Radiography & 3-D Scanning

IMPLANTOLOGY YEAR COURSE
MODULE 3 – JULY 2018

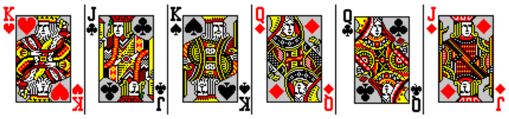
STUART ELLIS BDS MFGDP(UK) DPDS MSc

Aims & Objectives

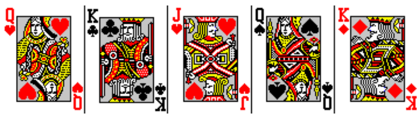
Aims:

- **Discuss basic principles of radiography**
- **Periapical radiography**
- **Panoramic radiography**
- **CT scanning**
- **Limitations of radiography**

Aims & Objectives



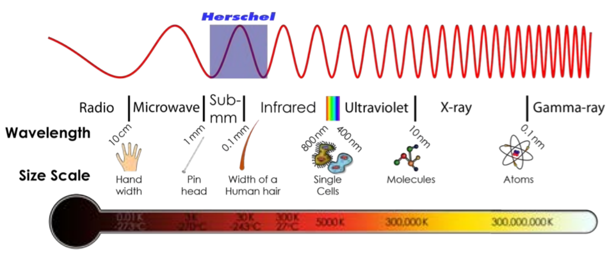
Aims & Objectives



What is an 'X-Ray'?

- **Wilhelm Röntgen in 1895**
- **1st Nobel Prize in Physics 1901**
- **Called 'X' because nature unknown**
- **High energy EM radiation**
- **Consist of photons (packets of energy)**

What is an 'X-Ray'?

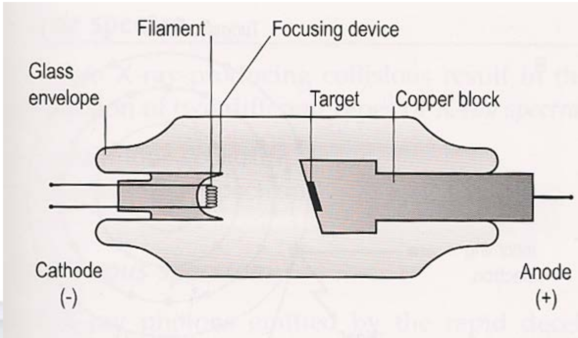


What is an 'X-Ray'?

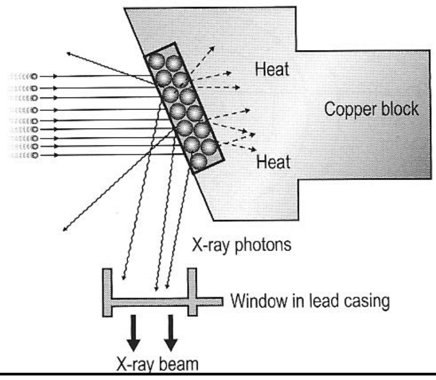
Wife Anna's hand 2 weeks after his initial discovery

'I have seen my death'

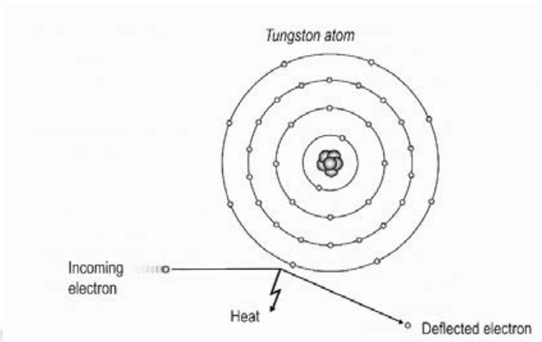
Creating a dental x-ray beam



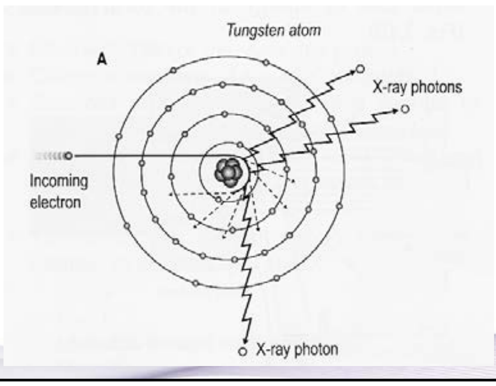
Creating a dental x-ray beam



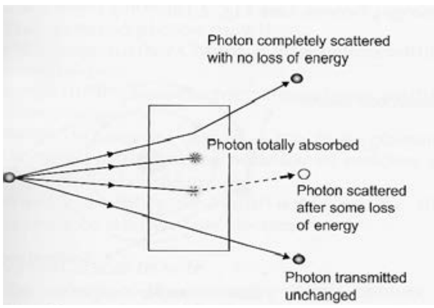
Creating a dental x-ray beam



Creating a dental x-ray beam



Creating a dental x-ray beam



Radiation doses

- Absorbed dose (D) (Gray –Gy)
- Effective dose (E) now used (Sievert–Sv)
- NRPB estimates annual UK radiation doses 2.7mSv

Radiation Source	Dose
Cosmic rays	300
Earth's crust	400
Food	370
Radon	700
TOTAL	2.7mSv

- 7.8mSv average annual dose in Cornwall

Radiation doses – Sizewell B

Workers allowed maximum of 20mSv per year

Radiation doses – Guarapari beach in Brazil

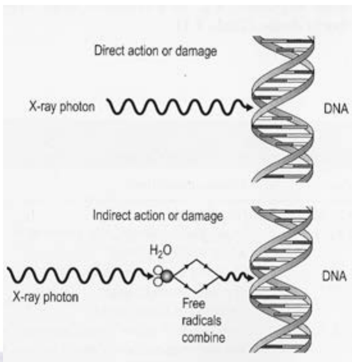
175 mSv per year

Radiation doses – Ramsar, Iran

250 mSv per year

Radiation doses – Brazil Nuts

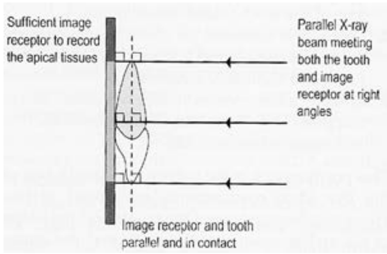
Radiation damage to human tissue



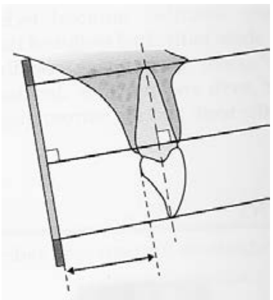
Estimated risks of fatal cancer (NRPB)

X-Ray examination	Risk of fatal cancer (est)
CT chest	1 in 2,500
CT head	1 in 10,000
OPG	1 in 1,000,000
Periapical	1 in 20,000,000

Periapical radiography

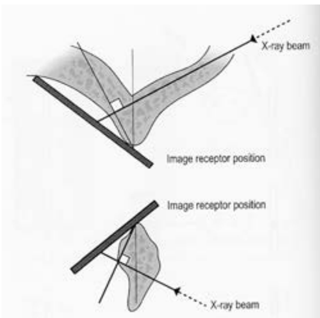


Periapical radiography



Periapical radiography

Periapical radiography

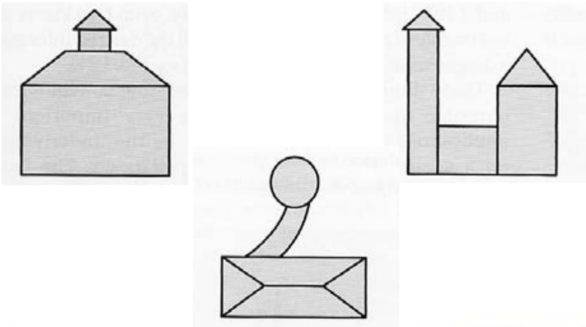


Periapical radiography

Interpretation problems:

- Shadowgraph
- 2 dimensional image of complex 3D structures
- Superimposition of overlying structures (zygoma)
- Partial image interpretation – differing conclusions

Periapical radiography



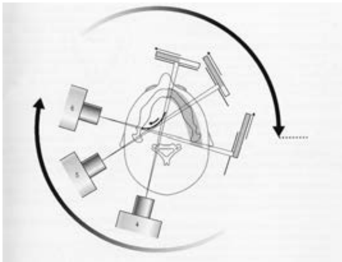
Periapical radiography

Periapical radiography

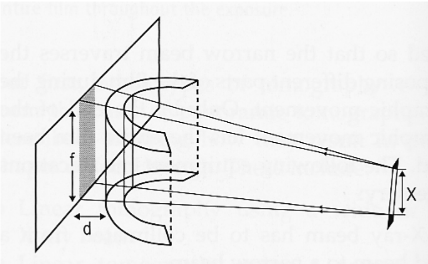
Interpretation issues

Panoramic radiography

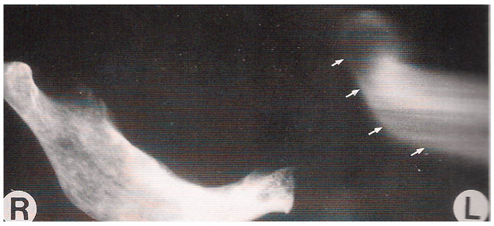
Panoramic radiography



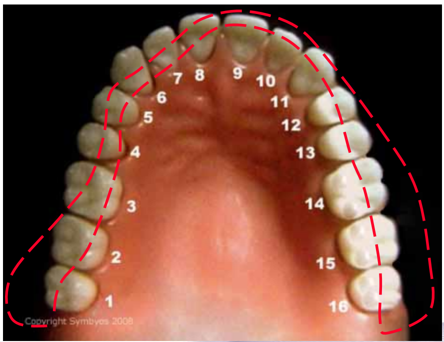
Panoramic radiography



Panoramic radiography - problems

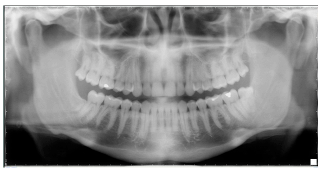


Panoramic radiography - problems



Panoramic radiography - problems

Panoramic radiography - problems



- **Shadowing**
- **Blurring if not in focal trough**
- **Magnification (around 1.8x)**
- **Image distortion variable throughout image**
- **Distortion & magnification NOT LINEAR OR EVEN**
- **2 Dimensional view – sublingual &submandibular gland fossas not visible.**

Medical CT scanning

Medical CT scanning

Computed Tomography:

=

Medical CT scanning

Computed Tomography:

EMI

Medical CT scanning

Computed Tomography:

EMI DEC 1100

Race to image the brain…

CT scanning

Johann Radon (1917):

- Austrian mathematician
- Discovered that any function can be completely recovered from the integrals over an infinite number of lines passing through the function
- A Greyscale is a mathematical function

CBCT scanning –basic principles

Medical CT scanning

First prototype (late 1960s):

Medical CT scanning

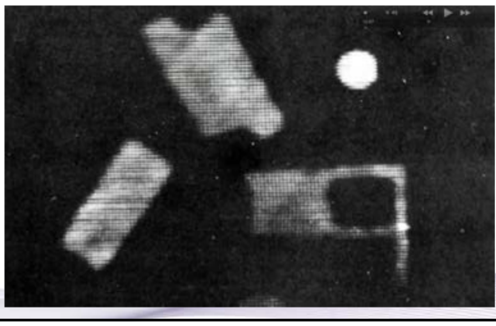
Medical CT scanning

First prototype (late 1960s):

- Machine ran continually for **9 days**!
- Took a supercomputer **2.5 hours** to process the data
- Computer solved equivalent of 28,000 simultaneous equations

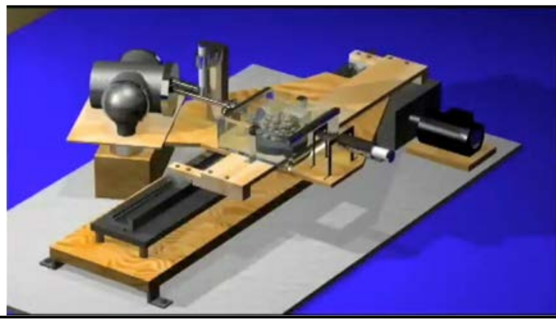
Medical CT scanning

First prototype (late 1960s):



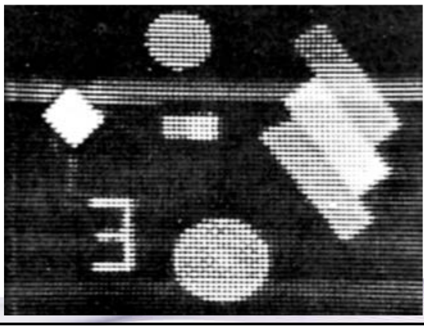
Medical CT scanning

Second prototype (late 1960s):



Medical CT scanning

Second prototype (late 1960s):



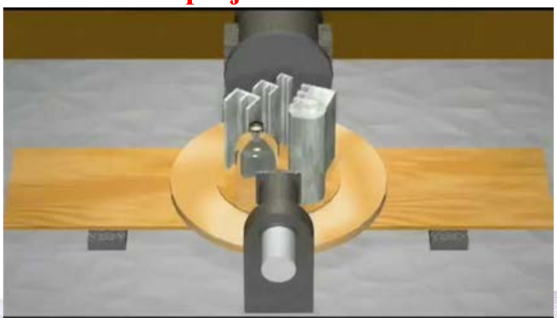
Medical CT scanning

Second prototype (late 1960s):

- Another team at EMI started working on faster ways to process the data
- They developed 'Filtered Backprojection'

Medical CT scanning

Filtered backprojection:



Medical CT scanning

Filtered backprojection:

Medical CT scanning

Computed Tomography:

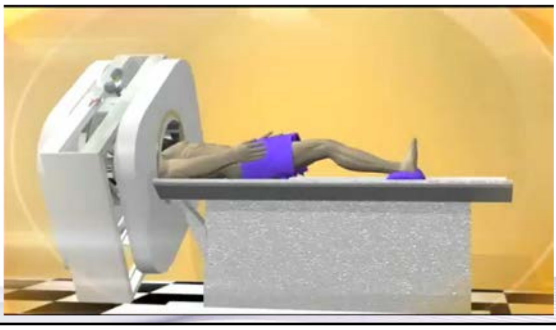
- Same rotate-translate mechanism as Prototype 2
- Original EMI scanner cost £100k
- Introduced in 1973
- Within 2 years became a £40m market

Medical CT scanning

CT – initially only for the brain:

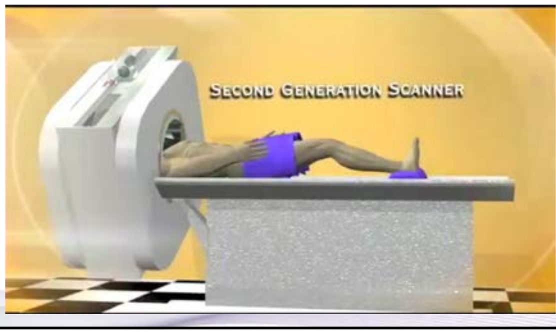
Medical CT scanning – 1st generation

CT – initially only for the brain:



Medical CT scanning – 2nd generation

2nd Generation – still RT but more detectors:

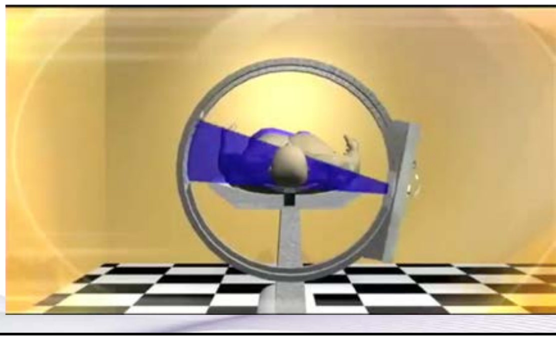


Medical CT scanning – 3rd generation

3rd Generation – now using 180 rotation:

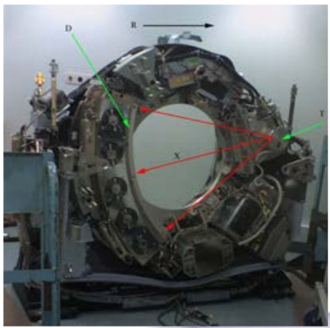
Medical CT scanning – 3rd generation

Helical Scanner:

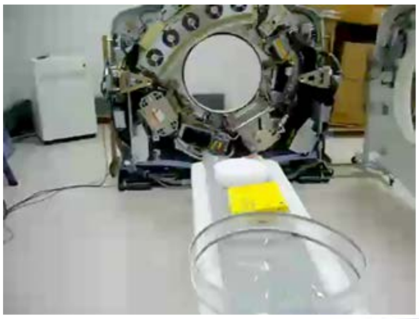


CT scanning – helical scanner

CT scanning



CT scanning



CT scanning

Advantages:

- Fast
- Detailed images
- Good visualisation of soft tissues
- Instant image

CT scanning

Disadvantages:

- Scanners expensive (latest generation $1.3m - $2m)
- Scans expensive for patient
- High radiation dose (CT Head 8mSv)
- Equivalent to almost 3 years average UK background radiation
- Artefacts

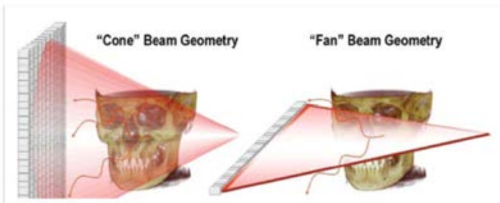
Cone Beam CT scanning (CBCT)

NewTom 9000 - 1996

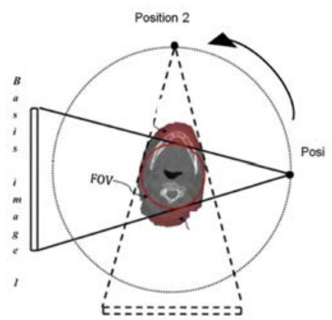
Cone Beam CT scanning (CBCT)

- Developed in early 1990's
- Specially for maxillofacial use
- Much lower radiation doses
- Seated position
- Lower cost machines
- Lower cost scans
- Fast scan times (approx 8 seconds)

Cone Beam CT scanning (CBCT)



Cone Beam CT scanning (CBCT)

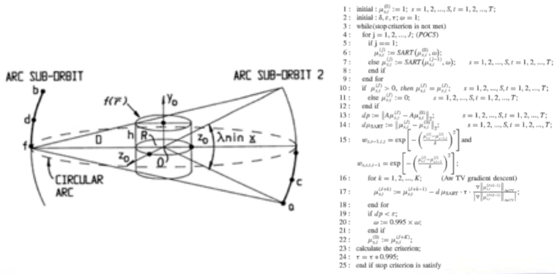


CT scanning – basis images

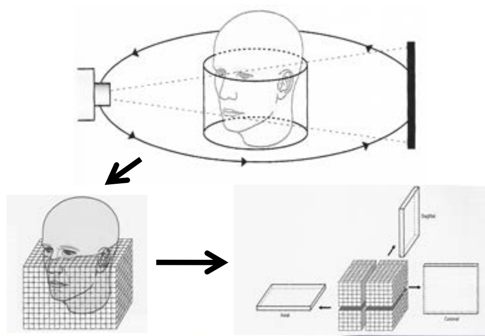
- **Standard 2D radiographic images**
- **Formed on a detector**
- **100 – 1,000 basis images**
- **250-300 individual images more common**
- **More basis images = better quality CBCT dataset**
- **However also = higher radiation dose and longer scan time**

CT scanning - reconstruction

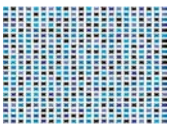
Feldkamp Algorithm (1984):



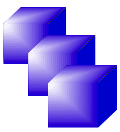
Cone Beam CT scanning (CBCT)



Cone Beam CT scanning (CBCT)



2D images
Pixel = Picture Element



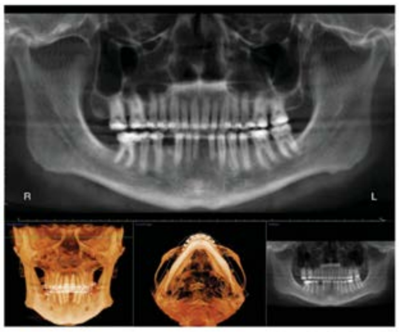
3D volume datasets
Voxel = Volume Element

DICOM

- **Standard 'RAW' data format of a CT scanner**
- **Digital Imaging COmmunication for Medicine**

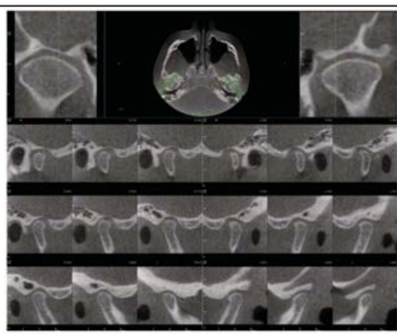
CBCT – MPR views

CBCT – Panoramic views

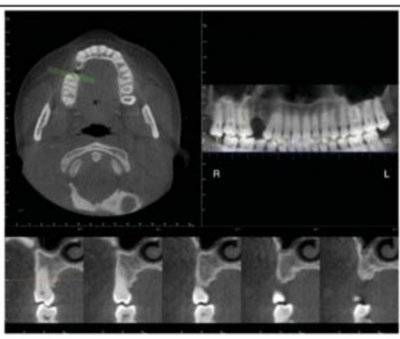


CBCT – Cephalometric views

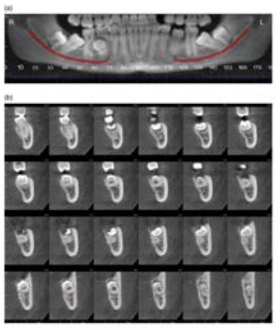
CBCT – TMJ views



CBCT – implant views



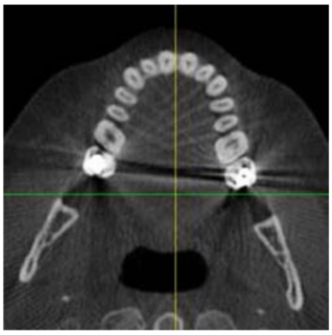
CBCT – IDN position



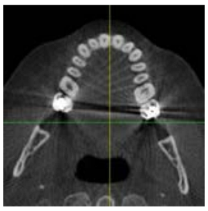
CBCT Core Curriculum

CBCT Limitations

CT scanning - artefacts

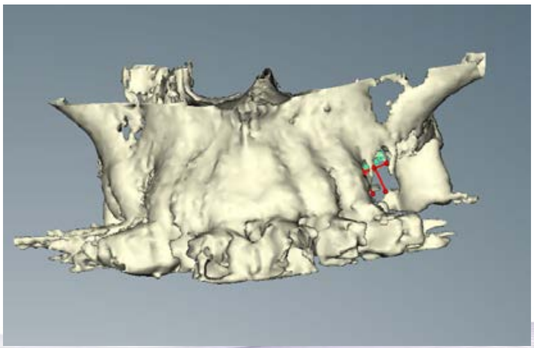


CT scanning - artefacts



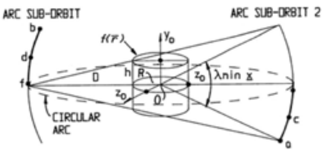
- Visualized structure that is not present in the imaged object
- Mainly due to mathematic inaccuracies

CT scanning - artefacts



CT scanning - artefacts

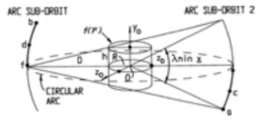
Feldkamp Algorithm (1984):



CT scanning - artefacts

Feldkamp Algorithm (1984):

- Relatively simple
- Can be processed by computers quickly
- Only requires desktop PC
- Uses many assumptions
- Attributes many average values



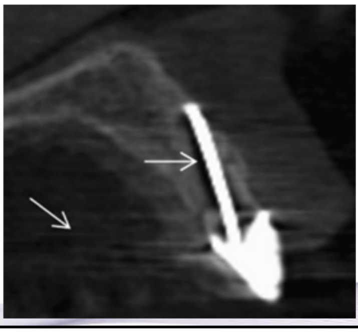
CT scanning - artefacts

Types of artifact:

1. **Beam hardening**
2. **White streak effects ('starburst', 'metallic streaks etc')**
3. **Ring artifacts**
4. **Image noise**
5. **Aliasing artifacts**
6. **Motion artifacts**

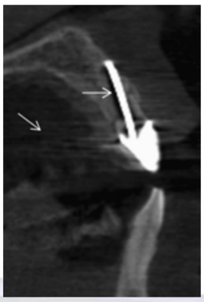
CT scanning - artefacts

1. Beam hardening:



CT scanning - artefacts

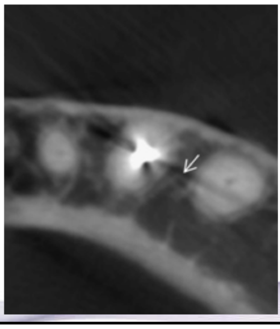
1. Beam hardening:



- Affects dense metals
- High atomic number metals worse
- Also affects gutta-percha (Barium)
- Mathematical assumption that x-ray beam is monochromatic
- Dense objects attenuate (remove) lower energy x-ray photons
- Greater percentage of high energy level x-rays are hitting detector than were leaving x-ray source
- Results in under sampling

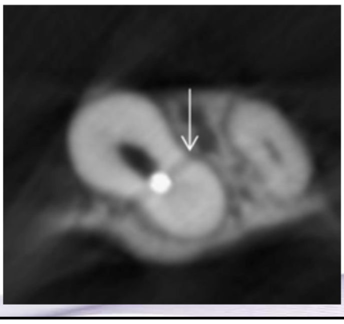
CT scanning - artefacts

1. Beam hardening – gutta percha:



CT scanning - artefacts

1. Beam hardening (fake fractures):



CT scanning - artefacts

1. Beam hardening (fake caries):

CT scanning - artefacts

2. White Streak Artifacts:

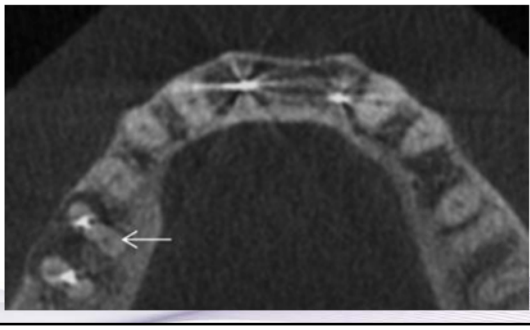
CT scanning - artefacts

2. White Streak Artifacts:

- Affects dense materials (high atomic number)
- Crowns, amalgam fillings, implants cause effect
- Also due to algorithm limitations
- Tend to be in plane of x-ray beam
- Can hide other lesions (caries etc)

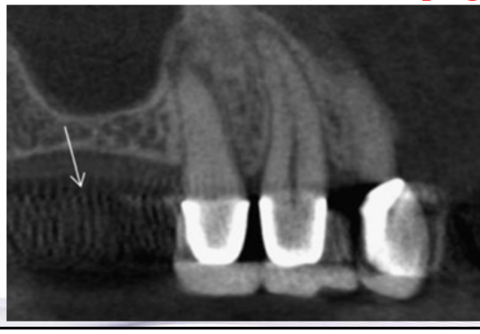
CT scanning - artefacts

2. White Streak Artifacts (metal posts):



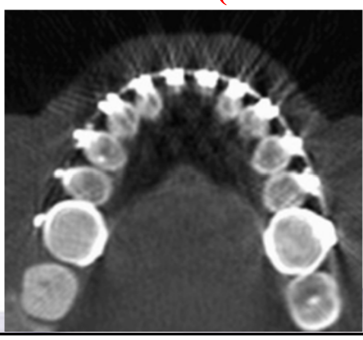
CT scanning - artefacts

2. White Streak Artifacts (metal copings):



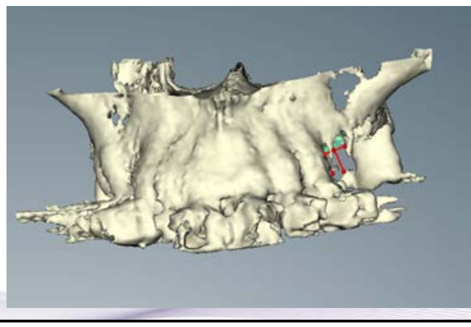
CT scanning - artefacts

2. White Streak Artifacts (ortho wire):



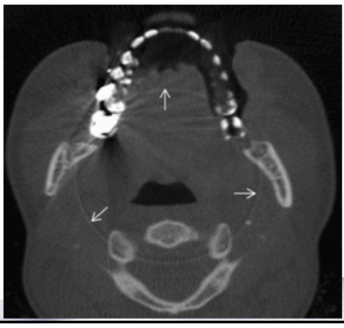
CT scanning - artefacts

2. White Streak Artifacts – 3D rendered:



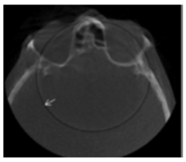
CT scanning - artefacts

3. Ring artifacts:



CT scanning - artefacts

3. Ring artifacts:



- Defective detector dexel
- Calibration problem (x-ray source and detector misaligned) – poor QA standards???
- Ring effect around axis of rotation
- Seen in axial views

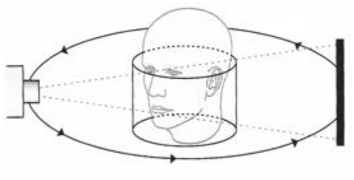
CT scanning - artefacts

4. Image Noise:

CBCT scanners – cheaper CBCT units

Noise = unstructured contribution to the image which has no counterpart in the object.

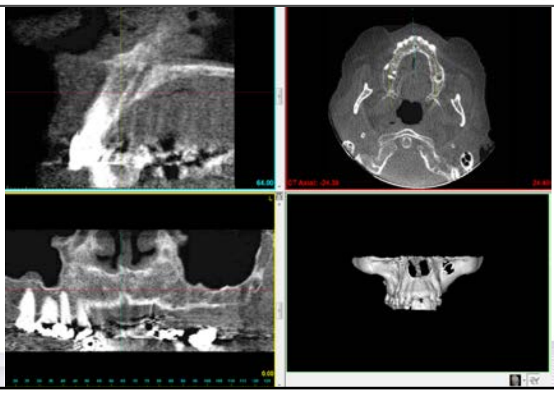
- Photon noise (not enough x-rays)



CT scanning - artefacts

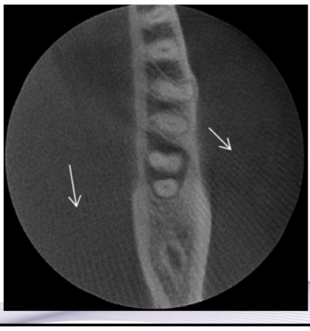
4. Image Noise:

CBCT scanners – Image Noise



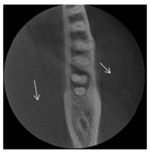
CT scanning - artefacts

5. Aliasing artifacts:



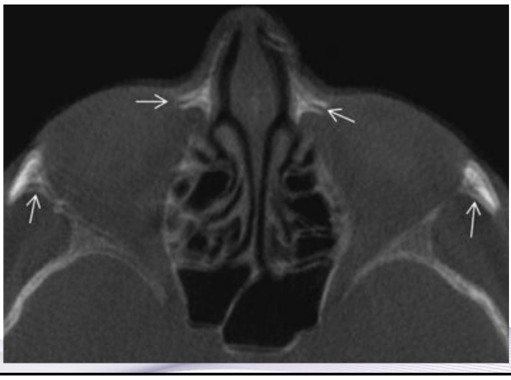
CT scanning - artefacts

5. Aliasing artifacts:



- Wavy lines diverging outwards towards edge of image
- Also called the 'Moire Pattern'
- Caused by undersampling
- Related to the size of the dexels in the flat panel receptor, number of basis images in the scan and mathematical algorithms
- Do not usually look like natural structure (apart from root fractures!)

CBCT scans – motion artifacts

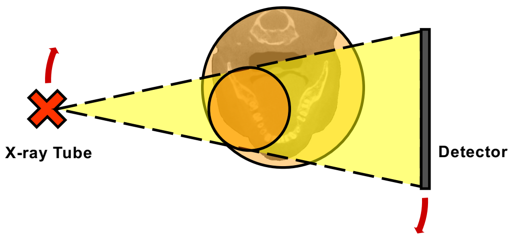


CBCT scans – terminology

Field of View (FOV)

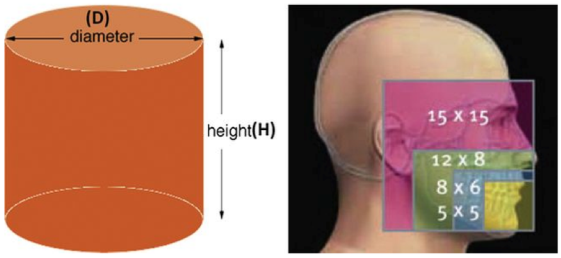
CBCT scanning – Field of View

FOV – 'Field of View



Size of the scanned object volume

CBCT scanning – Field of View



In Flat Panel CBCT machines this is a cylindrical shape

Data Protection and Security

CBCT scanning – Data Protection

CBCT scanning – Data Protection

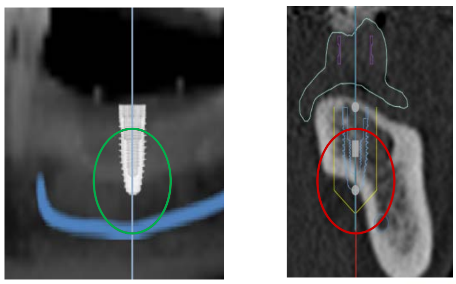
- Register with ICO
- Follow DPA requirements
- Consult with Defence Society?
- Safe data storage – passwords etc
- Safe data transfer (passwords for digital)
- Ensure backups made and stored offsite in locked fire proof safe

Medicolegal Issues

CBCT scanning – Medicolegal issues

To scan or not to scan????

The OPG gives 2D anatomical information, but what counts is the patient's anatomy in 3D



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CBCT scanning – Medicolegal issues

- Ensure full clinical assessment is always done first
- Ensure and record justification for exposure
- Must have an expected benefit for the patient
- Only image dento-alveolar region
- If other regions imaged – refer for report
- Obtain and record informed consent

THE END