



LESSON 1 - RADIATION BASICS

BASIC TERMINOLOGY

Remember the basic terminology:

- **Radiology**- The science or study of radiation as used in medicine; a branch of medical science that deals with the use of x-rays, radioactive substances, and other forms of radiant energy in the diagnosis and treatment of disease.
- **Radiation** - a form of energy carried by waves or a stream of particles.
- **X-radiation** - a high-energy radiation produced by the collision of a beam of electrons with a metal target in an x-ray tube.
- **X-ray**: A beam of energy that has the power to penetrate substances and record image shadows on receptors (photographic film or digital sensors)
- **Radiograph** - a two-dimensional representation of a three-dimensional object. In practice, often called an "x-ray"; this is not correct. X-ray is a term that refers to a beam of energy
- **Dental radiograph**- the production of radiographs of the teeth and adjacent structures by the exposure of an image receptor to x-rays.
- **Dental radiographer** - any person who positions, exposes, and processes dental x-ray image receptors.

Other terminologies (from the book):

- **Radiology**: The science or study of radiation as used in medicine; a branch of medical science that deals with the therapeutic use of x-rays, radioactive substances, and other forms of radiant energy
- **Radiography**: The art and science of making radiographs by the exposure of film to x-rays
- **Image**: A picture or likeness of an

object

- **Image receptor**: A recording medium; examples include x-ray film, phosphor plate, or digital sensor
- **Imaging, dental**: The creation of digital, print, or film representations of anatomic structures for the purpose of diagnosis

USES OF DENTAL RADIOGRAPH

- To **detect** lesions, diseases, and conditions of the teeth and surrounding structures that cannot be identified clinically.
- To **confirm** or classify suspected disease
- To **localize** lesions or foreign objects *sometimes when you broke a file (RCT) we can easily locate it using radiograph*
- To provide information during dental procedures. *This can be done prior to dental procedures (RCT, Extraction, Restoration)*
- To **evaluate** growth and development
- To **illustrate** changes secondary to caries, periodontal disease, and trauma *Take the radiograph first before we touch the old restoration (for secondary caries)*
- To **document** the condition of a patient at a specific point in time. *This will serve as a basis of our treatment*
- To **aid** in the development of a clinical treatment plan.
- *Dental Radiographs cannot be used to have final diagnosis, this is just used to supplement our diagnosis*
- *No no to take a radiograph first without seeing or checking the oral cavity of your patient*

DISCOVERY OF X-RADIATION

ROENTGENOLOGY

DRO1 32

2ND SEMESTER | DR. MELODY DECOLONGON

Feb 5, 2026



- **Wilhelm Conrad Roentgen** - a Bavarian physicist, discovered the x-ray on **November 8, 1895**.
- Professor of physics at the University of Würzburg in Germany
- *He discovered the x-radiation using the hittorf-crookes tube*

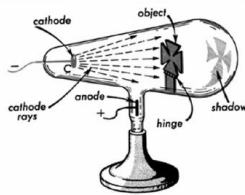


- **Roentgen** placed his wife's hand on a photographic plate and exposed into the unknown rays for **15 minutes**.
- He named his discovery **x-rays**. *Stands for unknown rays*
- He published a **total of three scientific papers** detailing the discovery, properties, and characteristics of x-rays
- In **1901** Roentgen was awarded the first Nobel Prize ever awarded in physics.

1A HITTORF-CROOKES TUBE



William Crookes
(1832-1919)

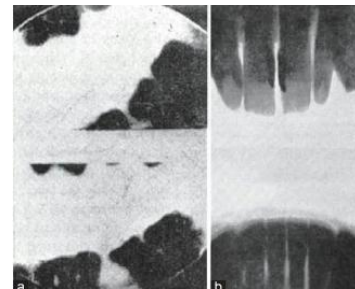


1B ROENTGEN OBSERVATION ABOUT CATHODE RAYS

- 1 The **x-ray** appeared as streams of colored light passing from one end of the tube to the other.
- 2 The **rays did not travel far** outside the tube.
- 3 The **rays caused fluorescent** screens glow.

1C FIRST RADIOGRAPH

OTHER DISCOVERIES



Take note the names; the radiograph in this picture is a type of bitewing radiograph

- **Dr. Otto Walkhoff** - In **January 1896** a dentist in Braunschweig, Germany, made the **first dental use of an x-ray**.
 - a. He used a small glass photographic plate wrapped in black paper and covered with rubber that he placed in his **own mouth** while lying on the floor.
 - b. The exposure time was 25 minutes.



- **February 1896**- a Physicist, **Walter Koenig**, obtained a **clearer image** using only 9 minutes of exposure.
- **Dr. C. Edmund Kells** - a New Orleans dentist, is credited with taking the **first intraoral radiographs** in U.S. in **April 1896**.
- **William Rollins** - developed the **first dental x-ray unit** in **1896**.
- **Dr. Frank Van Woert** - In **1913**, a New York dentist, was one of the first dentists to use and **lecture about the New Kodak dental film** *still exist today and its a quality dental film*
- **Dr. Howard Riley** - was the first to **introduce radiology into the dental school curriculum** at the University of Indiana.
 - He also invented the **dental bitewing**
- **1913** -**William D. Coolidge** invented the **hot-cathode x-ray tube**, which is the prototype of x-ray tubes used today. The hot filament provided a variable source of electrons in the tube and eliminated the need for residual gas as a source for ionization in the tube.
- **1913**-the first American **dental x-ray machine** was manufactured.
- **1923**-the Victor X-ray Corporation, which later became General Electric X-ray Corporation and now Gendex Corporation, **introduced a dental x-ray machine with a Coolidge tube** in the head of the unit cooled by oil immersion. *Masyadong mainit mga machine dati and its not safe to use*

- From **1896 to 1913**, dental x-ray packets consisted of glass photographic plates or film cut into small pieces and handwrapped in black paper and rubber.
- In **1913**, the Eastman Kodak Company manufactured the **first prewrapped intraoral films** and consequently increased the acceptance and use of x-rays in dentistry.
- The **first machine-made periapical film** packets became available in **1920**.
- The films currently used in dental radiography are greatly improved compared with the films of the past. At present, **fast film requires a very short exposure time**, less than 2% of the initial exposure times used in **1920**, which, in turn, reduces the patient's exposure to radiation.

HISTORY OF DENTAL RADIOGRAPHIC TECHNIQUES

- *2 dental techniques: Intraoral and Extraoral*
- The **intraoral techniques** used in dentistry include the bisecting technique, the paralleling technique, and the bite-wing technique. *Remember this*
- The dental practitioners who developed these radiographic techniques include **Weston Price**, a Cleveland dentist, who introduced the bisecting technique in **1904**, and **Howard Riley Raper**, who redefined the original bisecting technique and introduced the **bite-wing technique** in **1925**
 - **Raper** also wrote one of the first dental radiography textbooks in **1913**.
- The paralleling technique was first introduced by **C. Edmund Kells** in **1896**. Later, in **1920**, **Franklin W. McCormack** used the technique in practical dental radiography.
- **F. Gordon Fitzgerald**- the "**father of modern dental radiography**," revived interest in the paralleling technique with

HISTORY OF DENTAL X-RAY FILM



the introduction of the long-cone paralleling technique in **1947** *This is for the safety of practitioner*

- The extraoral technique used most often in dentistry is **panoramic radiography**.
- In **1933**, **Hisatugu Numata** of Japan was the first to expose a panoramic radiograph; however, the film was placed **lingually** to the teeth.
- **Yrjo Paatero** of Finland is considered to be the "**father of panoramic radiography**." He experimented with a slit beam of radiography, intensifying screens, and rotational techniques

HISTORY OF DENTAL IMAGING

- Radiographs have been produced using radiographic film for well over a century. Traditional radiography is being replaced by digital imaging in the dental office, and is one of the most significant advances that has occurred in dentistry. *It is evolving for the safety of the dentist and the patient*
- **Digital imaging** allows for instant and easy transmission of images and electronic storage. *It is also easier to edit and sent the image*
- The capability to **reduce patient exposure to radiation while increasing diagnostic potential** has profound implications. In addition, chemical waste associated with traditional radiography is reduced, which benefits the environment.
- In **1987** (*remember this year*), the technology that is used to support dental digital imaging was introduced in France when the first intraoral imaging sensor was introduced.
- In **1989**, an article describing direct digital imaging technology was first published in U.S. dental literature. Since then, digital imaging technology has become widely accepted and has evolved with

improvements in sensor design and supporting technology.

SUMMARY:

- An **x-ray** is a beam of energy that has the power to penetrate substances and record image shadows on photographic film.
- A **radiograph** is a two-dimensional representation of a three-dimensional object.
- An **image receptor** is a recording medium; examples include x-ray film, phosphor plate, or digital sensor.
- **Dental imaging** is the creation of digital, print, or film representations of anatomic structures for the purpose of diagnosis
- **Disease detection** is one of the most important uses for dental images.
- **Wilhelm Conrad Roentgen** discovered the x-ray in **1895**.
- Following the discovery of the x-ray, numerous investigators contributed to advancements in dental radiography
- **Digital imaging**, one of the most significant advances in dentistry, allows for instant review and transmission of images, reduces patient exposure, and improves the diagnostic potential.

FOR CRAMMING (names ppt) :

- **Wilhelm Conrad Roentgen**- a Bavarian physicist, discovered the x-ray ; Professor of physics at the University of Würzburg in Germany ; published three **scientific papers** detailing the discovery, properties, and characteristics of x-rays; was awarded the first Nobel Prize ever awarded in physics.
- **Dr. Otto Walkhoff**- a dentist in Braunschweig, Germany, made the **first dental use of an x-ray**.
- **Walter Koenig**- a Physicist, obtained a **clearer image** using only 9 minutes of exposure.



- **Dr. C. Edmund Kells** - a New Orleans dentist, is credited with taking the **first intraoral radiographs** in U.S. ; introduced paralleling technique
- **William Rollins** - developed the **first dental x-ray unit**
- **Dr. Frank Van Woert** - a New York dentist, was one of the first dentists to use and **lecture about the New Kodak dental film**
- **Dr. Howard Riley** - was the first to **introduce radiology into the dental school curriculum** at the University of Indiana; also invented the **dental bitewing**
- **William D. Coolidge** invented the **hot-cathode x-ray tube**, which is the prototype of x-ray tubes used today.
- **Weston Price and Howard Riley Raper**- The dental practitioners who developed these radiographic techniques
 - ◆ **Weston Price**, a Cleveland dentist, who introduced the bisecting technique
 - ◆ **Howard Riley Raper**, who redefined the original bisecting technique and introduced the **bite-wing technique** ;also wrote one of the first dental radiography textbooks.
- **Franklin W. McCormack**- used the paralleling technique in practical dental radiography.
- **F. Gordon Fitzgerald**- the "**father of modern dental radiography**," revived interest in the paralleling technique with the introduction of the long-cone paralleling technique
- **Hisatugu Numata**- was the first to expose a panoramic radiograph; however, the film was placed **lingually** to the teeth.
- **Yrjo Paatero** of Finland is considered to be the "**father of panoramic radiography**." He experimented with a slit beam

names sa book :

- **William Crookes** - an English chemist, redesigned the vacuum tube and **discovered that cathode rays** were streams of charged particles. The tube used in Roentgen's experiments incorporated the best features of the Hittorf and Crookes designs and was known as the Hittorf-Crookes tube
- **Heinrich Geissler**- built the **first vacuum tube**, a sealed glass tube from which most

of the air had been evacuated.

- **Johann Wilhelm Hittorf**- , a German physicist, used the **vacuum tube to study fluorescence** (a glow that results when a fluorescent substance is struck by light, cathode rays, or x-rays).
- **Philip Lenard**- discovered that **cathode rays could penetrate a thin window** of aluminum foil built into the walls of the glass tubes and cause fluorescent screens to glow.
- **W. J. Morton**- a New York physician, made the **first dental radiograph** in the United States using a skull. He also lectured on the usefulness of x-rays in dental practice and made the first whole-body radiograph using a 3 × 6 ft sheet of film.
- **William H. Rollins**- a Boston dentist who **developed the first dental x-ray unit**. While experimenting with radiation, Rollins suffered a burn to his hand. This initiated an interest in radiation protection and later the publication of the first paper on the dangers associated with radiation.

TABLE 1-1 Highlights in the History of Dental Imaging

Year	Event	Pioneer/Manufacturer	Year	Event	Pioneer/Manufacturer
1895	Discovery of x-rays	W. C. Roentgen	1978	Introduction of dental xeroradiography	
1896	First dental radiograph in United States (total)	O. Walkhoff	1981	Introduction of E-speed film (Kodak Ektaspeed)	
1896	First dental radiograph in United States (living patient)	W. J. Morton	1987	Introduction of intraoral digital imaging in France	
1901	First paper on dangers of x-radiation	C. E. Kells	1989	Dental tomography scanners become available	
1904	Introduction of bisecting technique	W. H. Rollins	1994	Introduction of Kodak Ektaspeed Plus film	
1913	First dental text	W. A. Price	1995	Introduction of digital sensor for panoramic unit	
1913	First prewrapped dental films	H. R. Raper	1998	Introduction of cone-beam computed tomography (CBCT) for dental use	
1913	First x-ray tube	Eastman Kodak Company	1999	Cone-beam CT scanners available in Europe	
1920	First machine-made film packets	W. D. Coolidge	1999	Oral and maxillofacial radiology becomes a specialty in dentistry	
1923	First dental x-ray machine	Eastman Kodak Company	2000	Introduction of F-speed film (Kodak Carestream Dental INSIGHT)	
1925	Introduction of bite-wing technique	Victor X-ray Corp, Chicago	2001	Cone-beam CT scanners available in the United States	
1933	Concept of rotational panoramics proposed	H. R. Raper			
1947	Introduction of long-cone paralleling technique	H. R. Raper			
1948	Introduction of panoramic radiography	F. G. Fitzgerald			
1955	Introduction of D-speed film (Kodak Ultra-speed)				
1957	First variable-kilovoltage dental x-ray machine	General Electric			

QUIZ QUESTIONS

- Matching
For questions 1 to 9, match each term (a to i) with its corresponding definition.
1. A photographic image produced on film by the passage of x-rays through teeth and related structures.
 2. A beam of energy that has the power to penetrate substances and record image shadows on photographic film.
 3. A form of energy carried by waves or a stream of particles.
 4. Any person who positions, exposes, and processes x-ray image receptors.
 5. The production of radiographs by the exposure of film to x-rays.
 6. A high-energy radiation produced by the collision of a beam of electrons with a metal target in an x-ray tube.
 7. The science or study of radiation as used in medicine.
 8. The production of radiographs of the teeth and adjacent structures by the exposure of image receptors to x-rays.
 9. A two-dimensional representation of a three-dimensional object.
- For questions 10 to 19, match the dental pioneers with their contributions (a to j).

- a. Used paralleling technique in practical dental radiography
 - b. Discovered x-rays
 - c. Developed first x-ray tube
 - d. Introduced bisecting technique
 - e. Exposed first dental radiograph
 - f. Wrote first paper on the danger of x-radiation
 - g. Exposed first dental radiograph in United States (skull)
 - h. Introduced long-cone paralleling technique
 - i. Wrote first dental text; introduced bite-wing technique
 - j. Exposed first dental radiograph in United States (living patient)
10. Coolidge
 11. Fitzgerald
 12. Kells
 13. McCormack
 14. Morton
 15. Price
 16. Raper
 17. Roentgen
 18. Rollins
 19. Walkhoff

- Ordering
Arrange the following in order of discovery from earliest to latest.
20. Introduction of F-speed film
 21. Introduction of D-speed film
 22. Introduction of panoramic radiography
 23. Cone-beam scanners available in United States
 24. Introduction of intraoral digital imaging
 25. Introduction of cone-beam computed tomography

- Essay
26. Discuss the importance of dental images.
27. Summarize the discovery of x-radiation.



LESSON 2 - RADIATION PHYSICS

- The world is composed of matter and energy.
- **Matter** - anything that has mass and occupies space.
 - a. **3 States:** Solid, liquid, and gas
 - b. When matter is altered, energy results.
- **Atom** - the fundamental unit of matter.
- **Bohr-** viewed the atom as a miniature solar system with a nucleus at the center and revolving electrons.

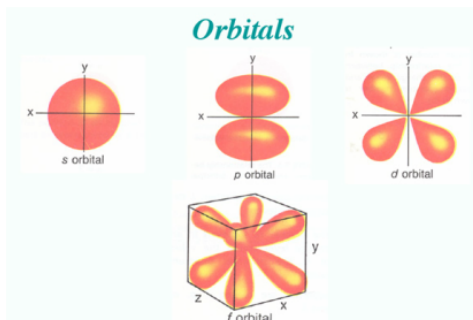
ANATOMIC STRUCTURE

- **Nucleus-** dense core of the atom, is composed of particles known as protons and neutrons. It occupies very little space.
- **Electrons-** tiny, negatively charged particles that have very little mass. Electrons travel around the nucleus in well-defined paths known as orbits or shells.

ELECTRON ORBITALS

2A QUANTUM MECHANICAL MODEL

- describes contemporary understanding of the arrangement of electrons in an atom.
- The previous concept of electrons circling around nuclei in two dimensional orbits has been replaced by the concept of electrons existing in three-dimensional volumes called orbitals



- **Orbitals-** represent the probability locations of the electron in space at any instant in time, the regions in which the electron is most likely to exist.
- Each kind of orbital is characterized by a set of quantum numbers **n, l, and m**. *remember this.*
- The principal quantum number (**n**) describes the size of the orbital, the average distance of the electron from the nucleus.
- The angular momentum quantum number (**l**) describes the shape of the orbital (can never be greater than n-1).
- The letters **s, p,d, f, g, and h** are used to describe orbital shapes and correspond with angular momentum values of **0, 1, 2, 3, 4, and 5**, respectively.

ORBITALS

S-orbital

- The s-type orbital is spherical.
- Are the first to be filled in every element

P-orbital

- Are bilobed and centered on the nucleus.
- Boron is the first element to contain an electron in a p orbital.

D-orbital

- Consist of **four** lobes arranged around the nucleus or they are bilobed with a ring.
- Scandium is the first element to contain an electron in a d orbital.

Magnetic quantum number (m)

- Describes the orientation of an orbital in space. In an atom with many electrons the electrons clouds of oone orbital are uperimposed with those of other orbitals



- No known atom has more than seven orbitals, Only two electrons may occupy an orbital.
- Electrons occupy the lowest energy available orbitals first (lowest principal quantum number then the lowest angular momentum).
- Finally, for the first 18 elements, the orbitals fill up first each of the available orientations (m) one at a time so that their spins are unpaired

ELECTRON BINDING ENERGY OF THE ELECTRON (OR IONIZING ENERGY)

- The amount of energy required to remove an electron from a given orbital must exceed the electrostatic force of attraction between it and the nucleus.
- It is specific for each orbital of each element

REMEMBER:

- Electrons in the 1s orbital of a given element have the greatest binding energy because they are **closest to the nucleus**.
- The binding energy of the electrons in each successively larger orbital decreases.
- For an electron to move from a specific orbital to another orbital farther from the nucleus, energy must be supplied in an amount equal to the difference in binding energies between the two orbitals. In contrast, in moving an electron from an outer orbital to one closer to the nucleus energy is lost and given up in the form of electromagnetic radiation.

IONIZATION

- The production of ions, or the process of converting an atom into ions.

- If such an atom loses an electron, the nucleus becomes a positive ion and the free electron a negative ion.
- To ionize an atom requires sufficient energy to overcome the electrostatic force binding the electrons to the nucleus. The binding energy of an electron is related to the atomic number of the atom and the orbital type

Question: Is ionization good or bad?

NATURE OF RADIATION

- Radiation is the transmission of energy through space and matter. It may occur in two forms: **particulate** and **electromagnetic**

RADIOACTIVITY

- Small atoms have roughly equal numbers of protons and neutrons, whereas larger atoms tend to have more neutrons than protons
- This makes them unstable and they may break up, releasing α or β particles or γ rays. This process is called radioactivity.
- Radioactivity can be defined as the process by which certain unstable atoms or elements undergo spontaneous disintegration, or decay, in an effort to attain a more balanced nuclear state.
- A substance is considered radioactive if it gives off energy in the form of particles or rays as a result of the disintegration of atomic nuclei.
- In dentistry, radiation (specifically x-radiation) is used, not radioactivity.

IONIZING RADIATION

- Can be defined as radiation that is capable of producing ions by removing or adding an electron to an atom.
- Two groups:
 - Particulate Radiation
 - Electromagnetic Radiation



2B PARTICULATE RADIATIONS

- Are tiny particles of matter that possess mass and travel in straight lines and at high speeds.
- Transmit kinetic energy by means of their extremely fast-moving, small masses.

FOUR TYPES OF PARTICULATE RADIATION

- 1 Electrons can be classified as beta particles or cathode rays. They differ in origin only.
 - Beta particles are fast-moving electrons emitted from the nucleus of radioactive atoms.
 - Cathode rays are streams of high-speed electrons that originates in an x-ray tube.
- 2 Alpha particles are emitted from the nuclei of heavy metals and exist as two protons and neutrons, without electrons.
- 3 Protons are accelerated particles, specifically hydrogen nuclei, with a mass of 1 and a charge of +1.
- 4 Neutrons are accelerated particles with a mass of 1 and no electrical charge.

ELECTROMAGNETIC RADIATION

- Electromagnetic radiation can be defined as the propagation of wavelike energy (without mass) through space or matter. The energy propagated is accompanied by oscillating electric and magnetic fields positioned at right angles to one another, thus the term electromagnetic (book).
- Electromagnetic radiations are man made or occur naturally; examples include cosmic rays, gamma rays, x-rays, ultraviolet rays, visible light, infrared light, radar waves, microwaves, and radio waves.

- Quantum theory considers electromagnetic radiation as small bundles of energy called photons. Each photon travels at the speed of light and contains a specific amount of energy.
- The unit of photon energy is the electron volt (eV), the amount of energy acquired by one electron accelerating through a potential difference of 1 volt (1.602×10^{-19} joules). The relationship between wavelength and photon energy is as follows: $E = h \times c / \lambda$ *no computation just familiarize yourself with this*
- where E is energy in kiloelectron volts (keV), h is Planck's constant (6.626×10^{-34} joule-seconds or 4.3×10^{-18} keV), c is the velocity of light, and λ is wavelength in nanometers. This expression may be simplified to the following: $E = 1.24 / \lambda$
- Electromagnetic radiations are believed to move through space as both a particle and a wave; therefore two concepts, the **particle concept and the wave concept**, must be considered.

2C PARTICLE CONCEPT

- The particle concept characterizes electromagnetic radiations as discrete bundles of energy called photons, or quanta.
- Photons are bundles of energy with no mass or weight that travel as waves at the speed of light and move through space in a straight line, "carrying the energy" of electromagnetic radiation.

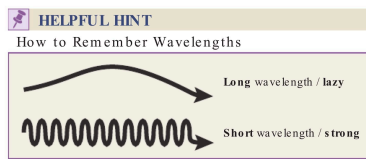
2D WAVE CONCEPT

- The wave concept characterizes electromagnetic radiations as waves and focuses on the properties of velocity, wavelength, and frequency, as follows:
 - **Velocity** - refers to the speed of the wave. All electromagnetic radiations travel as waves or a continuous sequence of crests at



the speed of light (186,000 miles per second) in a vacuum.

- **Wavelength** can be defined as the distance between the crest of one wave and the crest of the next. It determines the energy and penetrating power of the radiation; the shorter the distance between the crests, the shorter is the wavelength and the higher is the energy and ability to penetrate **matter**.
- Wavelength is measured in nanometers for short waves and in meters for longer waves
- Frequency refers to the number of wavelengths that pass a given point in a certain amount of time.
- Frequency and wavelength are inversely related.



X- RADIATION

- Is a high-energy, ionizing electromagnetic radiation. As with all electromagnetic radiations, x-rays have the properties of both waves (*can penetrate matter*) and particles (*can travel*)
- X-rays can be defined as weightless bundles of energy (photons) without an electrical charge that travel in waves with a specific frequency at the speed of light. X-ray photons interact with the materials they penetrate and cause ionization (book).

PROPERTIES OF X-RAY

- **Appearance:** X-rays are invisible and cannot be detected by any of the senses.
- **Mass:** X-rays have no mass or weight.
- **Charge:** X-rays have no charge.
- **Speed:** X-rays travel at the speed of light.

- **Wavelength:** X-rays travel in waves and have short wavelengths with high frequency.
- **Path of travel:** X-rays travel in straight lines and can be deflected, or scattered.
- **Focusing capability:** X-rays cannot be focused to a point and always diverge from a point.
- **Penetrating power:** X-rays can penetrate liquids, solids and gases. The composition of the substance determines whether x-rays penetrate or pass through, or are absorbed.
- **Absorption:** X-rays are absorbed by matter; the absorption depends on the atomic structure of matter and the wavelength of the x-ray.
- **Ionization capability:** X-rays interact with materials they penetrate and cause ionization. *For our health ionization is bad*
- **Fluorescence capability:** X-rays can cause certain substances to fluoresce or emit radiation in longer wavelengths.
- **Effect on film:** X-rays can produce an image on photographic film.
- **Effect on living tissues:** X-rays cause biologic changes in living cells.

X-RAY MACHINE



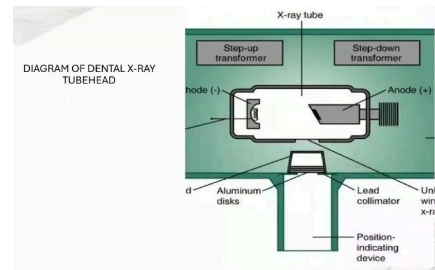
2D CONTROL PANEL





- The control panel of the dental x-ray machine contains an on-off switch and an indicator light, an exposure button and indicator light, and control devices (time, kilovoltage and milliamperage selectors) to regulate the x-ray beam.
- The control panel is plugged into an electrical outlet and appears as a panel or a cabinet mounted on the wall outside the dental operatory.

- The x-ray tubehead is a tightly sealed, heavy metal housing that contains the x-ray tube that produces dental x-rays



2E EXTENSION ARM/POSITIONING ARM/SUPPORT ARM



- Function: It positions the tube head in the desired position and stabilizes the tubehead.

2F TUBE HEAD



- The main part of the machine.
- *This is where the x-ray exits; it shouldn't be touch during the exposure*
- The part of the machine where the x-ray is emitted
- It contains the x-ray tube and other components necessary for generating x-rays.

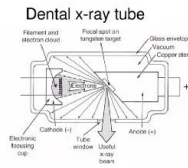
COMPONENTS PARTS OF TUBE HEAD

1. **Metal housing or the metal body** of the tubehead that surrounds the x-ray tube and transformers and is filled with oil-protects the x-ray tube and grounds the high voltage components
2. **Insulating oil, or the oil** that surrounds the x-ray tube and transformers inside the tubehead- prevents overheating by absorbing the heat created by the production of x-rays.
3. **Tubehead seal, or the aluminum or leaded-glass** covering of the tubehead that permits the exit of x-rays from the tubehead- seals the oil in the tubehead and acts as a filter to the x-ray beam.
4. **X-ray tube**, or the heart of the x-ray generating system.
5. **Transformer**, or a device that alters the voltage of incoming electricity.
6. **Aluminum disks**, or sheets of 0.5-mm-thick aluminum placed in the path of the x-ray beam filter out the non-penetrating, longer wavelength X-rays.
7. **Lead collimator**, or a lead plate with a central hole that fits directly over the opening of the metal housing, where the x-rays exit - restricts the size of the x-ray beam
8. **Position-indicating device (PID)**, or open-ended, lead lined cylinder that extends from the opening of the metal



housing of the tubehead- aims and shapes the x-ray beam. The PID is sometimes referred to as the cone.

2G X-RAY TUBE



- *Heart of the system*
- An x-ray tube is composed of a cathode and an anode situated within an evacuated glass envelope or tube.
- Electrons stream from a filament in the cathode to a target in the anode, where they produce x-rays. For the x-ray tube to function, a power supply is necessary to:
 - (1) heat the cathode filament to generate electrons and
 - (2) establish a high-voltage potential between the anode and cathode to accelerate the electrons toward the anode.

2H CATHODE

- The cathode in an x-ray tube consists of a filament and a focusing cup.
- The filament is the source of electrons within the x-ray tube. It is a coil of tungsten wire about 2 mm in diameter and 1 cm or less in length. It is mounted on two stiff wires that support it and carry the electric current.
- The filament lies in a focusing cup, a negatively charged concave reflector made of molybdenum.
- **Focal spot-** The parabolic shape of the focusing cup electrostatically focuses the electrons emitted by the filament into a narrow beam directed at a small rectangular area on the anode.

- **Vacuum** - prevents oxidation, " burnout, " of the filament.

2I ANODE

- The anode consists of a tungsten target embedded in a copper stem. The purpose of the target in an x-ray tube is to convert the kinetic energy of the colliding electrons into x-ray photons. The target is made of tungsten, an element that has several characteristics of an ideal target material.
- It has a high atomic number (74), a high melting point, high thermal conductivity, and low vapor pressure at the working temperatures of an x-ray tube.
- The tungsten target is typically embedded in a large block of copper. Copper, also a good thermal conductor, removes heat from the tungsten, thus reducing the risk of the target melting.
- Additionally, insulating oil between the glass envelope and the housing of the tube head carries heat away from the copper stem. This type of anode is a stationary anode because it has no moving parts
- The sharpness of a radiographic image increases as the size of the focal spot decreases
- The heat generated per unit target area, however, becomes greater as the focal spot decreases in size. To take advantage of a small focal spot while distributing the electrons over a larger area of the target, the target is placed at an angle to the electron beam.
- Another method of dissipating the heat from a small focal spot is to use a rotating anode. In this case the tungsten target is in the form of a beveled disk that rotates when the tube is in operation.
- As a result, the electrons strike successive areas of the target, widening the focal spot by an amount corresponding to the circumference of



the beveled disk, thus distributing the heat over this extended area.

2J POWER SUPPLY

- The primary functions of the power supply of an x-ray machine are:
 - (1) provide a low-voltage current to heat the x-ray tube filament.
 - (2) generate a high potential difference between the anode and cathode.
- The x-ray tube and two transformers lie within an electrically grounded metal housing called the head of the x-ray machine.
- An electrical insulating material, usually oil, surrounds the tube and transformers,
- Tube Current** - The tube current is the flow of electrons through the tube; that is, from the cathode filament, across the tube to the anode, and then back to the filament
- Tube Voltage** - A high voltage is required between the anode and cathode to give electrons sufficient energy to generate x rays. The actual voltage used on an x-ray machine is adjusted with the autotransformer.
- Timer**- A timer is built into the high-voltage circuit to control the duration of the x-ray exposure. The electronic timer controls the length of time that high voltage is applied to the tube and therefore the time during which tube current flows and x rays are produced. *Using joystick*

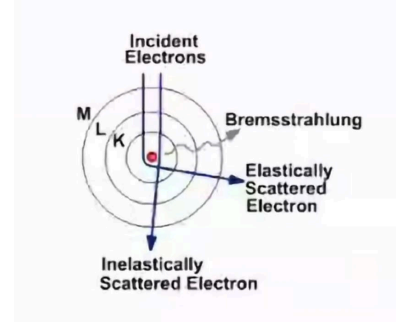
2K TUBE RATING AND DUTY CYCLE

- X-ray tubes produce heat at the target while in operation. The heat buildup at the anode is measured in **heat units (HU)**, where $HU = kVp \times mA \times seconds$.
- The heat storage capacity for anodes of dental diagnostic tubes is approximately 20 kHU.
- Heat is removed from the target by conduction to the copper anode and then

to the surrounding oil and tube housing and by convection to the atmosphere.

- Each x-ray machine comes with a **tube rating chart** that describes the longest exposure time the tube can be energized for a range of voltages (kVp) and tube current (mA) values without risk of damage to the target from overheating.
- Duty cycle** relates to the frequency with which successive exposures can be made. The interval between successive exposures must be long enough for heat dissipation. This characteristic is a function of the size of the anode and the method used to cool it.

2L PRODUCTION OF X-RAY



- Most high-speed electrons traveling from the filament to the target
- interact with target electrons and release their energy as heat.
- Occasionally, however, electrons convert their kinetic energy into x-ray photons by the formation of **bremsstrahlung and characteristic radiation**

BREMSSTRAHLUNG RADIATION/GENERAL RADIATION/BRAKING RADIATION

- Bremsstrahlung means " **braking radiation** " in German.
- Bremsstrahlung radiation is produced by the direct hit of an electron on a nucleus in the target or more frequently, by the passage of an electron near a nucleus, which results



in electrons being deflected and decelerated.

- Bremsstrahlung interactions generate x-ray photons with a continuous spectrum of energy.
- The energy of an x-ray beam is usually described by identifying the peak operating voltage (in kVp), **A dental x-ray machine operating at a peak voltage of 70 kVp** (*remember this*), for example, applies a fluctuating voltage of up to 70 kVp across the tube. *This can be used just to know the machine works well. The lower the kVp the more unclearer image is produced.* This tube therefore produces a continuous spectrum of x-ray photons with energies ranging to a maximum of 70 keV.

The reasons for this continuous spectrum are as follows: (*just read nalang from your text book*)

- 1 The continuously varying voltage difference between the target and filament which is characteristic of half-wave rectification, causes the electrons striking the target to have varying levels of kinetic energy.
- 2 The bombarding electrons pass at varying distances around tungsten nuclei and are thus deflected to varying extents. As a result, they give up varying amounts of energy in the form of bremsstrahlung photons.
- 3 Many electrons participate in many bremsstrahlung interactions in the target before losing all their kinetic energy. As a consequence, an electron carries differing amounts of energy at the time of each interaction with a tungsten nucleus that results in the generation of an x-ray photons.

2M CHARACTERISTIC RADIATION

- Characteristic radiation contributes only a small fraction of the photons in an x-ray beam.
- It occurs when an incident electron ejects an inner electron from the tungsten target. When this happens, an electron from an outer orbital is quickly attracted to the void in the deficient inner orbital.

FACTORS CONTROLLING THE X-RAY BEAM

2N EXPOSURE TIME

- Changing the time controls the duration of the exposure and thus the number of photons generated. When the exposure time is doubled the number of photons generated at all energies in the x-ray emission spectrum is doubled, but the range of photon energies is unchanged

2O TUBE CURRENT (mA)

- The quantity of radiation produced by an x-ray tube (i.e., the number of photons that reach the patient and film) is directly proportional to the tube current (mA) and the time the tube is operated.
- As the mA setting is increased, (*this can be altered*) more power is applied to the filament, which heats up and releases more electrons that collide with the target to produce radiation.

2O TUBE VOLTAGE (kVp)

- Increasing the kVp increases the potential difference between the cathode and the anode thus increasing the energy of each electron when it strikes the target
- This results in an increased efficiency of conversion of electron energy into x-ray photons and thus an increase in (1) the number of photons generated, (2) their



mean energy, and (3) their maximal energy.

- The ability of x-ray photons to penetrate matter depends on their energy. High-energy x-ray photons have a greater probability of penetrating matter, whereas lower-energy photons have a greater probability of being absorbed,
- Therefore the higher the kVp and mean energy of the x-ray beam, the greater the penetrability of the beam through matter.
- A useful way to characterize the penetrating quality of an x-ray beam (its energy) is by its **half-value layer (HVL)**. The HVL is the thickness of an absorber, such as aluminum, required to reduce by one half the number of x-ray photons passing through it.

FILTRATION

- Although an x-ray beam consists of a spectrum of x-ray photons of different energies, only photons with sufficient energy to penetrate through anatomic structures and reach the **image receptor (film or digital)** are useful for diagnostic radiology.
- Photons that are of such low energy that they cannot reach the receptor contribute to patient exposure (risk) but do not offer any benefit.
- **ALUMINUM FILTER**- placed in the path of the beam to reduce patient dose, such low-energy photons (should be removed from the beam). Preferentially removes many of the lower-energy photons with lesser effect on the higher-energy photons that are able to contribute to making an image.

INHERENT FILTRATION

-(equivalent of 0.5 to 2 mm of aluminum)

TOTAL FILTRATION

-equivalent of 1.5 mm of aluminum up to 70 kVp and 2.5 mm of

-consists of the materials that x-ray photons encounter as they travel from the focal spot on the target to form the usable beam outside the tube enclosure.

-(the glass wall of the x-ray tube, the insulating oil that surrounds many dental tubes, and the barrier material that prevents the oil from escaping through the x-ray port).

aluminum for all higher voltages)

- the sum of the inherent filtration plus any added external filtration supplied in the form of aluminum disks placed over the port in the head of the x-ray machine. *Even if we have this filtration, the tube head shouldn't be touch during the exposure the radiographer must go outside the x-ray room and the patient shouldn't be asked to hold the tube head*

COLLIMATION

2P COLLIMATOR

- A collimator is a metallic barrier with an aperture in the middle used to reduce the size of the x-ray beam and thereby the volume of irradiated tissue.
- Dental x-ray beams are usually collimated to a circle **2 3/4 inches (7 cm)** in diameter. A round collimator is a thick plate of radiopaque material (usually lead) with a circular opening centered over the port in the x-ray head through which the x-ray beam emerges.

ROUND COLLIMATOR

are built into open-ended aiming

RECTANGULAR COLLIMATOR

further limit the size of the beam to just



cylinders.

larger than the x-ray film, thereby further reducing patient exposure. **THIS IS MORE SAFE THAN THE ROUND COLLIMATOR**

- Use of collimation also improves image quality. When an x-ray beam is directed at a patient, the hard and soft tissues absorb about 90% of the photons and about 10% pass through the patient and reach the film.

2Q INVERSE SQUARE LAW

- The intensity of an x-ray beam (the number of photons per cross-sectional area per unit of exposure time) depends on the distance of the measuring device from the focal spot. For a given beam the intensity is inversely proportional to the square of the distance from the source.
- Therefore changing distance between the x-ray tube and patient has a marked **effect on skin exposure**. Such a change requires a corresponding modification of the kVp or mA to keep constant the exposure to the film or digital sensor.

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

- where I is intensity and D is distance. Therefore if a dose of 1 Gy is measured at a distance of 2 m, a dose of 4 Gy will be found at 1 m and 0.25 Gy at 4 m.
- the probability that a photon will be absorbed by a photoelectric interaction in bone is approximately 6.5 times ($13.8 / 2.1 = 6.5$) greater than in an equal thickness of soft tissue

INTERACTIONS OF X-RAY WITH MATTER

- Three means of beam attenuation:
 - **(1) Coherent scattering**
 - **(2) Photoelectric absorption**
 - **(3) Compton scattering**
- In addition, about 9% of the primary photons pass through the patient without interaction.

2R COHERENT SCATTERING

- A.K.A. **classical, elastic, or Thompson scattering**
- May occur when a low-energy incident photon (less than 10keV) passes near an outer electron of an atom.
- Coherent scattering accounts for only about 7% of the total number of interactions in a dental exposure.
- Coherent scattering contributes **little to film fog** because the number of scattered photons is small and their energy is too low for many of them to reach the film or sensor.

2S PHOTOELECTRIC ABSORPTION

- Photoelectric absorption is critical in diagnostic imaging.
- This process occurs when an incident photon interacts with an electron in an inner orbital of an atom of the absorbing medium.
- Ionization takes place.
- About **23%** of interactions in a dental x-ray beam exposure involve photoelectric absorption.

2T COMPTON SCATTERING

- Compton scattering occurs when a photon interacts with an outer orbital electron.
- About **49%** of interactions in a dental x-ray beam exposure involve Compton scattering



DOSIMETRY

- Determining the quantity of radiation exposure or dose.
- The term dose is used to describe the amount of energy absorbed per unit of mass at a site of interest.
- **Exposure** is a measure of radiation on the basis of its ability to produce ionization in air under standard conditions of temperature and pressure (STP).

UNITS OF MEASUREMENT

- The **SI system** uses base units including the kilogram (kg) (mass), the meter (length), the second (time), the ampere (electric current), and the mole (amount of substance). SI-derived units, including newton (force) and joule (energy), evolve from these base units. The following units are SI-derived units with special names.

2U EXPOSURE

- Exposure is a measure of radiation quantity, the capacity of radiation to ionize air.
- The SI unit of exposure is air kerma, an acronym for kinetic energy released in matter. Kerma measures the kinetic energy transferred from photons to electrons and is expressed in units of dose (gray [Gy where 1 Gy equals 1. joule/kg.])
- Kerma is the sum of the initial kinetic energies of all the charged particles liberated by uncharged ionizing radiation (neutrons and photons) in a sample of matter, divided by the mass of the sample. It has replaced the roentgen (R), the traditional unit of radiation exposure measured in air.

2V ABSORBED DOSE

- Absorbed dose is a measure of the energy absorbed by any type of ionizing radiation per unit of mass of any type of matter.
- The SI unit is the Gy, where 1 Gy equals 1 joule/kg
- The traditional unit of absorbed dose is the rad (radiation absorbed dose), where 1 rad is equivalent to 100 ergs per gram (g) of absorber. One gray equals 100 rads.
- For instance, deposition of 1 Gy of high-energy protons causes five times as much damage as 1 Gy of x-ray photons. The W R of photons, the reference, is 1. The W R of 5 keV neutrons and high-energy protons is 5 and the W R of a particle is 20.
- To account for this difference, the HT is computed as the product of the absorbed dose (D T) averaged over a tissue or organ and the WR :
 - **HT =WR x DT**
- The unit of equivalent dose is the sievert (Sv). For diagnostic x-ray examinations 1 Sv equals 1 Gy.
- The traditional unit of equivalent dose is the **rem (roentgen equivalent man). One sievert equals 100 rem.**

2W EFFECTIVE DOSE

- The effective dose (E) is used to estimate the risk in humans.
- For exposures to a part of the body, for instance, the jaws, the effective dose measures the equivalent whole-body dose.
- The unit of effective dose is the Sv.

2X RADIOACTIVITY

- The measurement of radioactivity (A) describes the decay rate of a sample of radioactive material. The SI unit is the becquerel (Bq); 1 Bq equals 1 disintegration/second.



- The traditional unit is the curie(Ci), which corresponds to the activity of 1 g of radium (3.7×10^{10} disintegrations/second).
- Accordingly, 1 mCi equals 37 mega Bq and 1 Bq equals 2.7×10^{-11} Ci.