



Computed Tomography: CT & CBCT

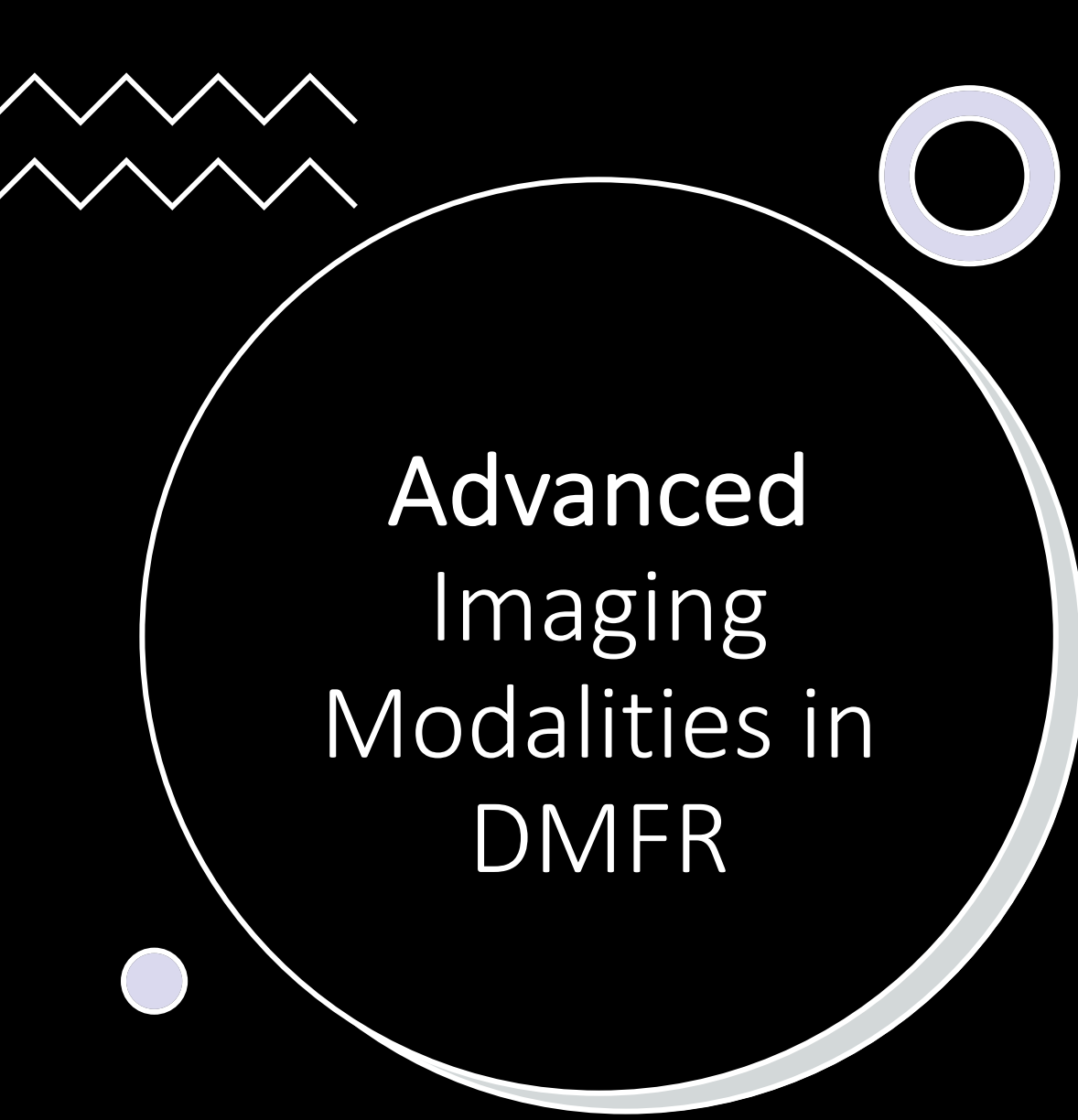
Dr Dayea Oh

OMF Radiologist



Learning Objectives

- To understand the basic theory of computed tomography
- What is Hounsfield Unit?
- What are the indications for Multislice CT?
- What are the indications for Cone Beam CT?
- What are the CBCT artefacts?
- What are the differences between Multislice CT and Cone Beam CT?

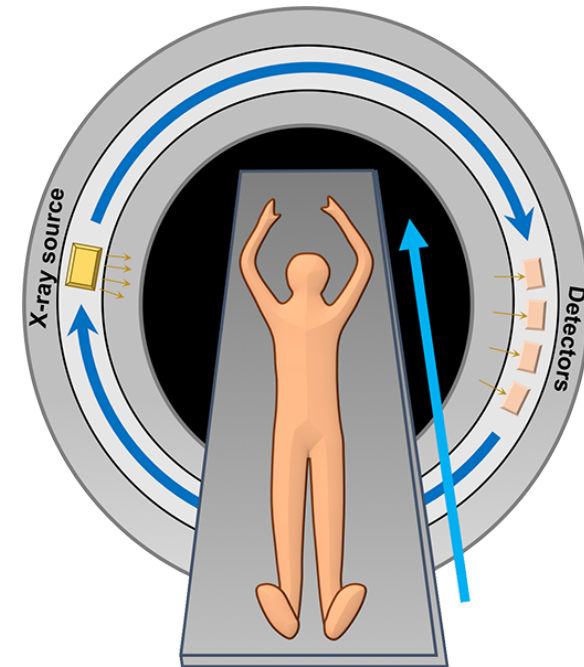
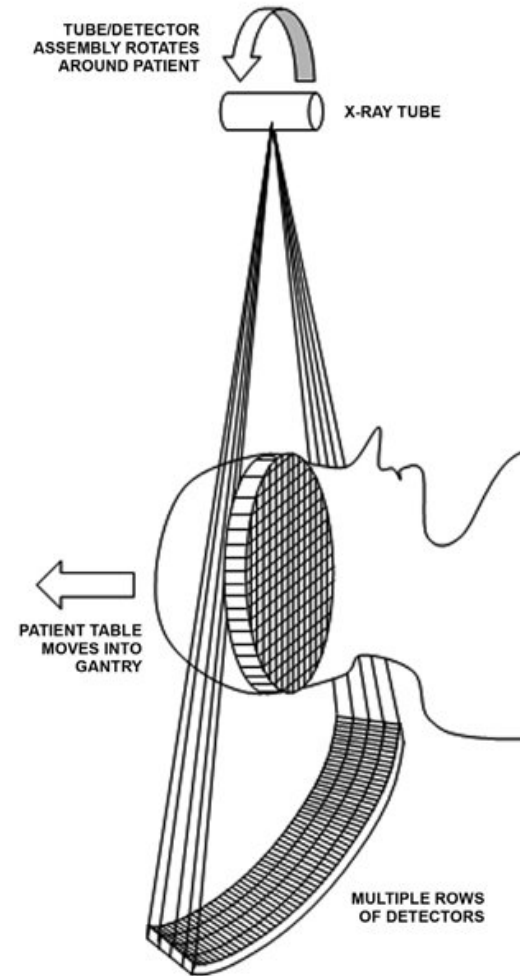


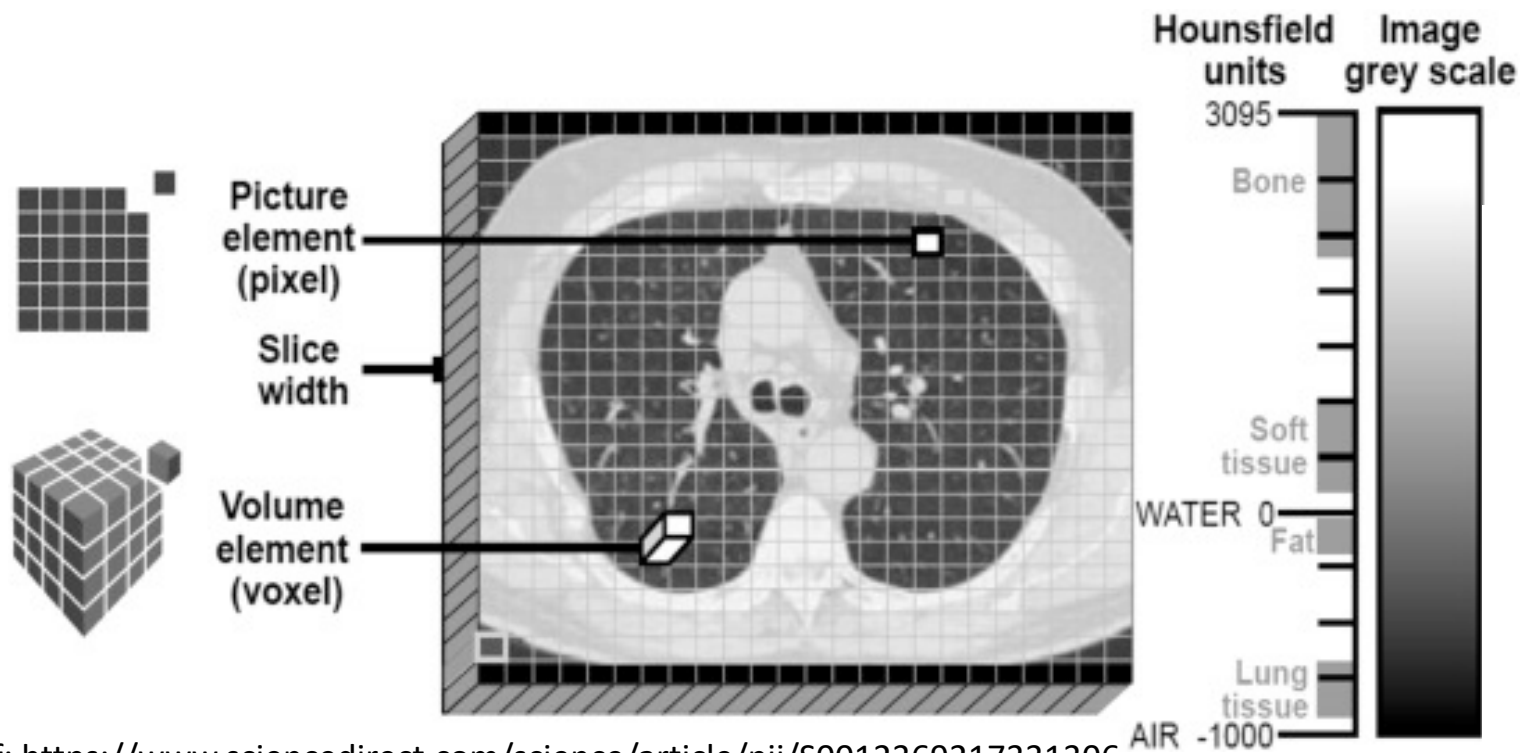
Advanced Imaging Modalities in DMFR

- **Multi-slice / Multi-detector Computed Tomography (MSCT / MDCT)**
 - **Cone Beam Computed Tomography (CBCT)**
 - Magnetic Resonance Imaging (MRI)
 - Ultrasound
 - Nuclear Medicine Imaging (NMI)
- 

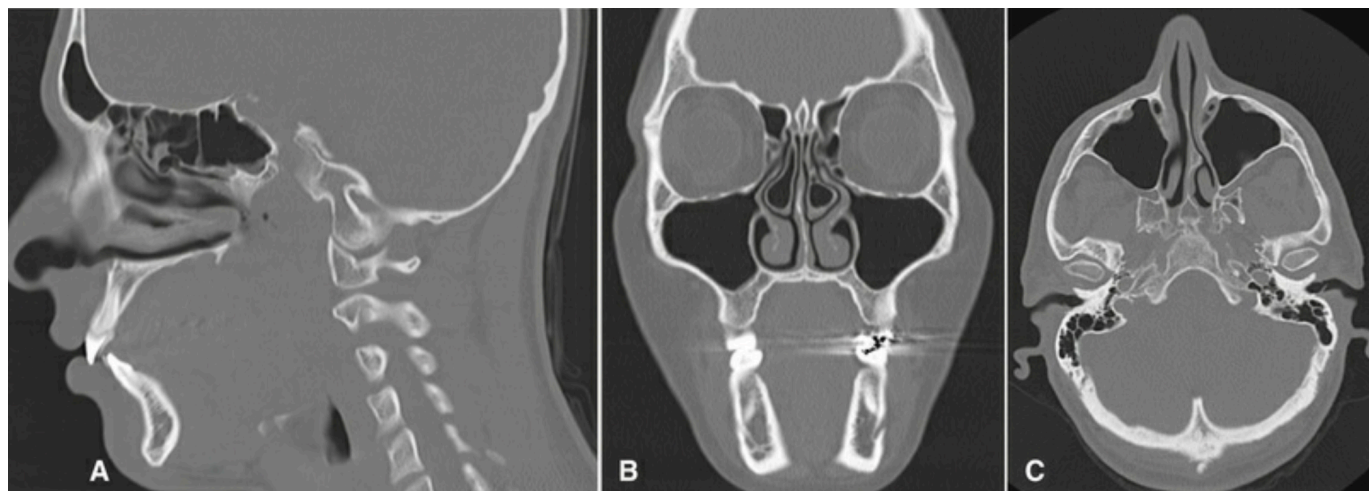
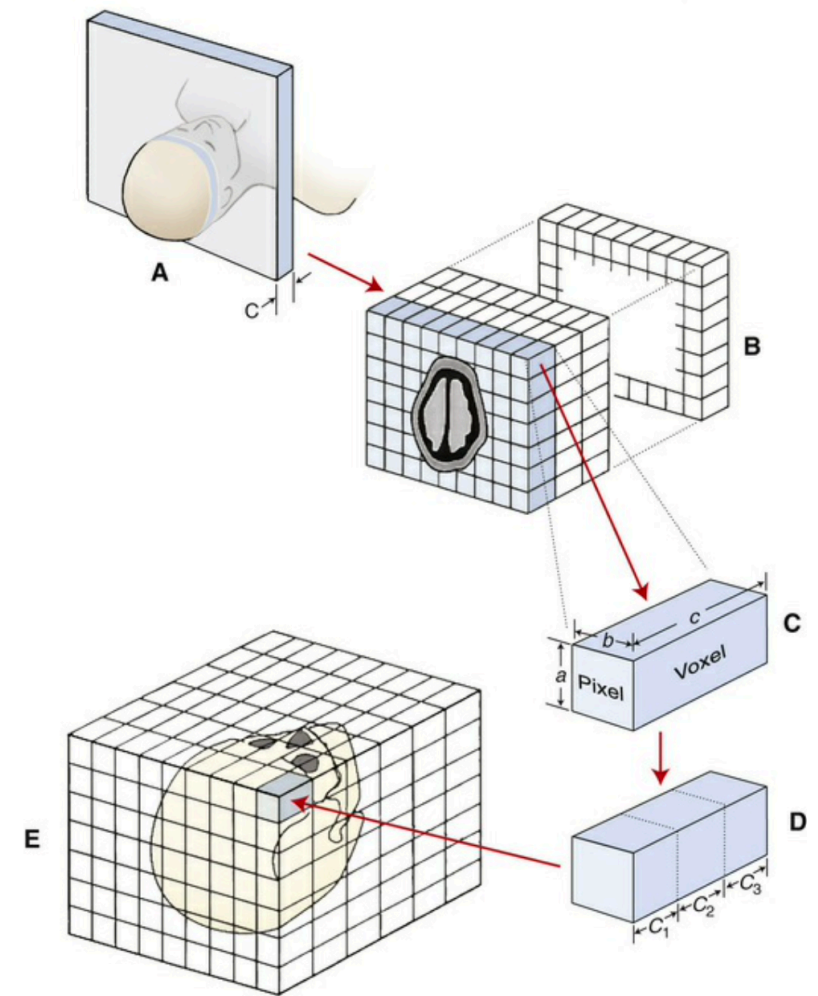
Computed Tomography, CT

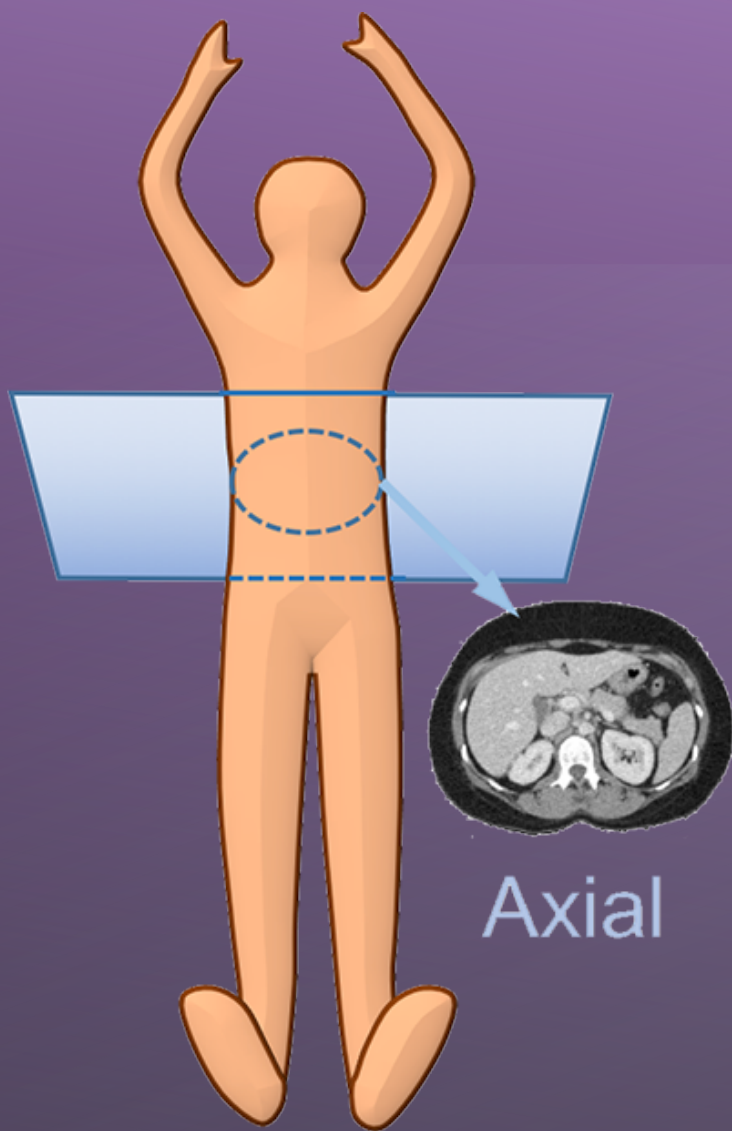
- Invented in 1971 by Sir Godfrey Hounsfield
 - First CT scan was Brain CT
- Fan-shaped, continuous, rotational x-ray beam
- “Slices” of cross-sectional / transverse / axial images
 - Hundreds to thousands of acquired slices are later **reconstructed** (= digitally stacked together) to form volumetric imaging



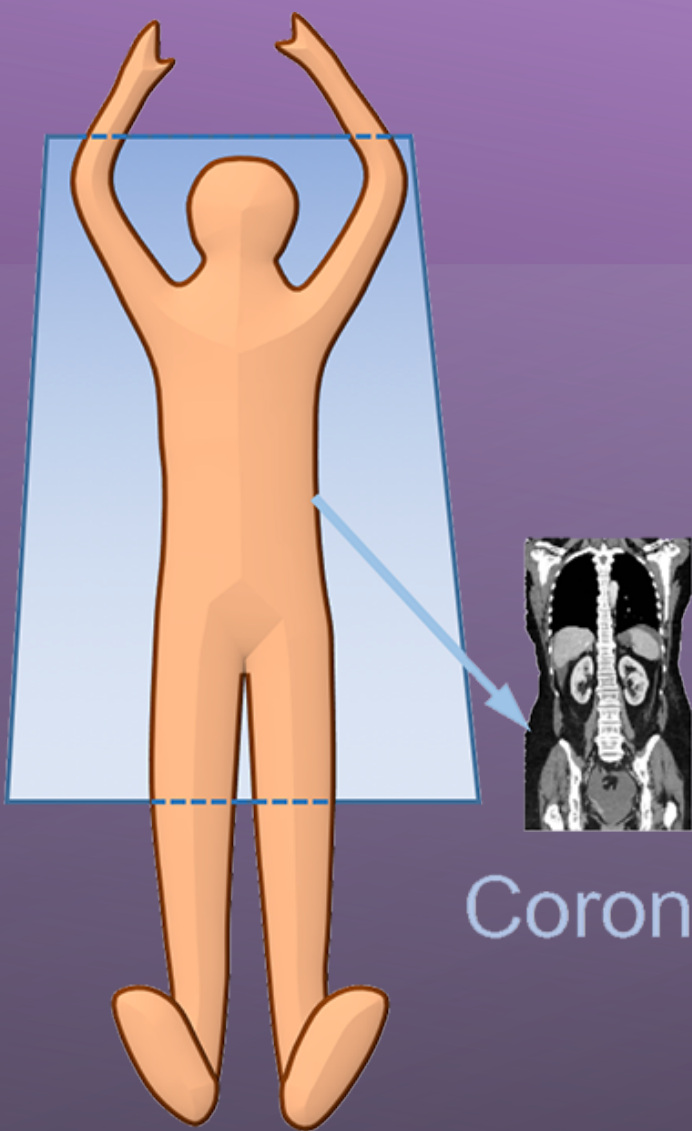


Ref: <https://www.sciencedirect.com/science/article/pii/S0012369217331306>

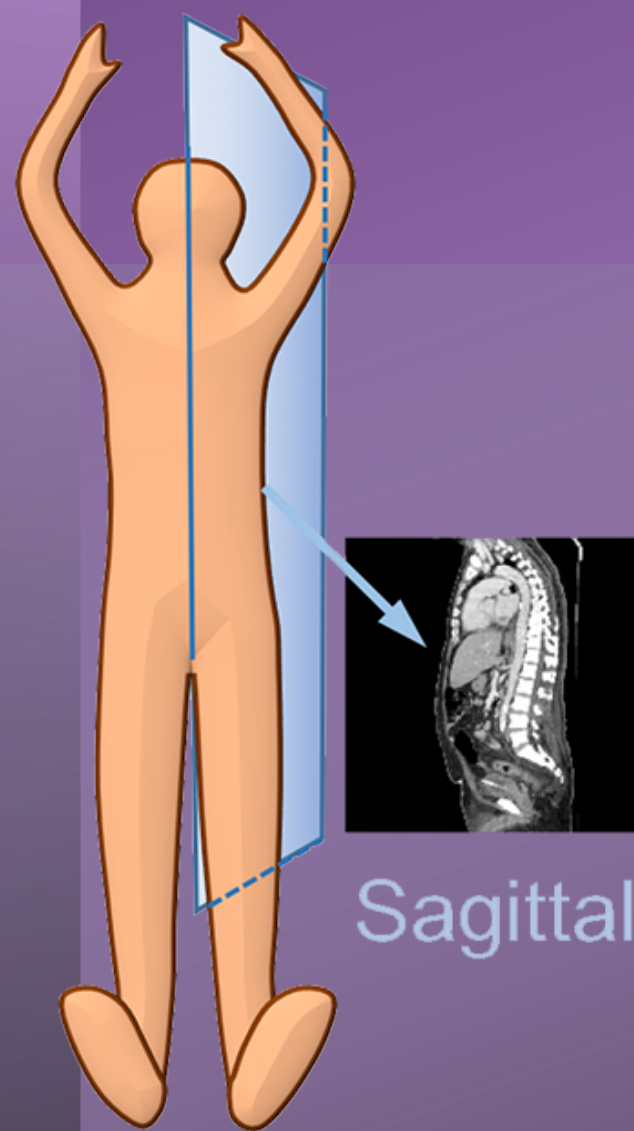




Axial



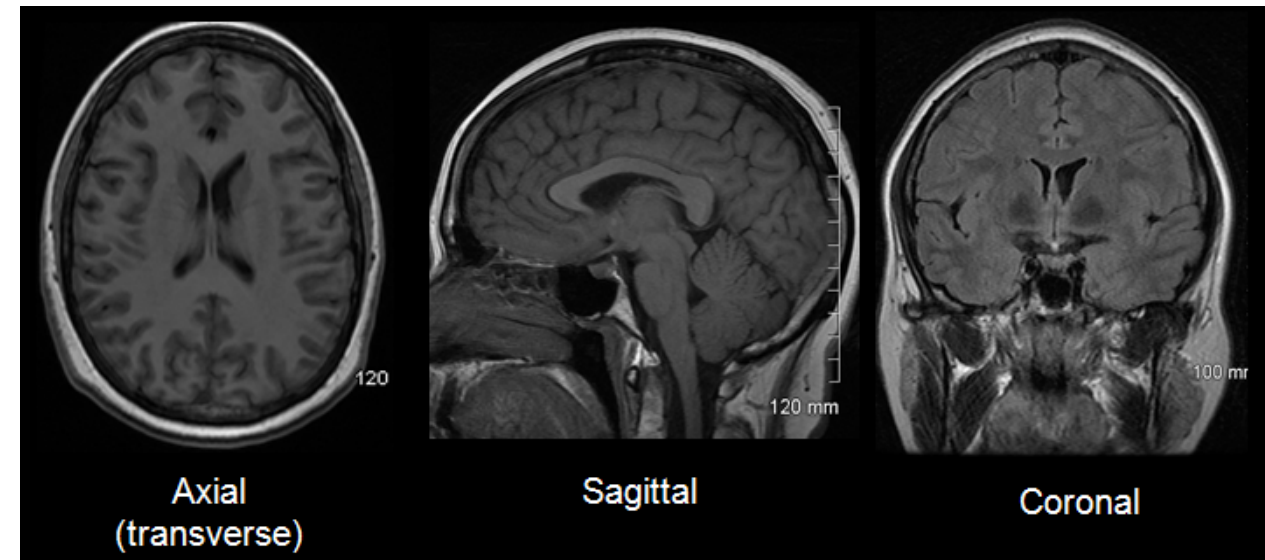
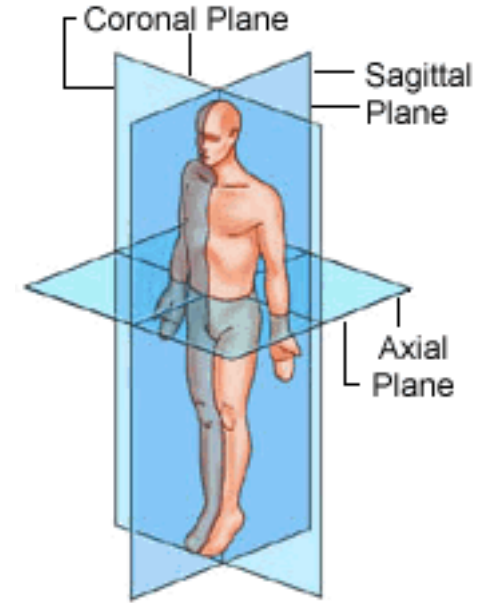
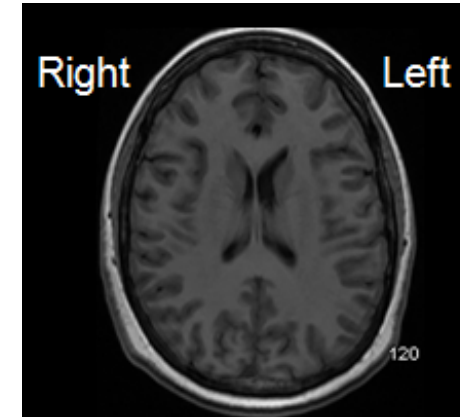
Coronal



Sagittal

3D Imaging Orientation - Terminology

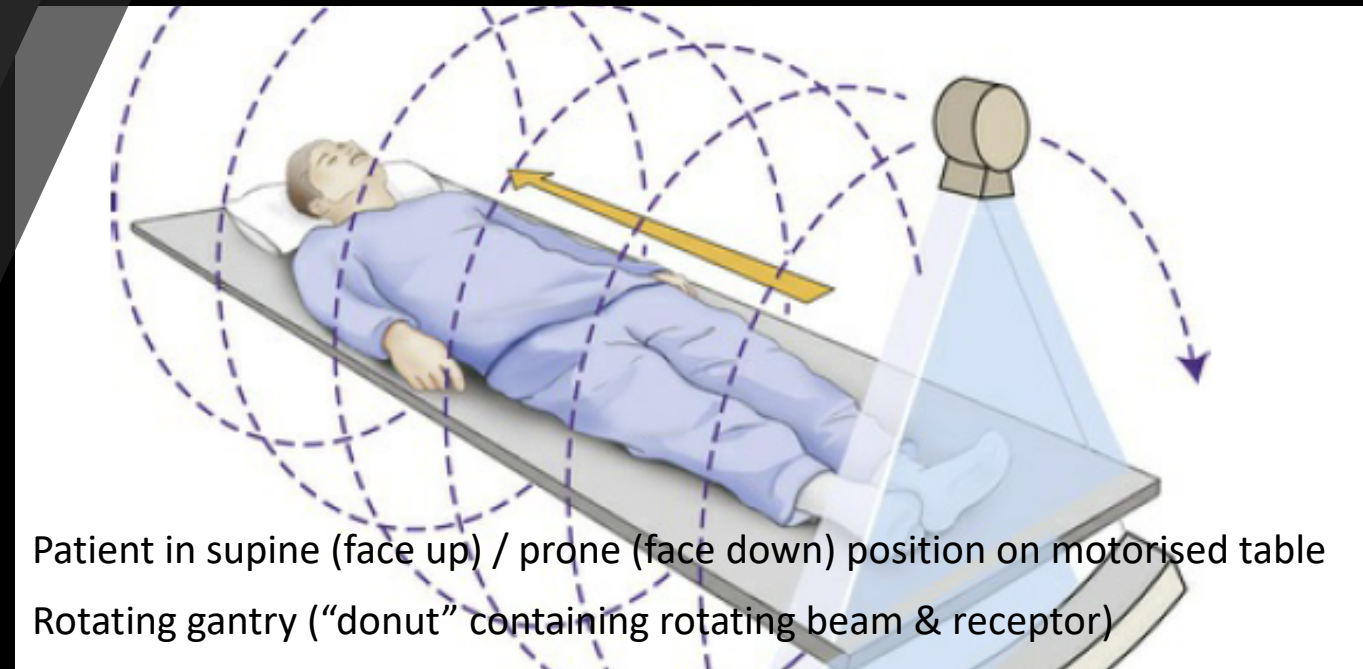
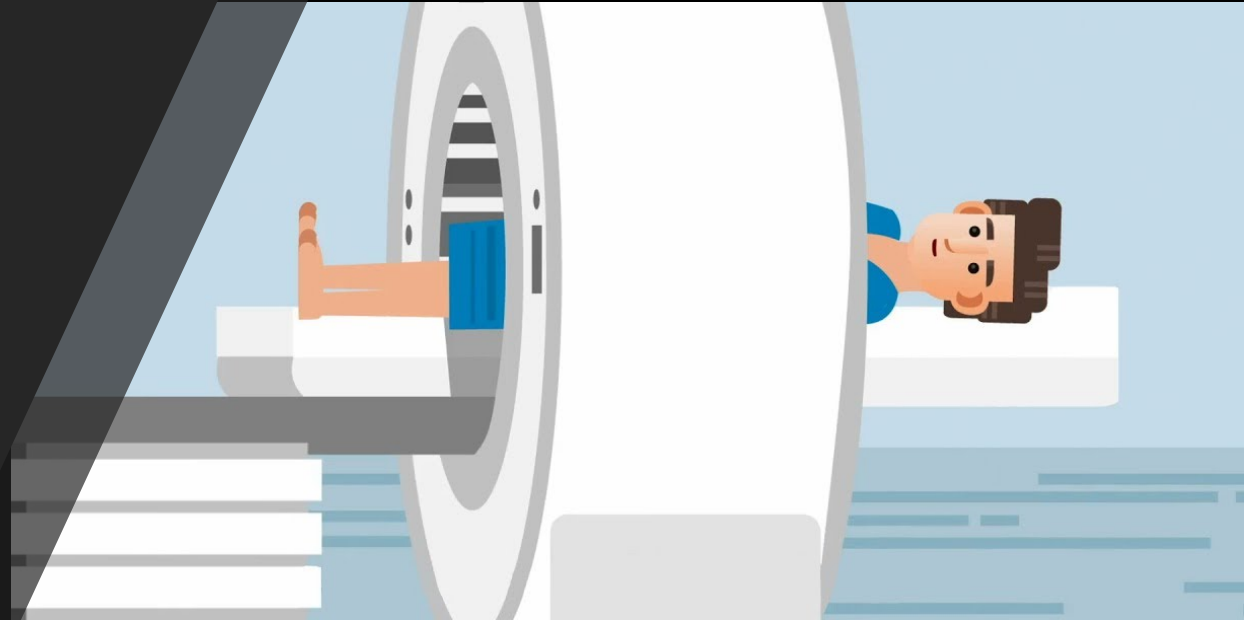
- Anterior
- Posterior
- Superior
- Inferior
- Medial
- Lateral
- Superficial
- Deep
- Ipsilateral
- Contralateral



MRI images

Modern CT Machine

- Helical CT
 - 3rd generation
 - Multi-detector CT aka Multislice CT
 - V Fast scan time (~ 1 second to scan jaws)
- X-ray tube & detectors continuously revolve around the patient while the patient table moves through the gantry
 - Continuous helix of data is acquired as the x-ray beam moves down the patient



Patient in supine (face up) / prone (face down) position on motorised table
Rotating gantry ("donut" containing rotating beam & receptor)

CT Applications – Head and Neck

- Trauma
- Pathology
 - Jaw pathology (cysts, tumours, malignancies, etc.)
 - Sinus pathology
 - Salivary gland pathology
 - Oral cancer
- TM Joints
- Non-specific dental pain
 - Rule out neuropathic pain
- **Dentistry (low dose protocol)**
 - Implant dentistry
 - Other:
 - Special needs dentistry

Not used in General Dentistry

CT Workflow

- Referral
- Protocol
- Acquisition (scan)
- Data preprocessing
- Reconstruction
- Interpretation
- Report

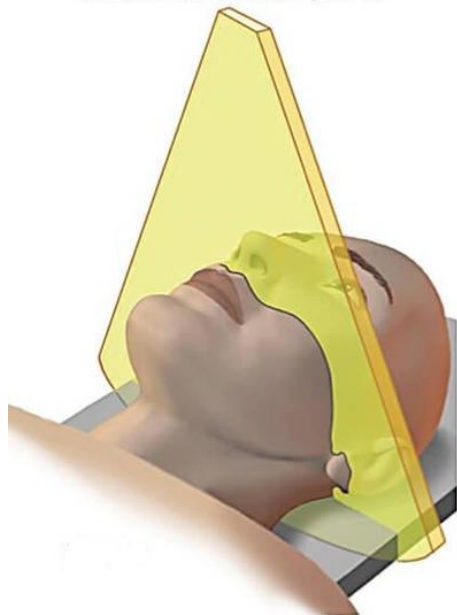


Cone Beam CT

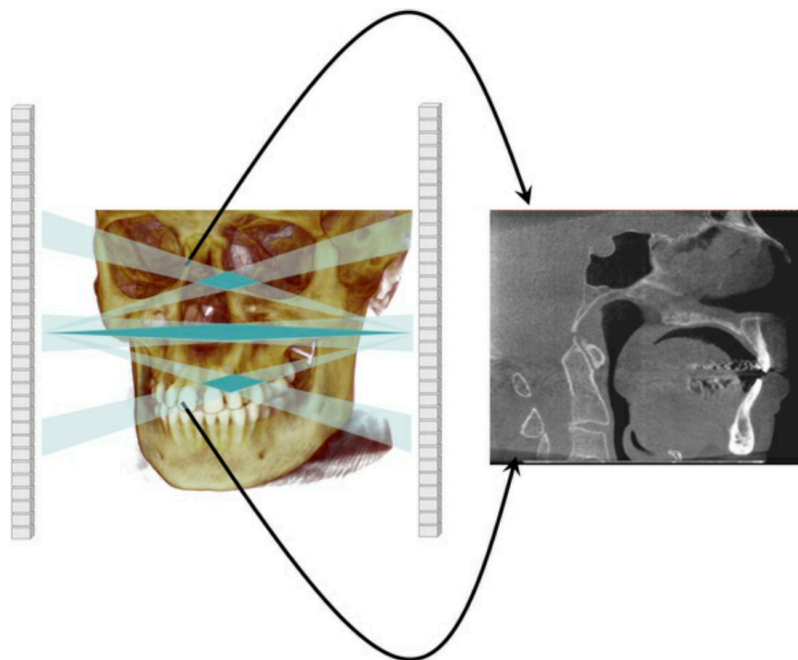
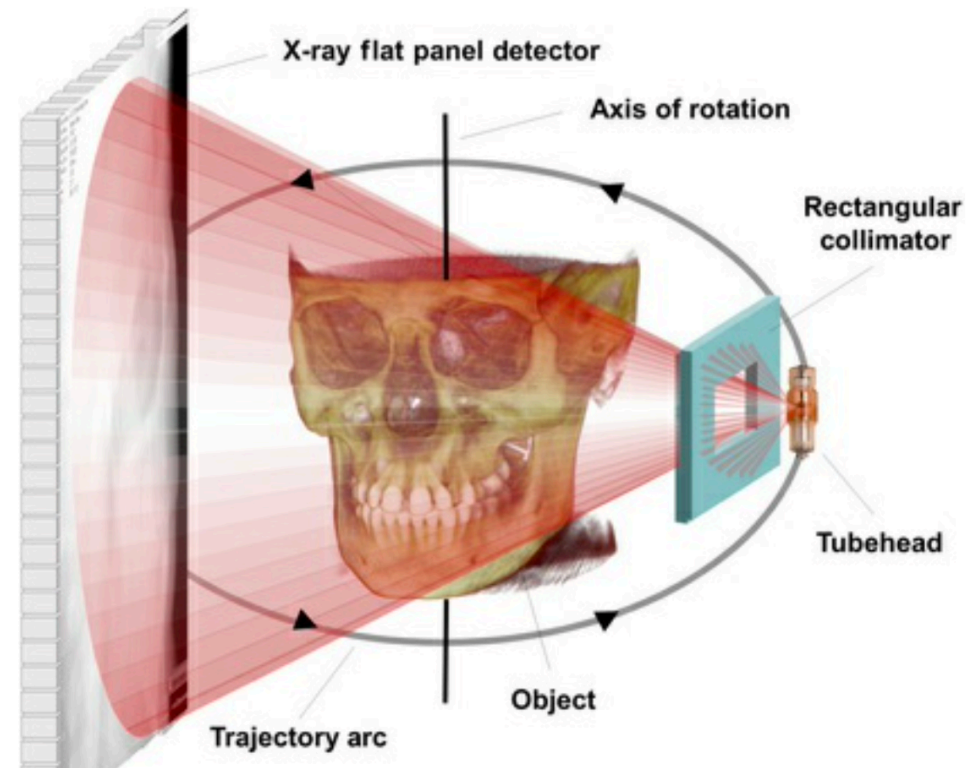


Fan Beam CT

Used in 'conventional' Spiral CT



Cone Beam CT

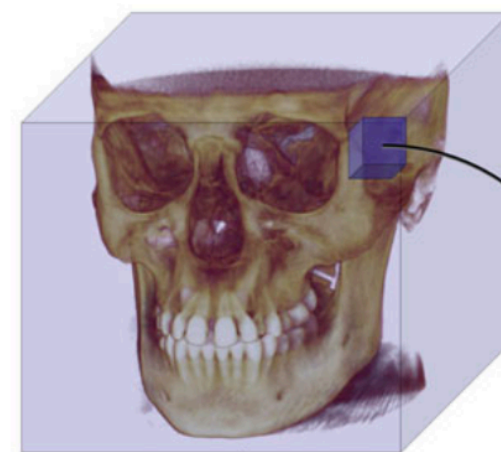


Basis
Projection



Projection data

Secondary Reconstructions



voxel



CBCT Machine

- Early
 - Similar design to MDCT
 - Supine
 - Fixed table (not mobile)
- Modern CBCT
 - Compact design
 - Some are similar to PR units
 - Stand-up or Seated





**Imaging Sciences iCAT FLX
CBCT**



Morita Veraview X800 CBCT



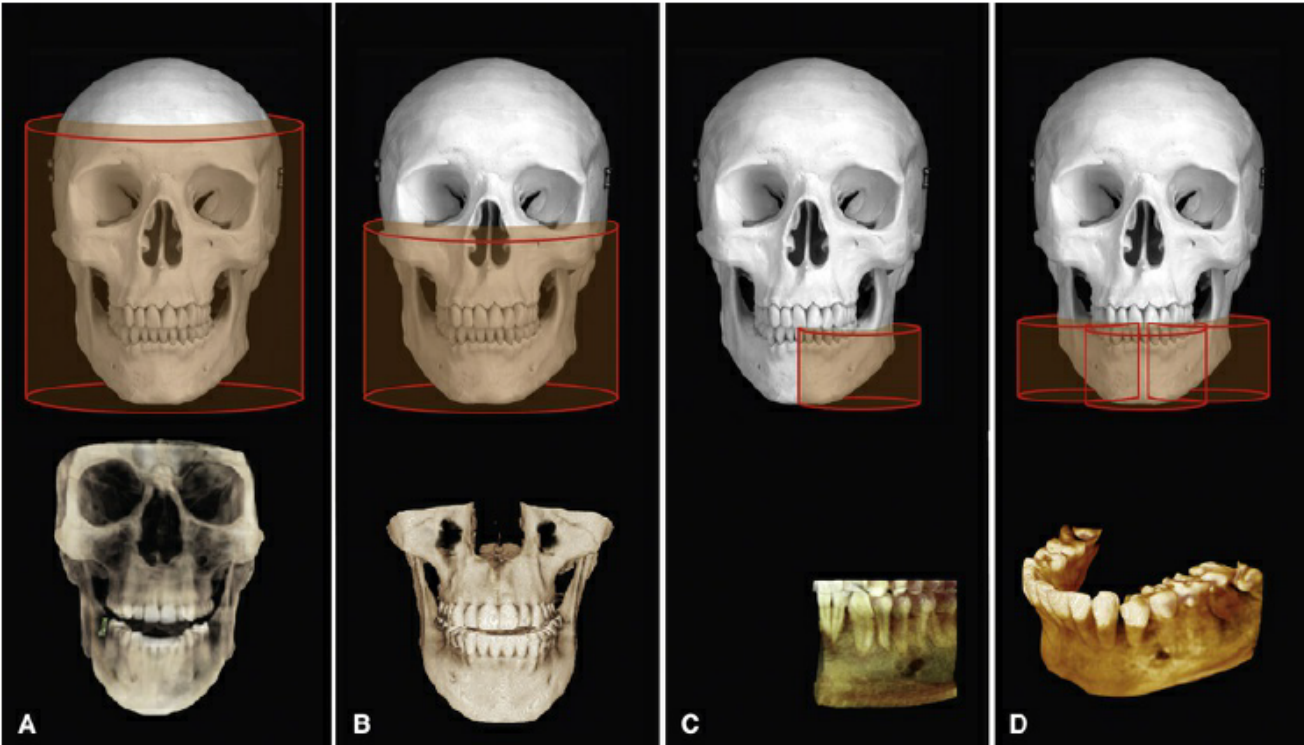
Kavo OP 3D Pro Panoramic



KaVo OP 3D Pro



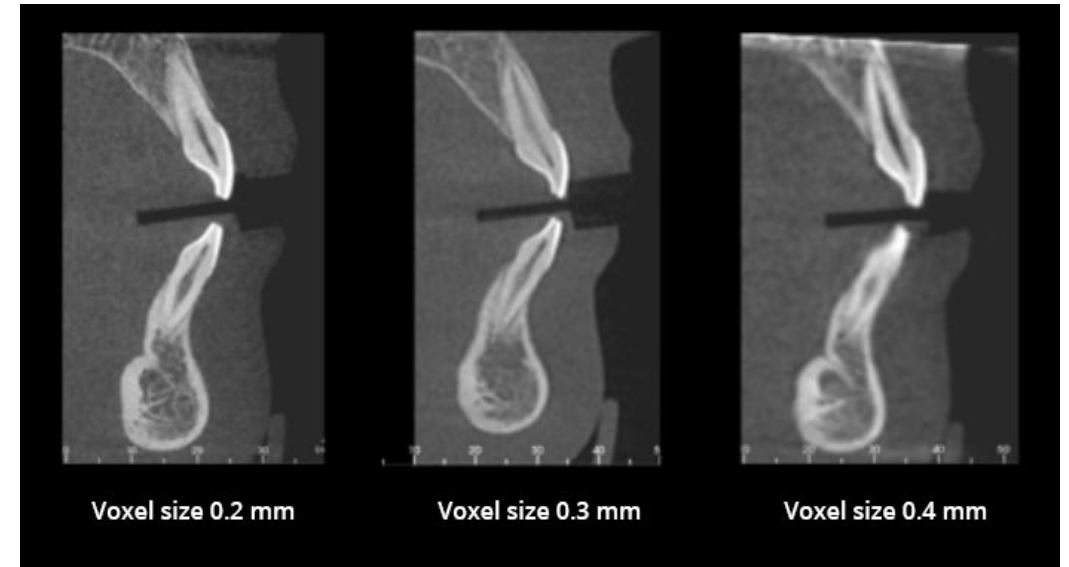
**Planmeca ProMax 3D CBCT
Family**



Large field of view (FOV)

Small FOV

Spatial Resolution & Voxel Size



Voxel size 0.2 mm

Voxel size 0.3 mm

Voxel size 0.4 mm

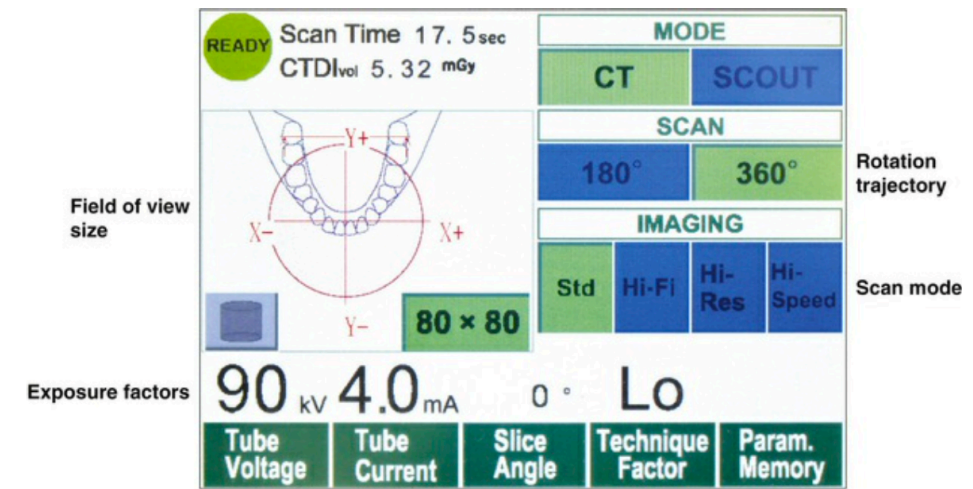
Indications for CBCT in Dentistry

- Dental Trauma
- Third molar assessment
- Supernumerary teeth
- Impacted Canines
- Implant assessment
- Periodontal assessment
 - 3D bone loss
- Complex endodontic therapy
 - High res for root canal morphology
- Root resorption
- Root fractures
- Orthodontic assessment
- Orthognathic surgical planning
- Digital dentistry
 - 3D printing eg. surgical guides
- TM Joint (limited to osseous)
- Pathology (limited to osseous)

Radiation Safety in CBCT

- Effective Radiation Dose

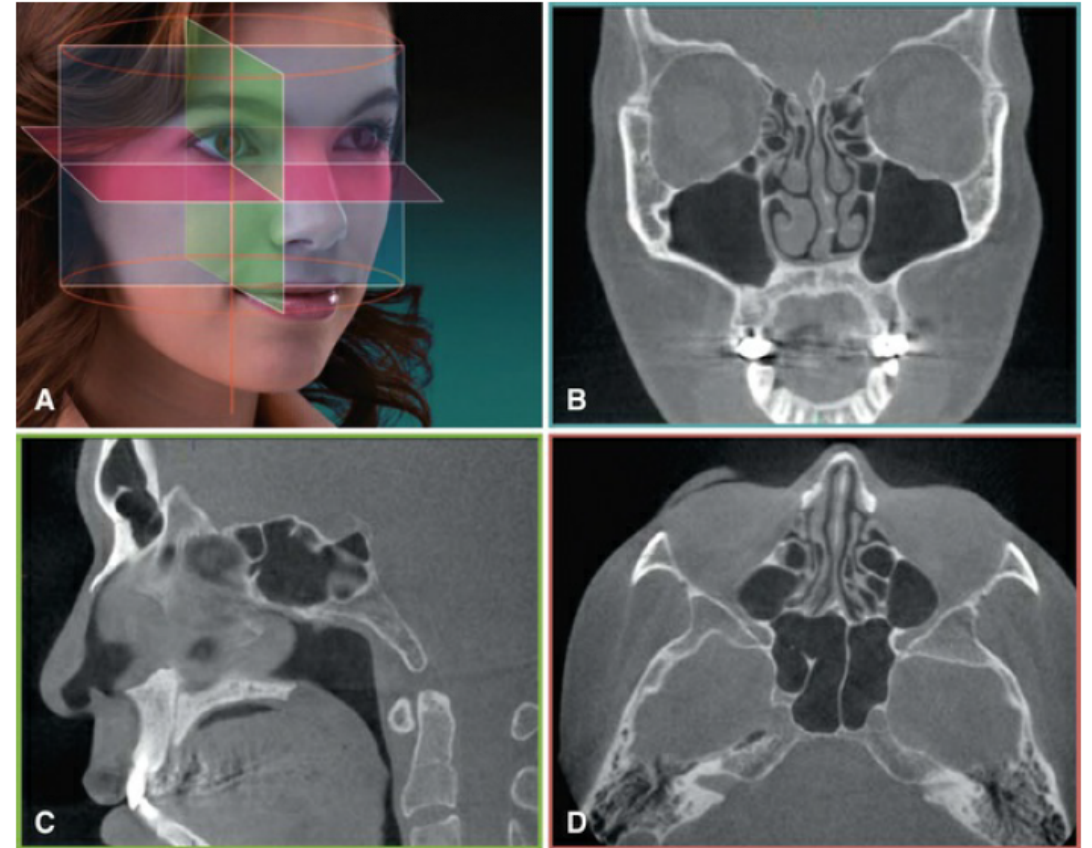
- Background at sea level: 1.5mSv / year in Australia
- 1 PA is approximately 0.004 mSv (1 day of background radiation)
- 1 OPG: 0.008 – 0.01 mSv (2-3 days of background radiation)**
- 1 Lat Ceph: ~0.005 mSv
- CBCT dose varies and largely depends on FOV, voxel size, mA, kVp, rotation trajectory, etc.**
 - iCAT large FOV (maxillofacial region): **~0.07 mSv** (2-3 weeks of background radiation)
 - Planmeca 3D small FOV: **~0.03mSv** (1 week of background radiation)
 - Note: the radiation dosage of high resolution, small FOV can be as high as standard large FOV
- Low dose MSCT dosage is comparable to CBCT dosage*



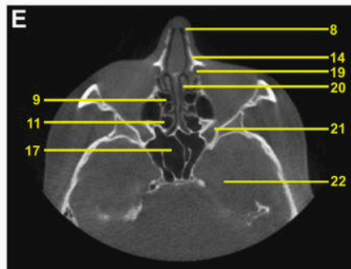
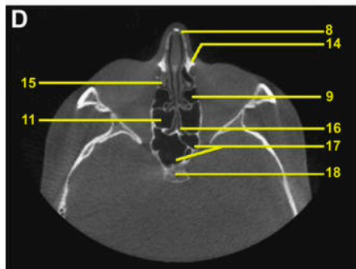
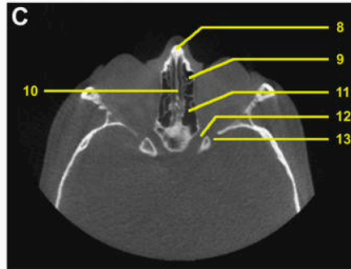
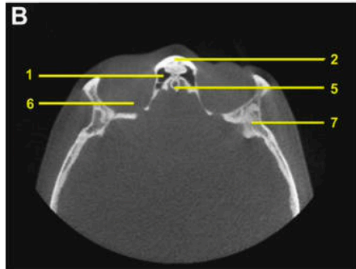
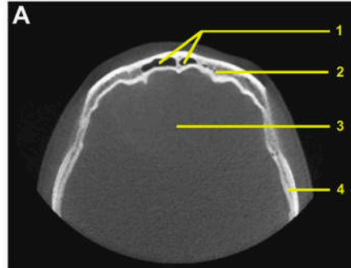
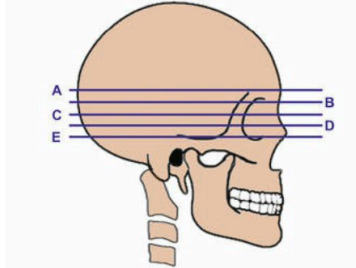
CBCT control panel with exposure settings

CBCT Data Display

- Standard display (Orthogonal / Multiplanar view)
 - Axial
 - Coronal
 - Sagittal

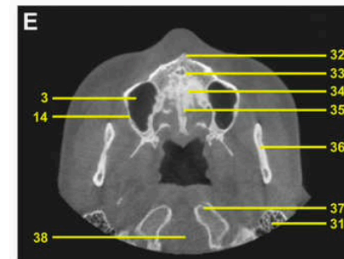
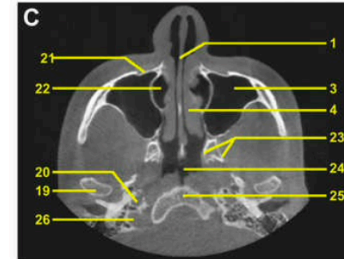
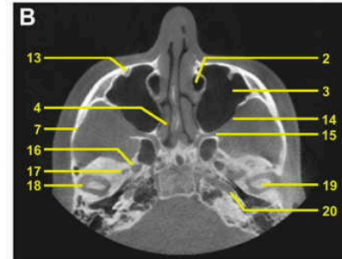
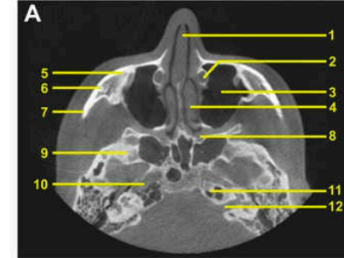
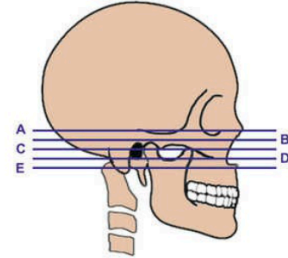


Axial CBCT Anatomy



1. Frontal sinus
2. Frontal bone
3. Anterior cranial fossa
4. Squamous portion of temporal bone
5. Crista galli
6. Orbit
7. Greater wing of sphenoid bone
8. Nasal bone
9. Anterior ethmoid air cells
10. Perpendicular plate of ethmoid bone
11. Posterior ethmoid air cells

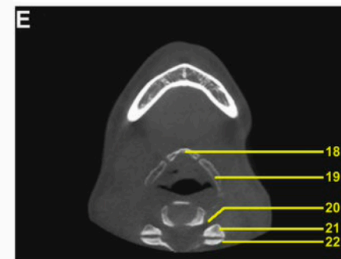
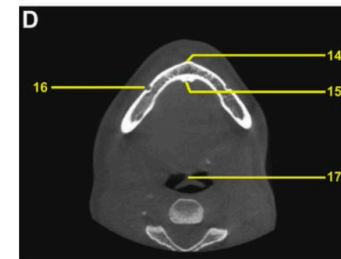
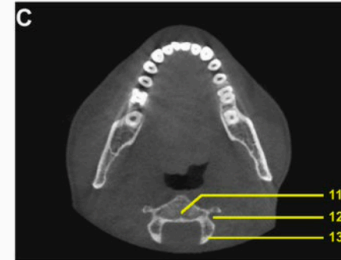
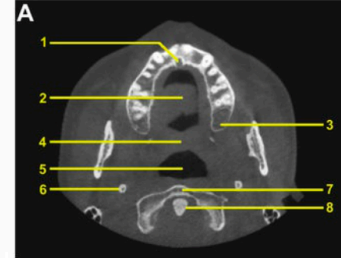
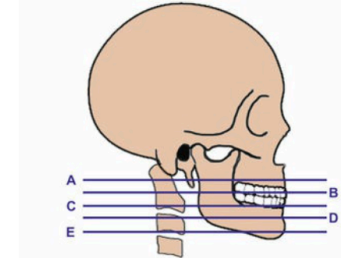
12. Optic canal
13. Superior orbital fissure
14. Nasal process of maxillary bone
15. Uncinate process
16. Sphenothmoid recess
17. Sphenoid sinus
18. Floor of sella turcica
19. Nasolacrimal duct
20. Superior turbinate
21. Inferior orbital fissure
22. Middle cranial fossa



1. Nasal septum
2. Nasolacrimal duct
3. Maxillary sinus
4. Nasal turbinate
5. Zygomatic process of maxilla
6. Zygomatico-maxillary suture
7. Zygomatic arch
8. Pterygopalatine fossa
9. Greater wing of sphenoid bone
10. Carotid canal
11. Petrous portion of temporal bone
12. Internal auditory canal
13. Infraorbital canal

14. Lateral wall of maxillary sinus
15. Pterygomaxillary fissure
16. Foramen ovale
17. Foramen spinosum
18. Glenoid fossa
19. Mandibular condyle
20. Carotid canal
21. Infraorbital foramen
22. Nasal cavity
23. Pterygoid plates
24. Nasopharyngeal airway
25. Occipital bone
26. Jugular foramen

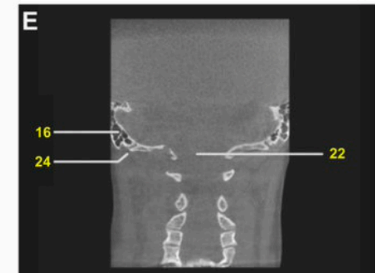
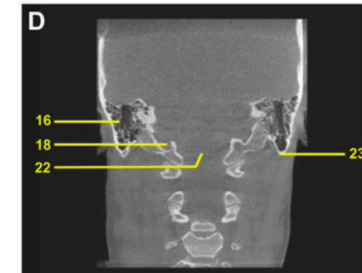
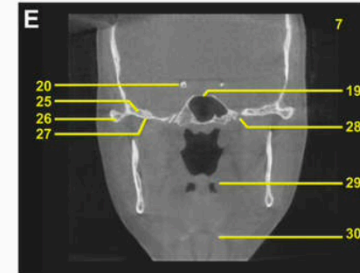
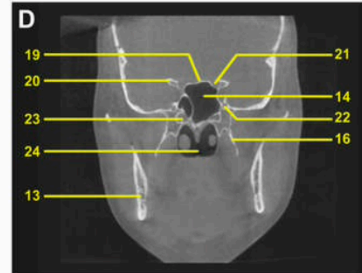
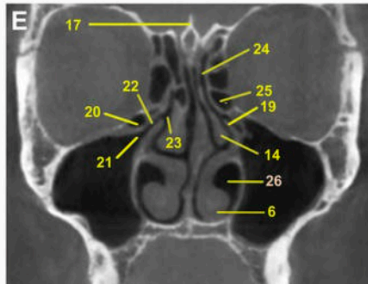
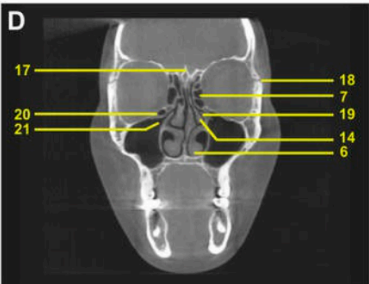
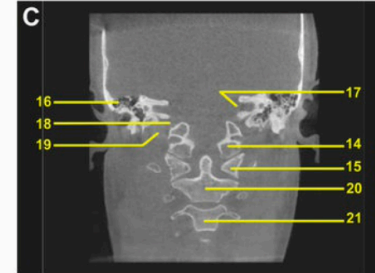
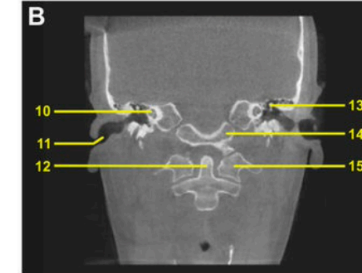
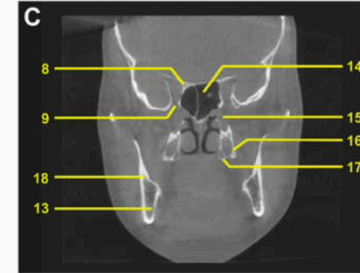
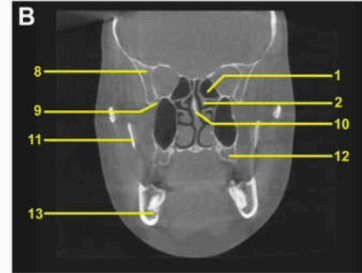
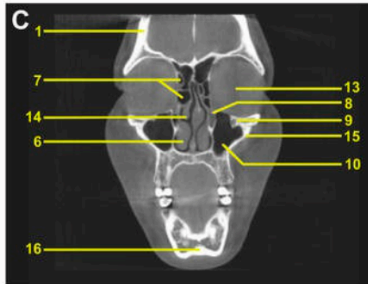
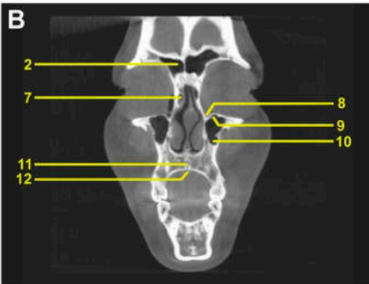
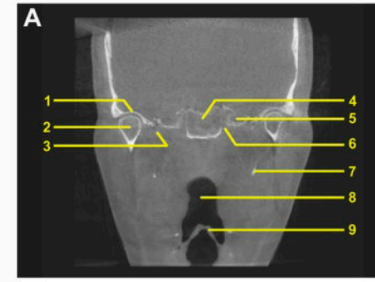
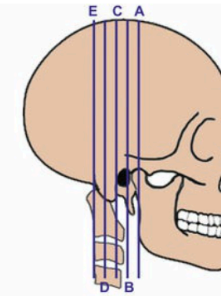
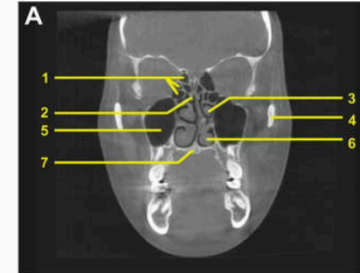
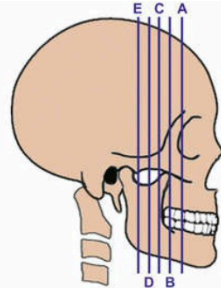
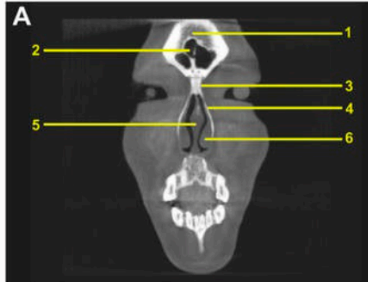
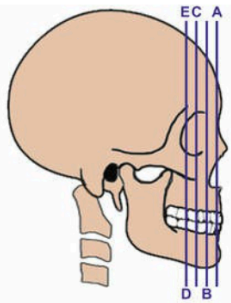
27. Medial wall of maxillary sinus
28. Coronoid process
29. Pharyngeal wall
30. External auditory meatus
31. Mastoid process
32. Anterior nasal spine
33. Nasopalatine canal
34. Hard palate
35. Intermaxillary suture
36. Ramus of mandible
37. Anterior arch of atlas (C1)
38. Foramen magnum



1. Incisive foramen
2. Tongue
3. Maxillary tuberosity
4. Soft palate
5. Oropharyngeal airway
6. Styloid process
7. Anterior arch of atlas (C1)
8. Odontoid process of C2
9. Ramus of mandible
10. Mandibular foramen
11. Inferior body of C2

12. Transverse foramen
13. Lamina of C2
14. Mandibular symphysis
15. Genial tubercles
16. Mental foramen
17. Epiglottis
18. Body of hyoid bone
19. Greater cornu of hyoid bone
20. C2-C3 neural foramen
21. Superior articular process of C3
22. Inferior articular process of C2

Coronal CBCT Anatomy

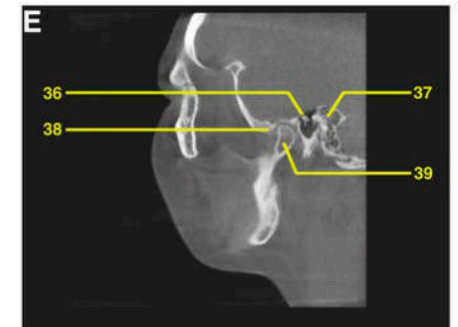
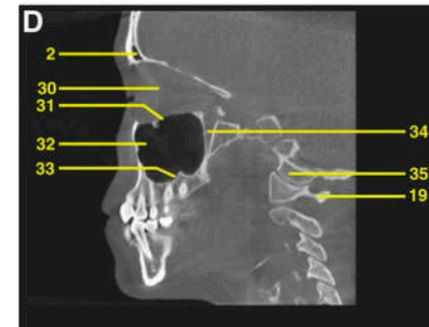
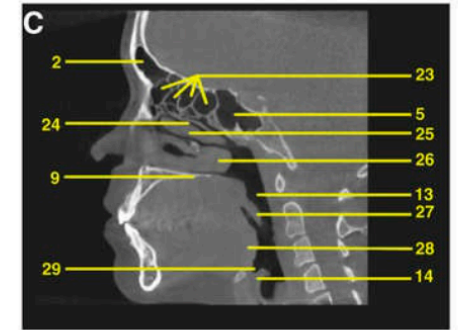
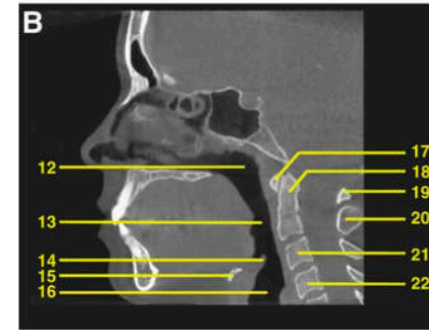
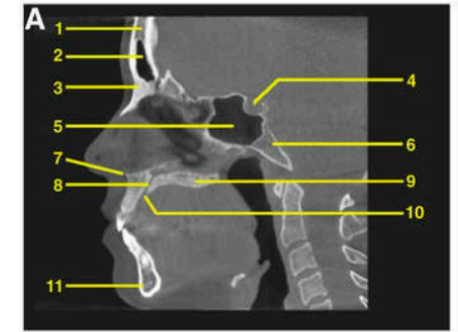
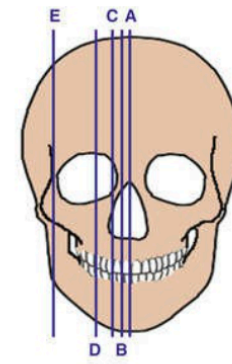
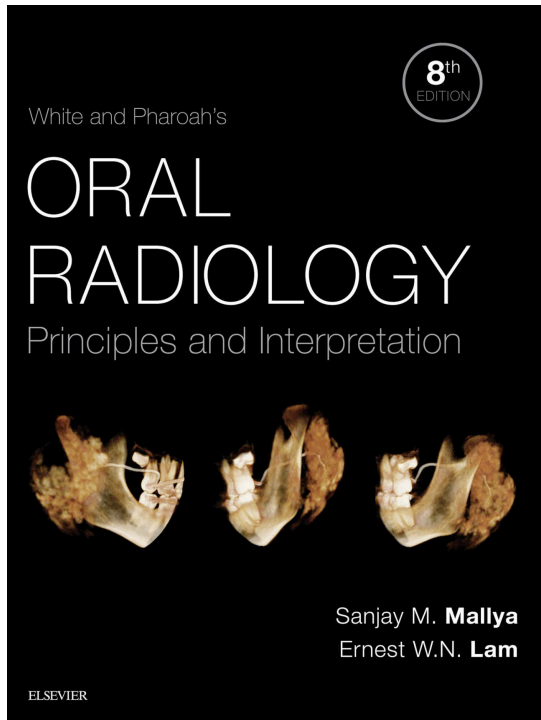


- | | | |
|-----------------------------|--------------------------------------|---|
| 1. Frontal bone | 10. Maxillary sinus | 19. Uncinate process |
| 2. Frontal sinus | 11. Nasopalatine canal | 20. Infraorbital ethmoid air cells (Haller cells) |
| 3. Nasal bone | 12. Incisive foramen | 21. Ostium of maxillary sinus |
| 4. Maxillary bone | 13. Orbit | 22. Infundibulum |
| 5. Nasal septum | 14. Middle nasal turbinate | 23. Hiatus semilunaris |
| 6. Inferior nasal turbinate | 15. Zygomatic process of the maxilla | 24. Frontal recess |
| 7. Ethmoid air cells | 16. Mandible | 25. Ethmoid bulla |
| 8. Nasolacrimal duct | 17. Crista galli of ethmoid bone | 26. Inferior meatus |
| 9. Infraorbital canal | 18. Fronto-zygomatic suture | |

- | | | |
|---|----------------------------------|--|
| 1. Ethmoid air cells | 11. Coronoid process of mandible | 21. Optic canal |
| 2. Superior nasal turbinate | 12. Maxillary tuberosity | 22. Foramen rotundum |
| 3. Middle nasal turbinate | 13. Inferior alveolar canal | 23. Pterygoid (vidian) canal |
| 4. Zygomatic arch | 14. Sphenoid sinus | 24. Nasopharyngeal airway |
| 5. Maxillary sinus | 15. Pterygopalatine fossa | 25. Squamous temporal bone |
| 6. Inferior nasal turbinate | 16. Lateral pterygoid plate | 26. Zygomatic process of temporal bone |
| 7. Hard palate (floor of nasal cavity) | 17. Medial pterygoid plate | 27. Sphenosquamous suture |
| 8. Sphenoid bone | 18. Mandibular ramus | 28. Foramen ovale |
| 9. Inferior orbital fissure | 19. Floor of sella turcica | 29. Palatine tonsils |
| 10. Perpendicular plate of ethmoid bone | 20. Anterior clinoid process | 30. Hyoid bone |

- | | | |
|--------------------------|------------------------------|-----------------------------|
| 1. Glenoid fossa | 11. External auditory meatus | 21. Body of C3 |
| 2. Mandibular condyle | 12. Odontoid process of C2 | 22. Foramen magnum |
| 3. Foramen spinosum | 13. Ossicles of ear | 23. Mastoid process |
| 4. Basiocciput | 14. Occipital condyles | 24. Occipito-mastoid suture |
| 5. Carotid canal | 15. Lateral mass of C1 | |
| 6. Petrooccipital suture | 16. Mastoid air cells | |
| 7. Styloid process | 17. Internal auditory meatus | |
| 8. Oropharyngeal airway | 18. Jugular foramen | |
| 9. Epiglottis | 19. Jugular bulb | |
| 10. Semicircular canal | 20. Body of C2 | |

Sagittal CBCT Anatomy



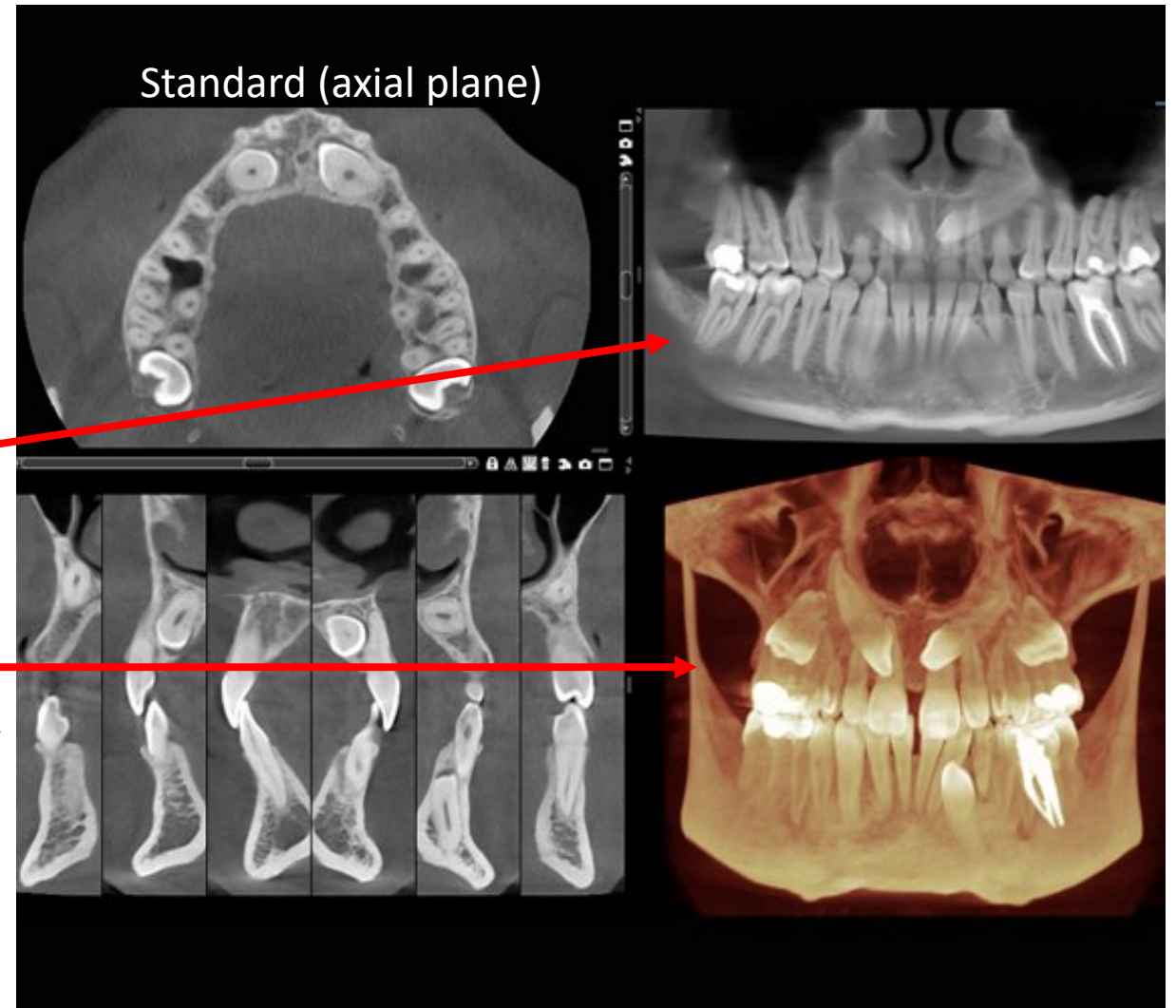
- | | | |
|---------------------------|----------------------------|--|
| 1. Frontal bone | 14. Epiglottis | 27. Soft palate |
| 2. Frontal sinus | 15. Hyoid bone | 28. Base of tongue |
| 3. Nasal bone | 16. Hypopharynx | 29. Vallecula |
| 4. Sella turcica | 17. Anterior arch of C1 | 30. Orbit |
| 5. Sphenoid sinus | 18. Odontoid process of C2 | 31. Floor of orbit/Roof of maxillary sinus |
| 6. Clivus | 19. Posterior arch of C1 | 32. Maxillary sinus |
| 7. Anterior nasal spine | 20. Spinous process of C2 | 33. Floor of maxillary sinus |
| 8. Nasopalatine canal | 21. Body of C3 | 34. Pterygopalatine fossa |
| 9. Hard palate | 22. Body of C4 | 35. Occipital condyle |
| 10. Incisive foramen | 23. Ethmoid air cells | 36. Ossicle of middle ear |
| 11. Mandibular symphysis | 24. Hiatus semilunaris | 37. Mastoid process |
| 12. Nasopharyngeal airway | 25. Middle turbinate | 38. Articular eminence |
| 13. Oropharyngeal airway | 26. Inferior turbinate | 39. Mandibular condyle |

CBCT Additional Display

IE. Secondary Reconstruction

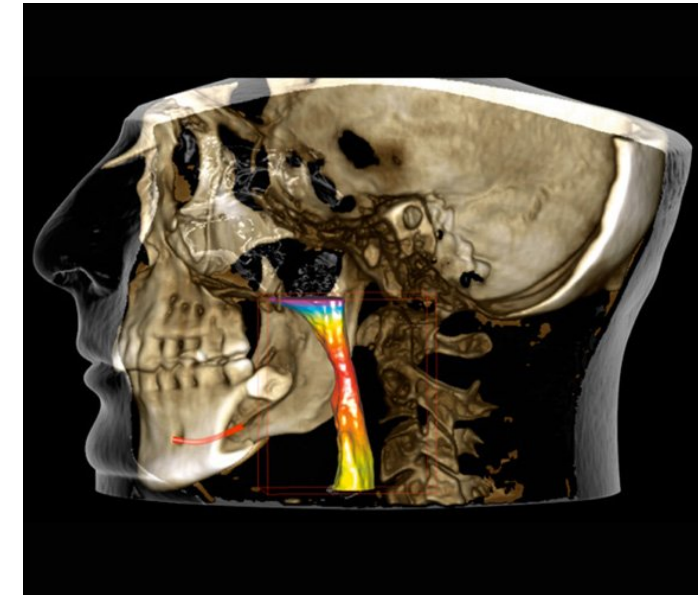
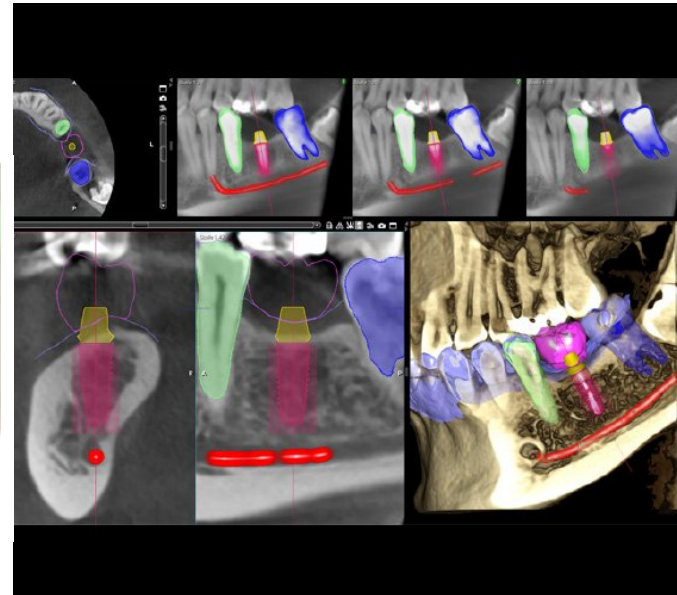
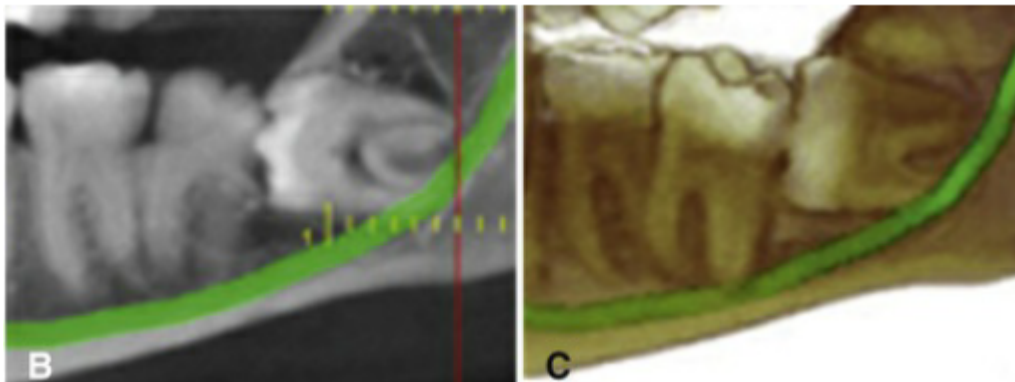
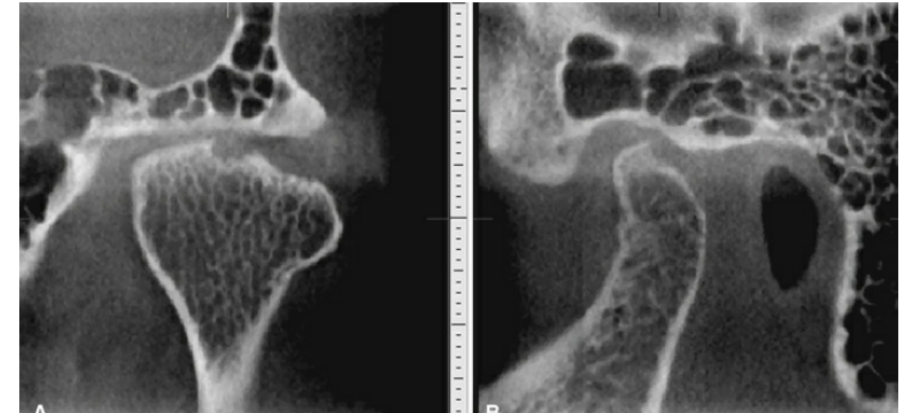
- Special algorithm required

1. Reconstructed panoramic / curved oblique view
2. Volume / 3D rendering
3. Transaxial / Cross-sectional



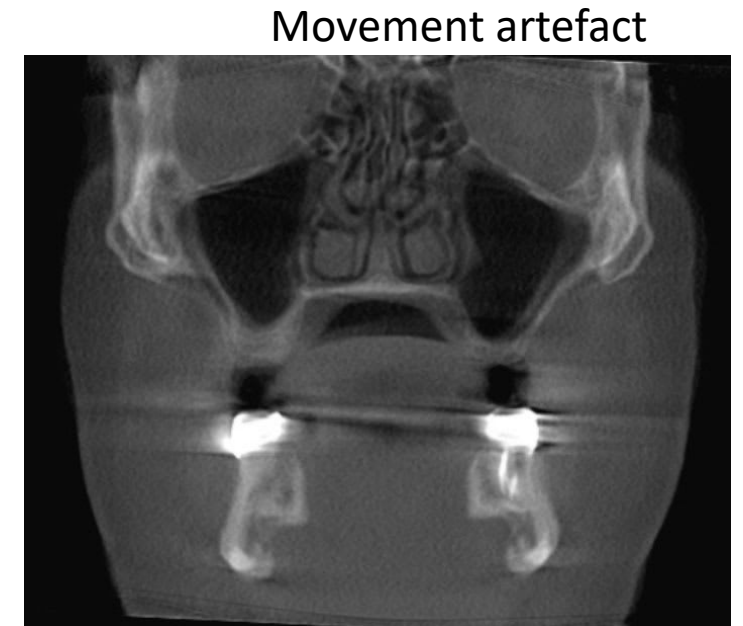
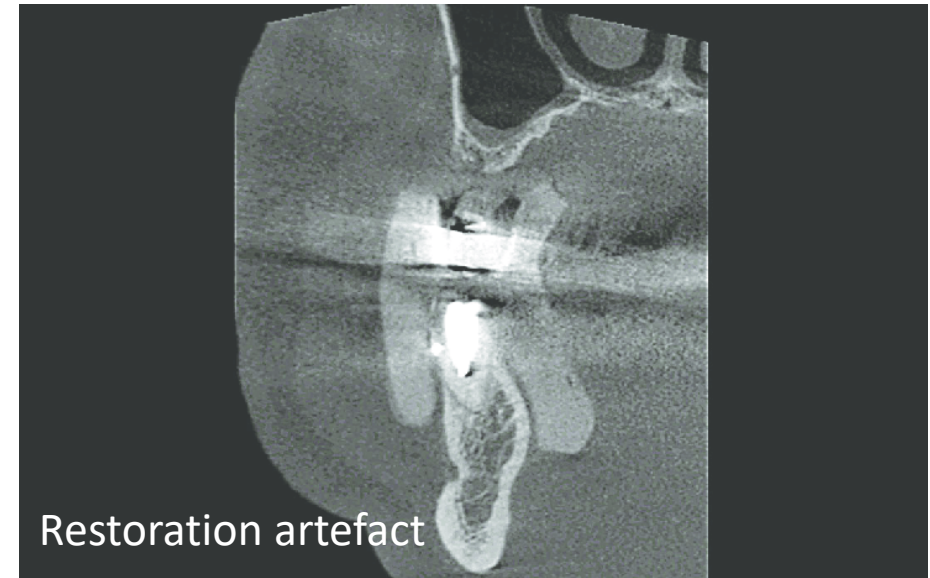
Other Additional Displays

- TMJ mode
- Mandibular Canal Tracing
- Implant placement simulator
- Airway mode



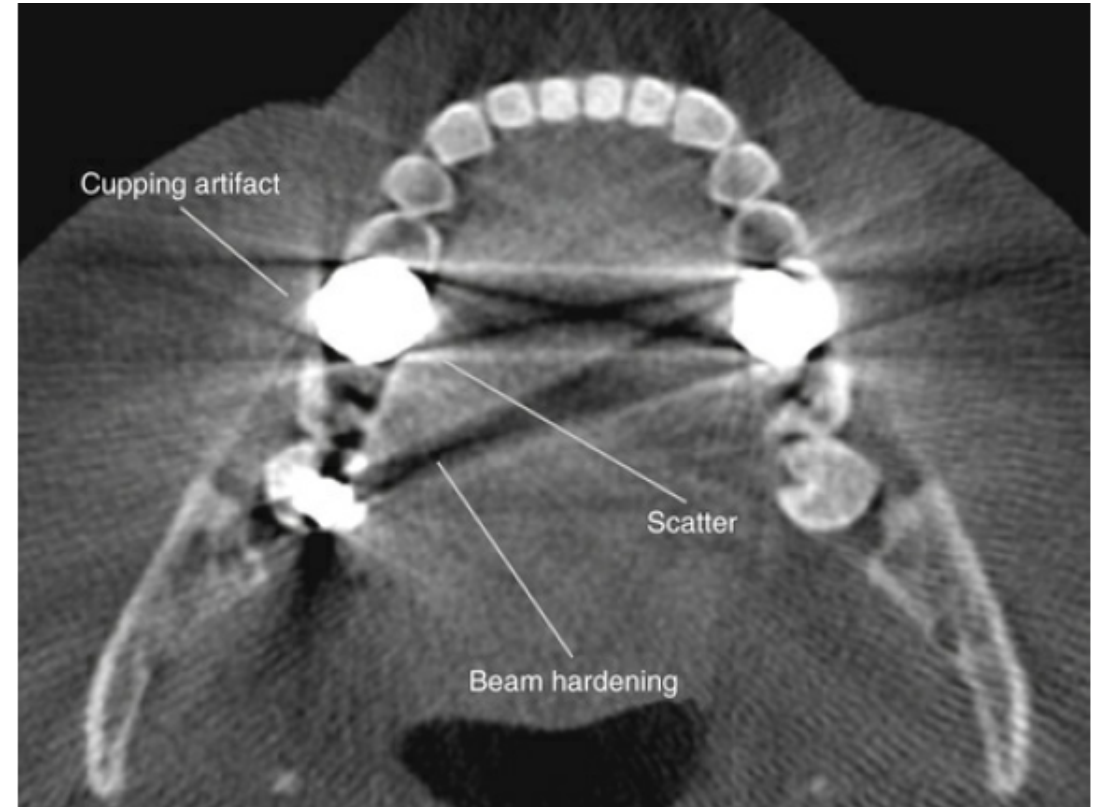
Limitations & Artefacts

- **Poor soft tissue contrast**
- **Noise**
- **Patient related**
 - **Movement**
 - Tremor
 - Child
 - **Restorations**
 - High density restorations eg. amalgams, crowns, implants, etc.
- **Under-sampling**
- **Partial volume averaging**
- **Beam hardening**
- **Cone beam effect**
- **Detector related**
 - Ring artefact
 - Dead pixel



Most pronounced artefacts:

- Patient movement artefact
 - CBCT takes up to 30 seconds to scan
- Restoration artefacts (or just dense object artefacts) →
 - Cupping artefact (shape distortion)
 - Scatter/Streaking (white lines)
 - Beam hardening (black lines)



CBCT Imaging – Medicolegal

- “Dental practitioners using CBCT must be adequately trained in the safe use of CBCT and should abide by the Code of Practice and Safety Guide for Radiation Protection in Dentistry (2005) produced and published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).” – Dental Board of Australia
- License required to operate CBCT units
 - Four (4) Licensing Courses Available in Australia:
<http://www.radiologicalcouncil.wa.gov.au/Pages/FAQ/Dentists.html>
- **Medicolegally, WA dentists MUST** refer their CBCT to registered OMF or medical radiologist for radiology reports
 - Dentists in other Australian States and Territories are able to write their own radiology reports with adequate training

References

- Dental board of Australia
- **Oral radiology – principles and interpretation 8th ed**
- Essentials of dental radiography and radiology 5th edition by Whaites, Eric; Drage, Nicholas Churchill Livingstone 2013

