CBCT imaging artefacts

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Learning objectives

- Define what an artefact is
- Recognise common artefacts encountered in CBCT
- Gain insight into the underlying mechanisms responsible for artefacts
- Appreciate the impact of artefacts on diagnostic accuracy and treatment planning
- Identify practical methods to reduce artefact

What is an artefact?

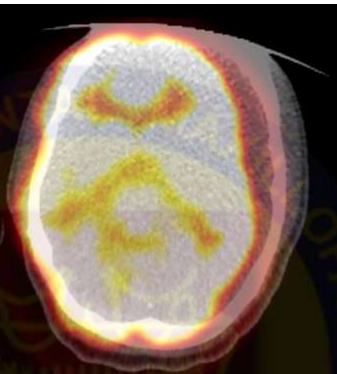
- Any artificial feature or distortion appearing on an image that does not represent a true anatomical structure or disease
- Certain artefacts are unique to specific imaging modalities

- May mimic or hide pathological processes
- Risk of inappropriate management

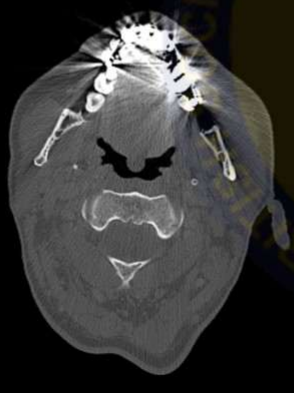
- Imaging examinations may need to be repeated

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Why do artefacts occur?

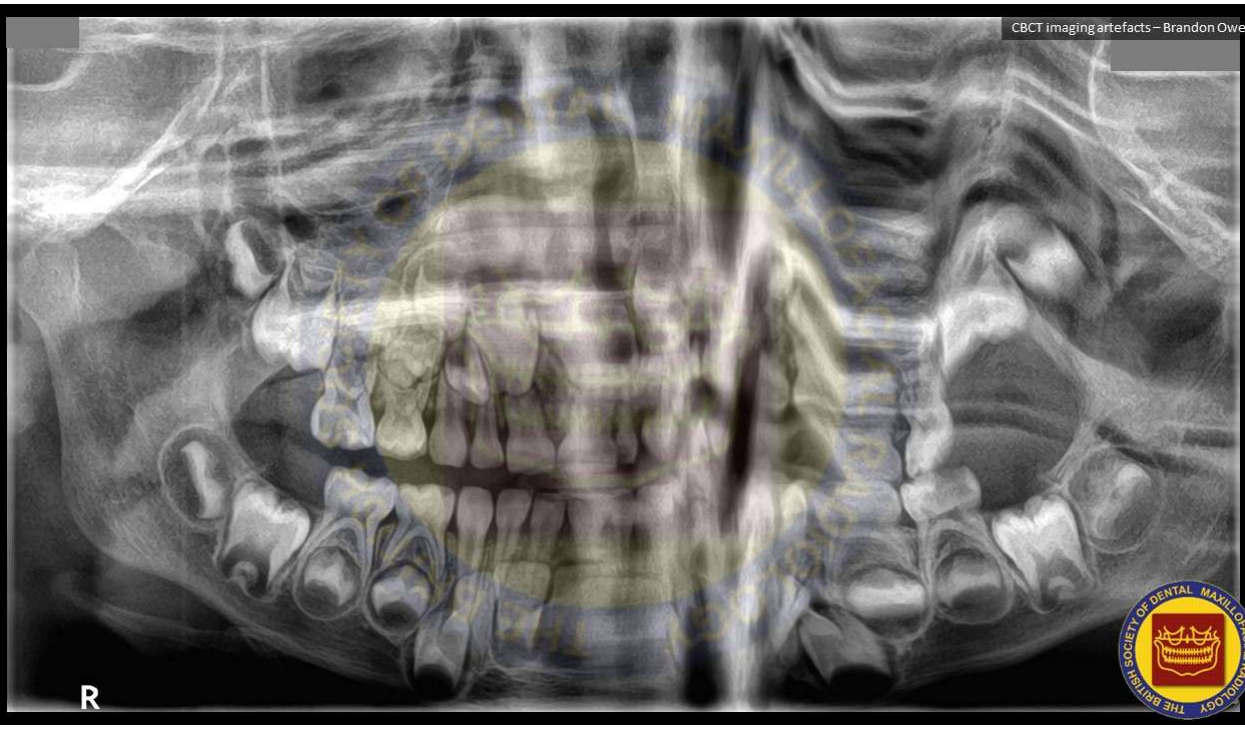
- Patient related
  - Motion
  - Metallic objects
  - Patient size / composition
- Physics related
  - How x-rays interact with the patient
  - Unique aspects of the specific imaging technique
- Equipment / hardware related
  - Wear and tear, and malfunction
  - Suboptimal maintenance

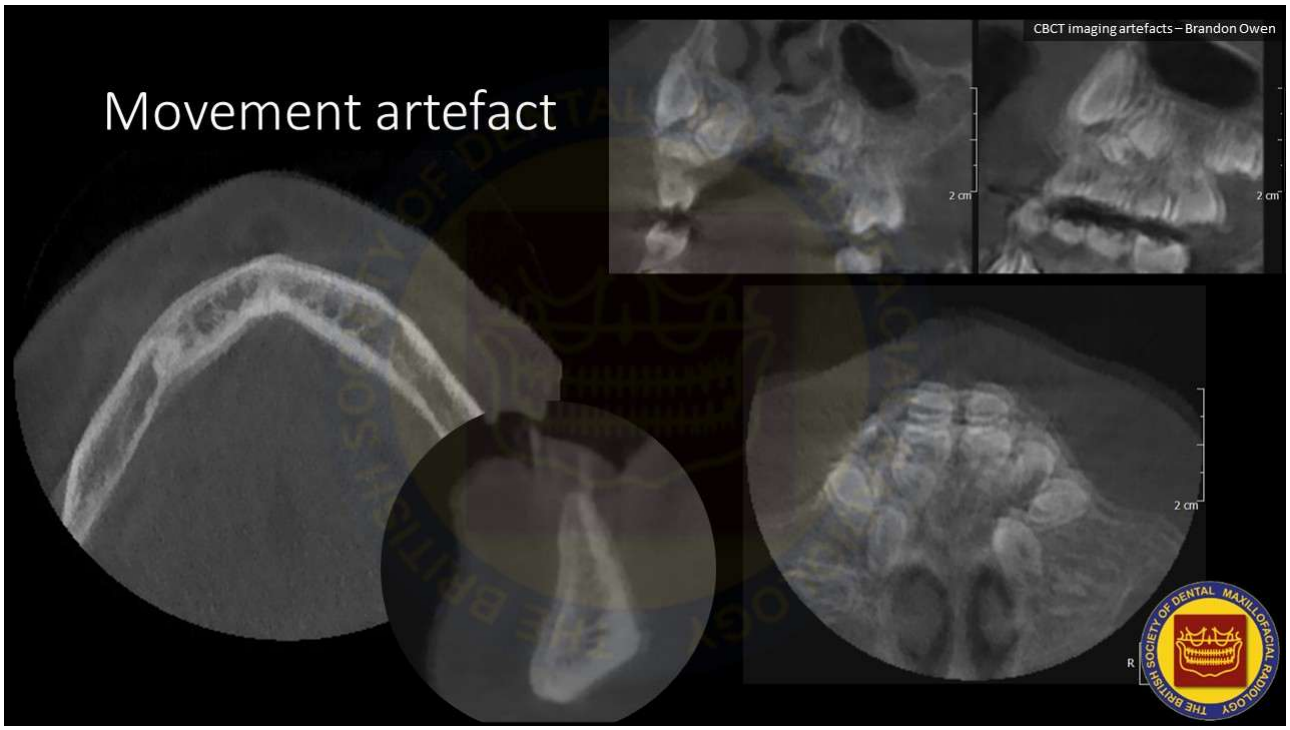
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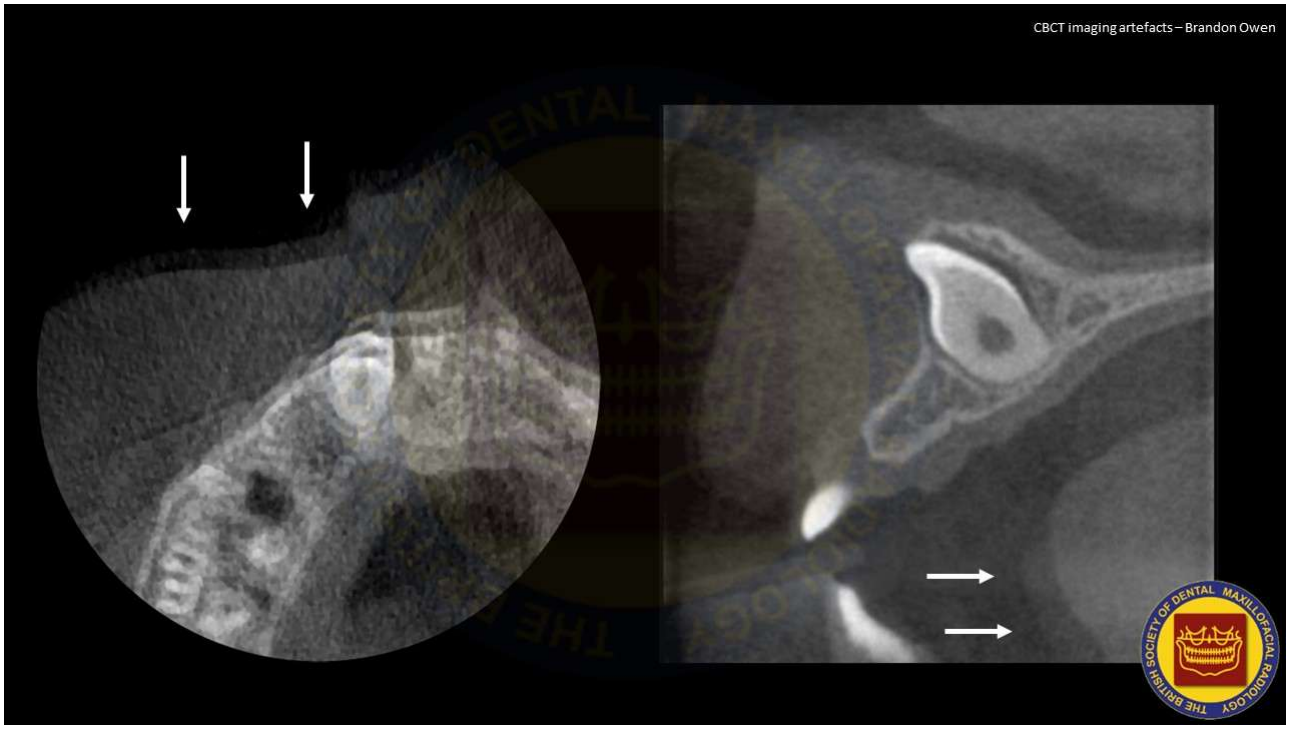
Artefact is a limitation of CBCT

- Inherent and somewhat predictable
- CBCT may be inappropriate in certain circumstances
- Is CBCT appropriate in the context of expected artefact?
- Can artefact be mitigated taking into account patient and technical factors?
- Is an alternative modality more appropriate?

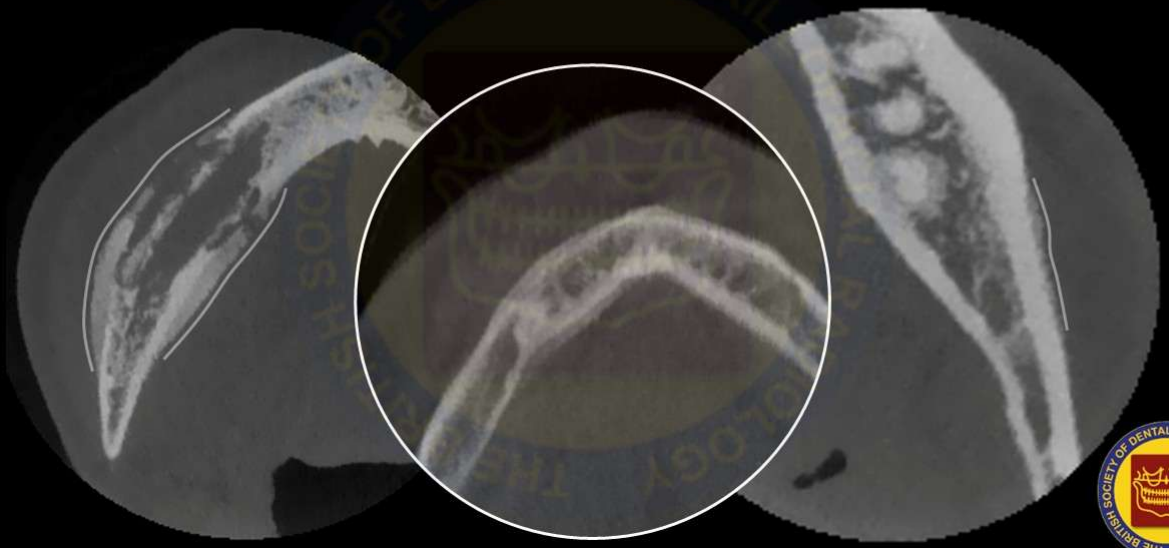
Movement artefact




Movement artefact
CBCT imaging artefacts – Brandon Owen
2 cm
2 cm
2 cm
R


CBCT imaging artefacts – Brandon Owen

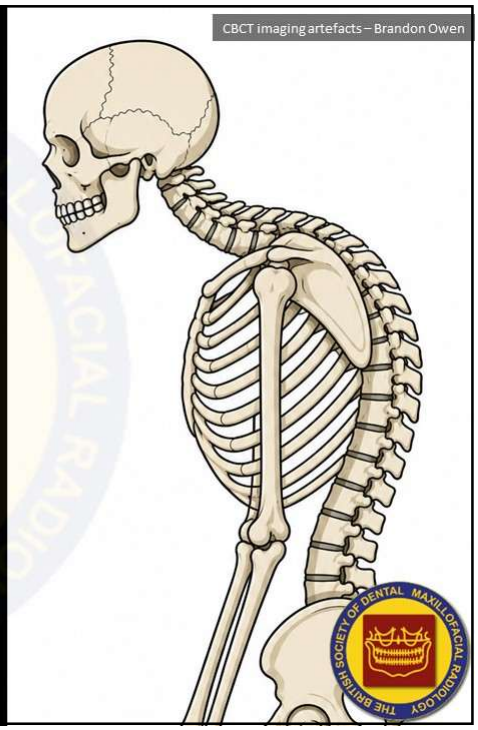
Periosteal bone formation



Minimise movement

- Explanation and reassurance
- Confident and efficient technique
- Stabilise patient – head support, bite peg
- Test run

- Scan time / rotation arc
- Motion artefact reduction



Seated/supine models may help to stabilise



DEXIS OP 3D



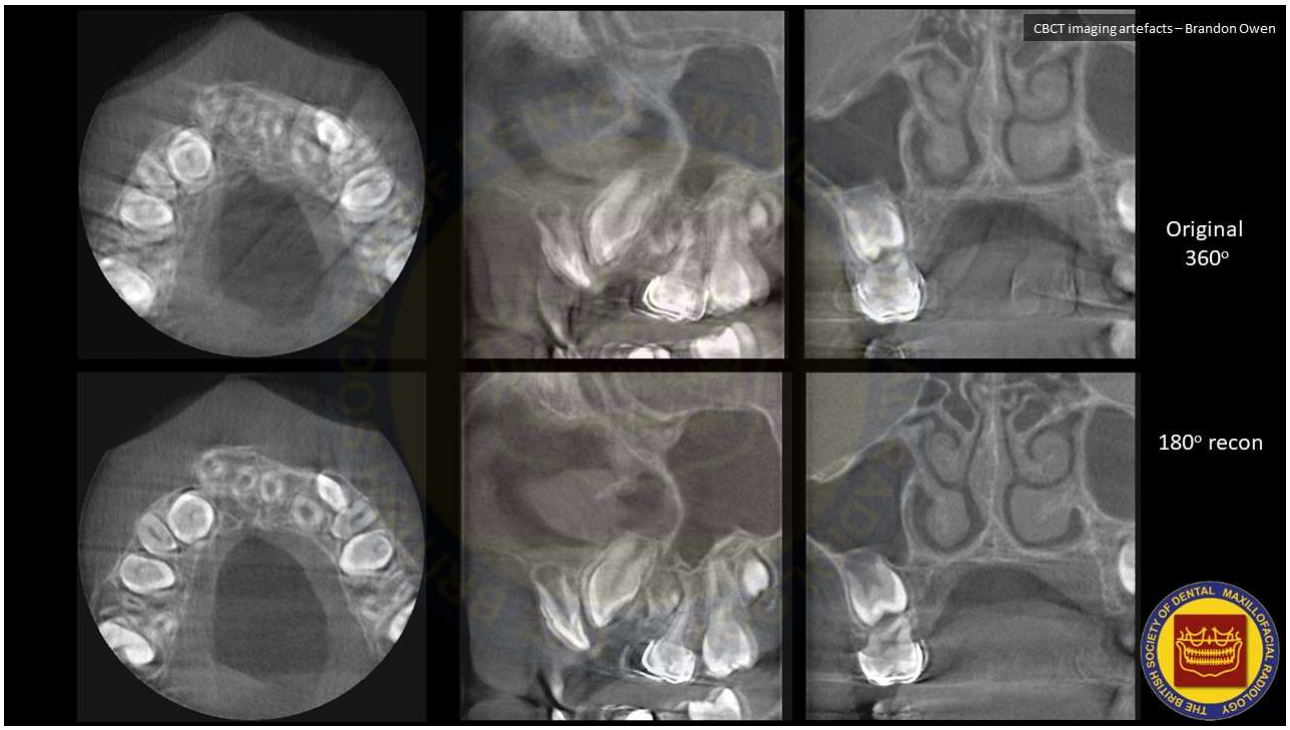
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NEWTOM 7G

Motion artefact reduction





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Movement artefact – do we need to repeat?

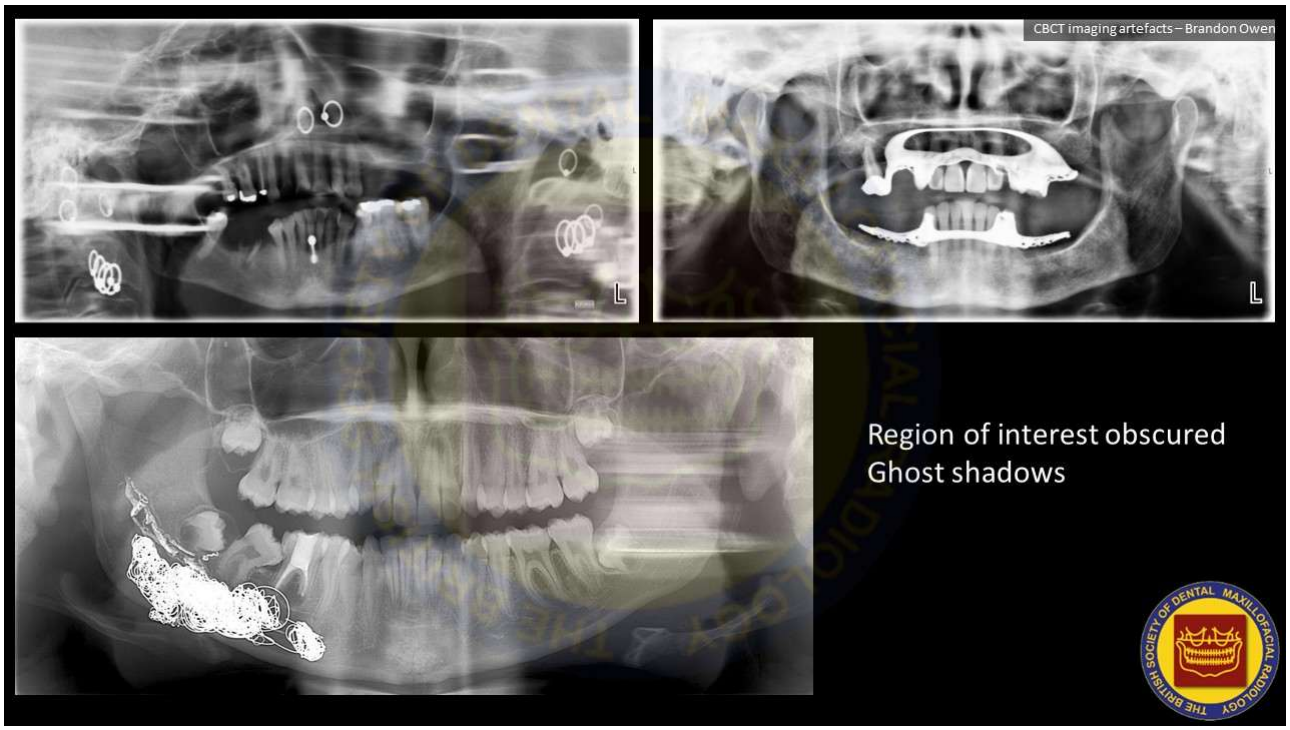
- Degree of movement artefact
- Purpose of the imaging
- Is the patient likely to remain stable for a second attempt?

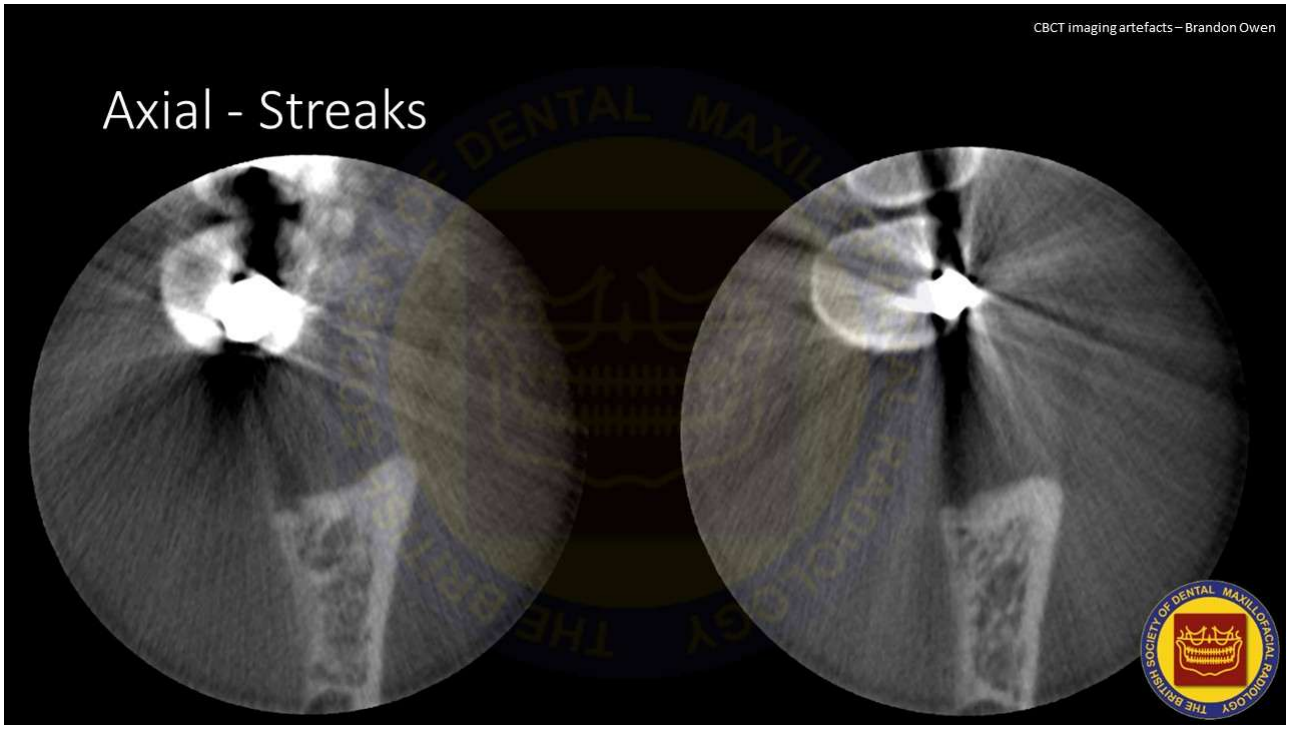
- May have to accept 'best attempt' if movement artefact on repeat imaging is likely

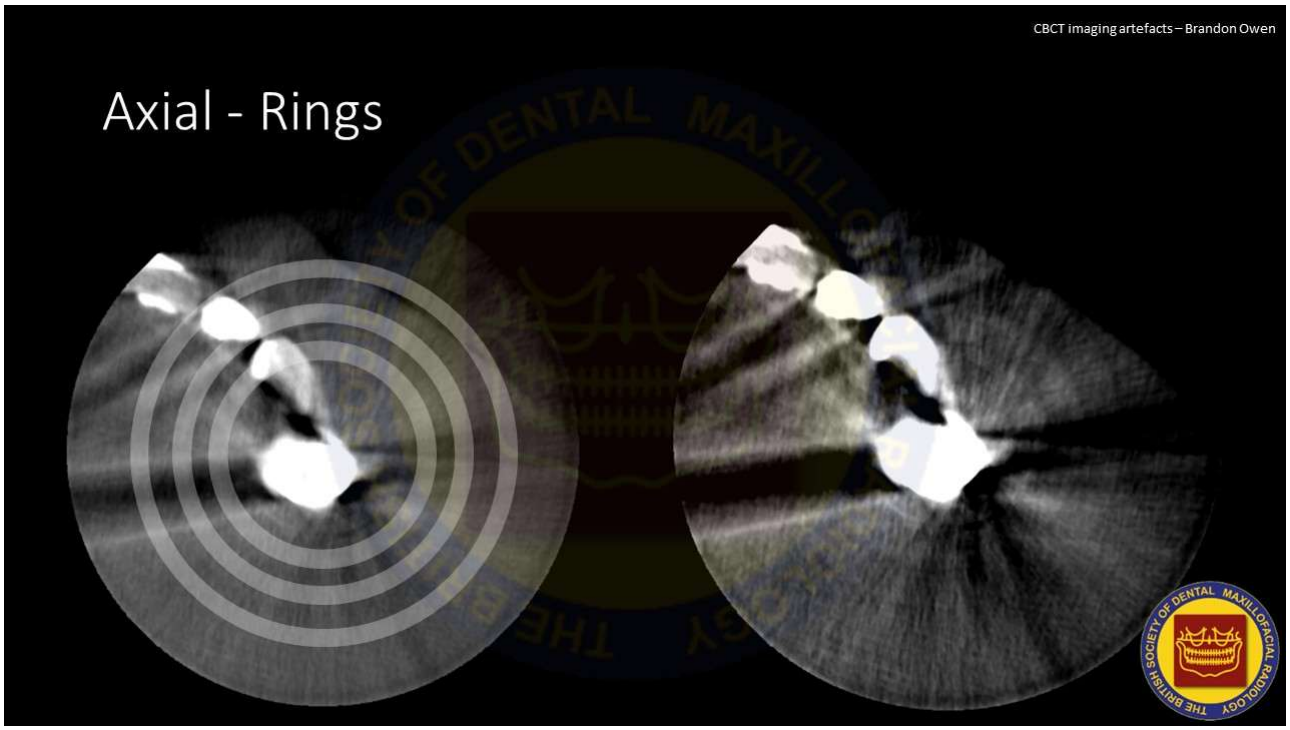
Metal artefact

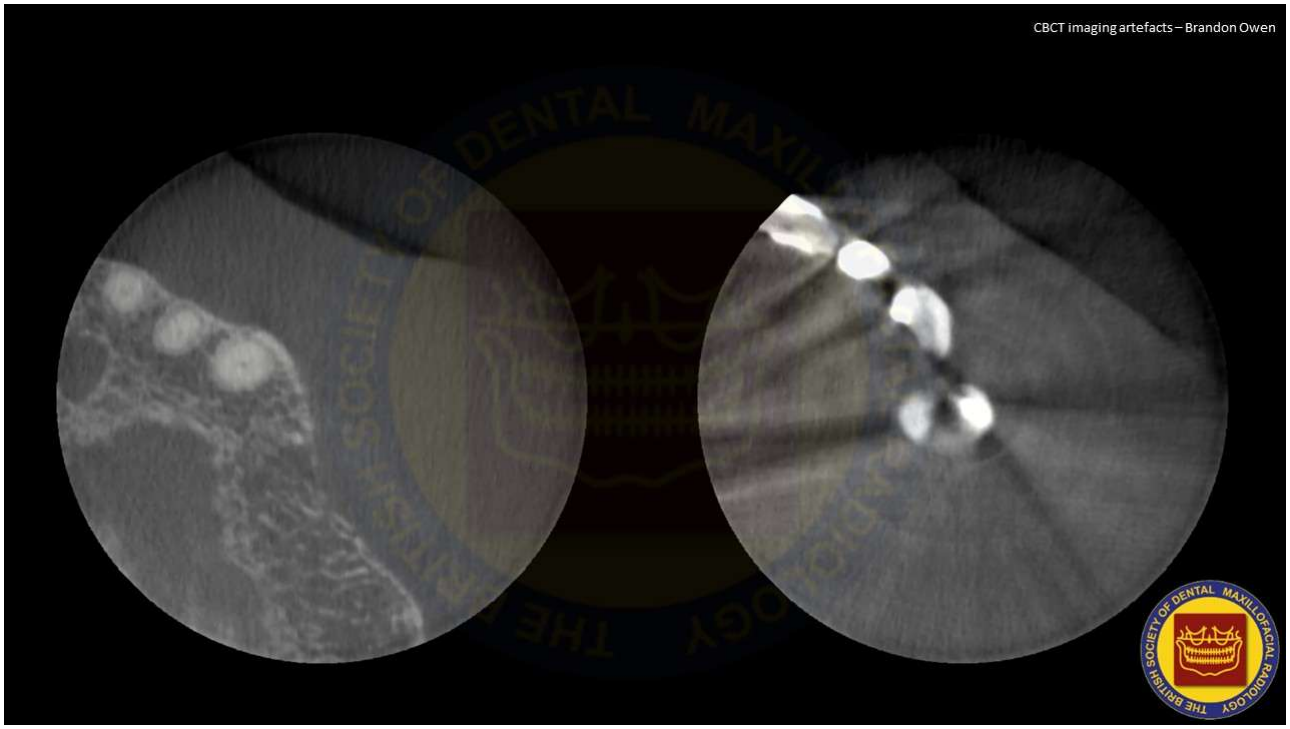
Metal artefact

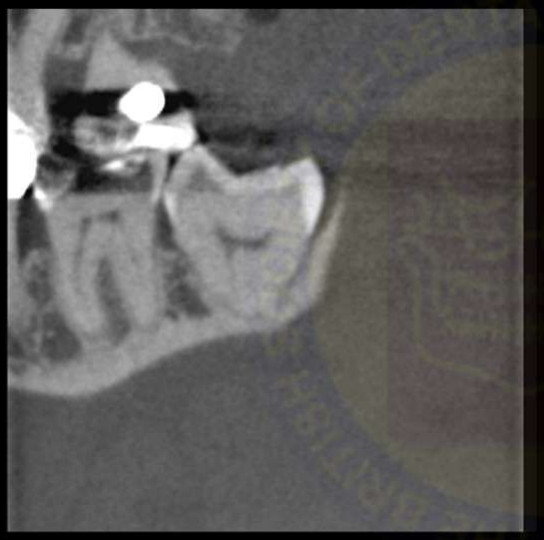
- Jewellery – nose, tongue, ear, lip piercings, necklaces, hair clips
- Hearing aids, dentures
- Amalgam
- Dental implants
- Orthodontic appliances
- Root filling material
- Surgical clips, plates and screws


CBCT imaging artefacts – Brandon Owen
L
L
Region of interest obscured
Ghost shadows


CBCT imaging artefacts – Brandon Owen
Axial - Streaks


CBCT imaging artefacts – Brandon Owen
Axial - Rings


CBCT imaging artefacts – Brandon Owen

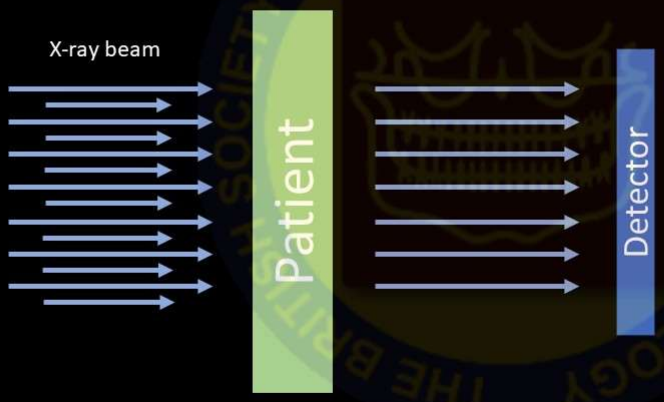




Three underlying processes

- Beam hardening
- Photon starvation
- Scatter

Beam hardening

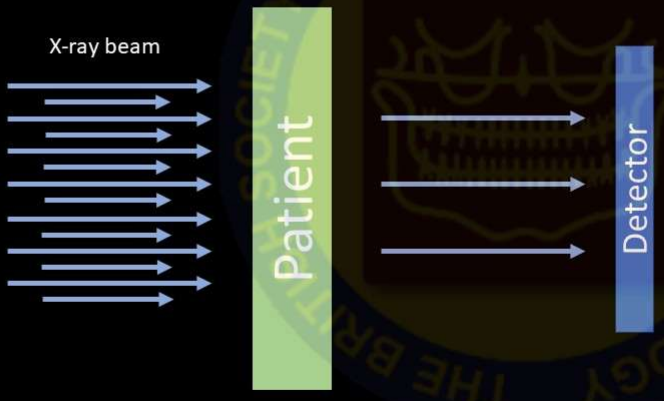


Lower energy 'softer' photons more likely to be absorbed

Results in increased average energy of the beam 'hardened'

Dark streaks

Photon starvation

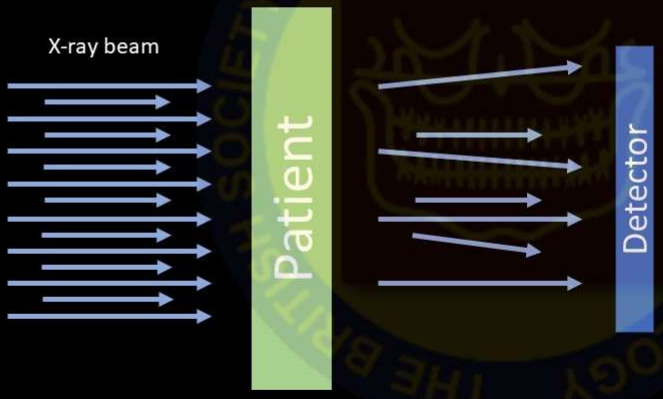


Significant attenuation of beam

Insufficient numbers of photons reach the detector

White streaks

Scatter



Scatter changes the path of x-ray photons

Scattered photons are mislocated by the detector

Reduce image contrast, resolution, increased noise

Streaks, washed out, blurry

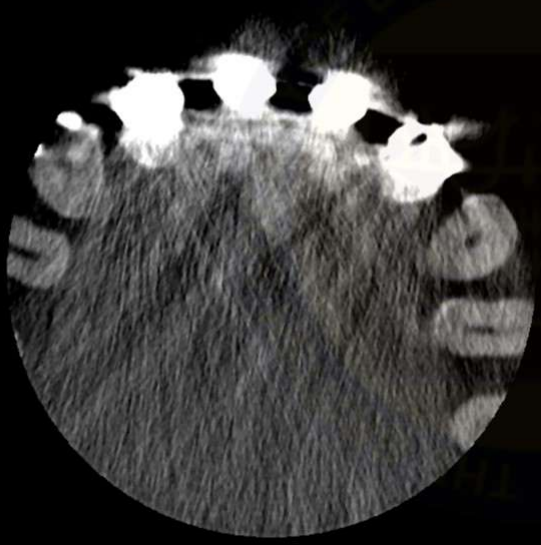
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Removable objects



Patient should be made aware of detrimental impact and remove object

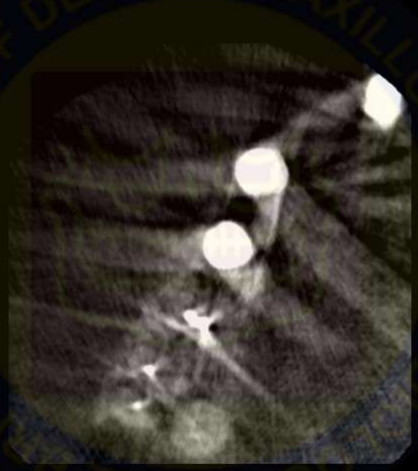
Not all metal objects can be removed (easily)



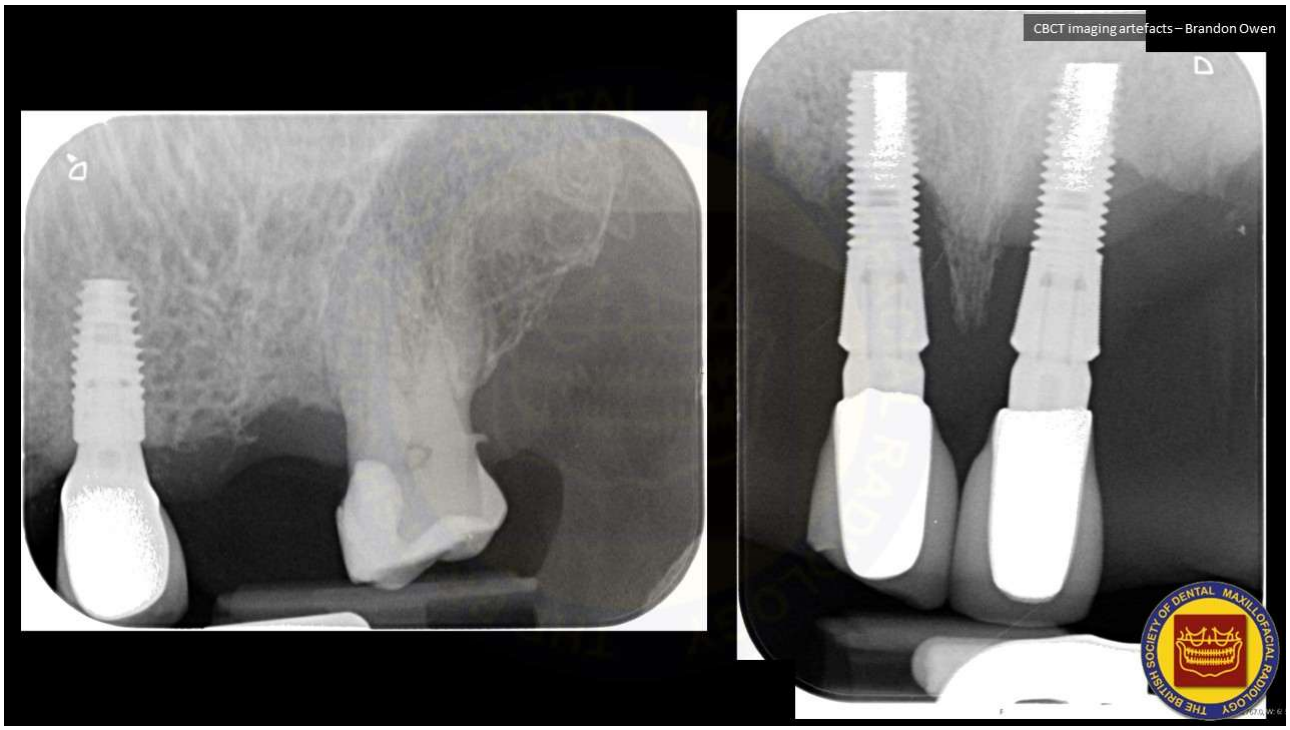


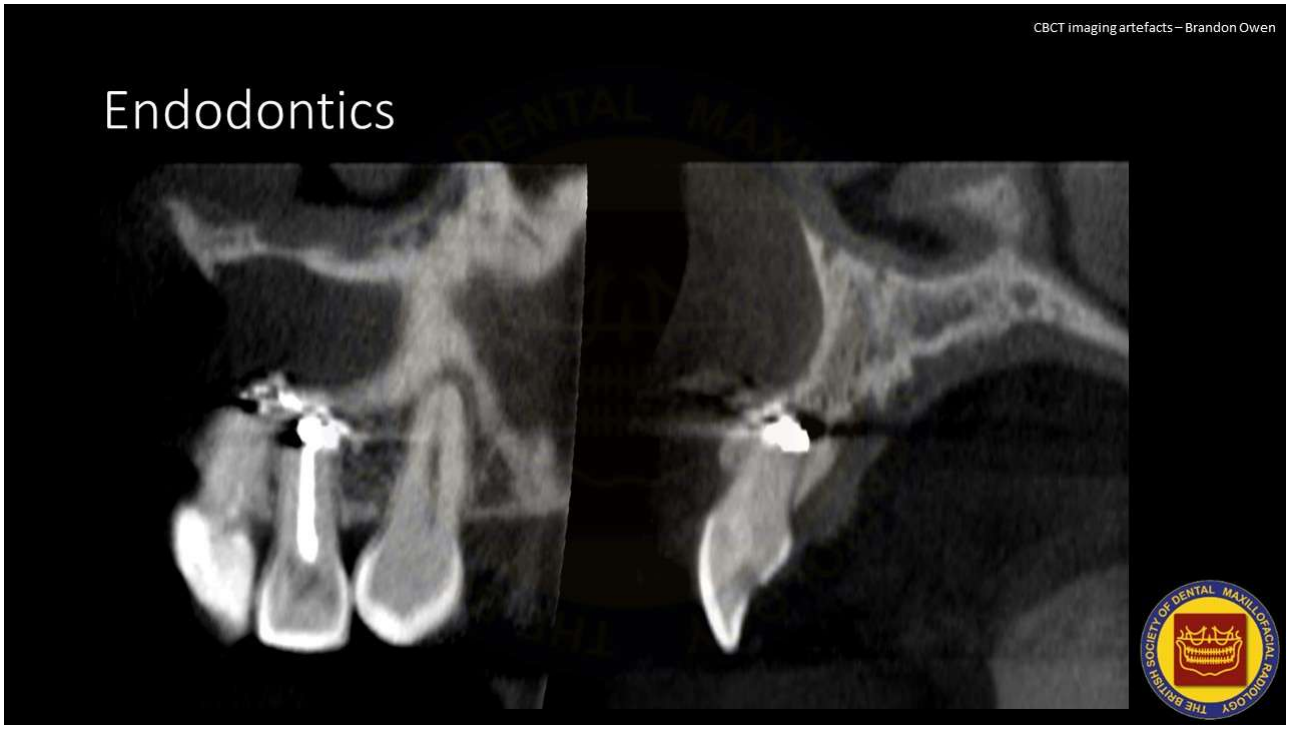
Implants



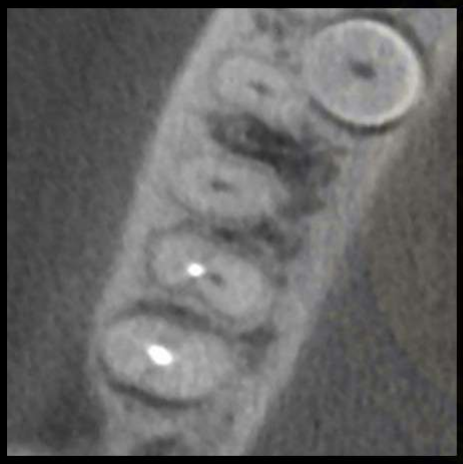





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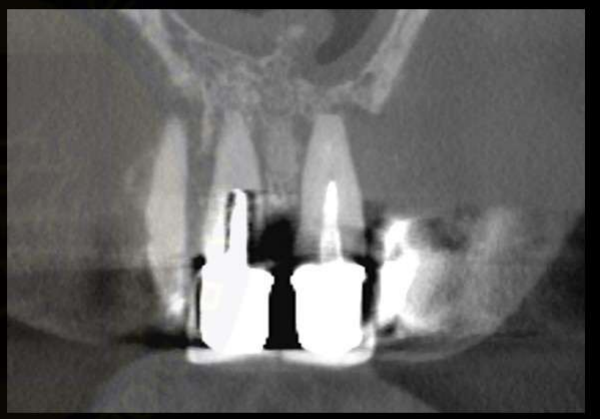

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Endodontics

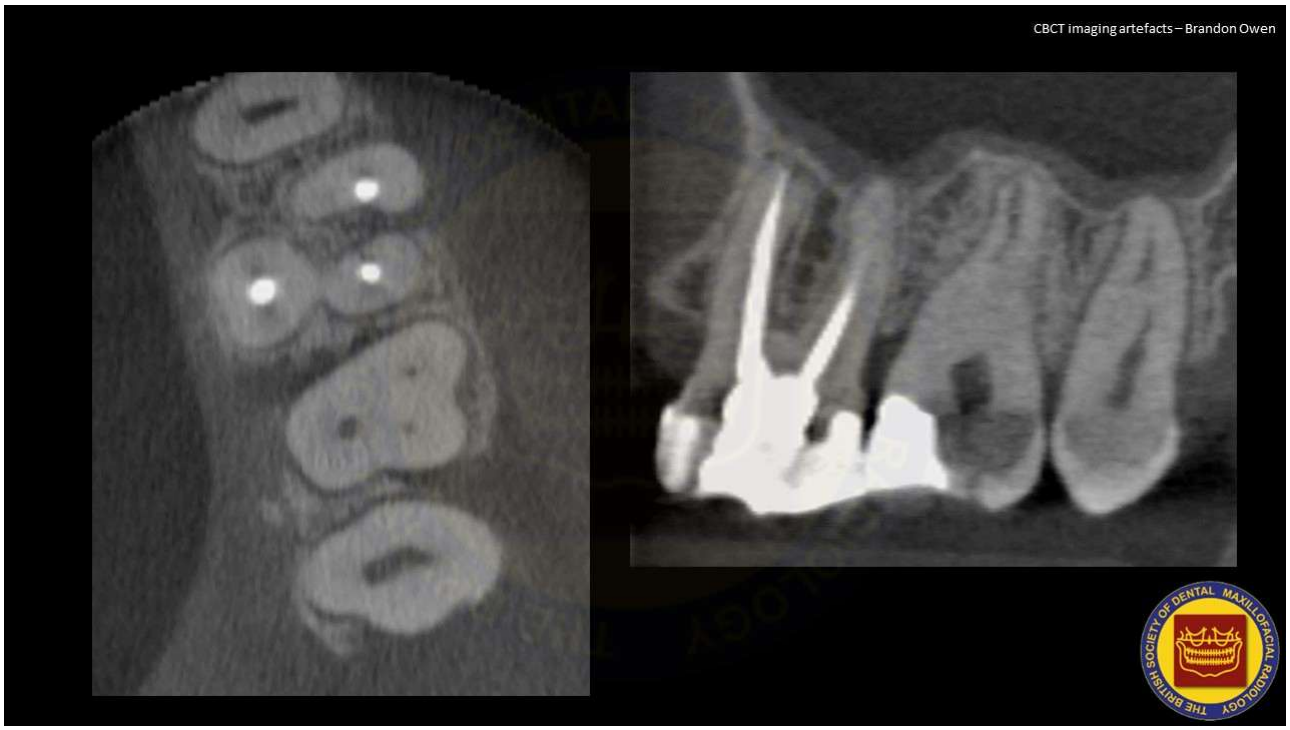
Endodontics

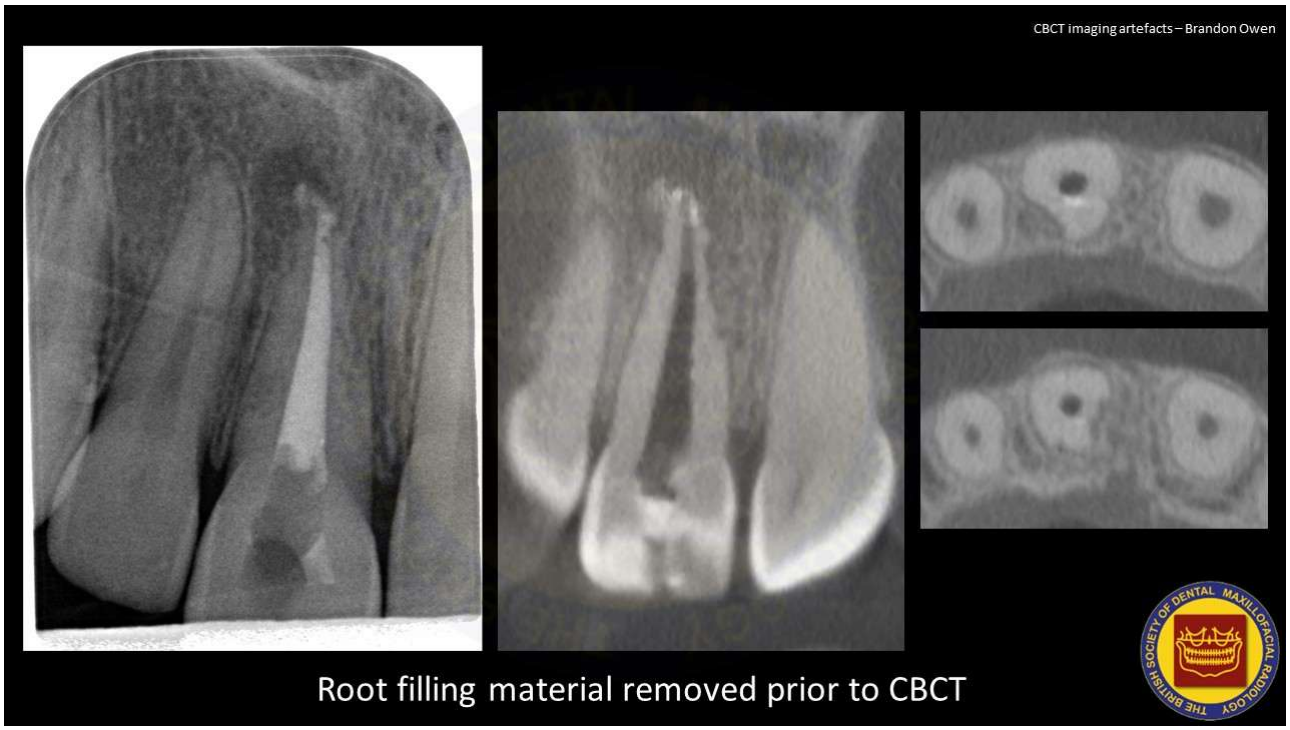




CBCT imaging artefacts – Brandon Owen


CBCT imaging artefacts – Brandon Owen


CBCT imaging artefacts – Brandon Owen
Root filling material removed prior to CBCT

Caries





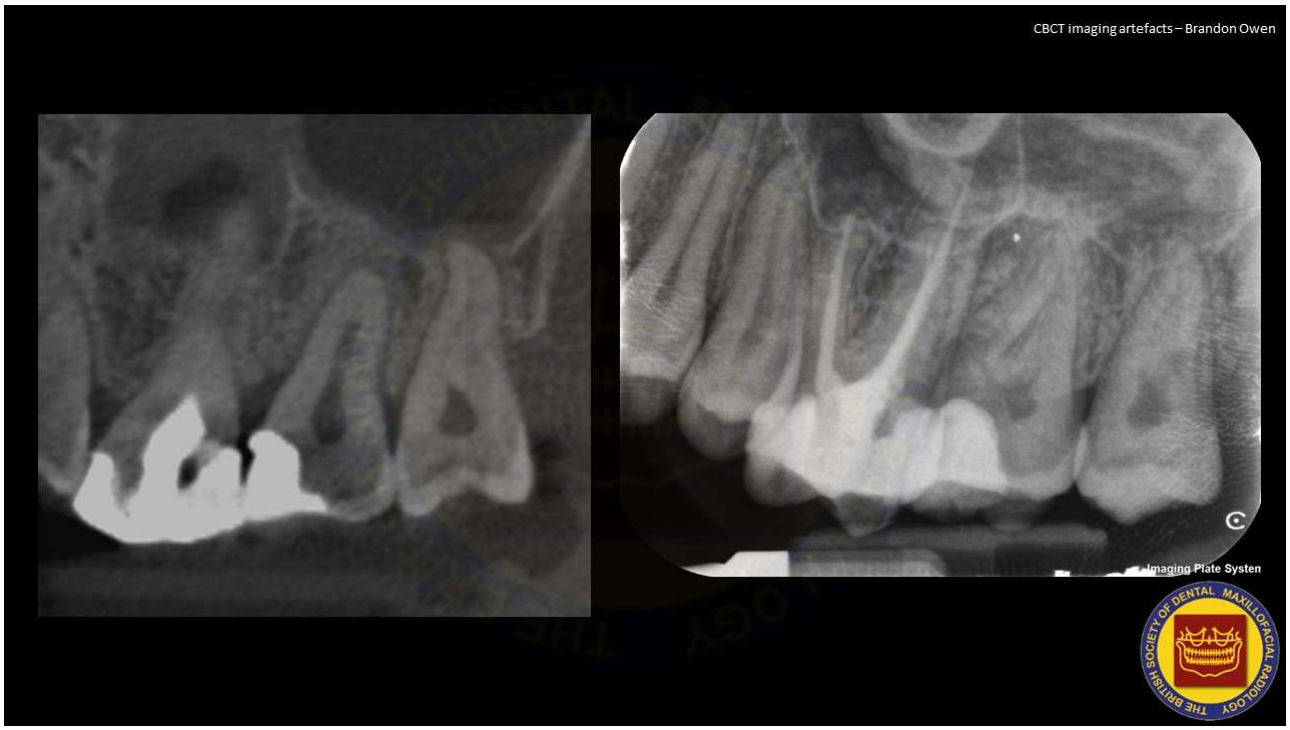
Artefact may mimic or obscure caries

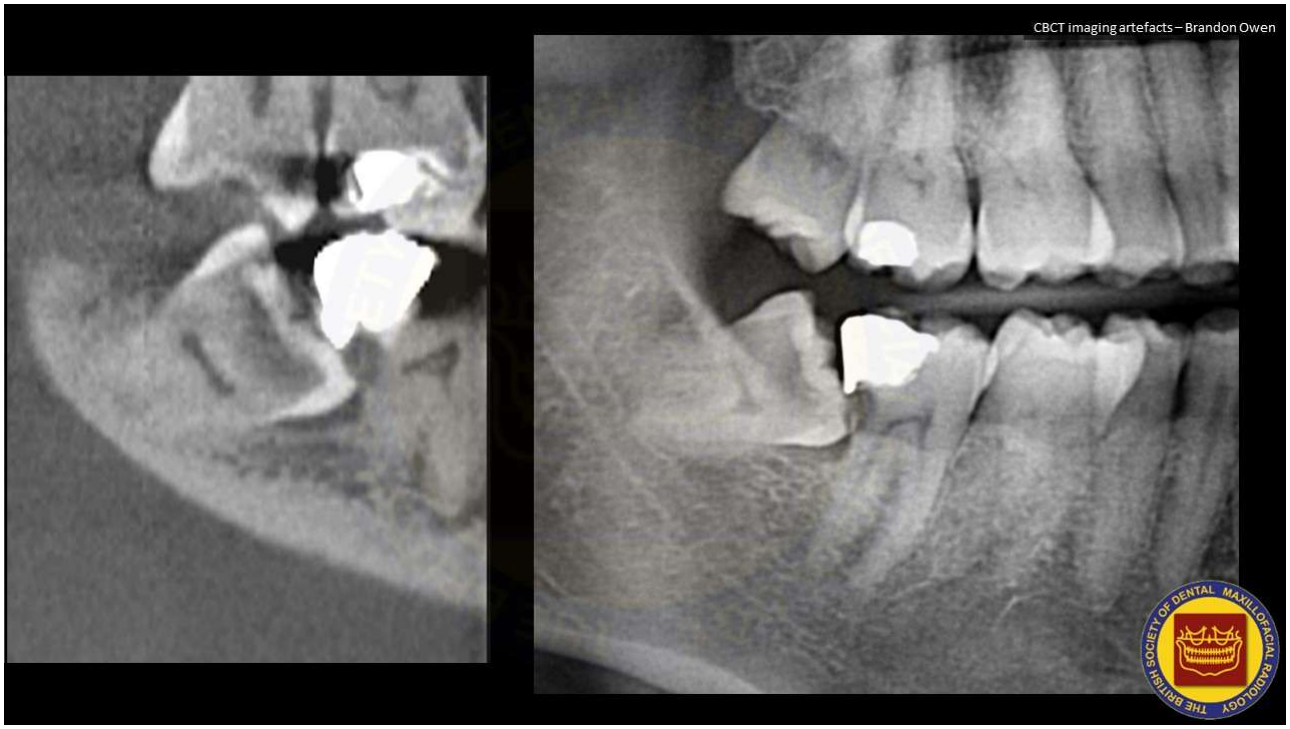
CBCT should not be used for routine caries diagnosis however you will see lots of caries

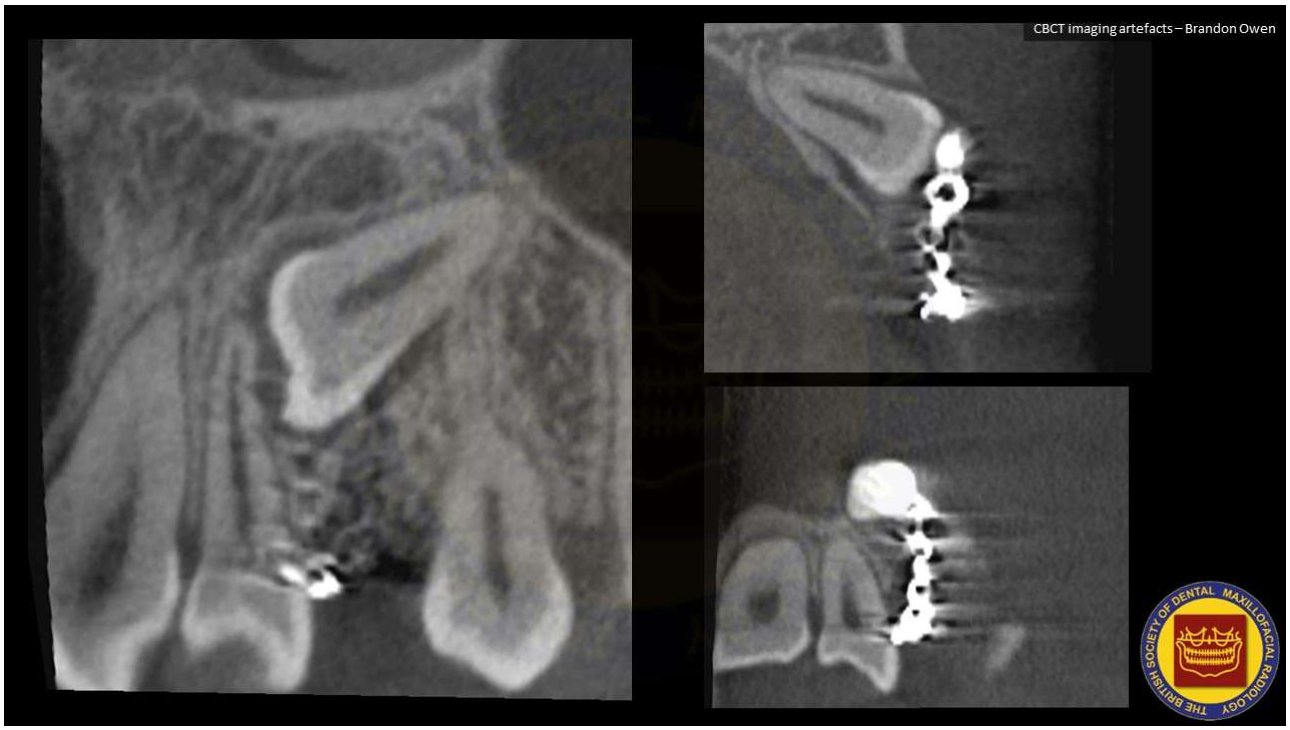
Refer to plain radiographs

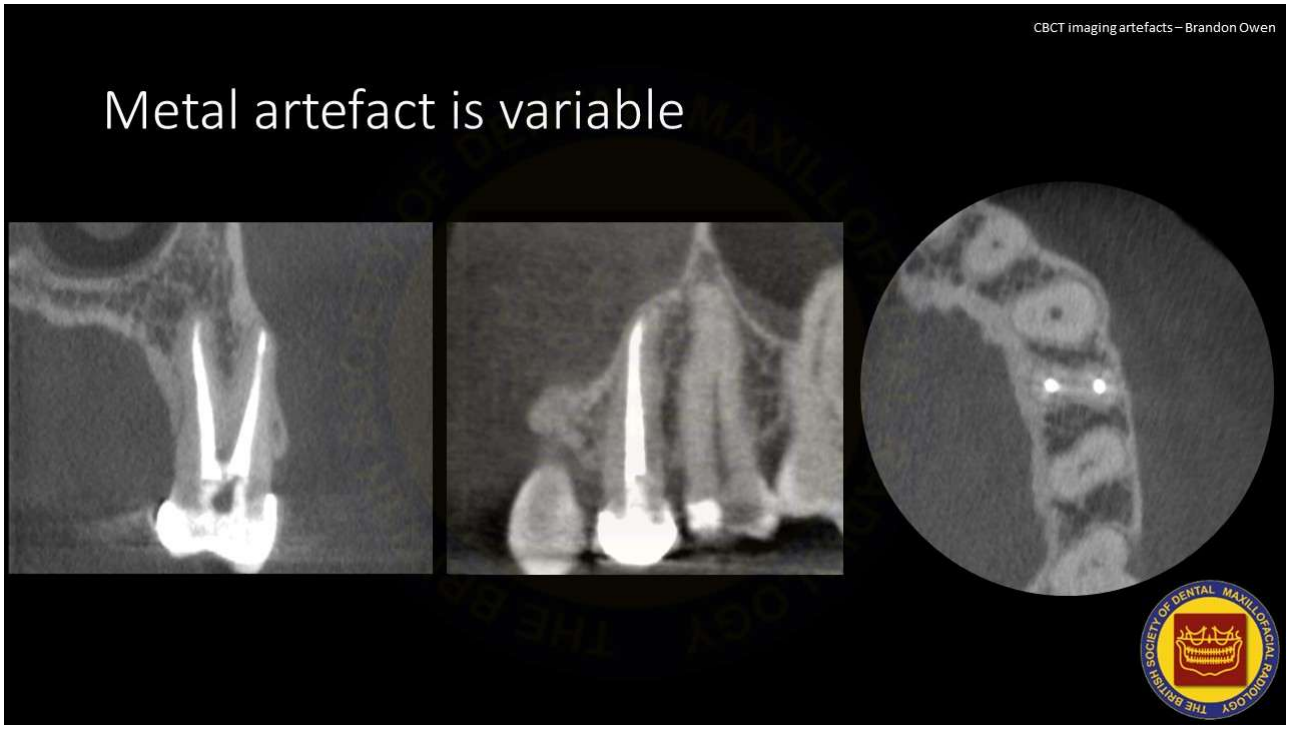


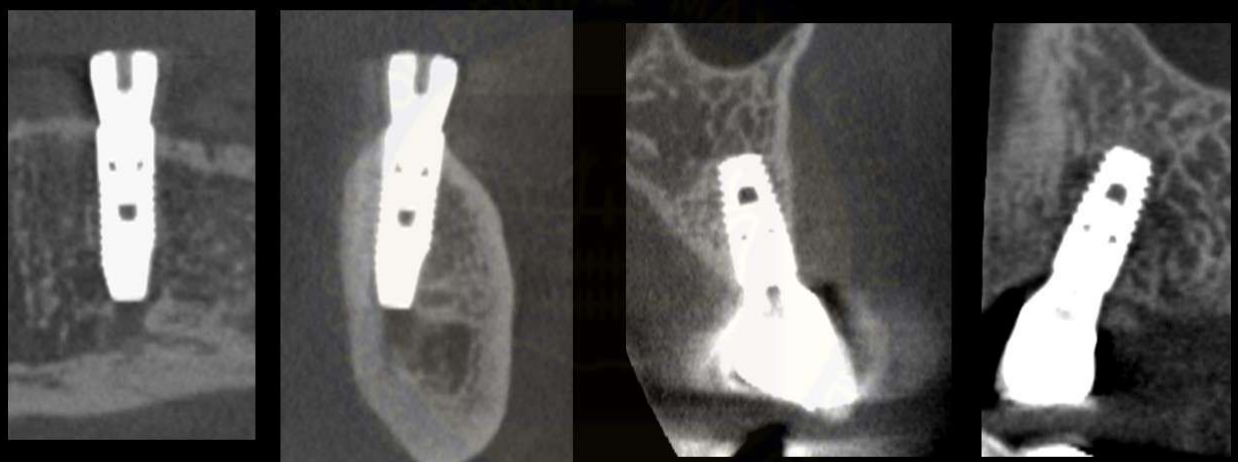



CBCT imaging artefacts – Brandon Owen
Imaging Plate Systen
THE BRITISH SOCIETY OF DENTAL MAXILLOFACIAL RADIOLOGY


CBCT imaging artefacts – Brandon Owen
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CBCT imaging artefacts – Brandon Owen

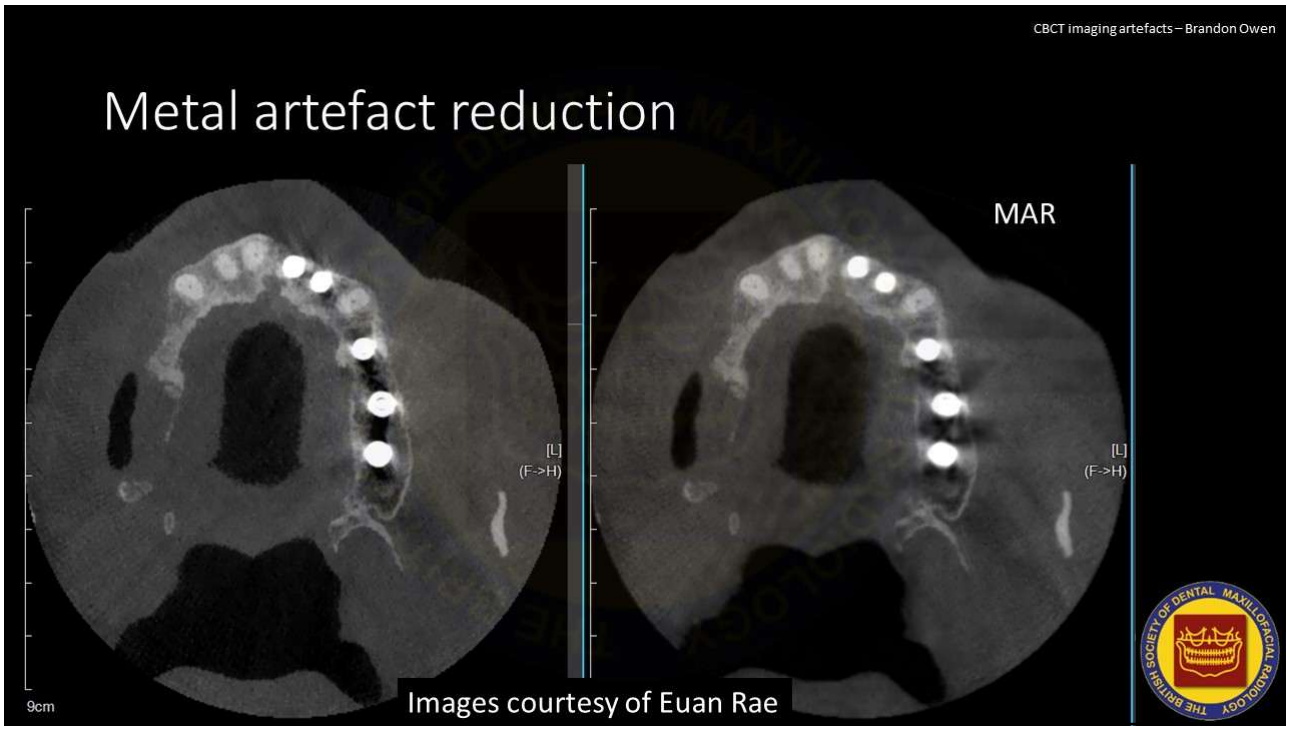

CBCT imaging artefacts – Brandon Owen
Metal artefact is variable

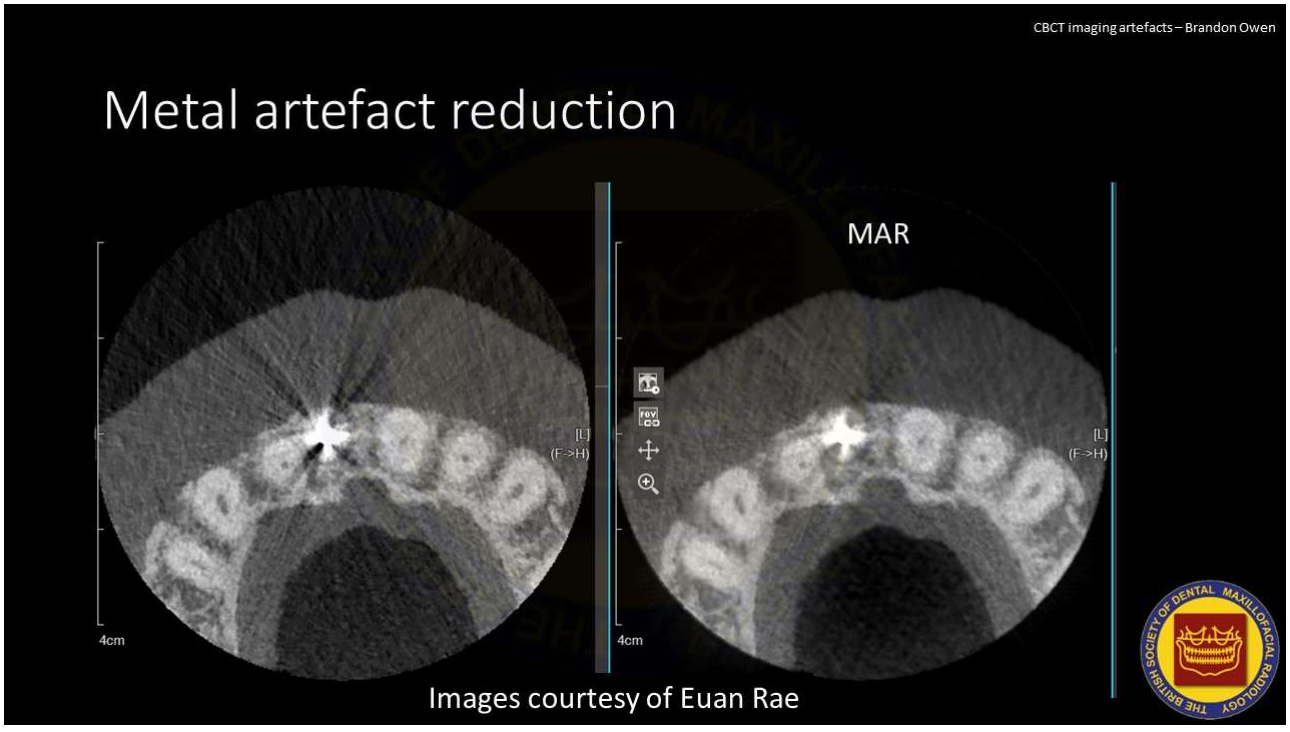


Factors influencing metal artefact

- Patient positioning
- Direction of the primary beam
- Density / size / form and position(s) of object
- Exposure factors
- Metal artefact reduction algorithms

- Ensure removable objects are absent
- Utilise existing plain radiographs (complementary to CBCT)

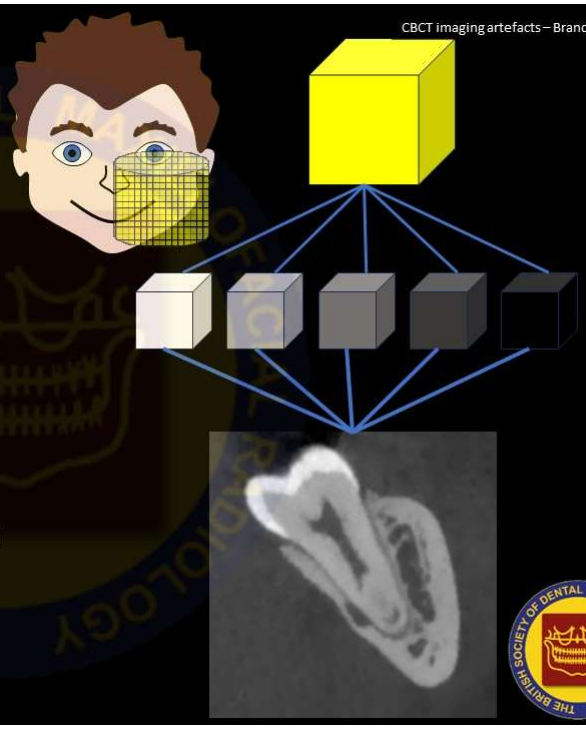

CBCT imaging artefacts – Brandon Owen
Metal artefact reduction
MAR
[L]
(F->H)
[L]
(F->H)
9cm
Images courtesy of Euan Rae


CBCT imaging artefacts – Brandon Owen
Metal artefact reduction
MAR
[L]
(F->H)
[L]
(F->H)
4cm
4cm
Images courtesy of Euan Rae

Partial volume effect

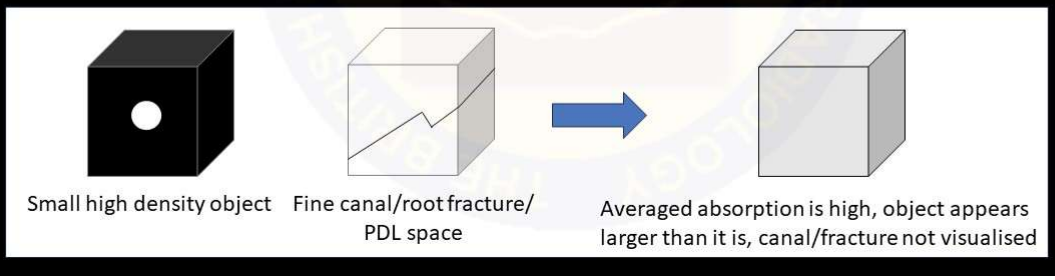
Partial volume effect

- The imaged volume is composed of voxels which are assigned a gray value
- The gray value is a measure of how much x-ray radiation is absorbed within the voxel
- The voxels are a finite size
- If a voxel contains different densities the degree of x-ray absorption (and therefore the gray value) represents an average of that voxel



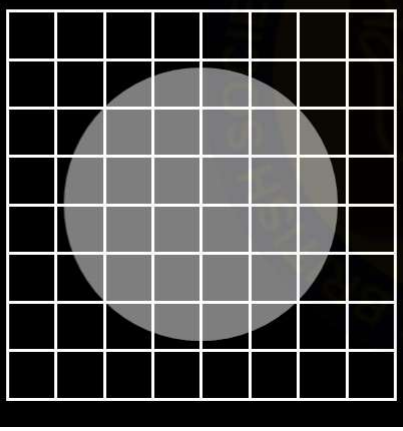
PVE - objects may appear absent or larger

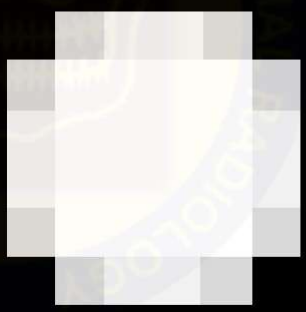




PVE - blurring of boundaries

- Voxels spanning structural borders display an intermediate gray value instead of true sharp transitions.

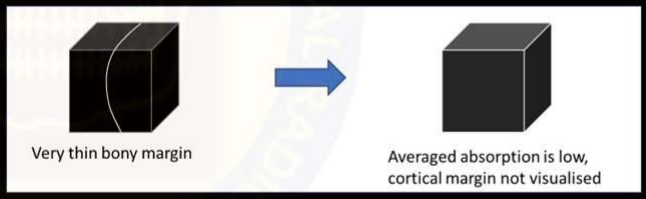




Absent bony separation from the IAC?

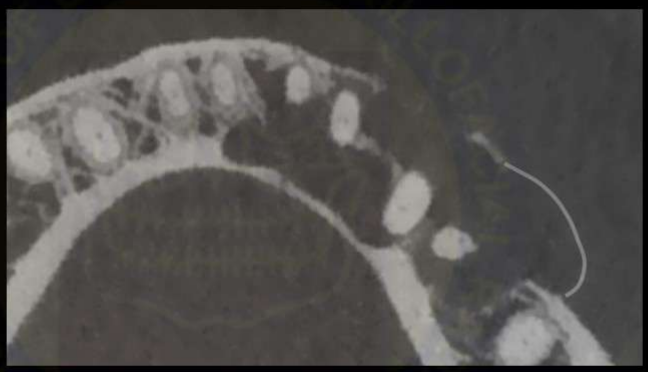
- "No visible bony separation"

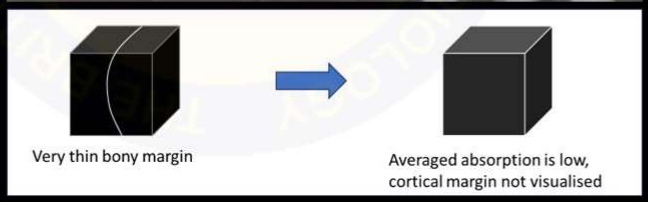


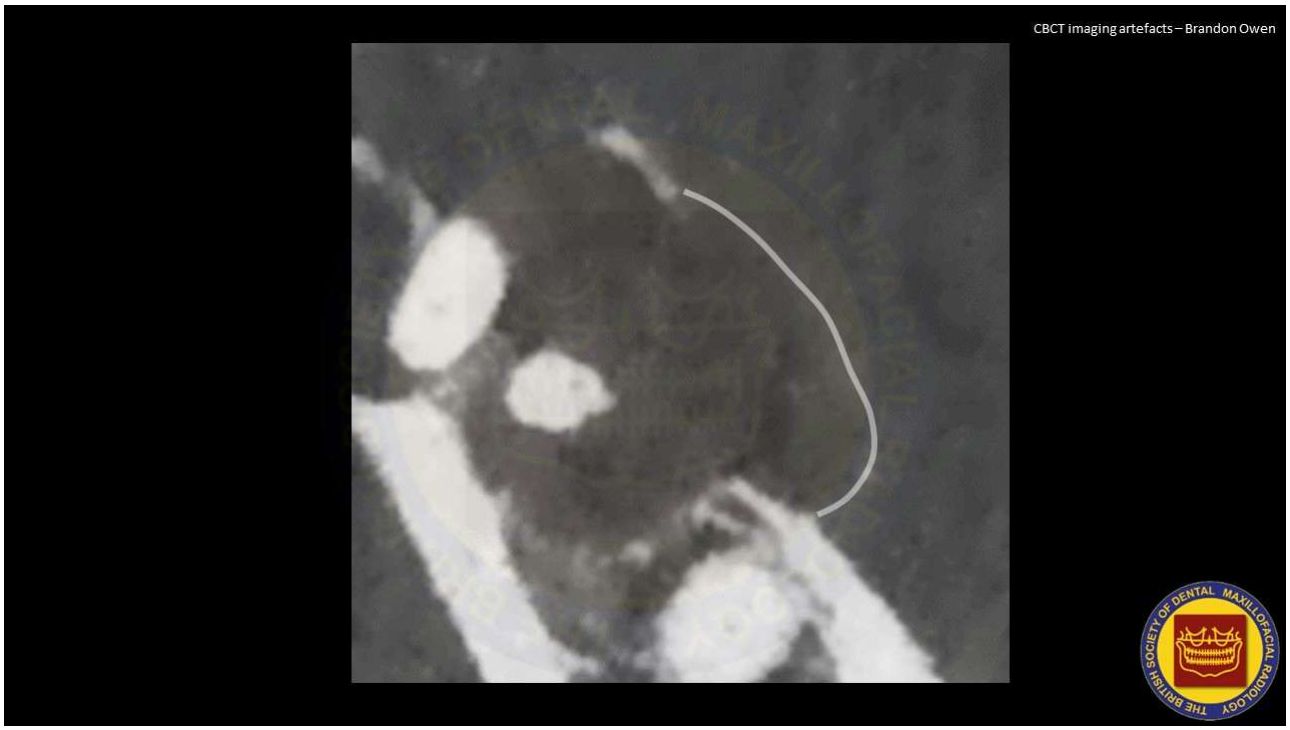


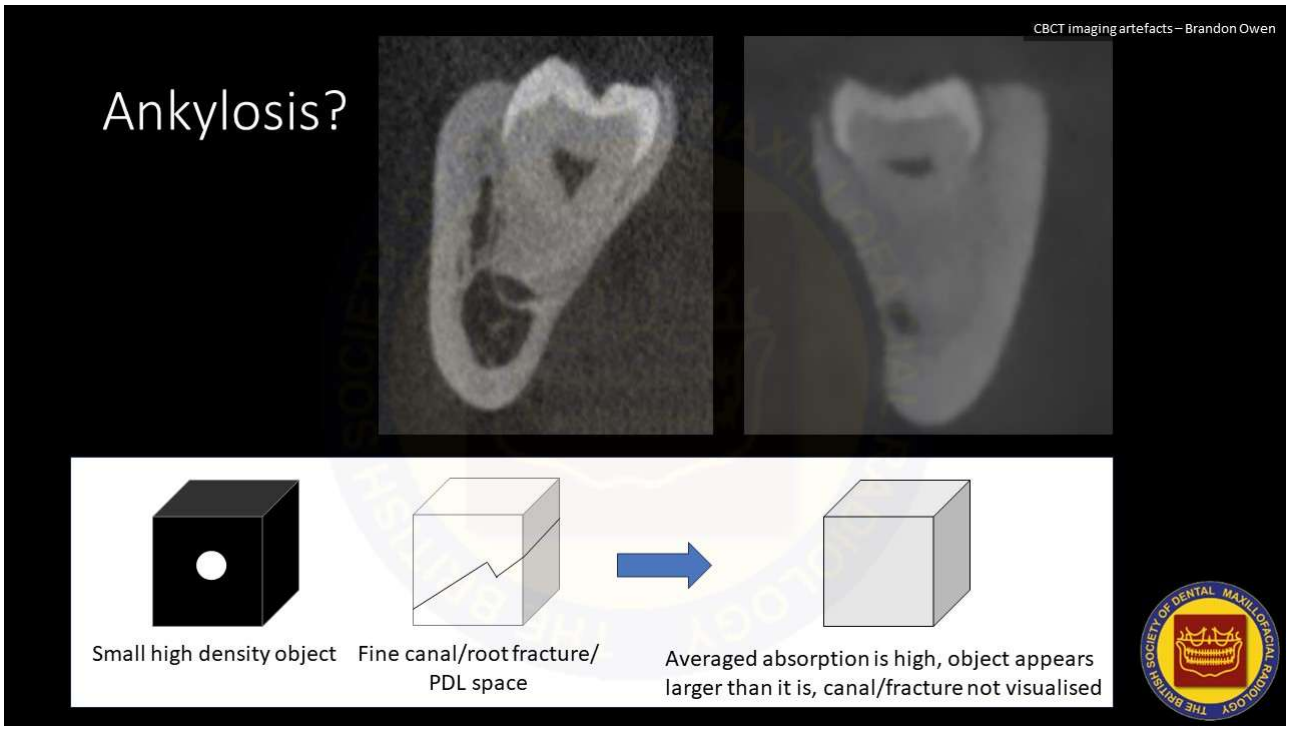
Perforation of the cortex, or marked thinning?








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Ankylosis?
Small high density object
Fine canal/root fracture/ PDL space
Averaged absorption is high, object appears larger than it is, canal/fracture not visualised

PVE, voxel size and resolution

- PVE is a consequence of limited spatial resolution
- Objects smaller than the voxels will not be resolvable or may appear larger, with blurring of boundaries - beware false negatives as a result
- For an anatomical feature or object to be clearly resolved with accurate borders, it needs to be at least two times larger than the chosen voxel size

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PVE, voxel size and resolution

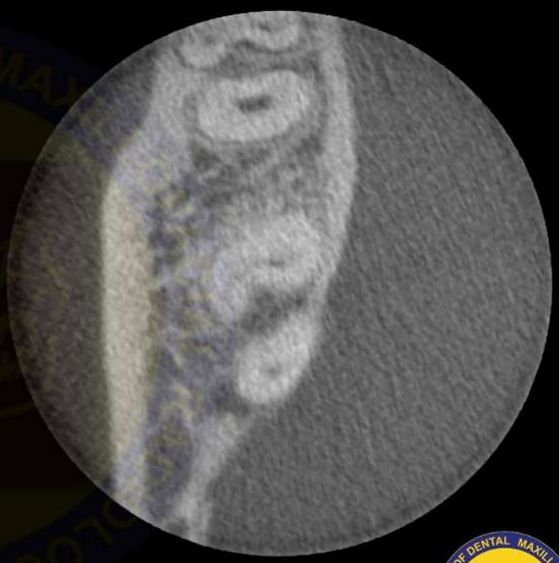
- Voxel size is a crude predictor of resolution
- Focal spot, detector type and pixel size, FOV, number of projections, reconstruction algorithm, viewing monitor
- Exposure factors and artefacts such as movement and noise further impact image quality

- Dose consequences
- Consider purpose / objectives of imaging
- Sclerosed canals or fine fractures – high res protocol but beware limitations

Noise

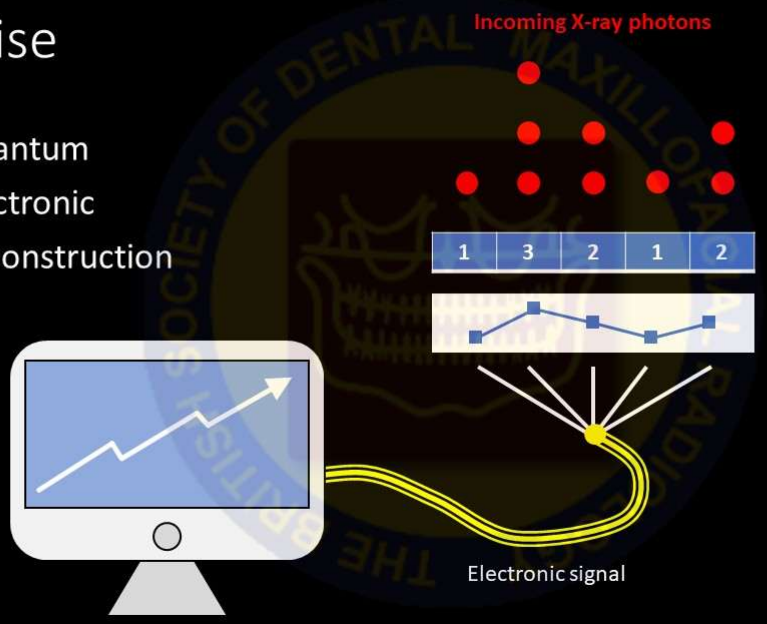
Noise

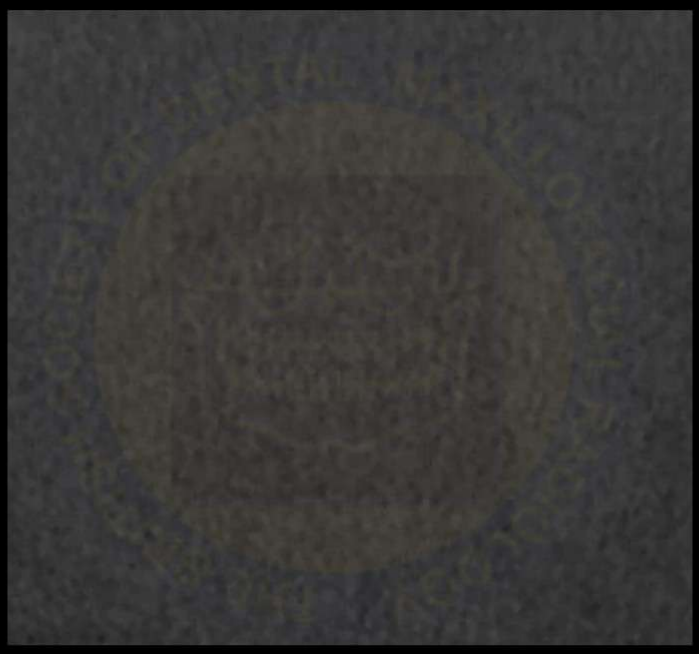
- Describes the grainy, speckled pattern across the image
- Due to unwanted, random signal variations
- Obscures fine detail and subtle differences between tissues
- The comparison between what you want to see (signal) and the background distraction (noise)
  - Signal to noise ratio



Noise

- Quantum
- Electronic
- Reconstruction





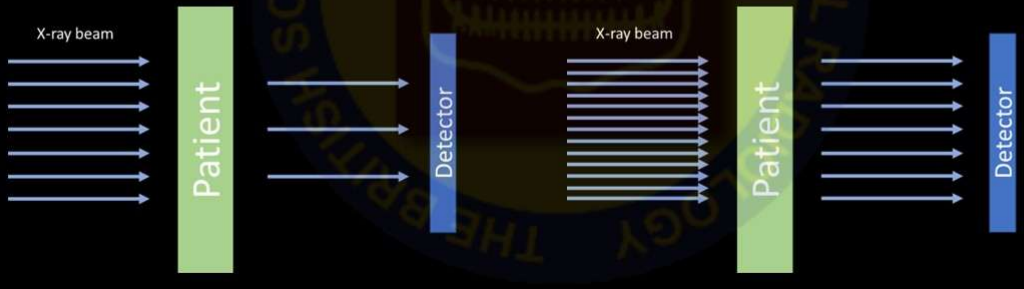
Factors that influence noise

- Radiation dose (kV, mAs, number of frames)
- Voxel size and slice thickness
- Patient size
- Reconstruction algorithms (sharp vs smooth filters)

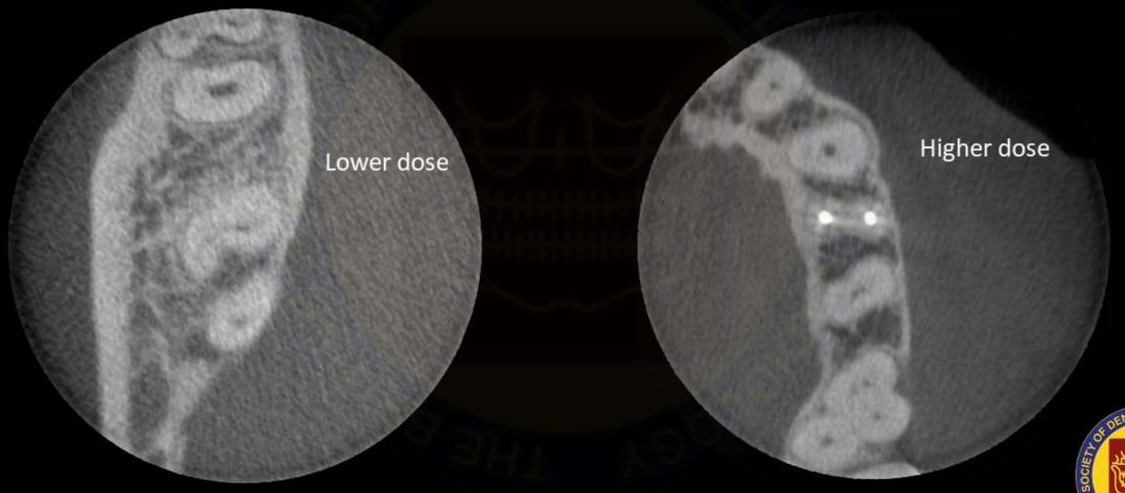
Influence of kV and mAs

- kV – number, average and maximum energy of x-rays produced
- mAs – number x-rays produced

More signal at the detector
→ Higher SNR

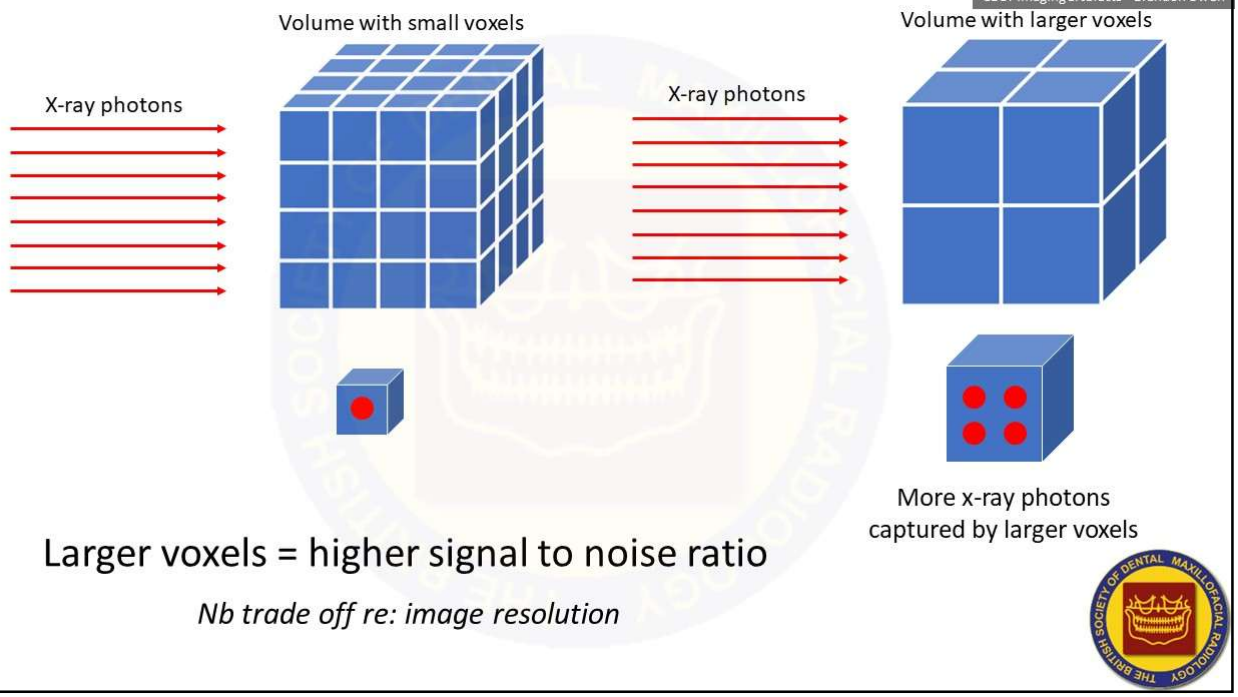


Noise – more apparent at lower doses



Higher Kv or mAs = more x-ray photons = higher SNR

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Larger voxels = higher signal to noise ratio

Nb trade off re: image resolution

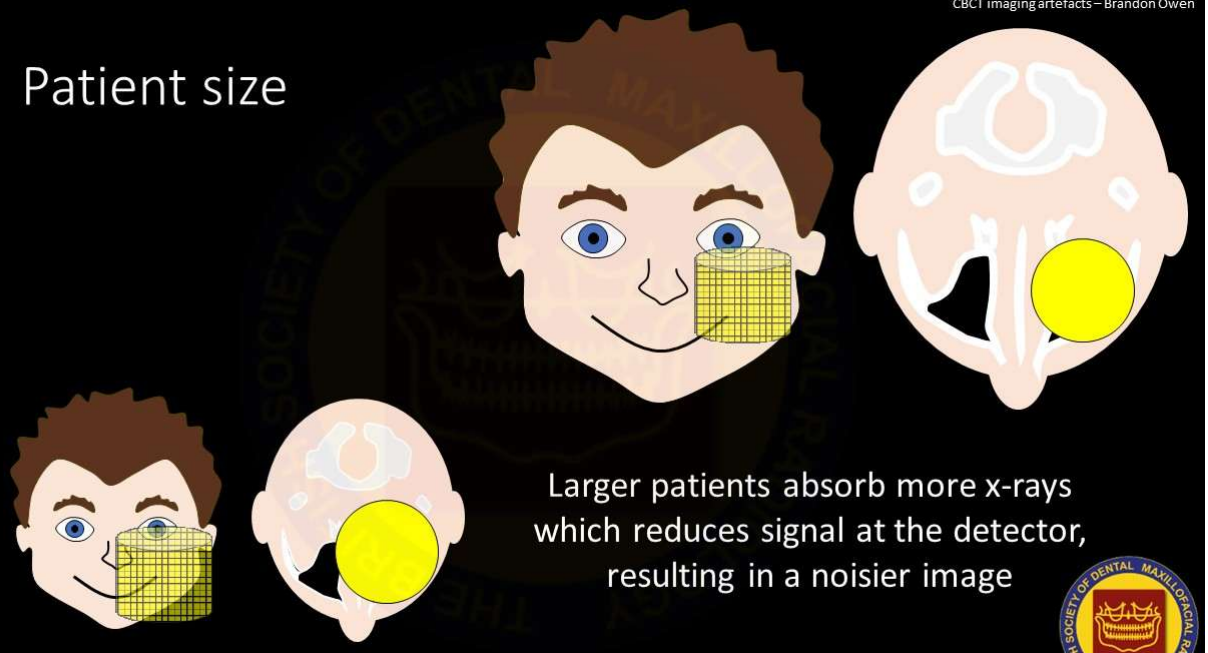
Voxel size



Larger voxels = less noise

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Patient size



Larger patients absorb more x-rays which reduces signal at the detector, resulting in a noisier image

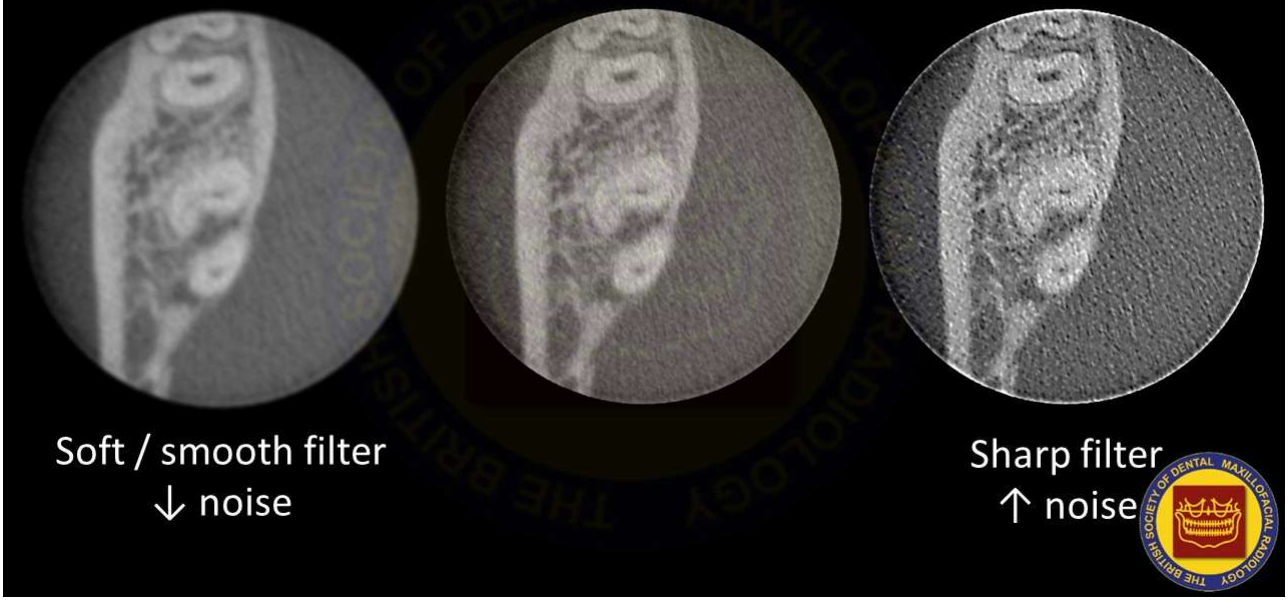
Sharp filter

Enhances contrast at boundaries between different tissues

Makes bright pixels brighter and dark pixels darker

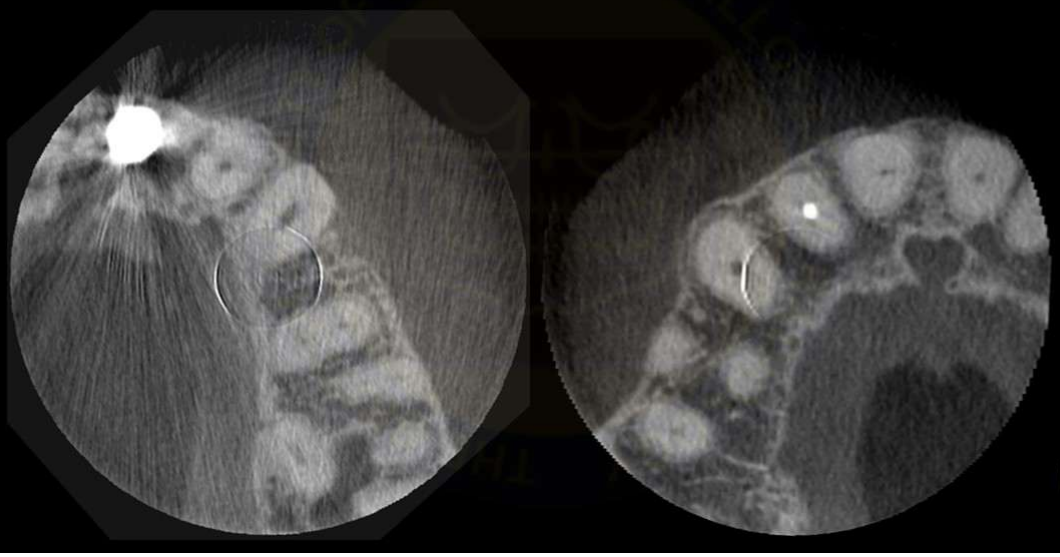
Results in increased noise





Detector malfunction

Ring artefact – faulty / miscalibrated element



Ring artefact

- Routine QA and maintenance
- Contact engineer

Aliasing

Aliasing

- Image artefact caused by undersampling
- Influenced by number of basis images
- Cone-shaped beam geometry
- Resulting image is reconstructed from 'insufficient' data

- Results in repeating lines / waves or Moiré Patterns
- Most prominent at the periphery

Aliasing may be more prominent in 'fast' scan modes – reduced frames / rotation arc

Cone shaped beam results in reduced sampling at the edge of the volume



Ensure volume well-centred over region of interest to reduce impact of aliasing





Practical tips for optimisation

- Carefully select patients
- Optimise patient positioning
- Consider removable metallic objects, surgical packs, root fillings…
- Select appropriate exposure parameters
  - Field of view
  - Voxel size and resolution
  - kV, mAs
  - Rotation arc and speed
- Post-processing – artefact reduction, filters

Conclusion

- Artefacts are common and important to recognise
- Consider how you can optimise before acquisition
- Be systematic and evaluate in at least two planes
- Correlate with plain radiographic imaging
- Remember that alternative imaging may be more appropriate