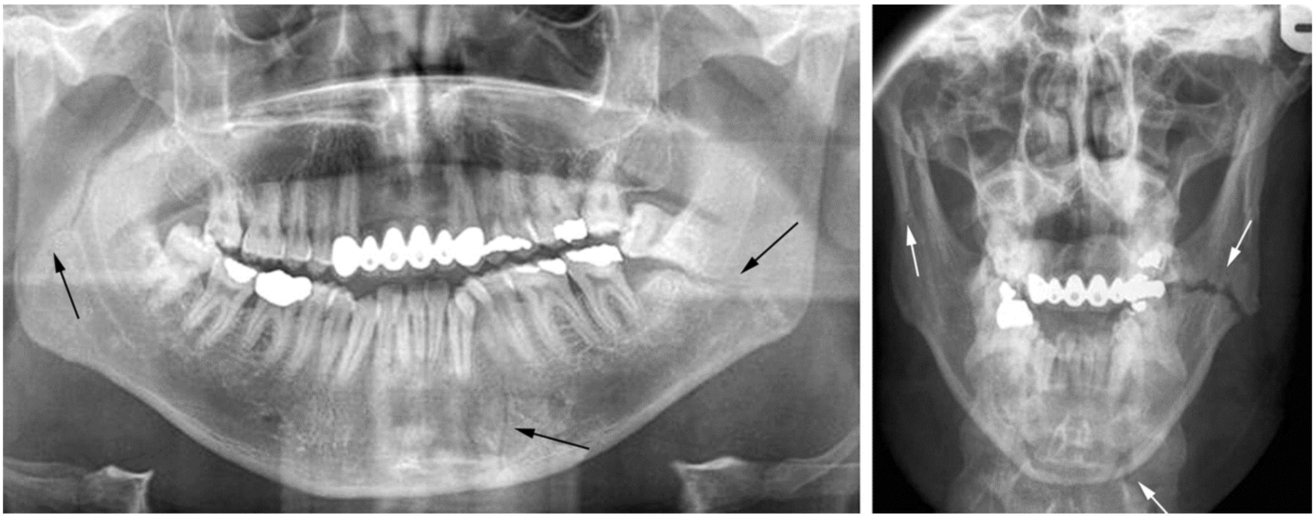


Figure 4. Panoramic and Townes view radiographs of mandibular fractures.

Trauma to temporomandibular joint region:

The complexity of the TMJ, as well as its anatomical proximity to other craniofacial structures, makes diagnosis and treatment specifically challenging.

Classification of TMJ region fracture:

Relationship of condylar fragment with mandibular fragment:

1. Non-displaced.
2. Deviated.
3. Displacement with medial or lateral overlap.
4. Displacement with anterior or posterior overlaps.
5. No contact between the fractured segments.

Relationship between condylar head and glenoid fossa:

1. Non-displaced.
2. Displacement.
3. Dislocation.

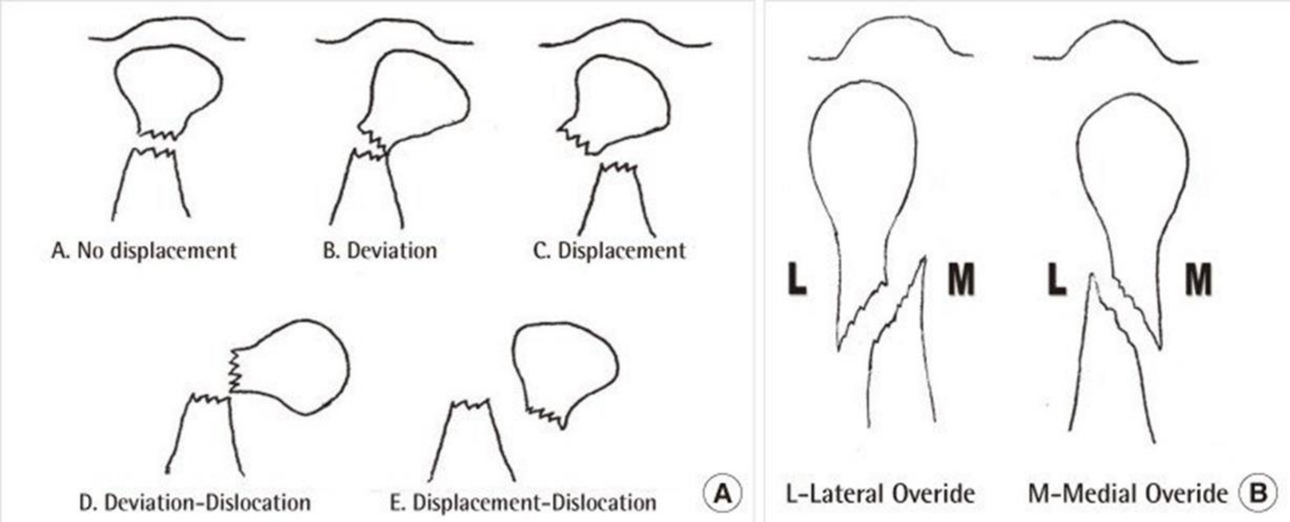


Figure 5. The classification of mandibular condyle fracture according to Lindahl classification. (**A**) The degree of fracture fragment. (**B**) Two type of the displacement of condyle proximal segment.

Radiographic Features:

At least two radiographs must be obtained at right angle to each other to adequately evaluate the TMJ region. Orthopantomography (OPG) and lateral oblique view of mandible.

Panoramic radiograph contains higher accuracy in detecting all the mandibular fractures. If OPG facilities are not available, lateral oblique view is more informative

Reverse Towne's view and PA mandible: It shows condylar head much better than more conventional PA or AP view of mandible in which these structures tend to be superimposed by base of the skull.

Transcranial and transorbital view of TMJ: This view may occasionally be helpful in defining the relationship of the condylar proximal fragment to the glenoid fossa.

CT scan: In difficult cases, CT scan has been demonstrated to show changes in the relationship of the condyle to the mandibular fossa more precisely than the conventional radiographic examination.

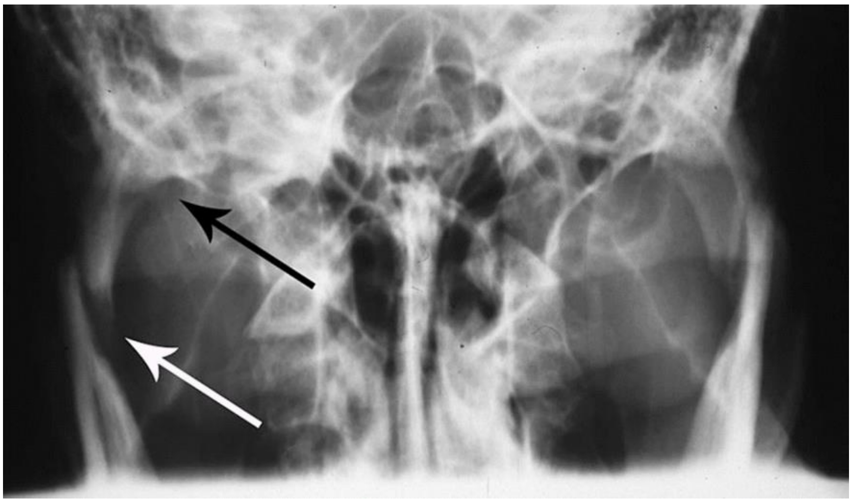


Figure 6. Towne's view of a bilateral condyle fracture. White arrow is a fracture on the neck of the condyle. Black arrow shows the condyle pulled to the medial. The same injury can be seen on the opposite side.

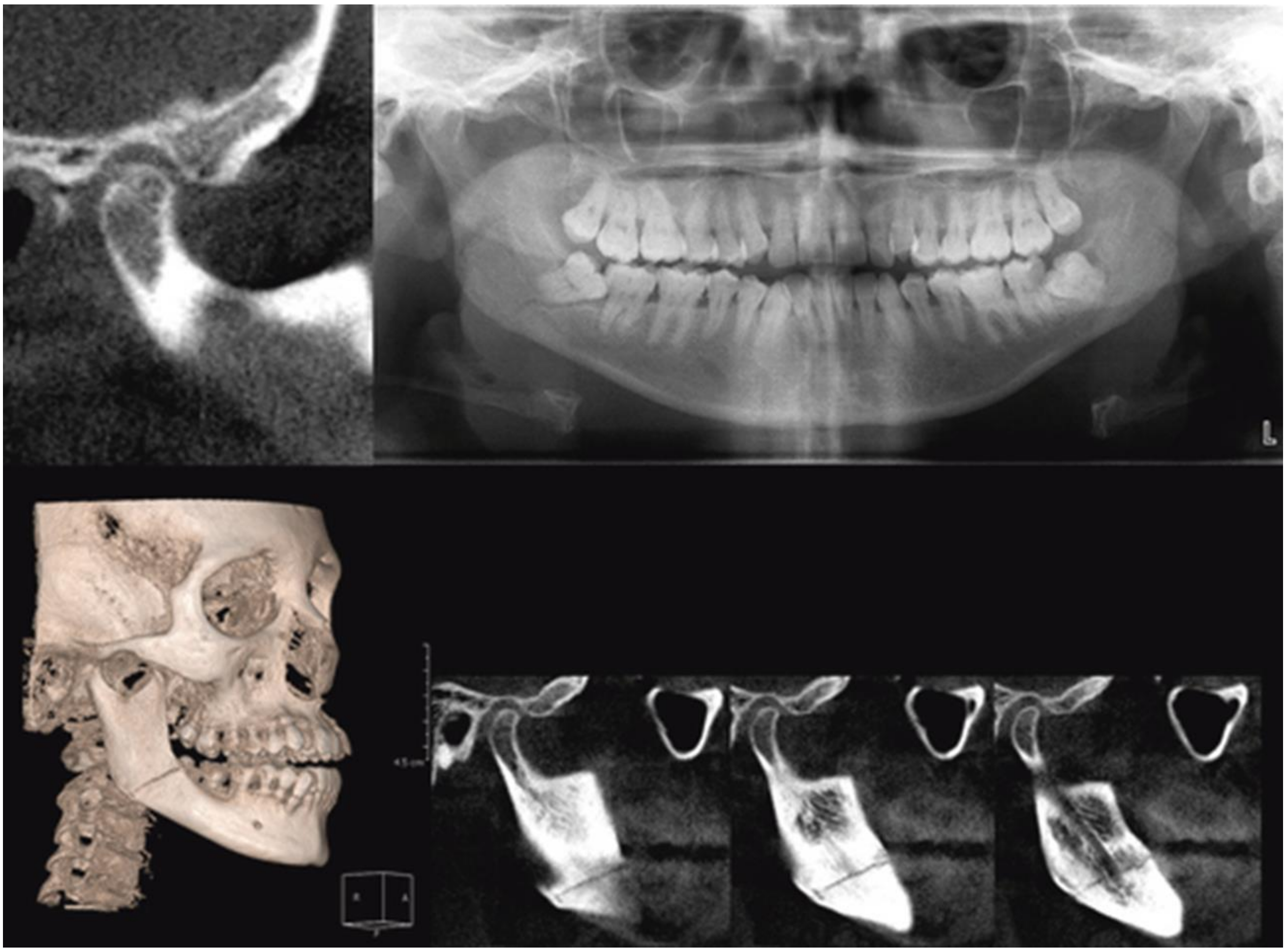


Figure 7. Fractured right condylar head and body of the mandible without significant displacement of the fragments. Note that the panoramic did not show the condylar involvement depicted clearly in the CBCT.

Middle third fracture of face:

Fracture of Maxilla:

Middle third consists of maxilla, zygomatic bones and zygomatic process of temporal bones, palatine bone, nasal bone, lacrimal bone, inferior conchae, pterygoid plates, sphenoid, vomer and ethmoid. Fractures of the midface, often classification owing to the severity of the force and the multidirectional source of the trauma.

Classification according to Rene Le Fort:

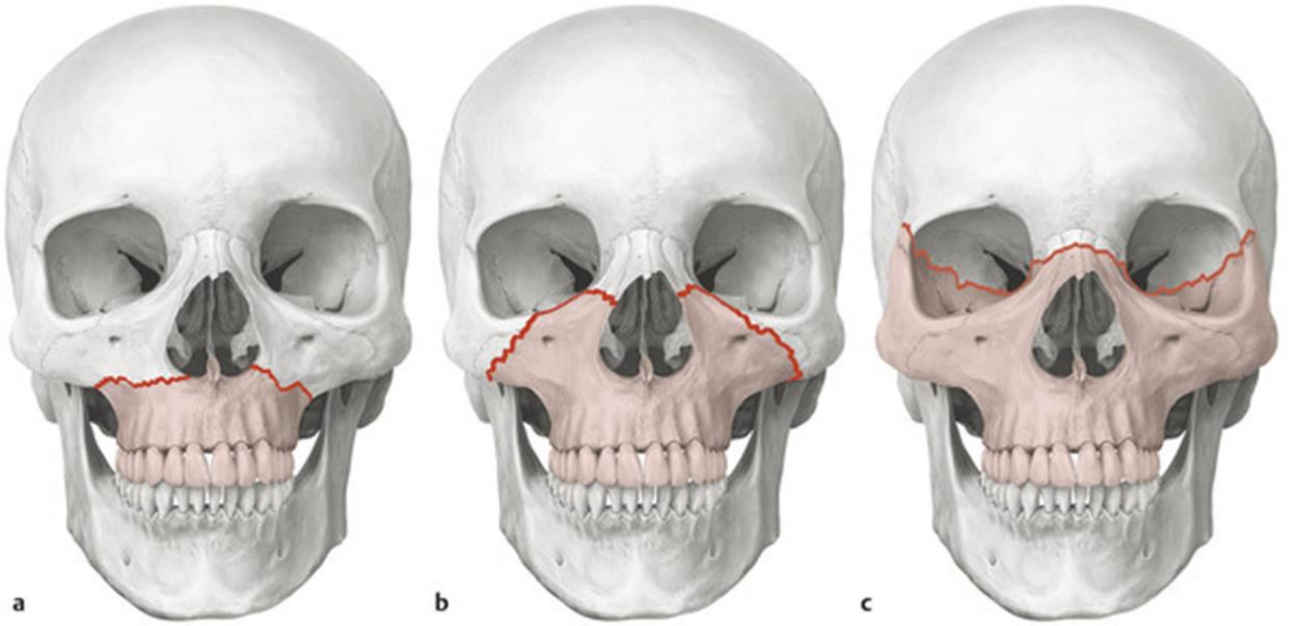


Figure 8. Le Fort fractures. **(a) Le Fort type I**: Horizontally oriented fractures through the maxilla, and the pterygoid plates, resulting in a "floating palate."

(b) Le Fort type 2: Angled fractures through the maxilla and inferior orbital rims, crossing the midline, as well as involvement of the pterygoid plates.

(c) Le Fort type 3: Horizontally oriented fracture through the zygomatic arches, lateral orbital wall, and across the midline through the ethmoid sinuses, also involving the pterygoid plates. This results in craniofacial dissociation ("floating face").

Le Fort I:

It is also known as **low-level fracture** or horizontal fracture of maxilla, Guerin fracture, floating fracture, horizontal fracture above the level of nasal floor.

Radiographic Features:

Le Fort I this type of fracture is identified on PA, lateral skull and Water projections. Both maxillary sinuses are cloudy and may show air-filled level. Lateral view shows slight posterior displaced fragments.

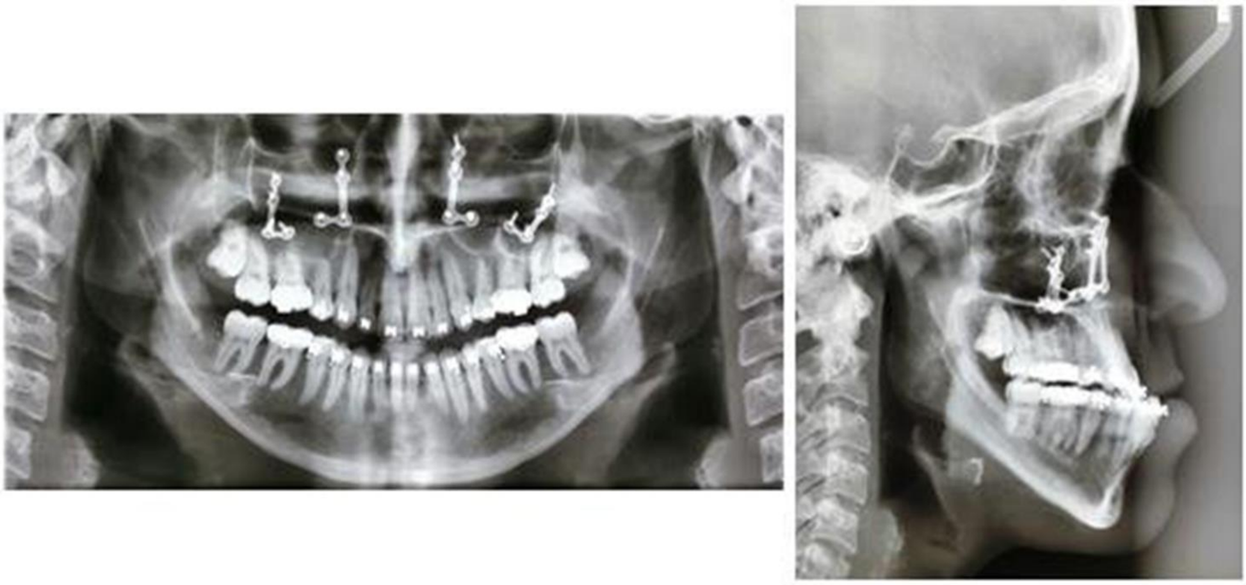


Figure 9. Panoramic and lateral cephalometric radiographs after Le Fort I osteotomy.

Le Fort II:

Le Fort II fracture is also known as **pyramidal fracture** or subzygomatic fracture.

This fracture runs from the thin middle area of the nasal bones down to either side crossing the frontal processes of maxilla into the medial wall of each orbit.

Radiographic Features:

Le Fort II fracture will reveal fracture of the nasal bone and both frontal processes of maxilla and infraorbital rims on both sides or separation of zygomatic sutures on both sides.

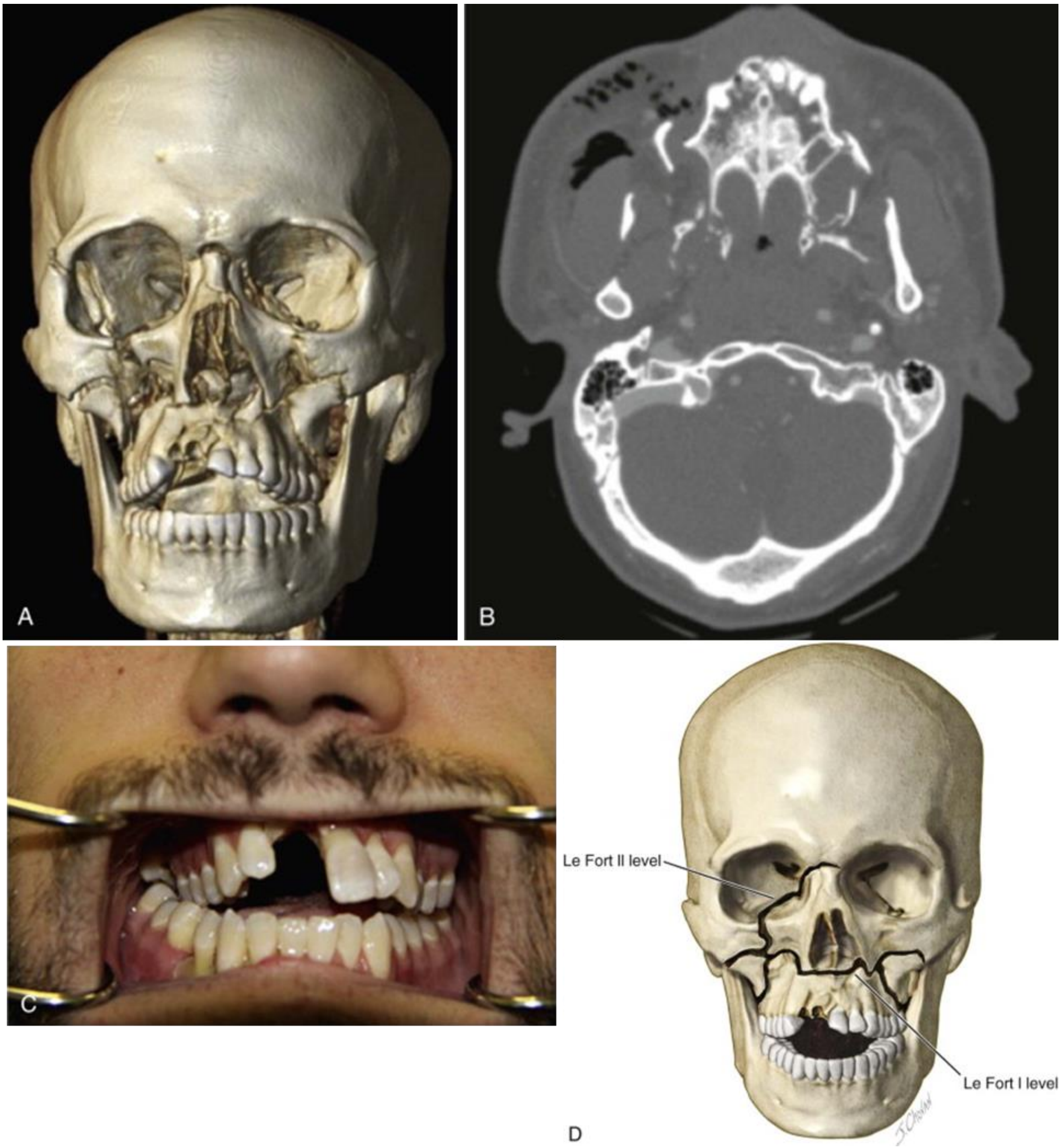


Figure 10. **A**, 3D CT scan of multiple midfacial fractures including a Le Fort I level pattern. B, Computed tomography scan axial cut bony window at the level of the maxilla demonstrating fracture of bilateral pterygoid plates—the hallmark of Le Fort fractures. **C**, Clinical photograph demonstrating an anterior open bite as a result of a Le Fort fracture. This photo also demonstrates collapse of the maxillary width as a result of a palatal fracture component. **D**, Most midfacial fractures do not follow the classical "pure" Le Fort pattern. The fracture pattern on the patient's right reflects a Le Fort II pattern, whereas the fracture pattern on the patient's left is at the Le Fort I level.

Le Fort III:

Le Fort III fracture is also called high **transverse fracture** or suprazygomatic fracture.

The fracture runs from near the frontonasal suture transversely, parallel with the base of the skull and involves the full depth of the ethmoid bone, including the cribriform plate

Radiographic Features:

CT coronal and sagittal scans are the most useful imaging aids in determining the extent of the injuries.

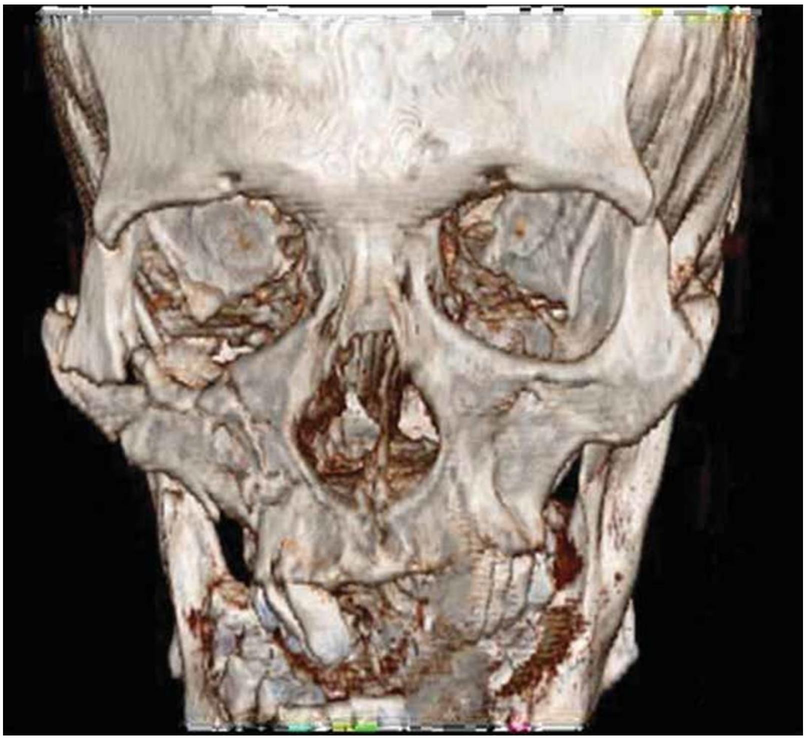


Figure 11. 3D CBCT of right Le Fort III fracture.

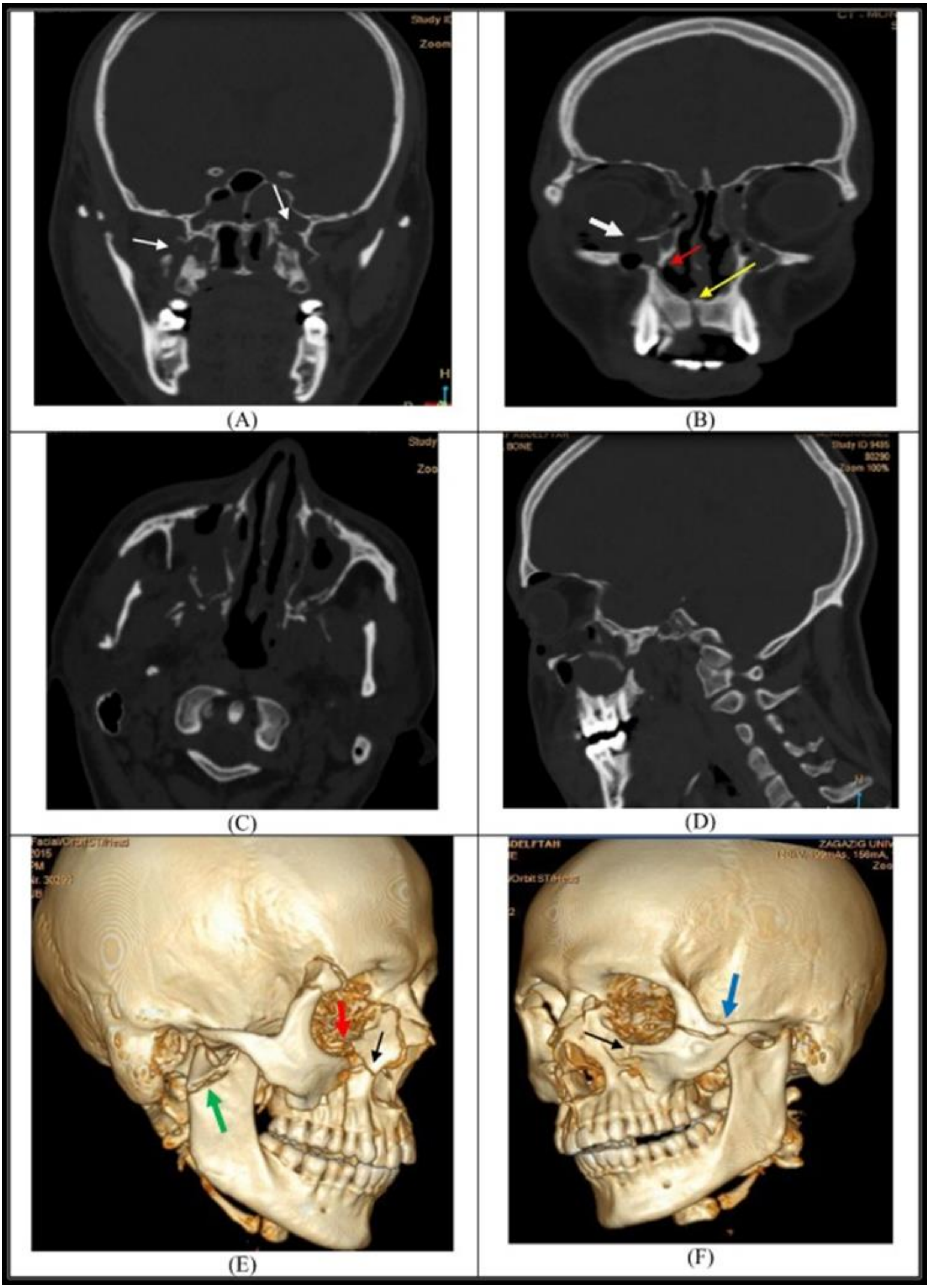


Figure 12. Right Le Fort type 1 & 2 and Left Le Fort type 2 & 3. [A] Coronal CT image, (bone window) reveals fractures of pterygoid bones on both sides [arrows]. [B]

Coronal CT image, (bone window) reveals fractured antero-lateral border of right nasal bone [red arrow]; so right Le Fort type 1 is existed. Fracture of inferior rim of the right orbit [white arrow]; so right Le Fort type 2 is existed. Associated fractured hard palate [yellow arrow]. [**C**] Axial CT image, (bone window) reveals comminuted displaced fracture of both pterygoid plates and maxillary sinus walls. [**D**] Sagittal CT image, (bone window) shows comminuted displaced fracture of right maxillary sinus with intrasinus bone fragments and hemosinus. [**E**] Three-dimensional reconstructed image (right oblique projection) shows fracture of antero-lateral border of right nasal bone above alveolar margin of maxilla [black arrow] [Le Fort type 1 is existed]. Fracture inferior rim of the right orbit [red arrow] [Le Fort type 2 is existed]. Intact right zygomatic arch [Le Fort type 3 is not existed]. Displaced fracture of right mandibular condyle [green arrow]. [**F**] Three-dimensional reconstructed image (left oblique projection) shows intact antero-lateral border of left nasal bone above alveolar margin of maxilla [Le Fort type 1 is not existed]. Fracture inferior rim of left orbit [black arrow] [Le Fort type 2 is existed]. Fracture of left zygoma [blue arrow] [Le Fort type 3 is existed].

Lecture 23

Dental Implantology

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

Dental implant is a device made of alloplastic (foreign) material implanted into the jaw bone beneath the mucosal layer to support a fixed or removable dental prosthesis.

Dental implants are gaining immense popularity and wide acceptance because they not only replace lost teeth but also provide permanent restorations that do not interfere with oral function or speech or compromise the self-esteem of a patient.

Imaging plays an important part in dental implant procedures.

The imaging modalities vary from standard projections to more complex radiographic techniques.

Implant imaging provides accurate and reliable diagnostic information of the patient's anatomy at the proposed implant site.

Standard projections include intra-oral (periapical, occlusal) and extra-oral (panoramic, lateral cephalometric) radiographs.

More complex imaging techniques includes computed tomography (CT), and cone beam computed tomography (CBCT).

Multiple factors influence the selection of radiographic techniques for a particular case including cost, availability, radiation exposure, and patient's anatomy.

The goals of imaging are:

1. To measure bone height and width (bone dimensions).
2. To assess bone quality.
3. To determine the long axis of alveolar bone.
4. To identify and localize internal anatomy.
5. To establish jaw boundaries.
6. To detect any underlying pathology.

As in the case of all imaging techniques, appropriate selection criteria must be applied before selecting one which is most suitable for each patient.

Intraoral radiography:

Intraoral radiography used is either periapical or occlusal radiography. It is usually done to determine the vertical height of bone, **bone architecture, and bone quality**. Intraoral radiography is recommended for the use of single-tooth implants.

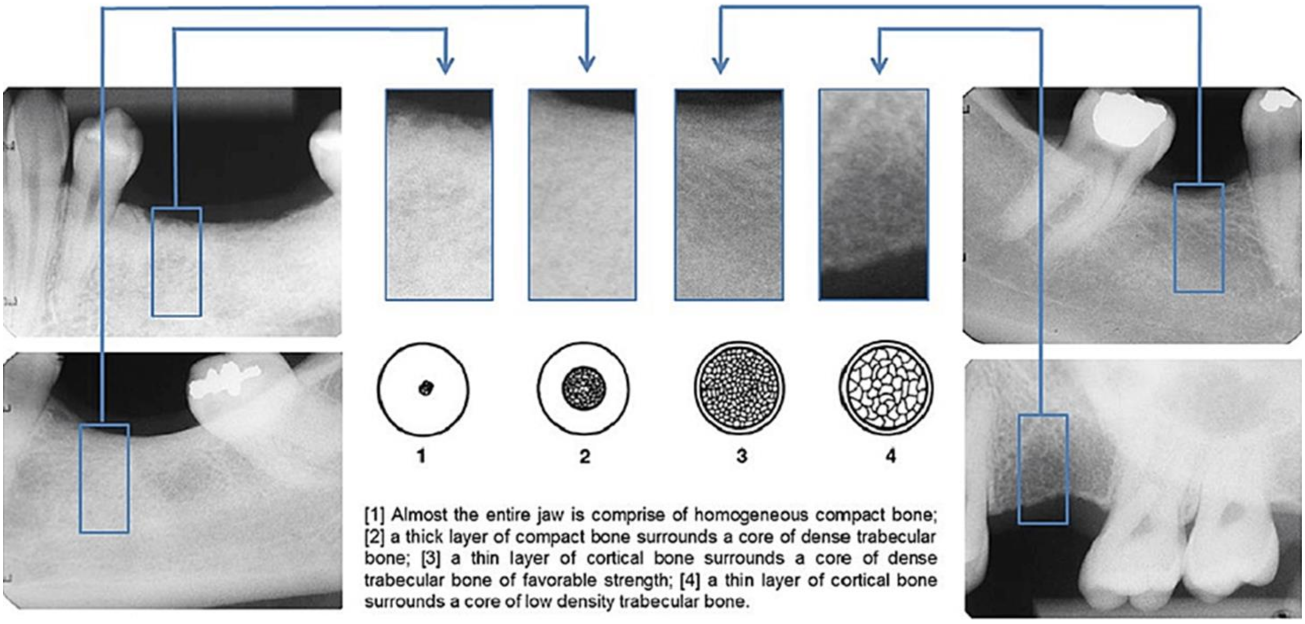


Figure 1. Jawbone site radiographic images according to Lekholm and Zarb's bone classification. **Type 1** = large homogenous cortical bone; type 2 = thick cortical layer surrounding a dense trabecular bone; type 3 = thin cortical layer surrounding a dense trabecular bone; **type 4** = thin cortical layer surrounding a sparse trabecular bone).

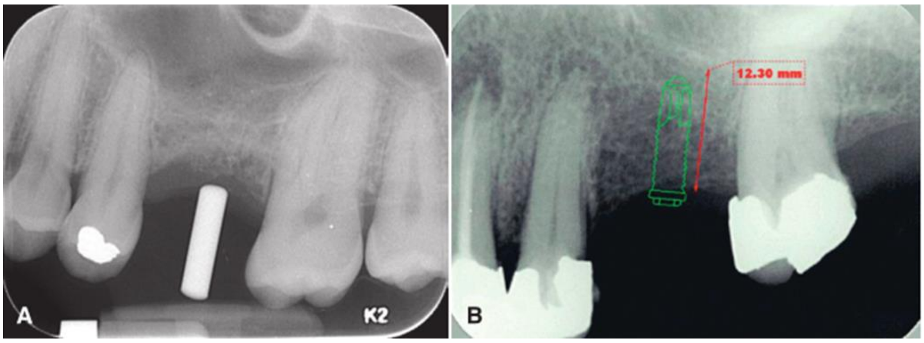


Figure 2. Intraoral periapical radiographs of a potential implant site. **A**, Imaging guide/stent may be used to indicate the desired axis of insertion. **B**, Digital overlay

library allows simulated implant placement as well as measurements in the two-dimensional plane.

The disadvantages of using intraoral periapical radiography for placing dental implants:

1. There is limited area of exposure; it can be used only in case of single-tooth implant.
2. There is foreshortening and elongation of the image which results due to anatomical variation.
3. It is very difficult to reproduce the same image as the technique is not standardized.

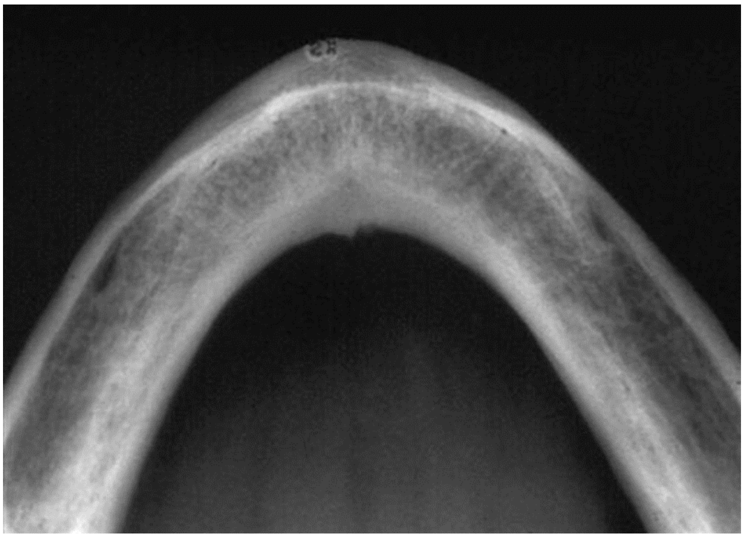


Figure 3. Intraoral mandibular cross-sectional occlusal radiograph depicts the maximal buccolingual dimension of the mandible but not the residual alveolar ridge.

Panoramic radiograph:

In comparison with the intraoral radiography, panoramic radiography has got advantage of broader visualization of the image. But in case of panoramic radiography, sharpness and resolution is less.

Panoramic radiography is also helpful in preliminary estimation of bone height and position of inferior nerve canal. It is usually indicated when implant is planned for more than one teeth.

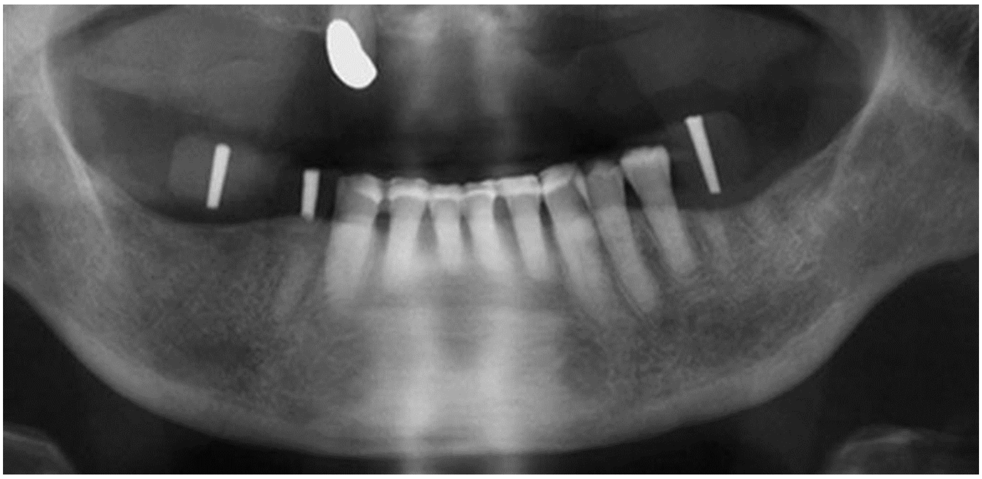


Figure 4. Cropped portion of panoramic radiograph with imaging guide/stent in place to indicate the desired axis of insertion at three mandibular sites.

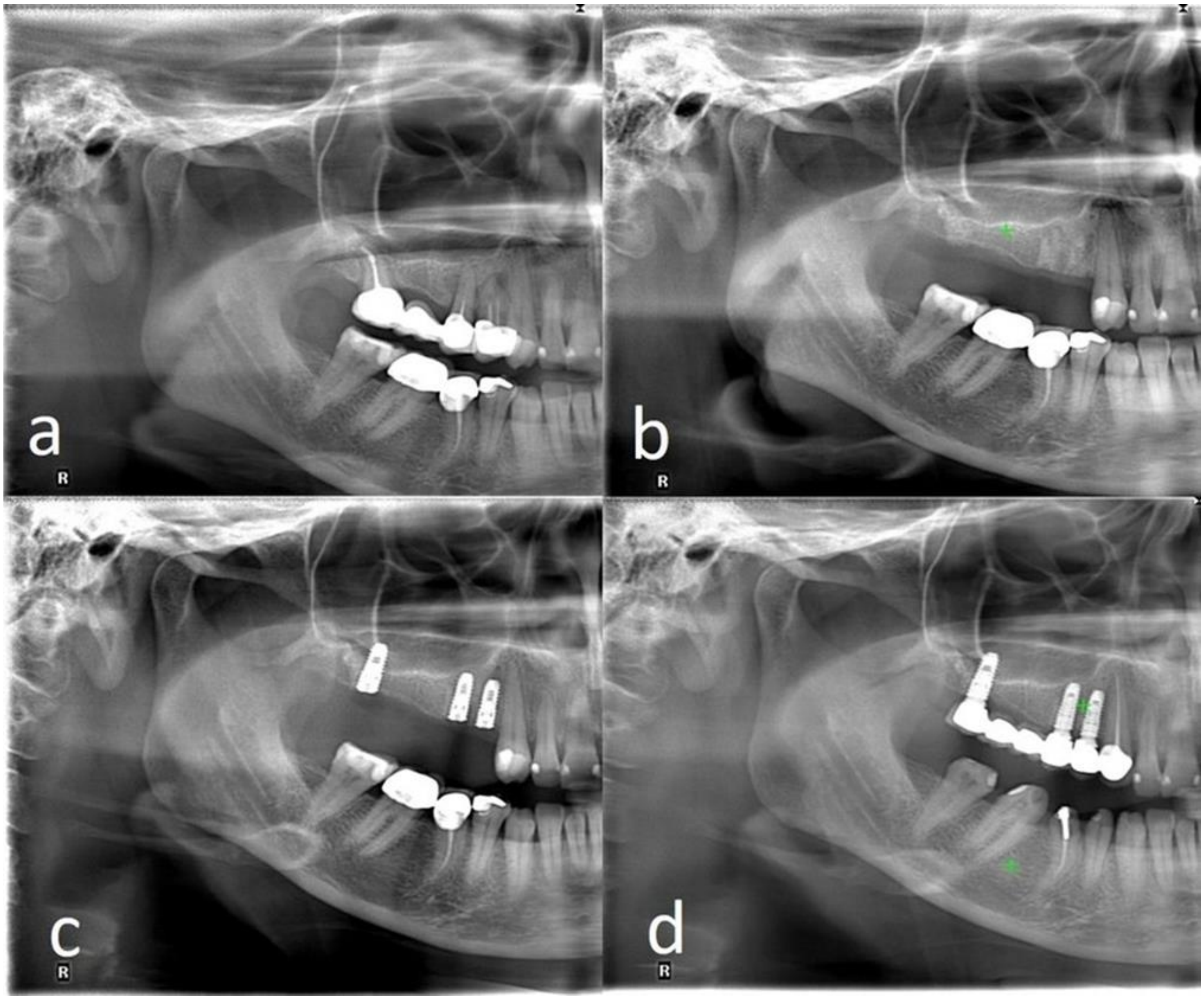


Figure 5. Planning implant surgery on panoramic radiographs: (a) Before extraction of the right maxillary posterior teeth; (b) Nine months after extraction of the teeth.

Alveolar bone healing and bone quality is evaluated for implant surgery; (**c**) After the implant surgery. The positions of the dental implants relative to the maxillary sinus and the adjacent tooth; (**d**) Nine months after implant surgery. Evaluation of the fixed prosthetic restoration and success of the implants.

The disadvantages of using panoramic radiography for placing dental implants:

1. It has got image size distortion, foreshortening and elongation.
2. Dimensional accuracy in the case of panoramic radiography is also limited due to superimposition of various structures.
3. Horizontal image magnification with panoramic radiographs can be twice the actual size.

CBCT imaging in dental implant:

CBCT is the most accurate radiographic means for dental implant planning. It allows for complete 3D evaluation of bone architecture with high accuracy and can be used for standardized estimation of bone quality.

According to the available literature, CBCT imaging is not required in cases in which the clinical examination reveals sufficient bone width. Where standard radiographic examination reveals adequate bone height and space for implant placement.

However, many clinical situations demand additional CBCT examination for optimal preoperative implant planning.

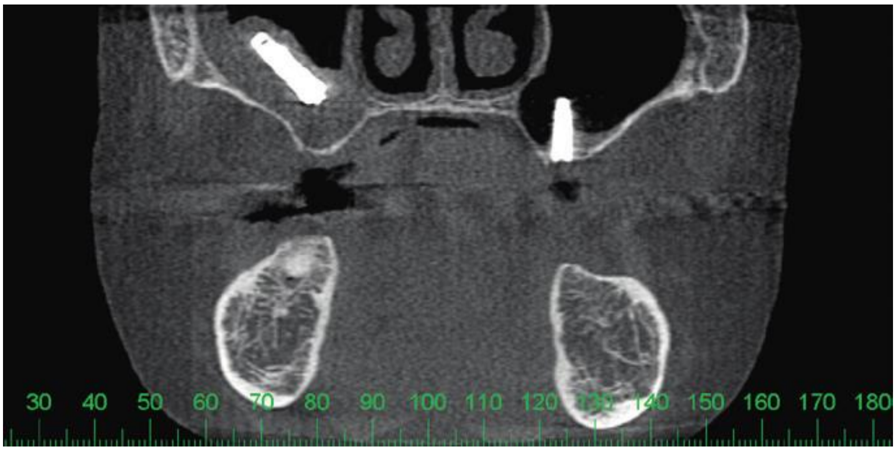


Figure 6. Reformatted CBCT study for postoperative assessment of an implant displaced into the right maxillary sinus and associated with mucositis in the

right antrum. The implant on the left alveolus is not well supported by bone and extends well into the antrum.

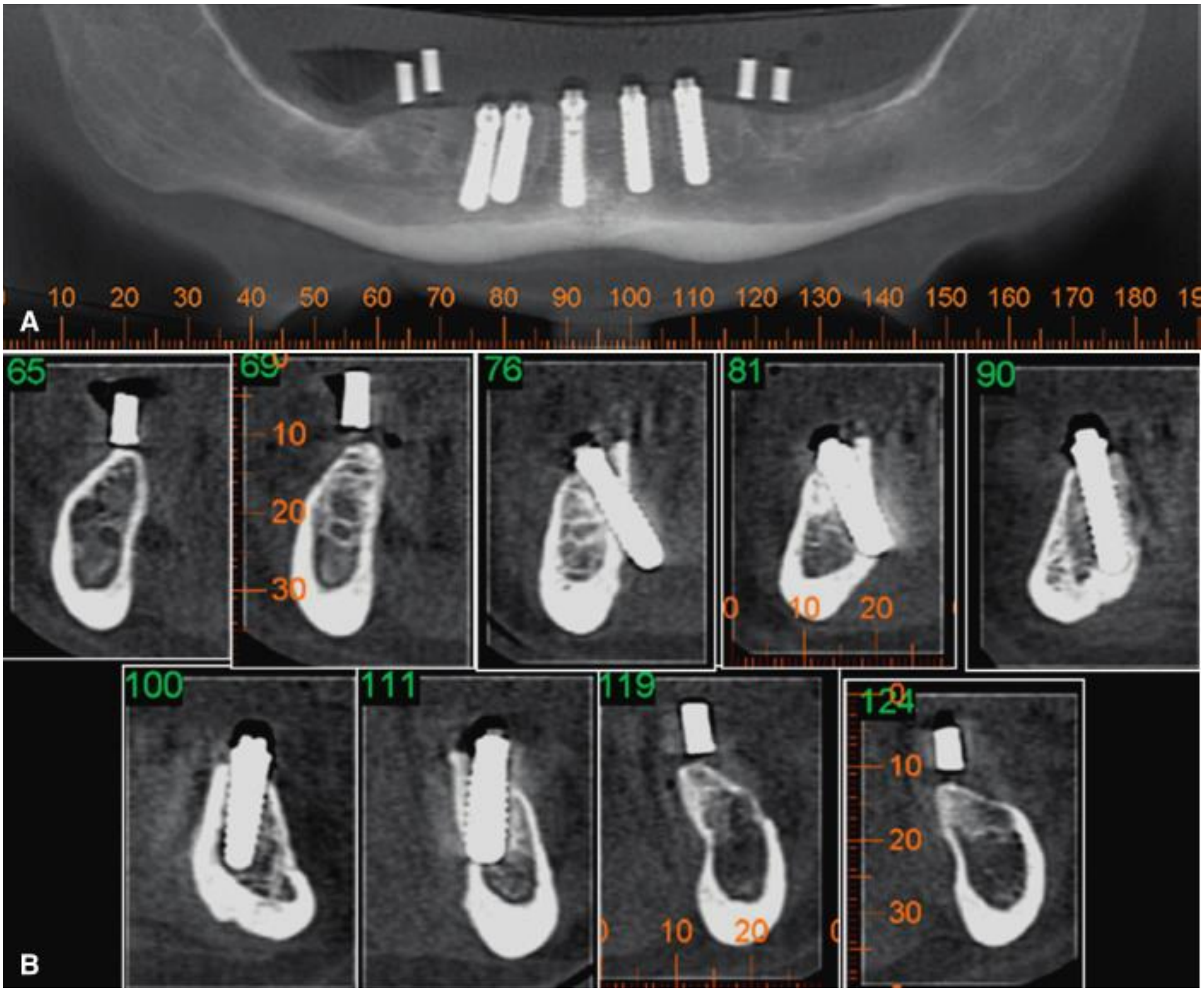


Figure 7. A, Pseudopanoramic reformatted CBCT image initially made to evaluate new implant sites as well as the existing implants. In this image, the existing implants appear reasonably normal in orientation. B, Cross-sectional reformatted CBCT images reveal nonrestorable ectopic placement of the existing implants with lingual cortical perforation and extension into the lingual tissues.

Imaging modality is useful in three phases:

Phase 1:

Pre-prosthetic implant imaging: Imaging in this phase determines the quantity, quality, and angulation of bone; relationship of critical structures to prospective implant sites; and the presence or absence of disease at the proposed surgical sites.

Phase 2:

Surgical and interventional implant imaging: Imaging in this phase evaluates the surgical sites during and immediately after surgery, assists in the optimal positioning and orientation of dental implants, and ascertains the healing and integration phase of implant surgery.

It also ensures appropriate abutment positioning and prosthesis fabrication.

Phase3:

Post-prosthetic implant imaging: This phase commences just after placement of the prosthesis and continues as long as the implant remains in the jaw.

Imaging in this phase evaluates the long-term change, if any defect in the implant's fixed position and function, including the crestal bone levels around each implant, and evaluates the status and prognosis of the dental implant.

It also helps to routinely assess the bone adjacent to the dental implant to note any changes in mineralization or bone volume.

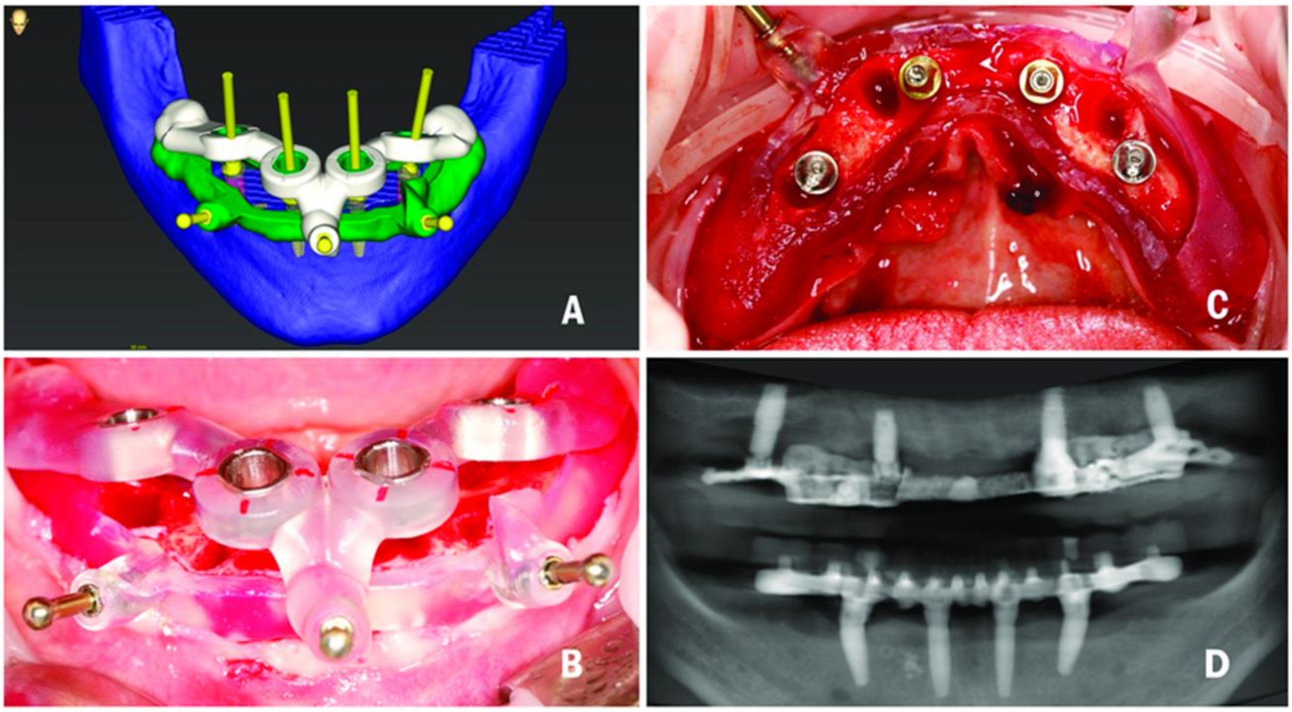


Figure 8. (A) Computer-assisted implant planning; (B) Implant placement surgery; (C) Implants a screw-retained abutments in situ; and (D) Postoperative CBCT.

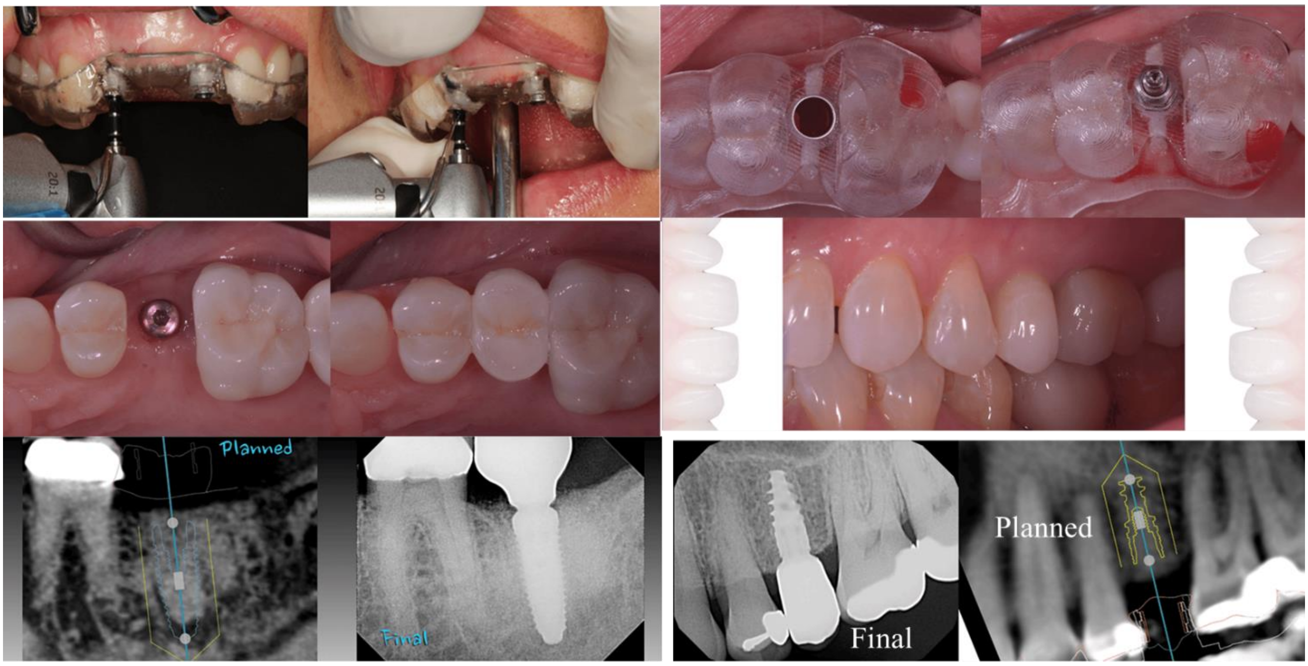


Figure 9. Implants placed through a guided surgery protocol.

Guided implant surgery is the safest, most predictable way of placing dental implants. The patient gets a **digital impression** with a digital scanner and a **CBCT scan** (3D x-ray). This allows the doctor to view the patient in a 3D realm and properly plan the surgery. On the computer, the surgeon can place the implant digitally all knowing the ideal position of the tooth. Any problems can be foreseen and the doctor can practice the surgery a few times before doing it on the patient. Once the ideal position is decided, the doctor can 3D print a guide which allows the doctor to place the implant in the ideal position. The guide looks like a mouthguard that has a hole in it in the perfect position for the implant. Every step of the surgery is done through the guide and ensures the best possible outcome of the surgery.

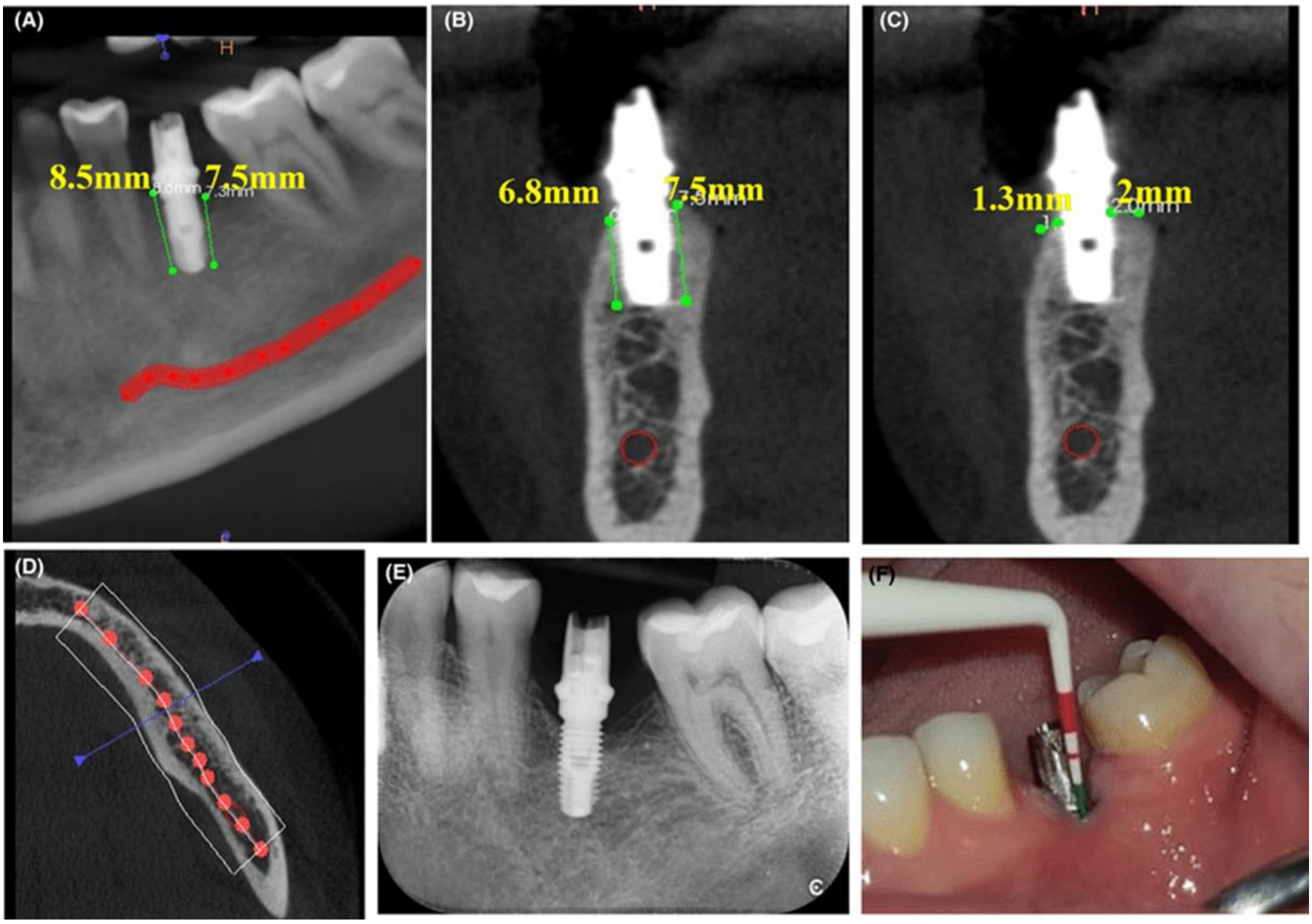


Figure 10. (A) The CBCT imaging of a peri-implantitis case showing bone healing in mesiodistal view, (B,C) buccolingual (cross sectional) view around dental implant, (D) axial view, (E) intraoral periapical radiograph of implant site, (F) pocket depth around the implant 1 year after treatment.

Lecture 24

Salivary gland imaging

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

Anatomy and outline of salivary imaging:

The parotid, submandibular and sublingual glands are regarded as major salivary glands and have bilaterally symmetric lobes.

The parotid gland (the largest salivary gland) is situated at the parotid space. The gland is divided into deep and superficial lobes by branches of the facial nerve. The duct of salivary secretion is known as Stensen's duct that runs anteriorly on the superficial portion of the masseter muscle and pierces the buccinator muscle.

The submandibular gland is located mainly in the so-called mandibular triangle. The secretory duct is known as Wharton's duct that runs on the surface of the mylohyoid muscle and opens at the anterior portion of the floor of the mouth.

The sublingual gland is located under the mucosal surface of the oral cavity and lies on the mylohyoid muscle.

The duct of Rivinus, also known as the minor sublingual duct, drains saliva from the sublingual gland into the floor of the mouth. Despite its name, it is not a single duct, but numerous small ducts all of which open into the floor of the mouth and are collectively termed the duct of Rivinus.

Occasionally, the anterior part of the sublingual gland is drained by a single larger duct, termed the major sublingual duct (duct of Bartholin) which opens together with the submandibular duct at the sublingual papilla at the base of the frenulum of the tongue.

{The gland has many small ducts known as 'ducts of Bartholin' that open directly on the mucosal surface of the floor of the mouth.}

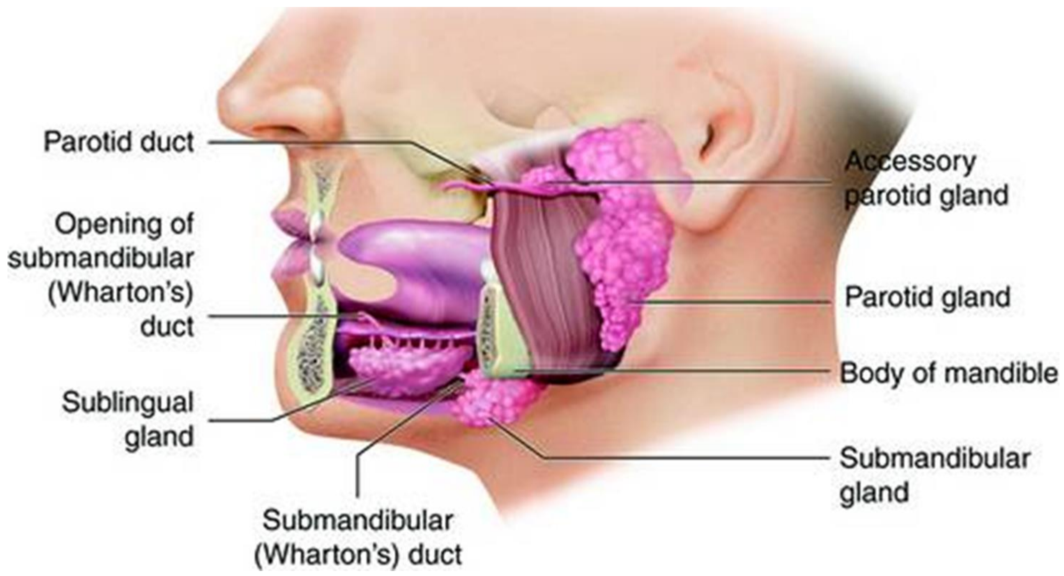


Figure 1. Anatomy and outline of major salivary glands.

Types of salivary glands imaging:

1. **Conventional imaging (CR):** This includes occlusal, panoramic or posteroanterior (PA) views.
2. **Sialography:** It is defined as a method of radiographic study of the salivary gland and alveoli of the parotid and submandibular salivary glands. However, the visualization of the sublingual gland ducts is not considered because it is difficult to visualize the very thin and short ducts, as seen in anatomy textbooks.
3. **CBCT imaging** is useful in evaluating structures in and adjacent to salivary glands but cannot resolve differences in soft tissue densities.
4. **Computed tomography (CT):** It demonstrates small differences in soft-tissue radiographic examination and distinction between gland and the adjacent soft tissues is greatly improved.
5. **Magnetic resonance imaging (MRI):** It is useful in discrete swelling of salivary glands and provides excellent soft-tissue details. It readily enables differentiation between the normal and the abnormal.

6. **Ultrasonography (USG):** It involves the transmission of energy into the salivary tissues, receiving of the energy after the tissues have reflected it and recording it so that it can be presented for interpretation.

Conventional radiography:

Mainly views taken in CR are occlusal, panoramic, and lateral oblique and PA views.

It is generally limited to detection of sialoliths, primarily in submandibular gland, Stensen's duct and Wharton's duct.

Sialoliths occur more frequently in submandibular gland than in parotid gland. They can rarely be seen in sublingual or minor salivary gland.

A sialolith of the submandibular gland usually appears as a round, isolated radio-opaque mass beneath the inferior border of the mandible.

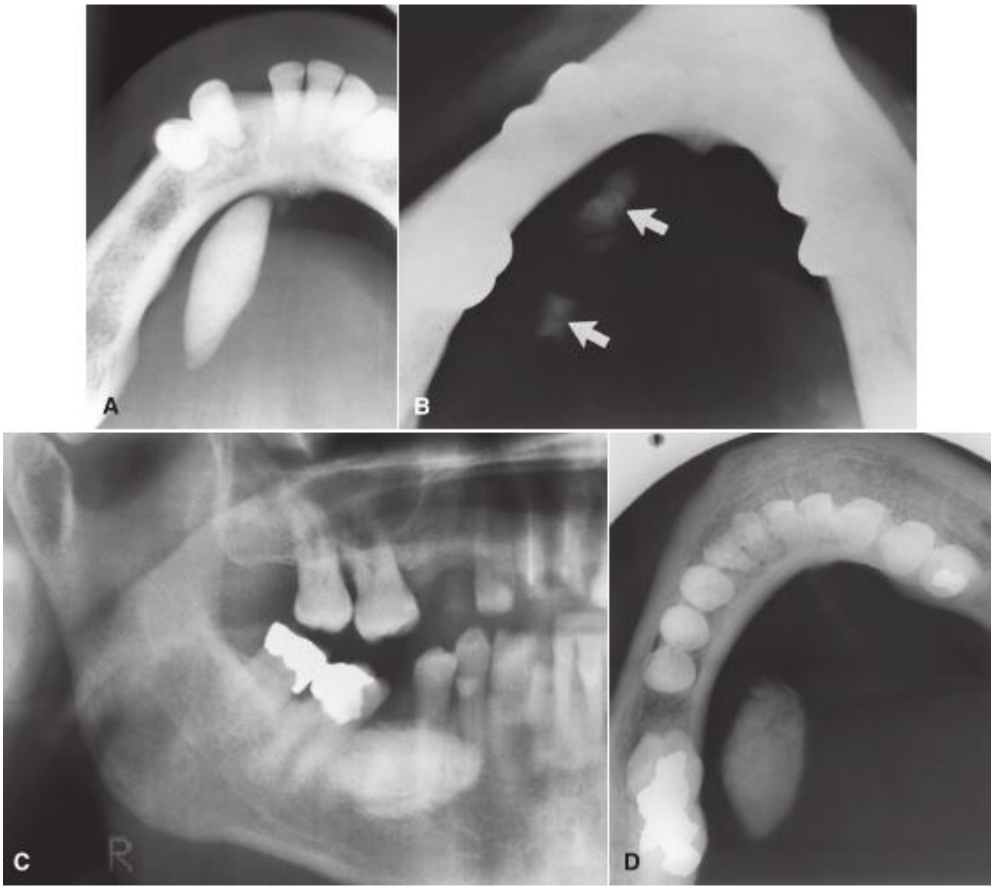


Figure 2. A and B, standard occlusal projections of single and multiple examples of calcified sialoliths (arrows) in the duct of the submandibular gland. Exposure times have been reduced to better show these calcifications, which are less calcified than

lower jaw. C, in another example, the sialolith is superimposed over the mandibular alveolar process in this cropped panoramic image picture. D, occlusal view of the same case described in C.

Sialography:

Sialography is a radiographic procedure for detection and monitoring salivary gland disease.

It is used to examine the ductal acinar system of major salivary gland by injecting radio-opaque contrast medium into the gland to make it visible on radiographs.

After injection of contrast agent, radiographs are taken on **plane film**. **The lateral oblique** is best to delineate submandibular gland because it projects image below the ramus of jaw.

For parotid gland, **anteroposterior (AP) and panoramic views** can be taken. After sialographic view is taken the catheter should be removed from duct orifice. Patient is instructed to chew gum or suck on lemon.

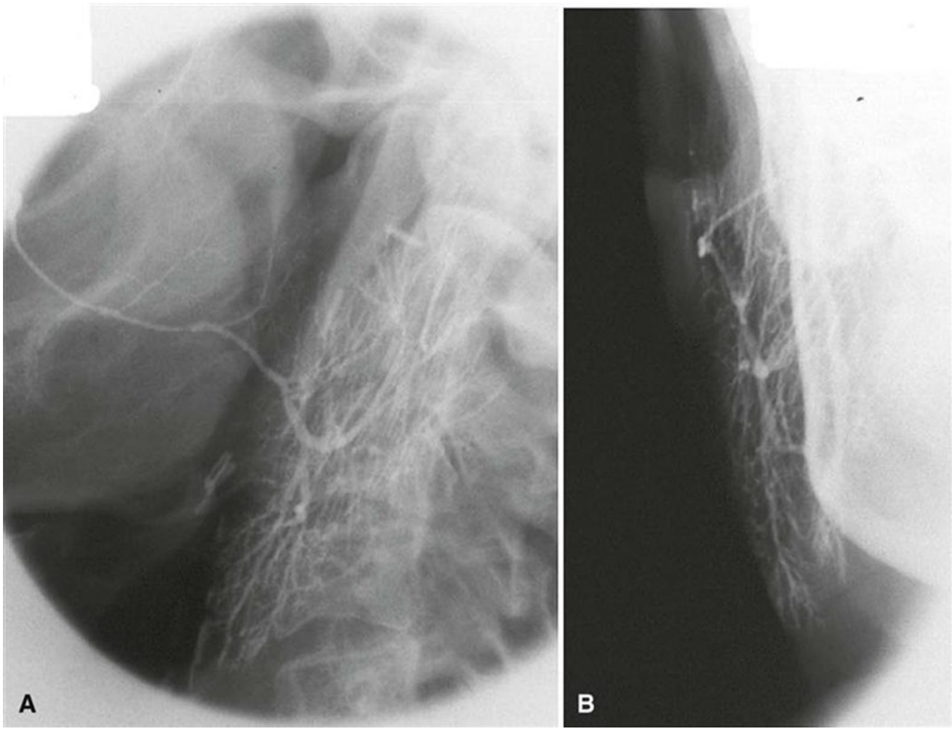


Figure 3. Imaging of the normal parotid gland. A, Lateral projection of the parotid demonstrates opacification all the way to the terminal ducts and acini. B, Anterior-posterior projection of the same gland shows "parenchymal blushing" of acinar opacification.

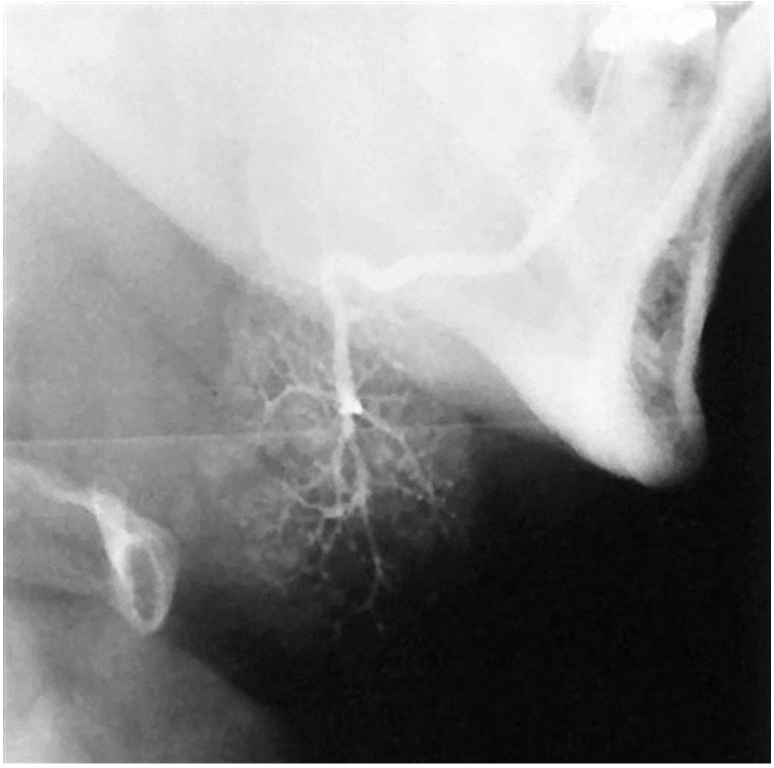


Figure 4. Sialography of normal submandibular gland. Lateral view demonstrates parenchymal blushing. Normal fine branching is visible. Lack of parenchymal blushing at the anteroinferior margin is caused by radiographic burnout.

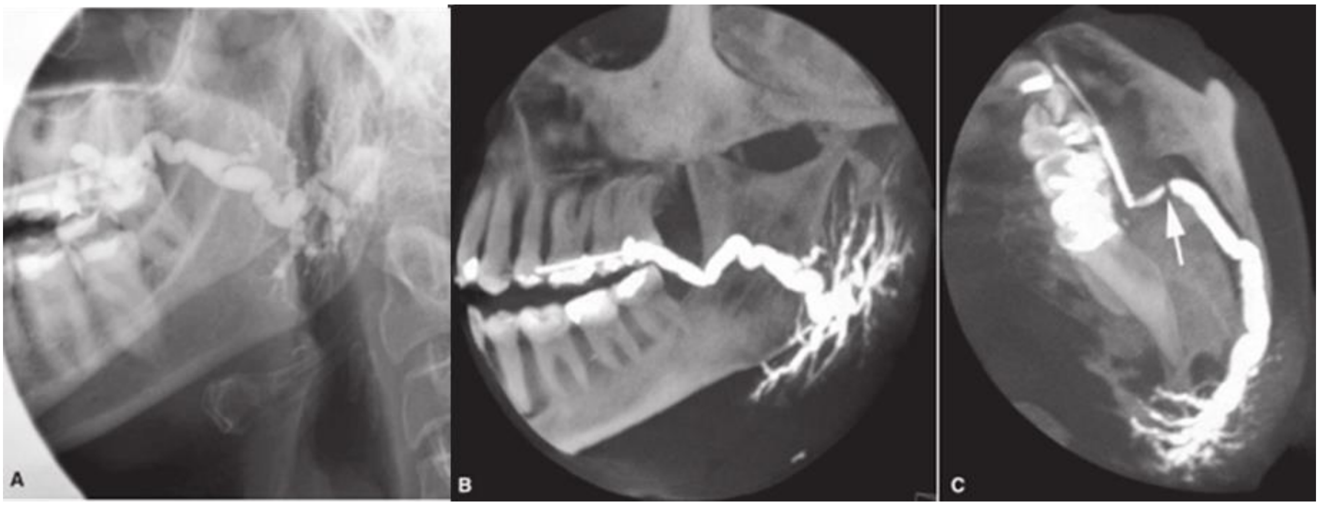


Figure 5. A Conventional sialography of the parotid recorded as a plain lateral projection (A) and on CBCT imaging as lateral (B) and axial (C) renditions. A negative (radiolucent) filling defect (arrow) in the proximal portion of Stensen's duct (C) is not depicted in the lateral plain projection; the defect suggests a minimally calcified sialolith. Prominent intermittent strictures and dilation of the main and secondary ducts are typical of advanced sialodochitis.

Cone-Beam computed tomographic imaging:

Minimally calcified sialolithiasis is well depicted on CBCT imaging. CBCT is useful as a recording modality for conventional sialography, providing three-dimensional visualization of the ductal structure.

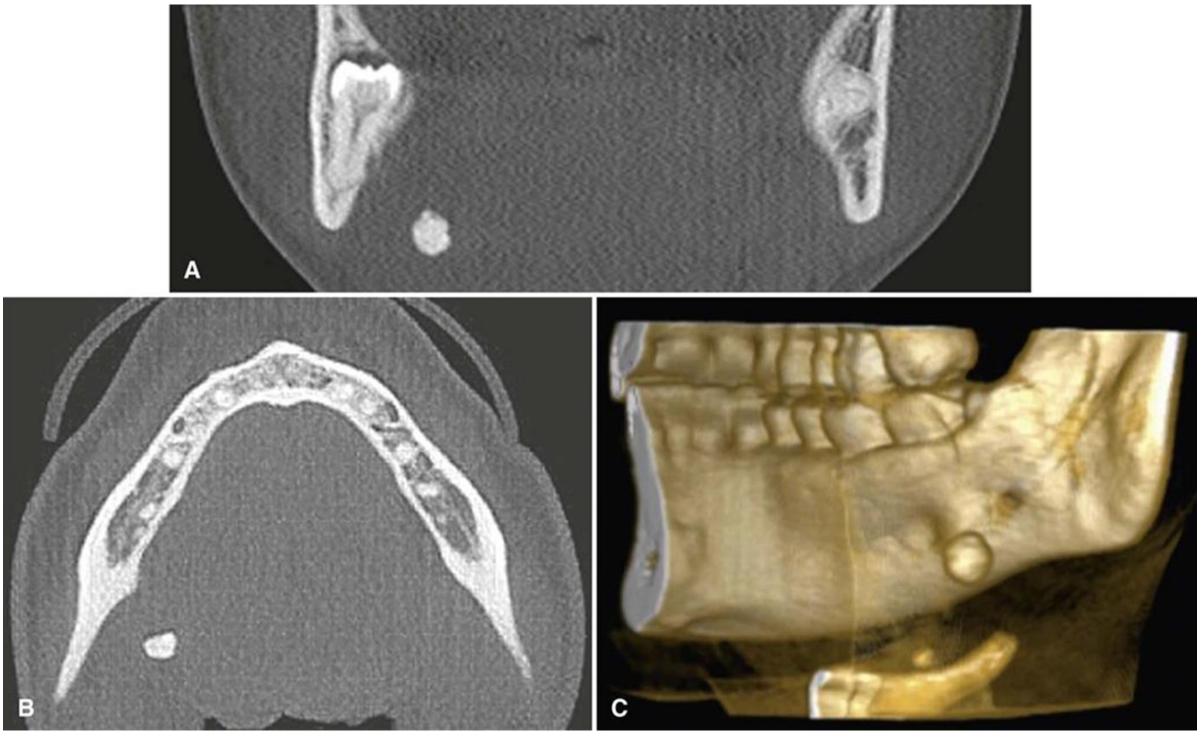


Figure 6. CBCT imaging of a submandibular sialolith. Coronal (A), axial (B), and three-dimensional renditions (C).

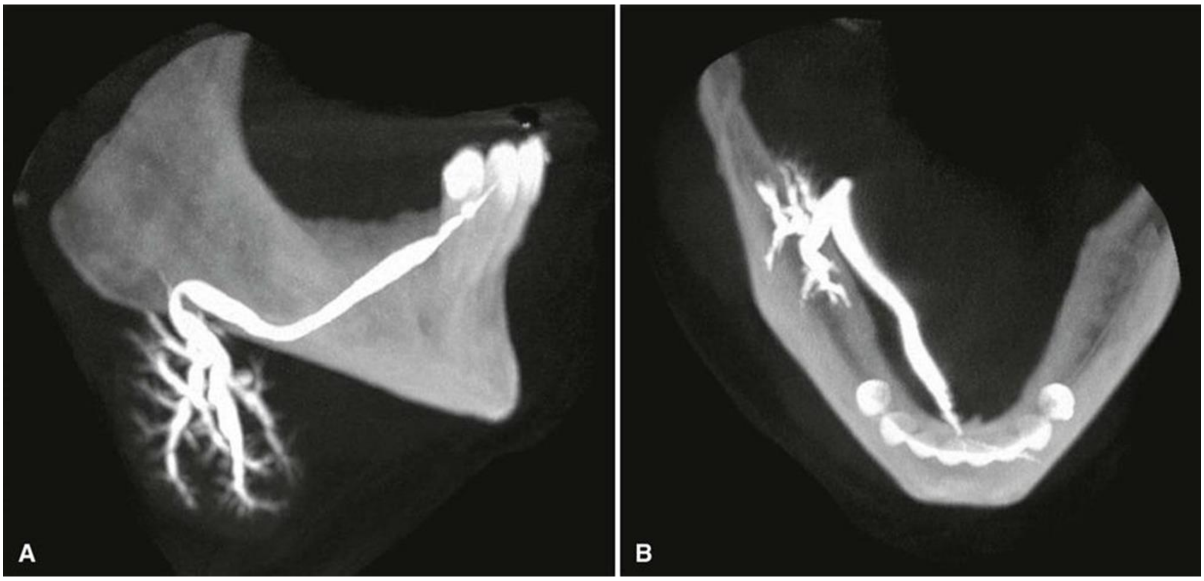


Figure 7. Conventional sialography of a submandibular gland imaged with CBCT imaging. The images are rendered in lateral (A) and axial (B) views.

Computed tomography:

It is valuable in examining salivary gland, particularly after injection of contrast media, i.e. CT sialography.

CT enables the lesions and changes in surrounding structures to be visualized.

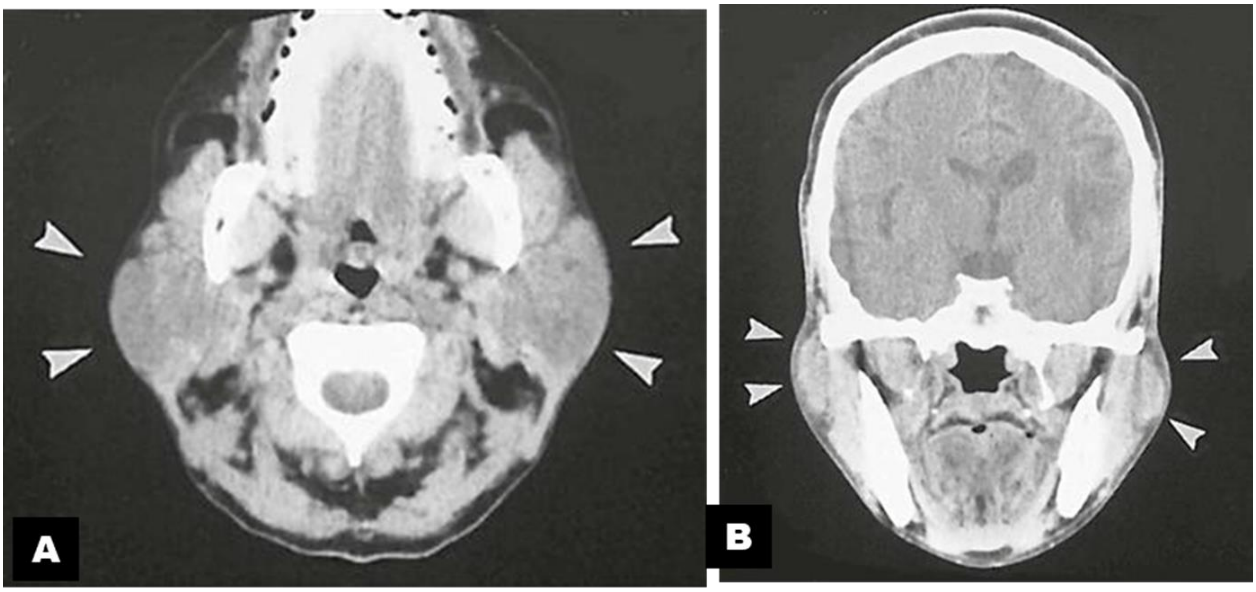


Figure 8. CT images with soft tissue algorithm. A, Axial view demonstrates bilateral enlargement of the parotid glands (arrowheads). B, Coronal view of the same patient. The clinical and histopathologic diagnosis was autoimmune parotitis.

Magnetic resonance imaging:

MRI, like CT, has several advantages over CR for disease localization. The difference between MRI and CT is in tissue differentiation. Because MRI is superior to CT for the tissue differentiation, it is more effective for qualitative diagnosis, such as determining whether a tumour is benign or malignant.

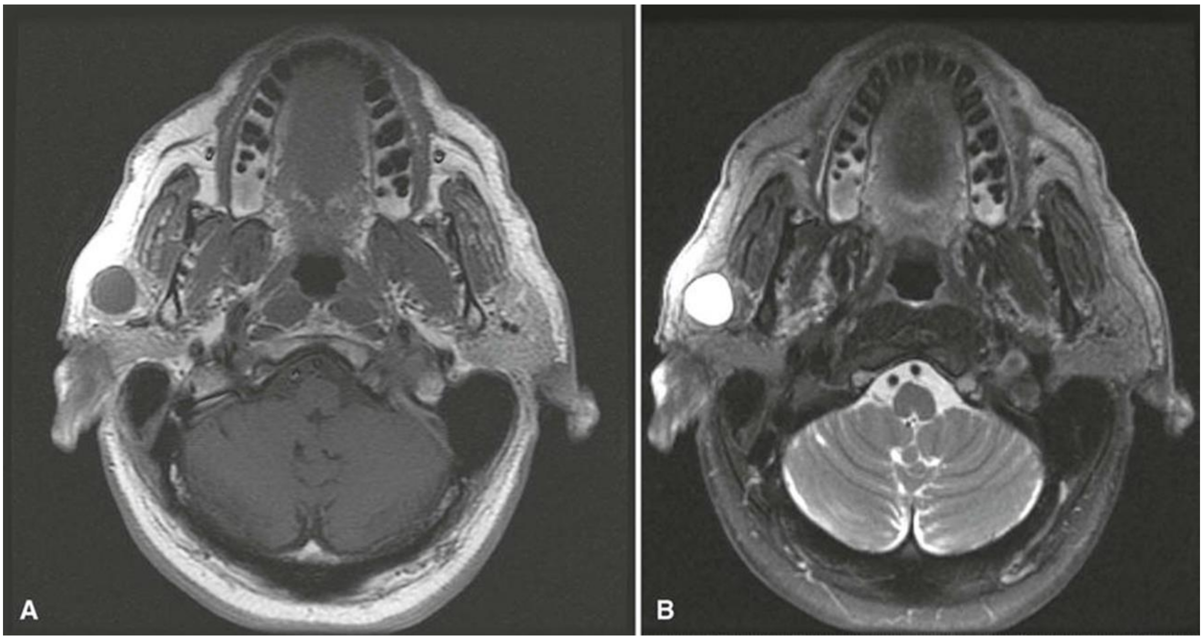


Figure 9. MRI reveal a lymphoepithelial cyst involving the right parotid gland. A, Axial T1-weighted image reveals a well-defined circular lesion involving the right parotid gland with an internal signal isointense to muscle. B, Matching T2-weighted image reveals that the lesion has a high internal signal because of the fluid content.

Normal appearance of parotid and submandibular glands in USG:

Parotid gland appears as a homogeneous hyperechoic area = (radiopaque).

The normal submandibular gland also appears as a homogeneous hyperechoic area relative to the surrounding muscle.

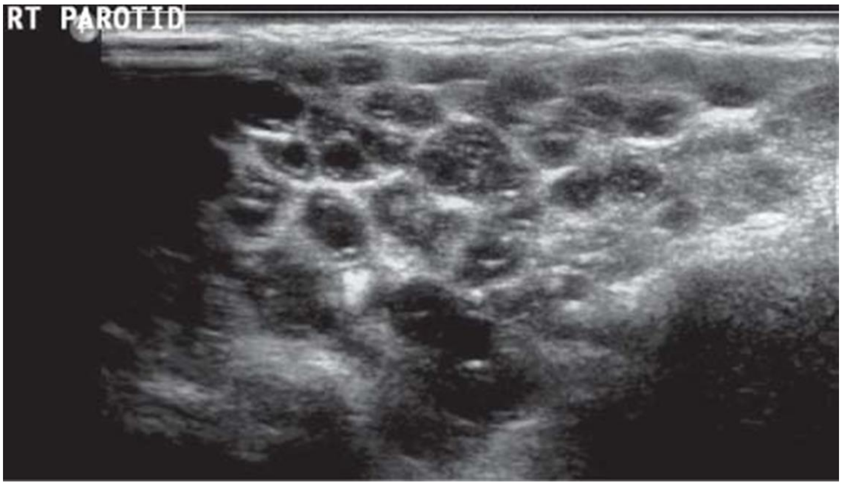


Figure 10. Human immunodeficiency virus lymphoproliferative disorder with multiple hypoechoic/anechoic cysts of varying sizes on longitudinal US of right parotid gland.

Doppler sonography:

Intraglandular blood flow can be demonstrated with doppler sonography.

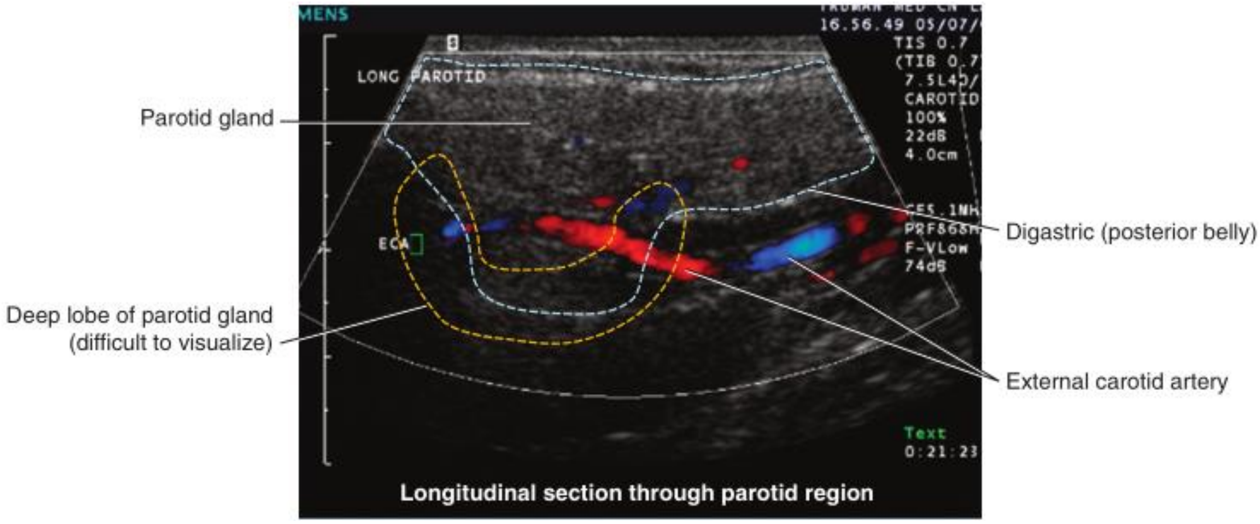


Figure 11. Doppler ultrasound examination. Longitudinal section through the parotid gland, including the deep lobe, and posterior belly of digastric muscle. With Doppler ultrasound, the transducer records small changes in the direction of blood flow. In this image, the external carotid artery is coded red where blood flows toward the transducer and blue where it moves away from the transducer.

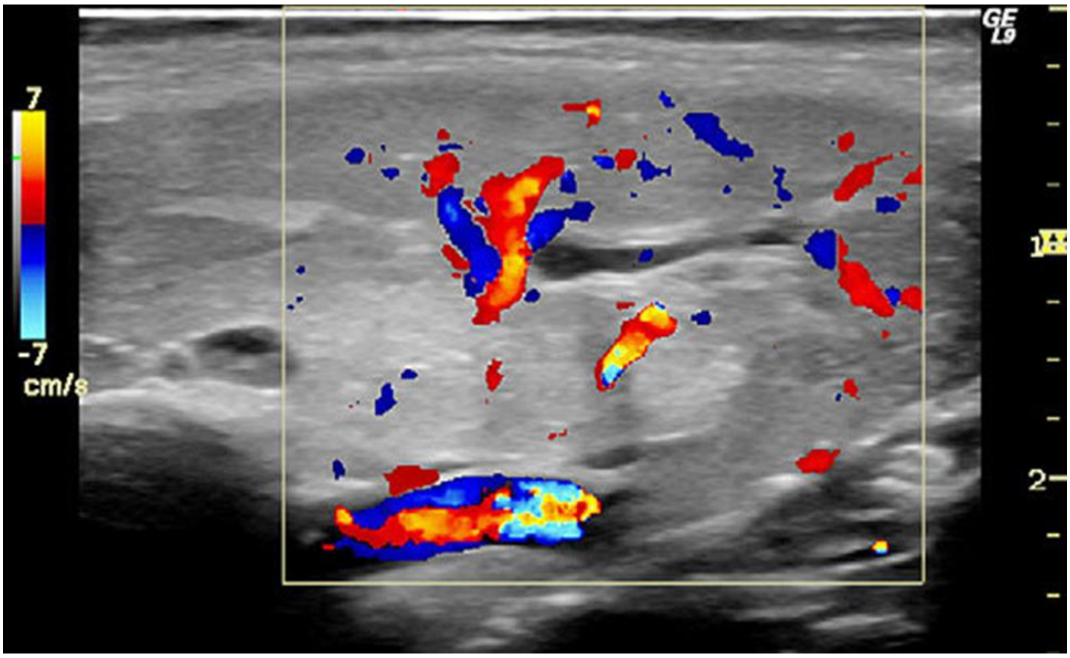


Figure 12. Longitudinal ultrasound of parotid gland. Color Doppler reveals hyperemia. Acute sialoadenitis.

Lecture 25 **Guidelines for Prescribing Radiographs**

By
Mahmood Al-Fahdawi B.S., M.Sc., Ph.D.
Oral Radiology Teacher, Anbar University

Radiographs can only be prescribed by a dentist and only after a clinical examination has been performed to determined which projections are required to give the maximum diagnostic information while follow up radiographs are necessary to judge the treatment outcome.

Patient imaging needs are determined by findings from the dental history and clinical examination and modified by patient age and general health.

It's very important to avoid taking radiographs that will not contribute diagnostic information (according to ALARA). If a patient is complaining of sensitivity to cold, taking a radiograph to examine the periapical area for pathosis is not required because no pathological periapical lucency will be seen in a vital tooth.

As a general principle, radiographs are indicated when a high probability of providing information about a disease that cannot be seen clinically is exist; i.e. the probable benefit to the patient outweighs any possible disadvantage.

The cost of the examination and the radiation dose should be considered when selecting views.

Conventional tomography, CBCT, CT or MRI will often be required to best see the lesions. However, do not request a CT where you feel a panoramic radiograph will be adequate. If one wishes to visualize the disc or position of the disc in the TMJ or soft tissue then MRI is required.

Radiographic examination:

After concluding that a patient requires a radiograph, the dentist should consider which radiographic examination is most appropriate to meet the patient's diagnostic and treatment planning needs. Some patients need simple periapical or panoramic imaging only while other more complicated cases require CBCT or CT or MRI.

The design of the type and scope of the imaging examination should be guided by:

1. The perceived nature or severity of an abnormality (including its size and accessibility).
2. The ability of the imaging technique to accurately reveal the characteristic diagnostic features of the abnormality (sensitivity and specificity).
3. The amount of image detail required (resolution).
4. The radiation dose to the patient.

Guidelines for ordering radiographs:

1. Make radiographs **only after a clinical examination**.
2. Order only those radiographs that **directly benefit the patient's diagnosis or treatment plan**.
3. Use the **least amount of radiation exposure** necessary to generate an acceptable view of the imaged area - ALARA Principle.

Caries:

Buccal, lingual and occlusal caries can be seen clinically. Early interproximal caries can only be seen radiographically. **The rate of caries varies** from person to person. **The rate of caries progression** is more rapid in deciduous teeth. In **carious prone patients** radiograph should be taken every 6-12 months; **in non-caries prone patients** every 18-24 months is adequate.

The best radiographic view for visualizing both interproximal caries and periodontal bone height is bite-wing radiographs.

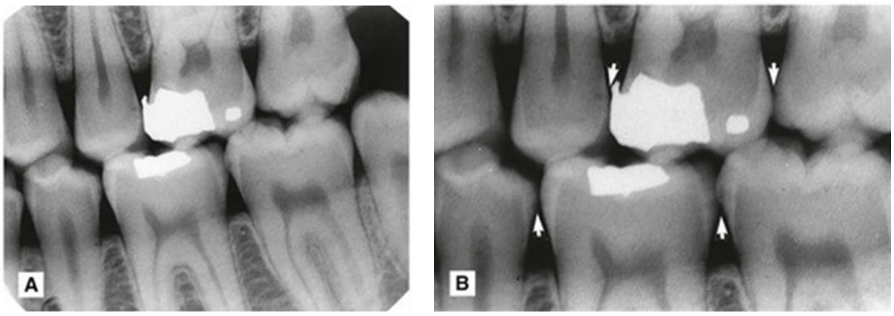


Figure 1. The effect of magnification. **A**, Bitewing radiograph showing almost invisible very early approximal lesions in the molar and premolar teeth. **B**, Magnified central portion of the same bitewing showing the approximal lesions (arrowed) more clearly.

Periapical inflammatory disease:

When patient presents with a toothache, deep caries, or large or deep restoration, the likelihood of an inflammatory lesion of pulpal origin occurring at the tooth apex increased. Radiographs are very helpful in the diagnosis of periapical radiolucencies as they demonstrate the differences between densities of structures.

Clinical examination combined with periapical radiograph is sufficient to make diagnosis and treatment planning. In some cases with [1]complex root canal anatomy, [2]failed endodontic treatment, [3]intra or postoperative complications, or [4]when periapical radiograph doesn't provide adequate information; therefore high resolution, limited volume CBCT may be required.

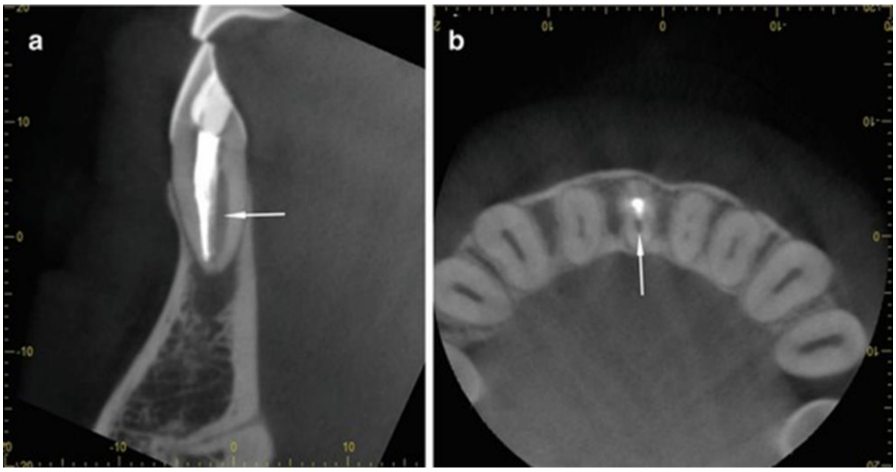


Figure 2. (a) Sagittal and (b) axial slices through the mandibular anterior region. Note the presence of an unfilled canal in the central incisor (arrows). This additional canal should not be confused with artifacts from the radiopaque gutta-percha.

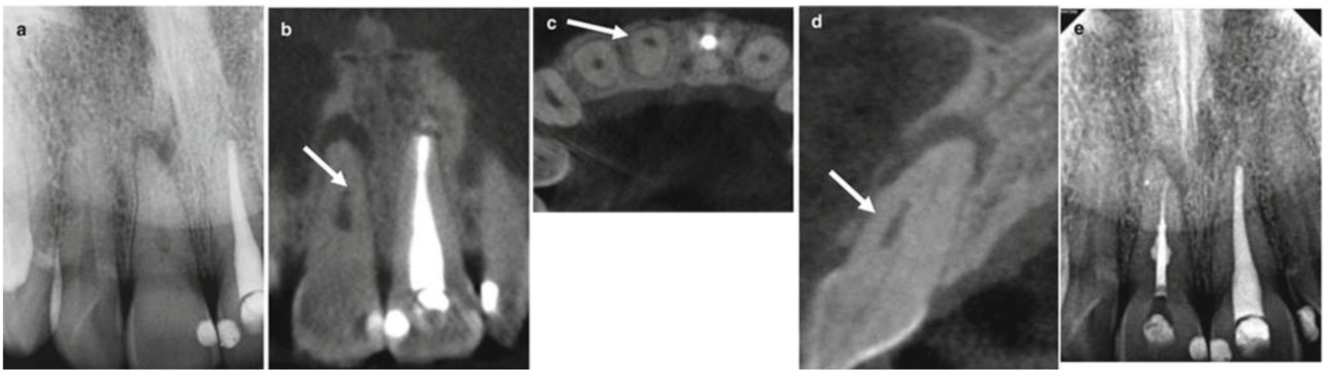


Figure 3. A 39-year-old male presented with a history of trauma to the maxillary anterior region. (a) Periapical radiograph of the maxillary right central incisor reveals an approximately 3–4 mm long, 1 mm diameter, oval, well-defined area of low density

centered mesiodistally, with calcification of the remaining pulp space (arrow); features consistent with internal resorption and canal calcification. CBCT images of the (**b**) sagittal reformation, (**c**) axial reformation, and (**d**) cross-sectional reformation show the location of the resorptive lesion (arrows) and its relationship to the calcified canal. The resorptive lesion was non-perforating, positioned facially, and separate from the pulp space. An area of low density extending facially to the junction of the middle and apical thirds was appreciated. Conventional nonsurgical endodontic treatment was performed (**e**) and the resorptive defect was incorporated into the three dimensional obturation.

Periodontal diseases:

The radiograph is **important and significant** in determining the amount of periodontal involvement. The radiographic examination shows the amount and type of bone loss and also whether it is localized or generalized.

After treatment, follow-up radiographs are important to monitor the progression of the condition. A combination of periapical and bitewing images is required.

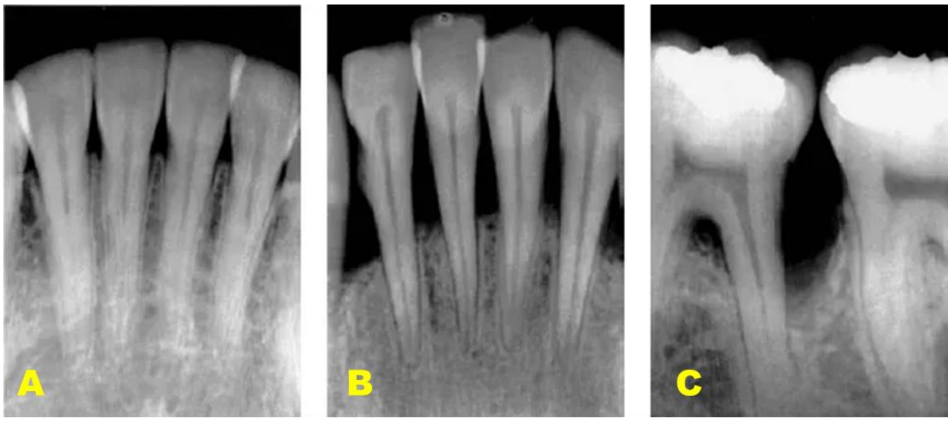


Figure 4. Types of bone loss: **A**, No attachment loss, normal alveolar septa. Lamina dura and alveolar crest remain intact. **B**, Horizontal bone loss, up to 50% loss of interdental septal bone. **C**, Vertical bone loss, furcation involvement, severe bone loss distal to the first molar. The furcation of this tooth is also involved.

Dental Anomalies:

Abnormalities occur **less frequently** in deciduous teeth. The impact of anomalies on the permanent dentition **is more serious**. The most common finding is additional or missing teeth.

Mesiodens is the most common additional tooth. The most common tooth missing is the last one in the series; incisors – the maxillary lateral; premolars - mandibular second; molars - all third molars. The same teeth are also most commonly peg shaped.

A panoramic radiograph is the best view for anatomic anomalies but there is no need for this before the age of about 10 years. Should there be a missing tooth, a periapical or an occlusal view of that area may be required.

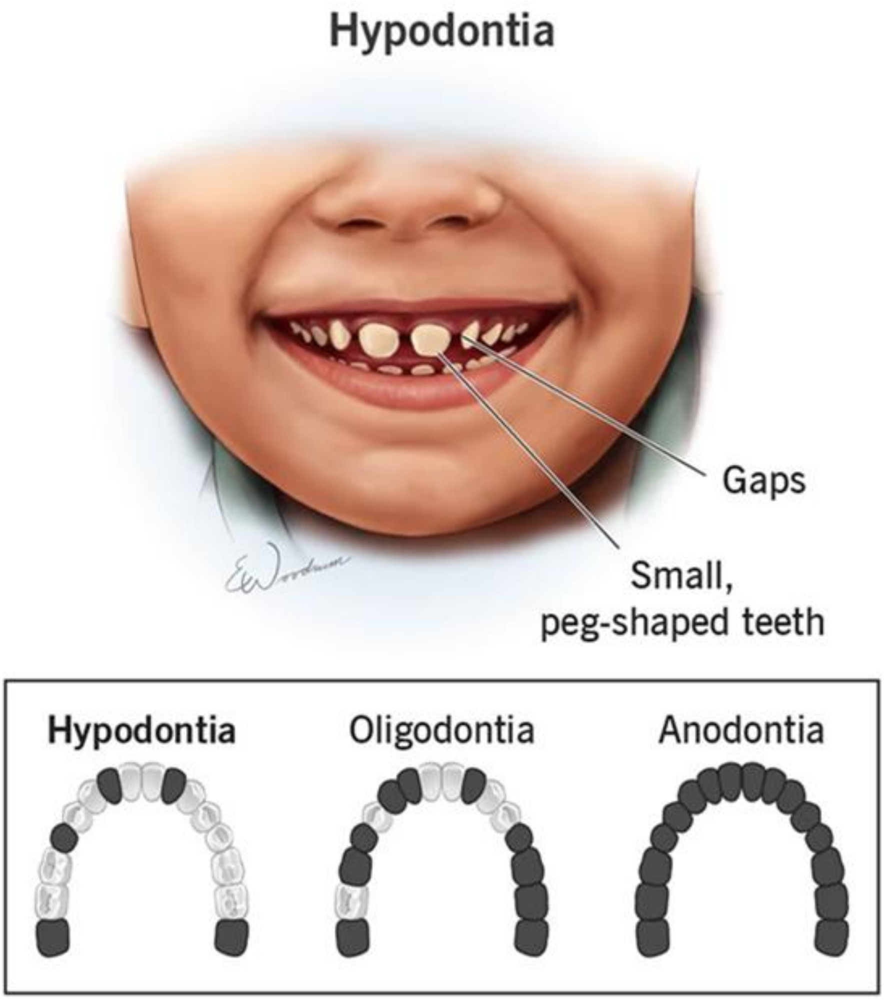


Figure 5. Schematic diagram demonstrating types of congenitally missing teeth.

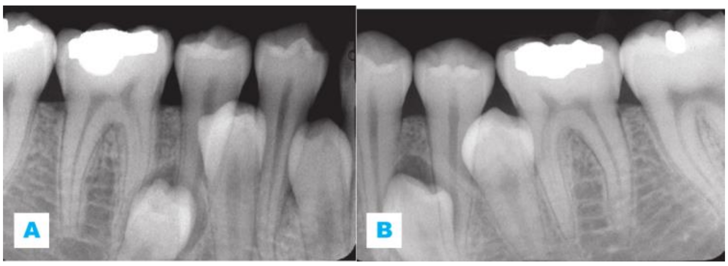


Figure 6. A and B, periapical images show bilateral supplemental premolar teeth (peridens).

Growth, Development and Malocclusion:

A radiographic examination for growth, development and dental malocclusion can involve several different views, depending on what is being examined. These can vary from **periapicals, an occlusal, a CBCT, a panoramic view to a cephalometric and a lateral skull** for orthodontics.

Sinus involvement could require an **occipitomental**; non symmetrical growth of the mandible could require a PA (**posteroanterior**). For impacted teeth, a **panoramic** radiograph is required at the age of about 17-20 years of age for general examination, while **CBCT** required for evaluation of roots relation with inferior alveolar nerve.

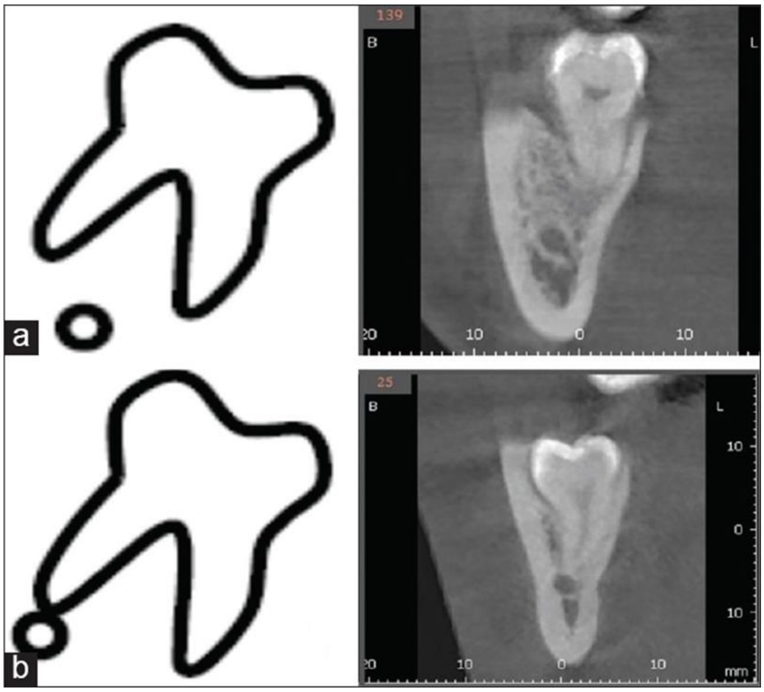


Figure 7. Schematic diagrams with cropped cone beam computed tomography coronal sections showing presence/absence of corticalization between root and inferior alveolar nerve canal. (**a**) Canal located apical to root with presence of corticalization. (**b**) Canal located apical to root with absence of corticalization.

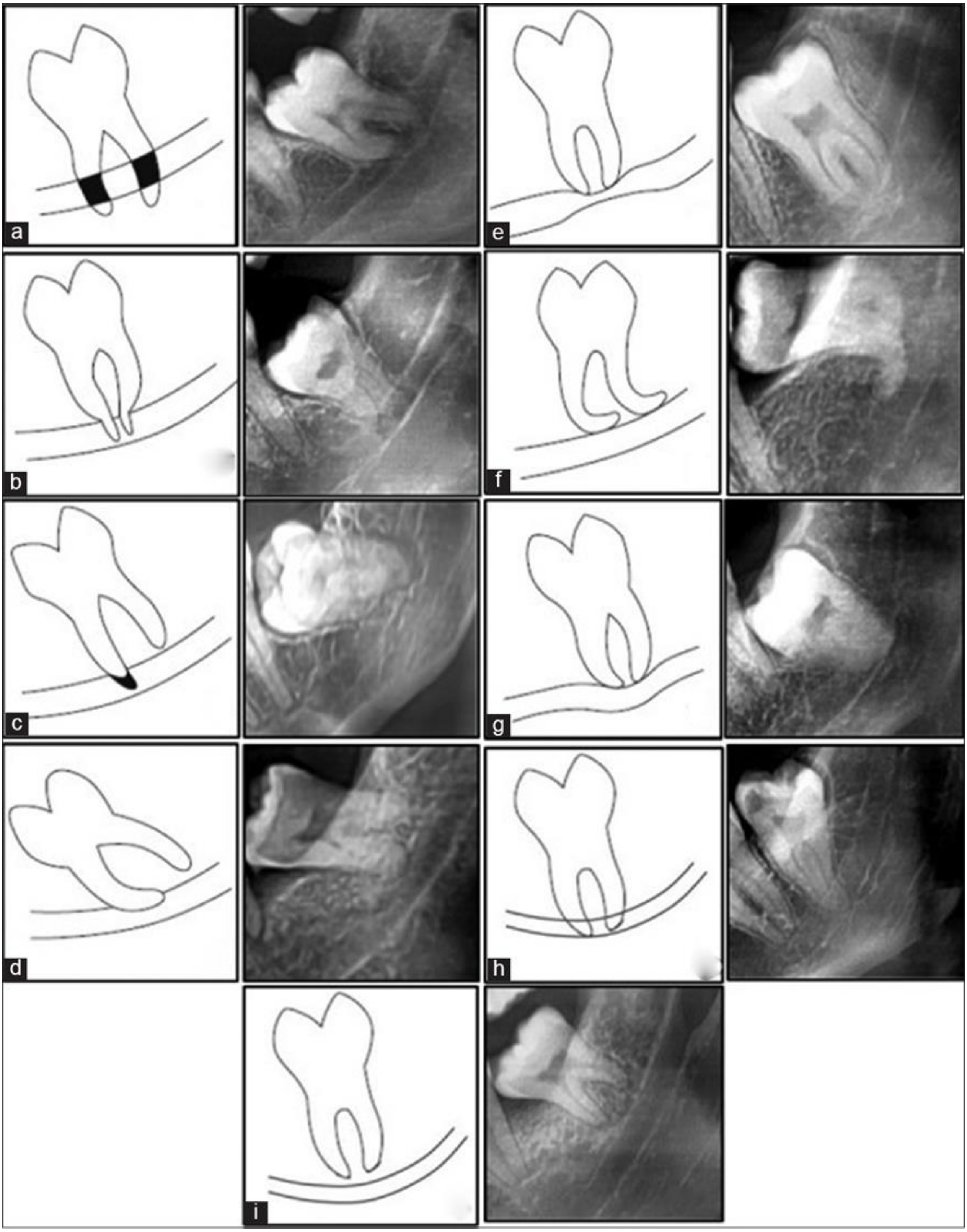


Figure 8. Schematic diagrams with cropped panoramic images showing radiographic signs. (a) Darkening of the root. (b) Narrowing of the root. (c) Dark and bifid apex. (d) Interruption of the white line of the canal. (e) Narrowing of the canal. (f) Deflection of the root. (g) Diversion of the canal. (h) Superimposition. (i) No relation

Occult Disease:

Occult disease refers to a disease process presenting no signs or symptoms; they can be dental or osseous. Dental findings vary from interproximal caries to root resorption, dilaceration, concrescence or hypercementosis. Intra-osseous findings can be impacted teeth, sclerosing/condensing osteitis, idiopathic osteosclerosis, tumors (benign or malignant) and cysts.

In edentulous patients who require dentures, there are often dental or general problems and this requires a **radiographic examination** to exclude occult disease. A clinical exam will determine whether a periapical, an occlusal or a panoramic radiograph is required.

Jaw Pathology:

Imaging of known jaw lesions, such as fibro-osseous diseases or neoplastic diseases, before biopsy and definitive treatment is also important for appropriate management of the patient.

For small lesions of the jaws, periapical or panoramic radiographs may be enough as long as the lesion can be seen in its entirety. If clinical evidence exists of swelling, some type of radiograph at 90 degrees to the original plane (often occlusal image) should be made to detect evidence of expansion of the jaw and perforation of the buccal or lingual cortical bone.

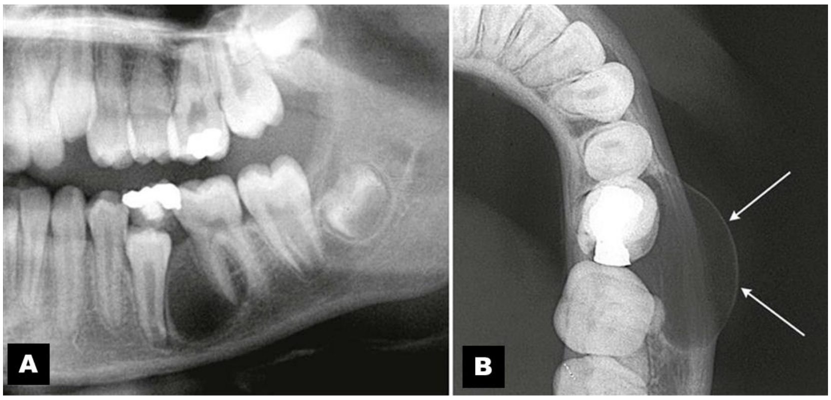


Figure 9. **A** and **B**, Two images of a radicular cyst originating from a nonvital deciduous second molar show expansion of the buccal cortical plate to a circular or hydraulic shape (arrows in B) and displacement of the adjacent permanent teeth.

If lesions are too large to fit on standard dental films, extend into the maxillary sinus or other portions of the head outside the jaws, or are suspected of malignancy, additional imaging such as CBCT or computed tomography (CT) is appropriate. These types of imaging can define the extent of the lesion, provide excellent bone details and provide information about the nature of the lesion.

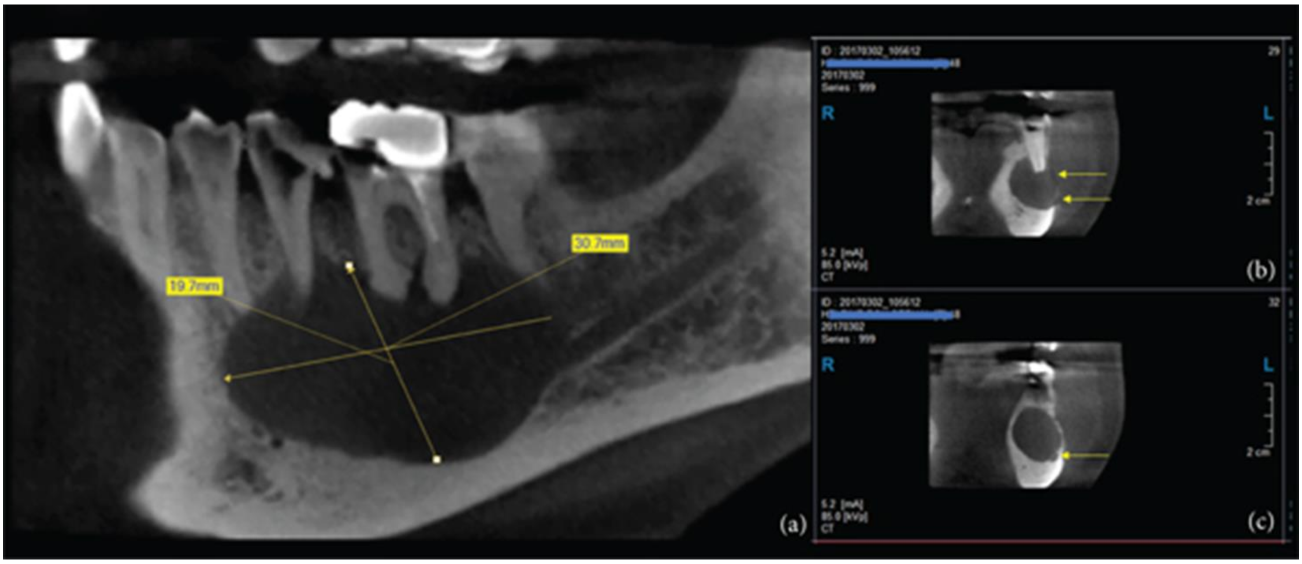


Figure 10. CBCT reconstruction of the left mandible. (a) The sagittal reconstruction with the approximative measurement of the bone destruction (30.7 mm × 19.7 mm). (b) Para-axial cut showing the discontinuity of the buccal cortical bone. (c) Para-axial cut showing the position of the mandibular canal.

Temporomandibular Joint:

A wide variety of diseases affect the TMJ, including congenital and developmental malformations of the mandible and cranial bones; acquired disorders such as disc displacement, neoplasms, fractures, and dislocations; inflammatory diseases including rheumatoid arthritis and osteoarthritis.

The goal of TMJ imaging should be to obtain new information that will influence patient care. Radiologic examination may not be needed for all patients with signs and symptoms referable to the TMJ regions, particularly if no treatment is contemplated.

The decision of whether and how to image the joints should depend on the results of the history and clinical findings, the clinical diagnosis, and results of prior examinations, as well as the tentative treatment plan and expected outcome. The cost of the examination and the radiation dose should also influence the decision if more than one type of examination can provide the desired information. For example, information about the status of the osseous tissues can be obtained from panoramic radiographs, CBCT, CT. while investigation of soft tissue component (disc), magnetic resonance imaging (MRI) is used.

Implants:

Preoperative planning is crucial to ensure success of the implants. The dentist must evaluate the adequacy of the height and thickness of bone for the desired implant; the quality of the bone, the location of anatomic structures such as the mandibular canal or maxillary sinus; and the presence of structural abnormalities such as undercuts that may affect placement or angulation of the implant.

Standard periapical and panoramic radiographs can supply information regarding the vertical dimensions of the bone. However, some type of cross-sectional imaging, like CBCT is recommended before implant placement for visualization of important anatomic landmarks, determination of size and path of insertion of implant, and evaluation of the adequacy of the bone for anchorage of the implant. Also evaluation of implants may be needed at later times to judge healing, complete seating of fixtures, and continued health of the surrounding bone.

Paranasal Sinuses:

Because sinus disease can present as pain in the maxillary teeth and because periapical inflammation of maxillary molars and premolars can also lead to changes in the mucosa of the maxillary sinus, the dentist needs to obtain an image of the maxillary sinus.

Sometimes sinus imaging is required to assess the need for bone augmentation or sinus lift before implant placement in posterior maxilla.

Periapical and panoramic radiographs demonstrate the floor of the maxillary sinus well, but visualization of other walls requires additional imaging techniques such as occipitomental (Waters') view, CBCT or CT.

Figure 11. (**a**) Waters' view X-ray showing a radio-opaque image at the floor of the left nasal cavity and (**b, c, d**) CT images of the naso-sinus cavities showing a clear center, calcified mass in the left nasal cavity measuring 21 mmx16 mmx13 mm with septum tear, associated with mucosal thickening in the maxillary sinus.

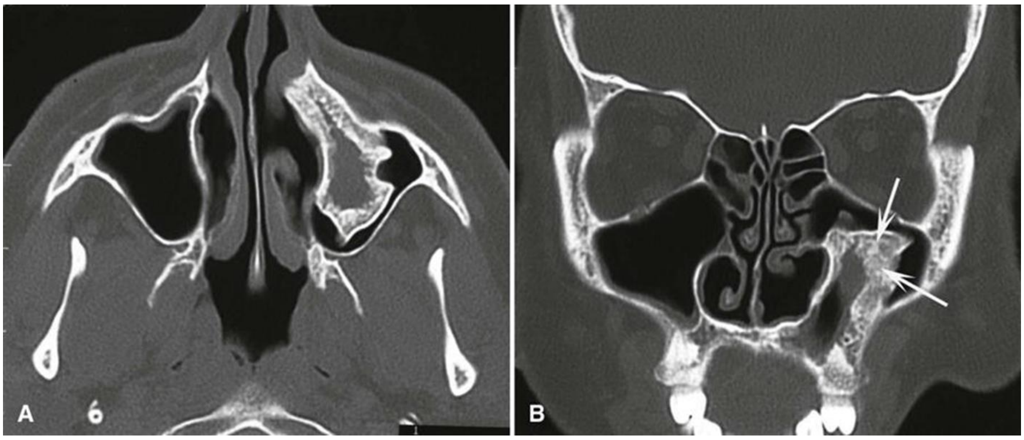


Figure 12. Axial (**A**) and coronal (**B**) CT images with use of a bone algorithm of a collapsing radicular cyst within the sinus. Note the unusual shape and the fact that new bone is being formed from the periphery (arrows in **B**) toward the center.

Salivary glands:

The common clinical indications of salivary gland imaging are pain and swelling. Imaging is useful in identifying the masses of salivary glands and also in differentiating them from the masses/pathologies of adjacent cervical spaces, especially parapharyngeal, masticator, and submental spaces and mandibular lesions.

Conventional radiography, sialography, ultrasonography, computed tomography, magnetic resonance sialography and sialoendoscopy. Digital subtraction sialography and ultrasonography are the methods of choice in the imaging of salivary gland calculi. E.g. Sialectasis (looks like "branchless fruit laden tree appearance" by sialography) is indicative of Sjogren's syndrome.

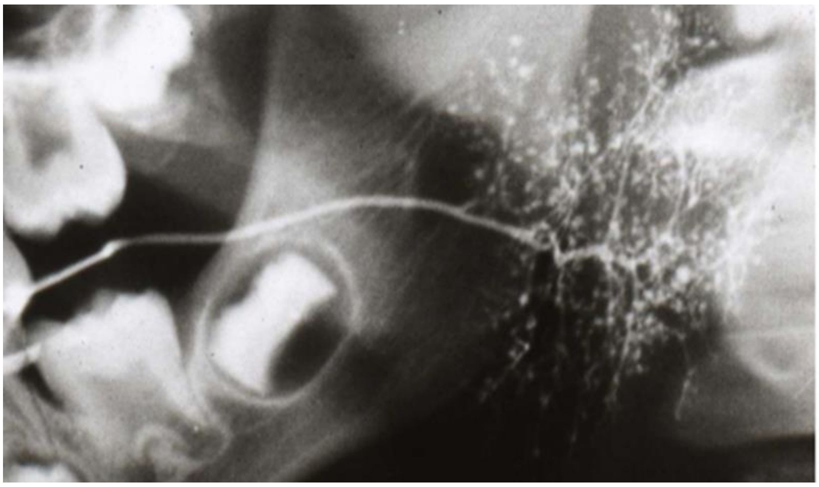


Figure 13. Sialogram of left parotid gland of patient with Sjogren's syndrome (fruit-laden, branchless tree appearance) on a panoramic radiograph.

Trauma:

For patients who experience trauma to the oral region, periapical and/or panoramic radiographs are helpful for evaluation of fractures of the teeth.

If a suspected root fracture is not visible on a periapical radiograph, a second radiograph made with a different angulation may be helpful.

A fracture that is not perpendicular to the beam may not be detectable. CBCT may be useful (if taken without artifact).

Otherwise a tooth **with a history of trauma** but no associated clinical finding should be monitored and evaluated radiographically on a periodic basis.

Fractures of the mandible can frequently be detected with panoramic radiographs, supplemented by images at 90 degrees such as a posteroanterior or reverse Towne's view.

Trauma to the maxilla and **midface** may require CBCT or CT for a thorough evaluation.

Summary of the more common types of radiographic examinations for general dental patients and factors to consider in choosing the most appropriate one (note: the table is required).

TABLE 16-1 Dental Radiographic Examinations and Their Properties

Type of Examination	Coverage	Resolution	Relative Exposure *	Detectable Disease
Intraoral Radiographs				
Periapical	Limited	High	1	Caries, periodontal disease, occult disease.
Bitewings	Limited	High	10	Caries, periodontal bone level.
Full-mouth periapical	Limited	High	14–17	Caries, periodontal disease, dental anomalies, occult disease.
Occlusal	Moderate	High	2.5	Dental anomalies, occult disease, salivary stones, expansion of jaw.
Extraoral Radiographs				
Panoramic	Broad	Moderate	1–2	Dental anomalies, occult disease, extensive caries, periodontal disease, periapical disease, TMJ.
Film tomography/slice	Moderate	Moderate	0.2–0.6	TMJ, implant site assessment.
CBCT imaging	Broad	Moderate to high	4–42	Implant, TMJ, craniofacial relationships, dental anomalies, extent of disease, fracture.
CT/head imaging	Broad	High	25–800	Extent of craniofacial disease, fracture, implants.
MR imaging	Broad	Moderate	—	Soft tissue disease, TMJ.
Skull	Broad	Moderate	30	Fracture, anatomic relation, jaw disease.

Note. The relative exposures assume use of F-speed film and rectangular collimation for periapical films, round collimation for bitewings and occlusal views, and rare-earth screens for panoramic examinations. With D-speed film, the intraoral values are more than doubled compared with F-speed film, and with round collimation the periapical values increase by 2.5 times compared with rectangular collimation.