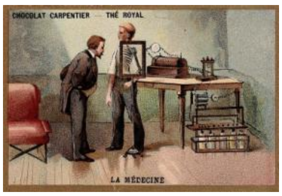
X-ray equipments

and X-ray room



Vecsei Bálint dr.

Dental X-ray generating equipment

- There are several dental X-ray sets available from different manufacturers. They are essentially very similar and can be either *fixed* (wall-mounted or ceiling-mounted) or *mobile*.
- They all consist of three main components:
  - A tubehead
  - Positioning arms
  - A control panel and circuitry

- Dental radiology makes use of specific types of equipment, needed for different purposes.
- *Frequent exposures though each with low dose involve a risk* for the practitioner and for the patient

Ideal requirements:

The equipment should be:

- Safe and accurate
- Capable of generating X-rays in the desired energy range and with adequate mechanisms for heat removal
- Small
- Easy to manoeuvre and position
- Stable, balanced and steady once the tubehead has been positioned
- Easily folded and stored
- Simple to operate
- Robust

Purpose of Shielding

- To protect:
  - the X Ray department staff
  - the patients (when not being examined)
  - visitors and the public
  - persons working adjacent to or near the X Ray facility

Radiation Shielding - Design Concepts

- Data required include consideration of:
  - Type, location and orientation of X Ray equipment
  - Usage (workload-weekly radiation dose)
  - Positioning
  - Whether multiple tubes/receptors are being used
  - Primary beam access (vs. scatter only)
  - Operator location
  - Surrounding areas
  - The nature of the floor, wall and ceiling construction

Shielding Design (I)

Equipment

- What equipment is to be used?
  - General radiography
  - Fluoroscopy (with or without radiography)
  - Dental (intraoral or extraoral)
  - Mammography
  - CT
  - CBCT

Shielding Design (II)

The type of equipment is very important for the following reasons:

- where the X Ray beam will be directed
- the number and type of procedures performed
- the location of the radiographer (operator)
- the energy (kVp) of the X Rays

- mA – Intensity
  - the number or quantity of X-ray photons in the beam
- kV – Quality
  - the energy carried by the X-ray photons, which is a measure of their penetrating power

X-rays can be distinguished according to the applied voltage

• Ultrasoft	5-20 kV
• Soft	20-60 kV
• Medium hard	60-120 kV
• Hard	120-250 kV
• Very hard	>250 kV


Photograph


Radiograph

Shielding Design (III)

Usage

- Different X Ray equipment have very different usage.
- For example, a dental unit uses low mAs and low (~70) kVp, and takes relatively few X Rays each week
- A CT scanner uses high (~130) kVp, high mAs, and takes very many scans each week.

Shielding Design (IV)

- The total mAs used each week is an indication of the total X Ray dose administered
- The kVp used is also related to dose, but also indicates the penetrating ability of the X Rays
- High kVp and mAs means that more shielding is required.

Shielding Design (V)

Positioning

- The location and orientation of the X Ray unit is very important:
  - distances are measured from the equipment (inverse square law will affect dose)
  - the directions the direct (primary) X Ray beam will be used depend on the position and orientation

Shielding Design (VI)

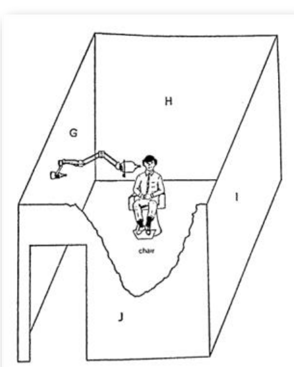
Number of X Ray tubes

- Some X Ray equipment may be fitted with more than one tube
- Sometimes two tubes may be used simultaneously, and in different directions
- This naturally complicates shielding calculation

Shielding Design (VII)

Surrounding areas

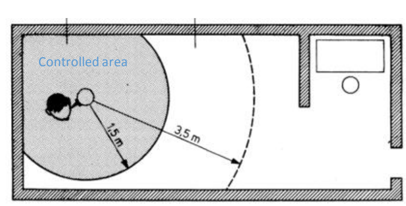
- The X Ray room must not be designed without knowing the location and use of all rooms which adjoin the X Ray room
- Obviously a toilet will need less shielding than an office
- First, obtain a plan of the X Ray room and surroundings (including level above and below)



The useful beam might strike walls G, H and I.

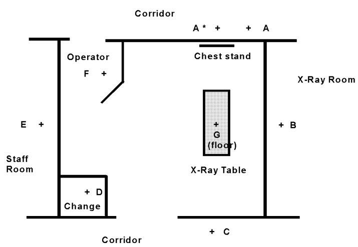
All of the walls, the ceiling, and the floor are likely to be struck by scattered radiation

Dental X-ray room

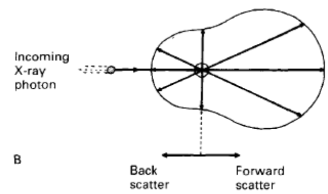


Radiation Shielding - Typical Room Layout

A to G are points used to calculate shielding



Typical scatter distribution diagram of a 70 kV X-ray set



Required minimal area for x-ray equipments

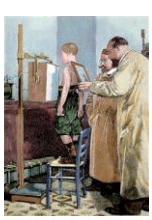
	area (m^2)	side (m)
Dental intraoral equipment inner switch	9	2,5
Dental intraoral equipment external switch	4	1,8
Dental panoramic equipment External switch	6	2,2
Mammogrphy	12	3,0
CT	25	4,0

Radiation Shielding - Design Detail

Must consider:

- appropriate calculation points, covering all critical locations
- design parameters such as workload, occupancy, use factor, leakage, target dose (see later)
- these must be either assumed or taken from actual data
- use a reasonable worst case more than typical case, since undershielding is worse than overshielding

X-ray equipments



Basic elements of the X Ray source

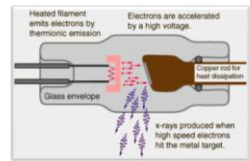
- Generator: power circuit supplying the required potential to the X Ray tube
- X Ray tube and collimator: device producing the X Ray beam

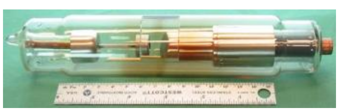
- X-rays are produced when energetic (high-speed) electrons bombard a target material and are brought suddenly to rest.
- This happens inside a small evacuated glass envelope called the

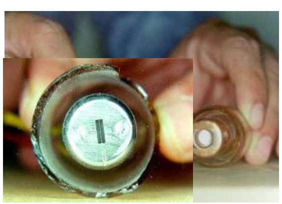
X-ray tube

X Ray tube components

- Cathode (negative): heated filament which is the source of the electron beam directed towards the anode
  - **tungsten filament**
- Anode (positive) (stationary or rotating): impacted by electrons, emits X Rays
- Metal tube housing surrounding glass (or metal)X Ray tube (electrons are traveling in vacuum)
- Shielding material (protection against scattered radiation)





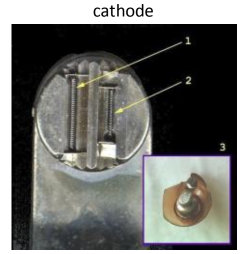


X Ray tube components

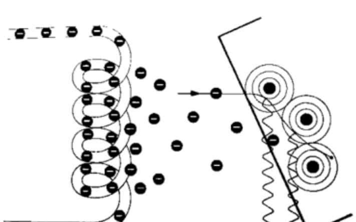
housing

1: mark of focal spot

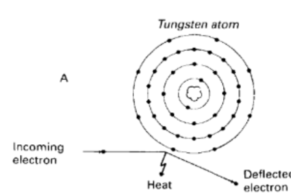
cathode

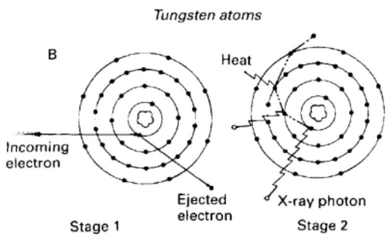


1: long tungsten filament
2 : short tungsten filament
3 : real size cathode



Heat-producing collision – the incoming electron is deflected by the tungsten electron cloud





Heat-producing

• The incoming electron is deflected by the cloud of outer-shell tungsten electrons, with a small loss of energy, in the form *of heat*

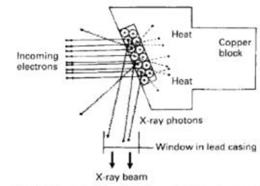
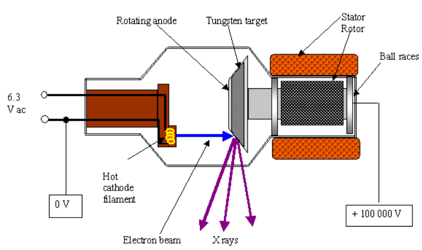


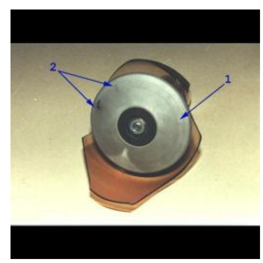
Fig. 2.3 Diagram of the anode enlarged, showing the target and summarizing the interactions at the target.

• The incoming electron collides with an outer shell tungsten electron displacing it to an even more peripheral shell (excitation) or displacing it from the atom (ionization), again with a small loss of energy in the form of heat

X-ray tube with rotating anode



Anode characteristic



1 : anode track
2 : anode track

X-ray tubes

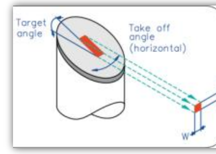
X Ray tube characteristics

- Anode mechanical constraints
  - Material : tungsten, rhenium, molybdenum, graphite
  - Focal spot : surface of anode impacted by electrons
  - Anode angle
  - Disk and annular track diameter (rotation frequency from 3,000 to 10,000 revolutions/minute)
    - **Thickness ⇒ mass and material (volume) ⇒ heat capacity**
- Anode thermal constraints
  - Instantaneous power load (heat unit)
  - Heat loading time curve
  - Cooling time curve

Anode heel effect

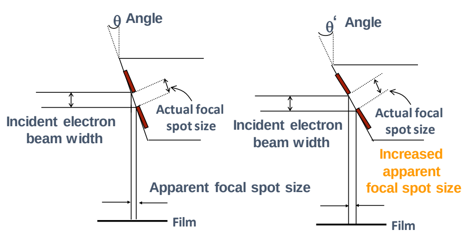
- Anode angle (from 7° to 20°) induces a variation of the X Ray output in the plane comprising the anode-cathode axis
- Absorption by anode of X-ray photons with low emission angle
- The magnitude of influence of the heel effect on the image depends on factors such as:
  - anode angle
  - size of film
  - focus to film distance
- Anode aging increases heel effect

Anode angle (I)

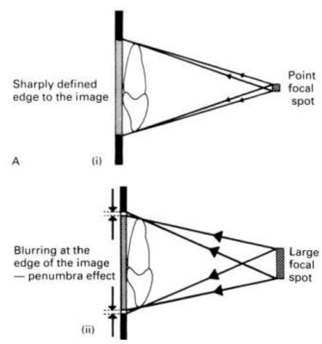


- The Line-Focus principle
  - Anode target plate has a shape that is more rectangular or ellipsoidal than circular
    - the shape depends on :
      - **filament size and shape**
      - **focusing cup's and potential**
      - **distance between cathode and anode**
  - Image resolution requires a small focal spot
  - Heat dissipation requires a large spot
    - This conflict is solved by slanting the target face

Anode angle (II)



THE SMALLER THE ANGLE
THE BETTER THE RESOLUTION



Focal spot size and imaging geometry

- Focal spot finite size ⇒ image unsharpened
- Improving sharpness ⇒ small focal spot size
- For mammography focal spot size ≤ 0.4 mm nominal
- Small focal spot size ⇒ reduced tube output (longer exposure time)
- Large focal spot allows high output (shorter exposure time)
- Balance depends on organ movement

X-ray generator (I)

It supplies the X-ray tube with :

- Current to heat the cathode filament
- Potential to accelerate electrons
- Automatic control of exposure (power application time)
- Energy supply ≈ 1000 × X-ray beam energy (of which 98.9% is dissipated as thermal energy)

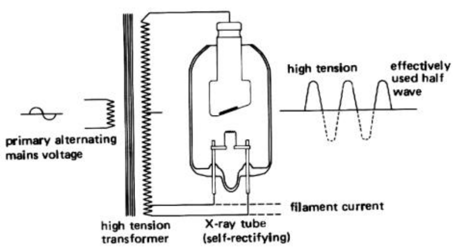
X-ray generator (II)

- Generator characteristics have a strong influence on the contrast and sharpness of the radiographic image
- The motion unsharpness can be greatly reduced by a generator allowing an exposure time as short as achievable
- Since the dose at the image plane can be expressed as:
  $D = k_0 . U^n . I . T$
  - **U**: peak voltage (kV)
  - **I**: mean current (mA)
  - **T**: exposure time (ms)
  - **n**: ranging from about 1.5 to 3

X-ray generator (III)

- Peak voltage value has an influence on the beam hardness
- It has to be related to medical question
  - **What is the anatomical structure to investigate ?**
  - **What is the contrast level needed ?**
  - For a thorax examination : 140 - 150 kV is suitable to visualize the lung structure
  - While only 65 kV is necessary to see bone structure

Generator Circuit



Generators & Pre-Heat

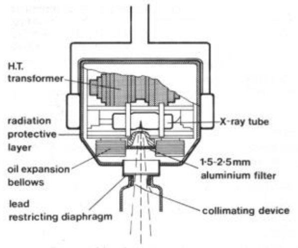
- ***Medium frequency*** - stable waveform
- ***Single phase (SP)*** - pulsed
- ***Pre-Heat***: separate circuit for heating filament
- Single Phase units without a pre-heat circuit
  - initial pulses of variable kV

Types of units

- "Intra-Oral" units
  - Standard dental tube
  - uses an intra-oral image receptor
  - has extra-oral x-ray tube
- Panoramic (OPG)
- Cephalometric (Ceph)
- CBCT

Intra-Oral Dental X-Ray Equipment

X-Ray Unit

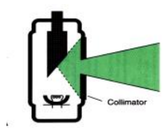


The transformer required to step-up the mains voltage of 240 volts to the 50,000-90,000 volts required across the X-ray tube

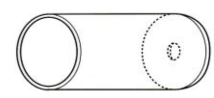
Control panel

Collimator

1. Lead Collimator with central hole

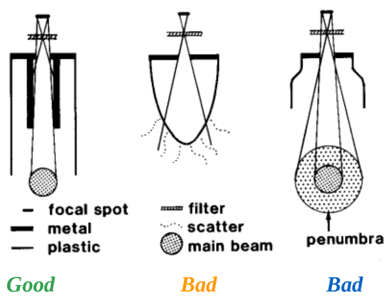


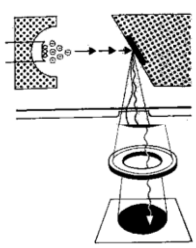
2. Spacer Tube



Tubehead design and material…

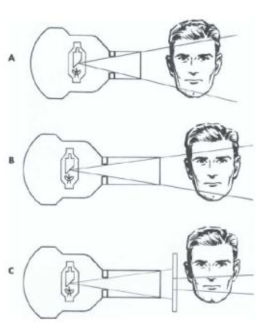
Applicator Cones



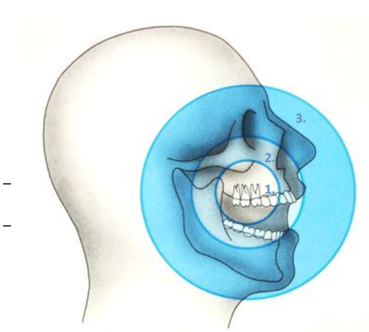


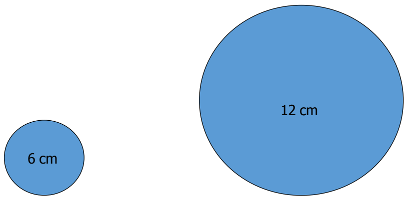
Effect of collimation on the volume of tissue irradiated

- *A* larger volume of irradiated tissue results from A than from B in which the longer produces a less divergent beam.
- The rectangular collimator (close to the patient in C) results in a smaller, less divergent beam and a smaller volume of tissue irradiated than in A or B.



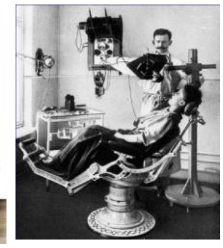
1. 1,75 cm diafragma – 6 cm
2. 2,65 cm diafragma – 11 cm átmérő
3. Without diafragma



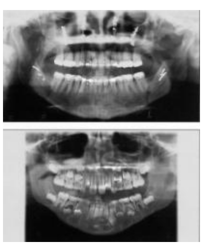


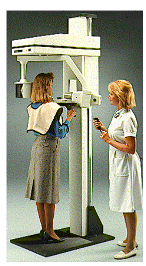
28,26mm²

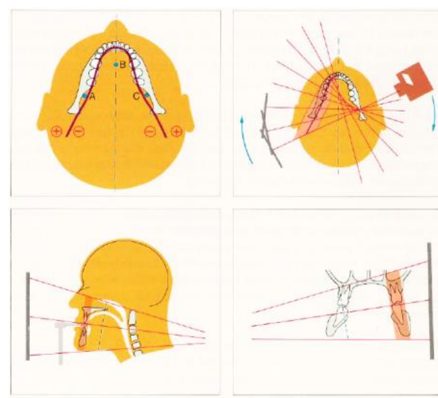
113,04 mm²



Panoramic X-Ray Equipment



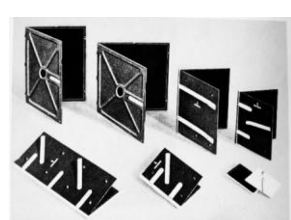


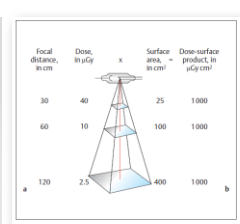


Cephalometric X-Ray Equipment

The inverse square law

The strength of the X-ray beam is inversely proportional to the square of distance from the source





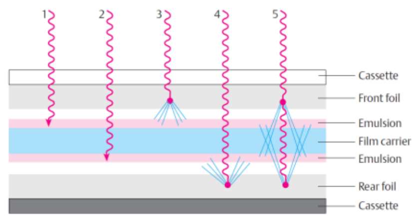
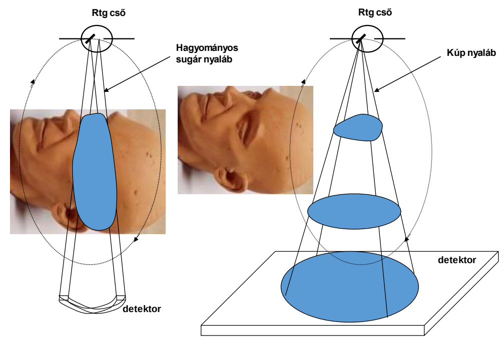
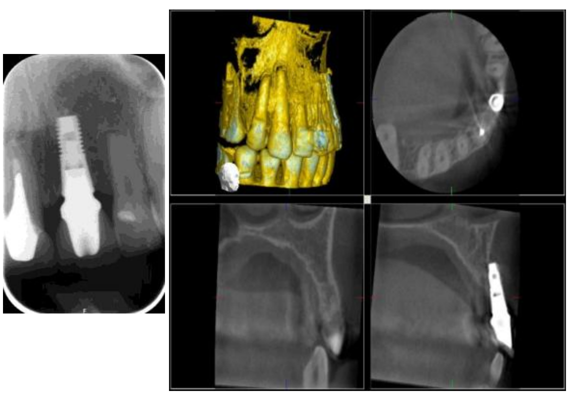


Fig. 182 **Schematic depiction of the effects of intensifying screens.** The roentgen rays impact the emulsion layers directly (**1** and **2** of the double-layered cassette film). Furthermore, the roentgen rays stimulate the fluorescing crystals of the front and back screens (**3** and **4**) to radiate long-wave light, thus enhancing the effect of the rays themselves. However, this also causes a simultaneous cross-over effect of scattered radiation (**5**) which diminishes image clarity.

(CB)CT





Intra-Oral Dental X-Ray Equipment (technical data)

Exposure time	from 60 ms to 2.5 s
Tube	Min. 50 kV, ~7mA
Focal spot size	≈1 mm
Inherent filtration	~2 mm Al equivalent
Focus-skin distance	30 cm
Irradiated field	28 cm^2 with round section, 6 cm diameter collimator

Panoramic X-Ray Equipment (technical data)

Focal spot	0.5 mm
kV	60 - 80 kV in 2 kV steps
mA	4 - 10 mA steps 4, 5, 6, 8, 10
Exposure time	12 s (standard projections) 0.16 - 3.2 s (cephalometric projections)
Flat panoramic cassette	15x30 cm (Lanex Regular screens))

Radiation Protection in Dental Radiology

Facts

- Very frequent examination (about 25% of all the radiological examinations)
- Delivered doses may differ of a factor 2 or 3. (entrance doses between 0.5 and 150 mGy)
- Organs at risk: parathyroid, thyroid, larynx, parotid glands

Radiation Protection in Dental Radiology

Technical hints to reduce patient doses
Lead apron and collar

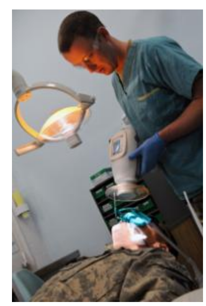
Useful when the path of primary beam intercepts the protected organs (downward bite-twin projection).

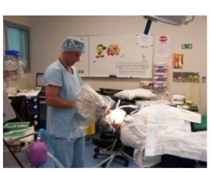
Radiation Protection in Dental Radiology

Panoramic examination

- Image quality not as good as in intra-oral films
- Important global information
- Relatively low dose
  (one panoramic examination ≈ 3-5 intra-oral films)

Portable x-ray devices…





Limiting the Number of Radiographs

- Individual patient assessment of necessity and number required
- Operator technique to minimize retakes
- Avoiding the temptation to take extra digital radiographs because of ease-of-use
- Consideration of alternative diagnostic tools

Patient and Operator Protection from Radiation Exposure

Primary Radiation	• Provide patient with lead collar and apron • Minimize total exposure • Operator must not stand directly in the primary beam
Scatter Radiation	• Operator must stand behind a barrier or stand a minimum of 6 feet from the X-ray source and at an angle of 90º–135º from the beam
Leakage Radiation	• Same operator precautions as for scatter radiation • Regular maintenance for X-ray unit

Thank you for your attention!

	Number taken (in millions)
Full-mouth series	170.20
Periapical	80.30
Bite-wing	112.80
Panoramic	20.80

Source: ADA. The 1999 Survey of Dental Services Rendered.

- Collimation. The ADA recommends the following23 :
- The tissue area (and volume) exposed to the primary
- x-ray beam should not exceed the minimum coverage consistent
- with meeting diagnostic requirements and clinical
- feasibility. The collimation should comply with federal
- and state regulations. For periapical and bitewing radiography,
- restriction of the beam cross section to conform to
- the size of the image receptor (rectangular collimation) is
- recommended. Furthermore, shielded open-end positionindicating
- devices should be used.

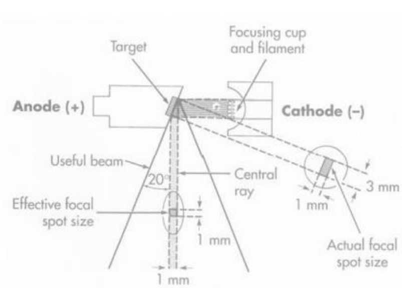
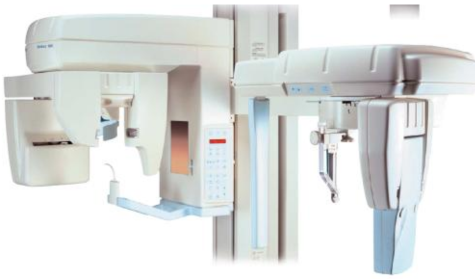


FIG. 1-10 The angle of the target to the central ray of the x-ray beam has a strong influence on the apparent size of the focal spot. The projected effective focal spot is much smaller than the actual focal spot size.

Cephalometric Holder



Egyéb röntgenberendezések…