Introduction to Cone Beam Computed Tomography

University of Manitoba | Rady Faculty of Health Sciences

Lecture Objectives:

Cone Beam Computed Tomography:

- COMPREHEND IMAGING PHYSICS OF CBCT VERSUS MULTI-DETECTOR CT:
- UNDERSTAND THE STRENGTHS AND LIMITATIONS OF CBCT

Presenter Disclosure

- **Faculty Member:** Dr. Meredith Brownlee
- **Relationships with commercial interests:**
  - None to report

Disclosure of Commercial Support

- This program has received financial support from J. Morita in the form of an unrestricted educational grant.

- Potential for conflicts of interest:
  - Dr. Brownlee has not received funding from an organization whose products are being discussed in this program.

What is CBCT?

- Three dimensional imaging modality utilized in dentistry since early 1990’s
- Initially used in angiography in 1980’s
- Introduced to dental market:
  - with the advent of X-ray detectors that could accommodate rapid acquisition of multiple basis images
  - high out-put X-ray generators
  - acquisition and integration algorithms
  - Inexpensive yet powerful computers that could process large amounts of acquired data

Fig. 11-1, White and Pharoah

Cone Beam Computed Tomography:

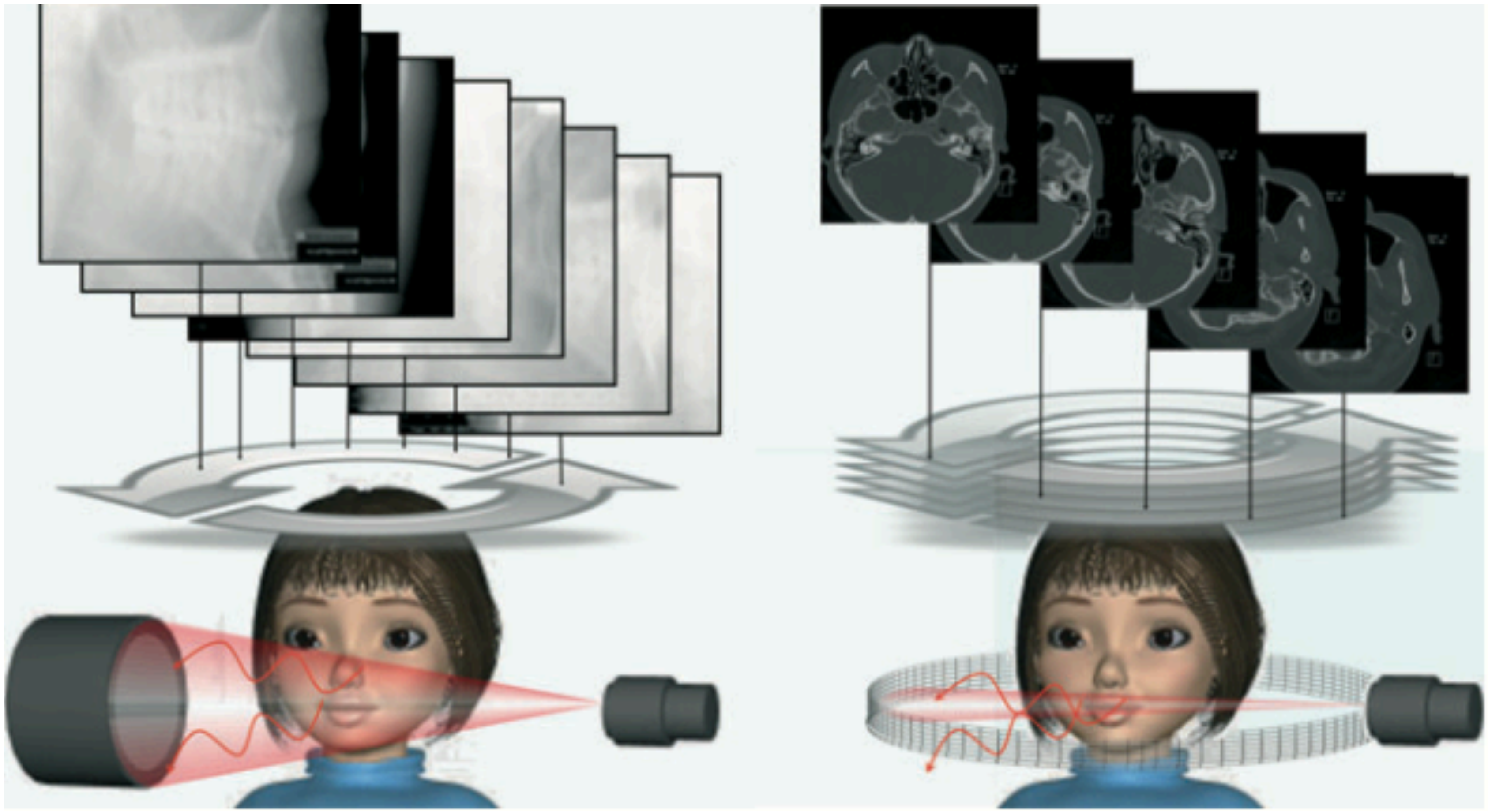


Fig. 1, Scarfe, et. al. 2012

University of Manitoba | Rady Faculty of Health Sciences

MDCT

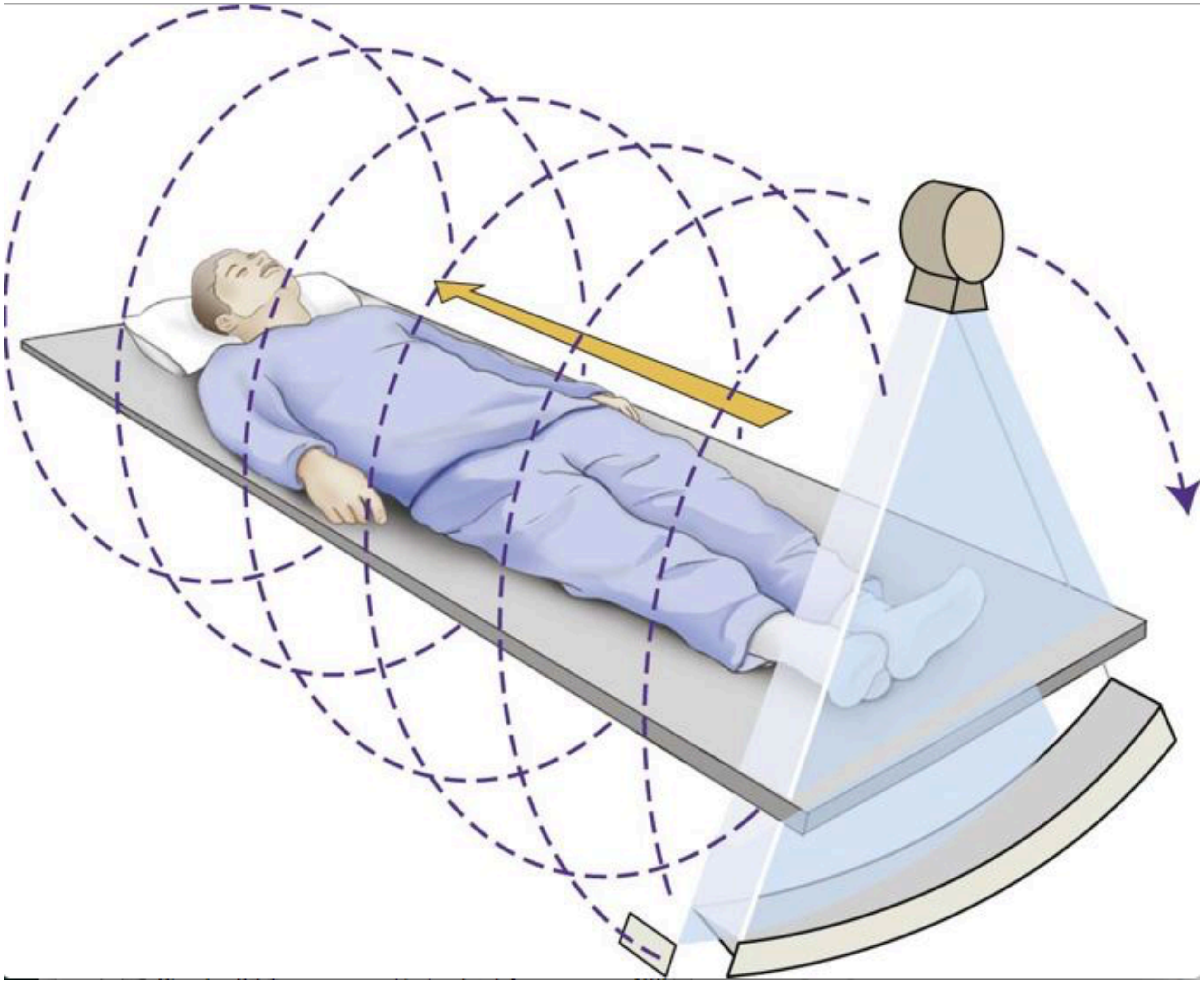


Fig. 14-2, White and Pharoah

Feature	CBCT	MDCT
Beam Shape	Cone shaped	Fan shaped
Rotation of Source	180-360 degree rotation	Multiple rotations
Detector	Flat panel detector	Multiple rows (array) of solid state detectors
Voxels	Isotropic	Anisotropic, isotropy is obtained via computation
Voxel Size	>0.065mm	0.9mm, but can be acquired at 0.3mm
Patient Position	Vertical; seated or standing. Some early models had supine patient positioning	Supine

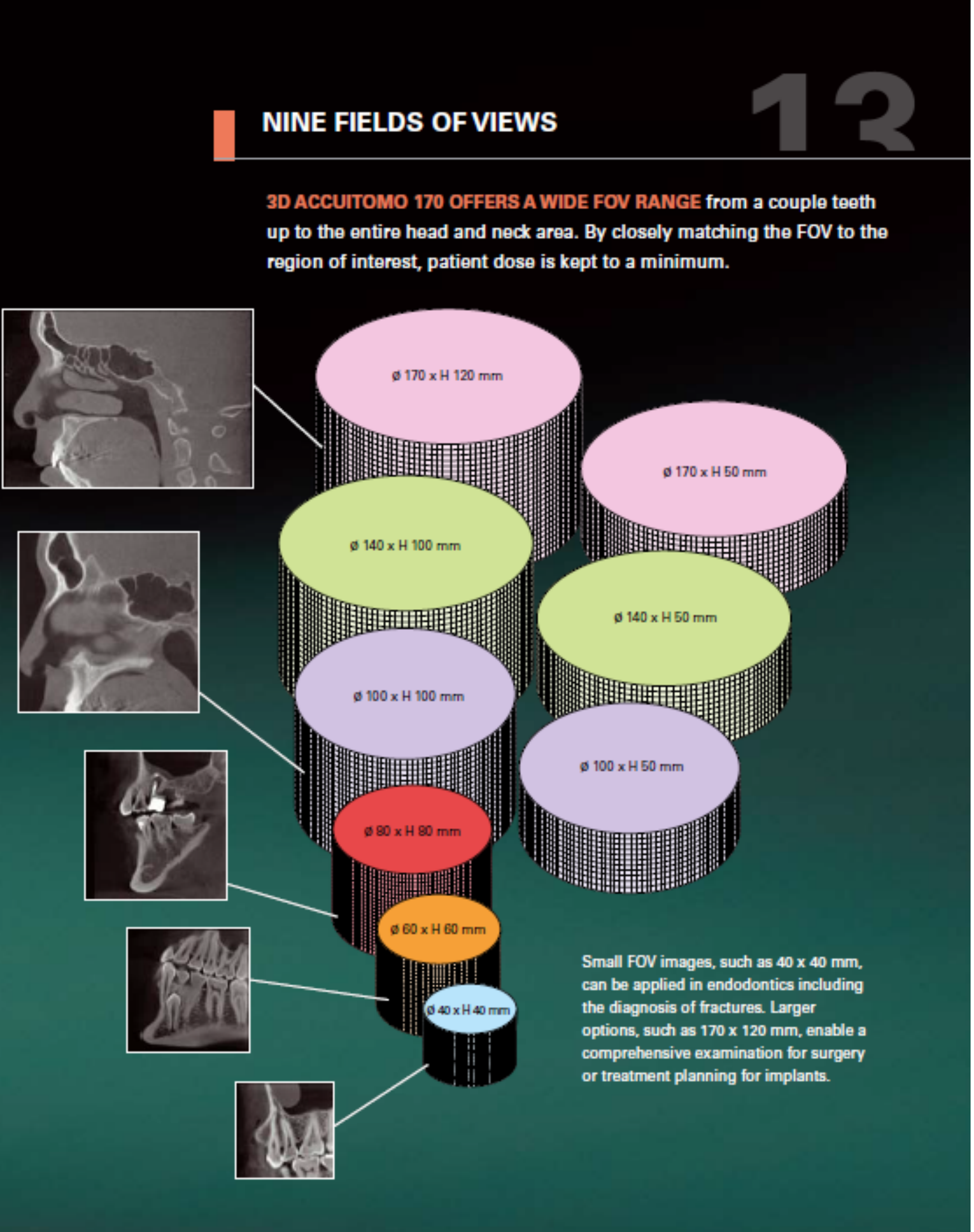
Feature	CBCT	MDCT
Spatial Resolution	Superior	Inferior
Contrast Resolution	Inferior, only bone windowing	Superior, multiple soft tissue and hard tissue windows
Generated Slices	Axial, Coronal, Sagittal, 3D renderings	Axial. Coronal, sagittal, and 3D renderings can be reformatted
Contrast Agents	No	Yes
Cost	Low ($$-$$$K)	High ($$$K+)
Radiation Dose	Conventional radiography < CBCT < MDCT	MDCT >> CBCT

Hounsfield Units (MSCT)

Material or Tissue	HU
Air	-1000
Lung	-500 to -200
Fat	-200 to -50
Water	0
Blood	25
Muscle	25 to 40
Bone	200 to 1000
Metal	900 to 1000

CBCT X-ray Generation

- Patient is stabilized (chin cup, bite block, head strap) to prevent patient movement
- X-rays produced in continuous or pulsed to coincide with the detector
- Exposure factors should be adjusted to patient parameters (child versus adult)
- Appropriate field of View (FOV) selected for region of interest (ROI)



< 80mm x 80mm are considered Small FOVs

Single arch (100mm x 50mm) FOVs are Medium FOVs

≥ 80mm x 80mm are Large FOVs

University of Manitoba | Rady Faculty of Health Sciences

FOVs of Other CBCT Manufacturers:

- Table 1 in Scarfe et. al. article included in your course package details numerous manufacturers, their CBCT models, and FOVs and voxel sizes available for those models
- This table may no longer be comprehensive, as 4 years old already

Table 1, Scarfe et. al. 2012

CBCT X-ray Generation

- Voxel size: determined by the matrix and pixel spacing of the receptor, and thus determines your spatial resolution

- Tube characteristics:
  - Focal spot size
  - Object-to-detector distance
  - Source-to-object distance

CBCT X-ray Generation

- Grayscale (Contrast Resolution): ability to detect different levels of gray
  - Determined by bit depth (12 bits or greater in CBCT)
  - E.g. 12-bit detector shows $2^{12} = 4096$ different shades of gray

CBCT Image Reconstruction

- 100-600 2 dimensional basis images are captured with 1 million + pixels (12 to 16 bit depth), or picture elements
- Basis images are reconstructed into a volumetric dataset of voxels (volume elements)

CBCT Acquisition of Basis Images

CBCT Image Reconstruction

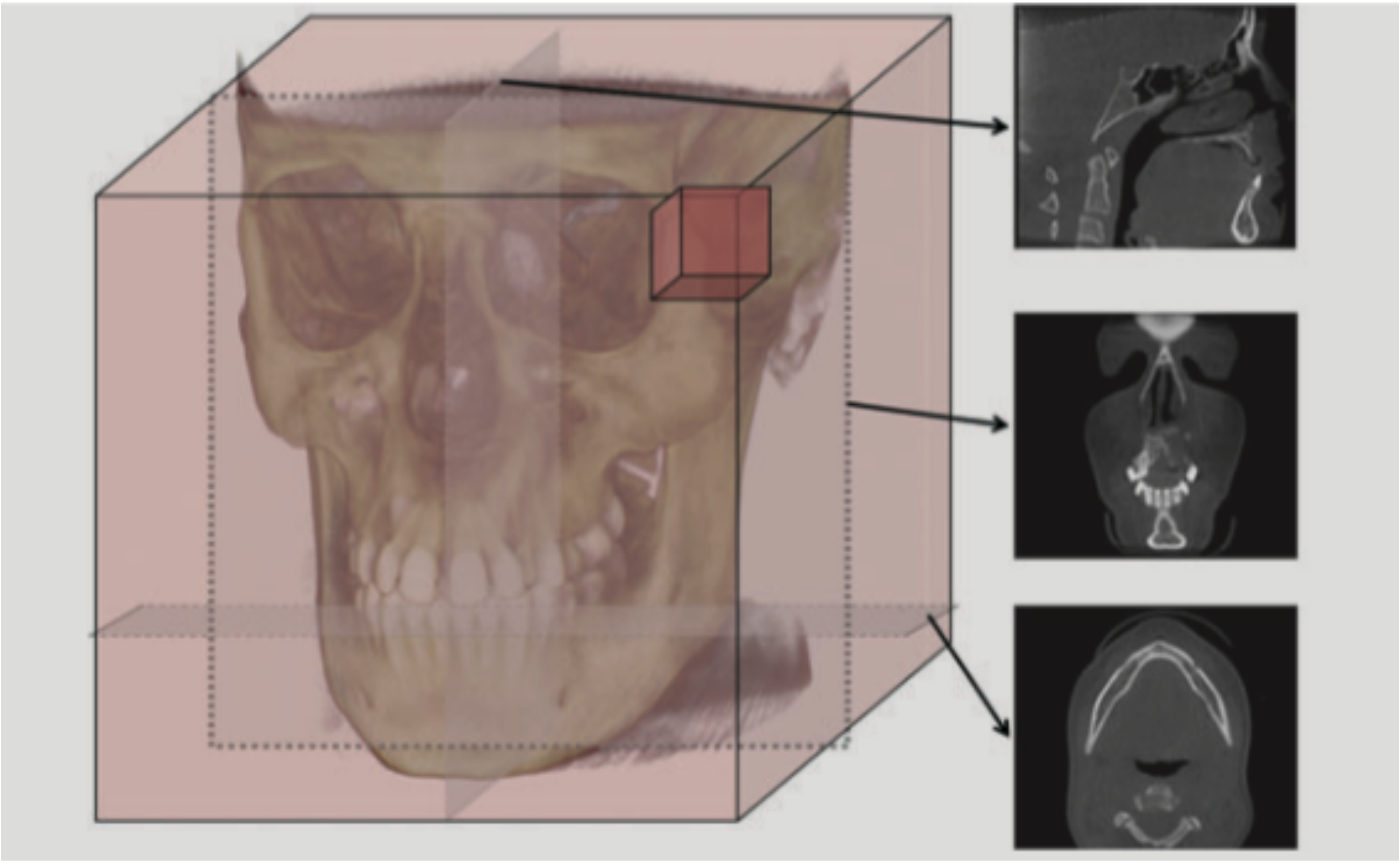


Fig. 3, Scarfe et. al. 2012

University of Manitoba | Rady Faculty of Health Sciences

CBCT Image Reconstruction

- Preprocessing or Acquisition Stage:
  - Basis images are corrected for:
    - Dark image offset
    - Pixel gain
    - Pixel imperfections
    - Temporal Artifact correction
    - Defect Interpolation

CBCT Detector Preprocessing

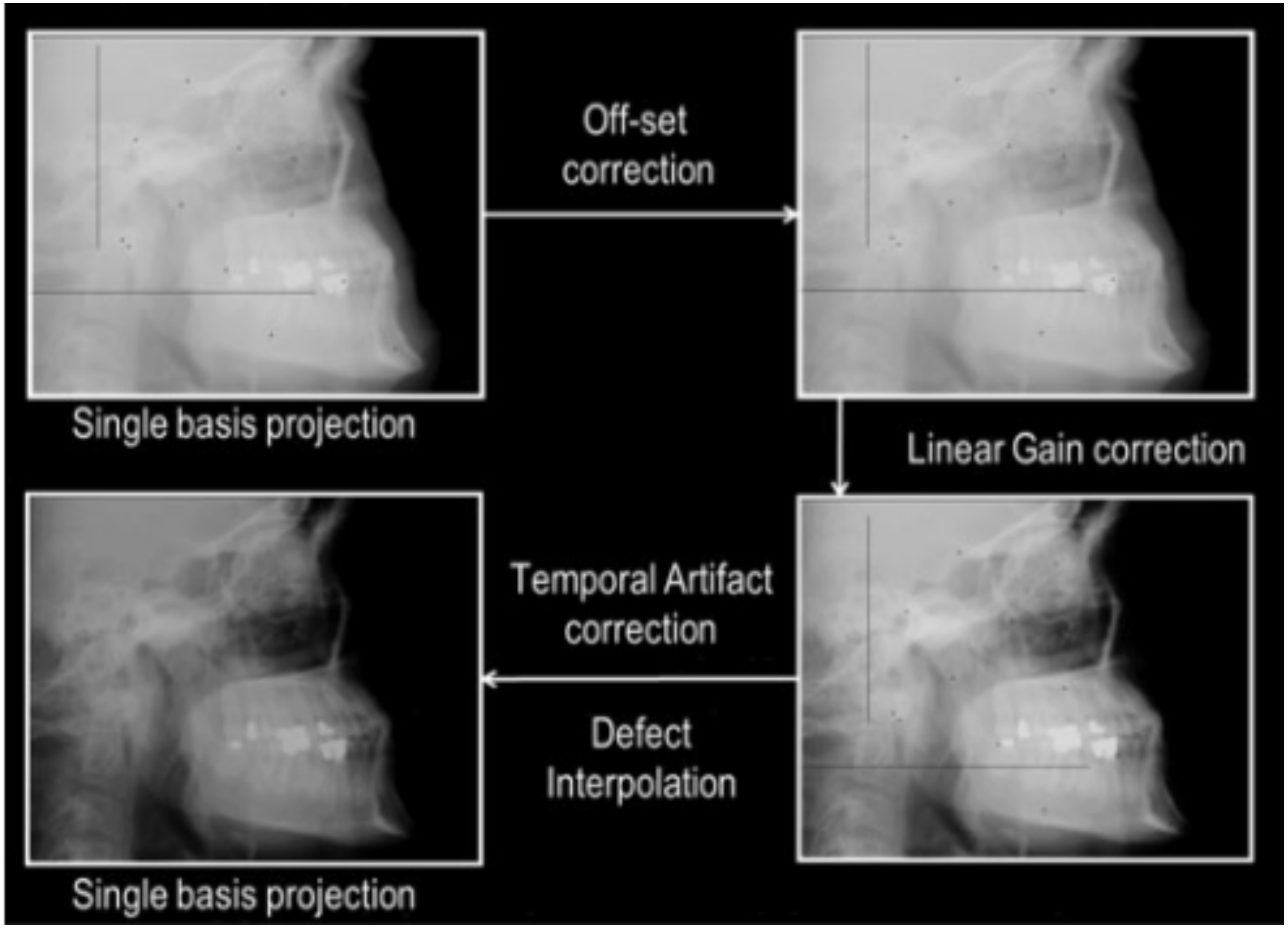


Fig. 4 Scarfe et. al. 2012

University of Manitoba | Rady Faculty of Health Sciences

Radon Transformation

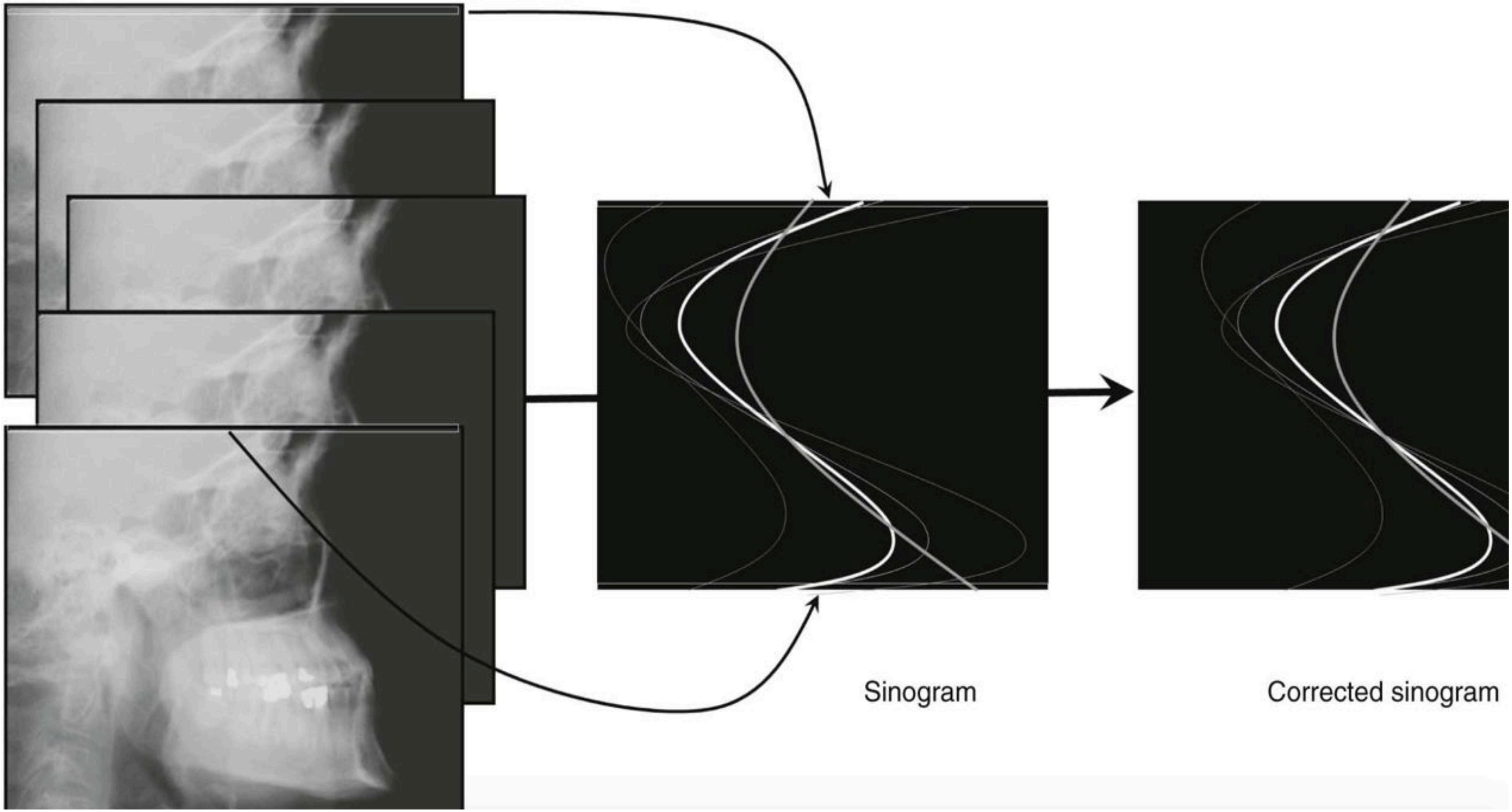
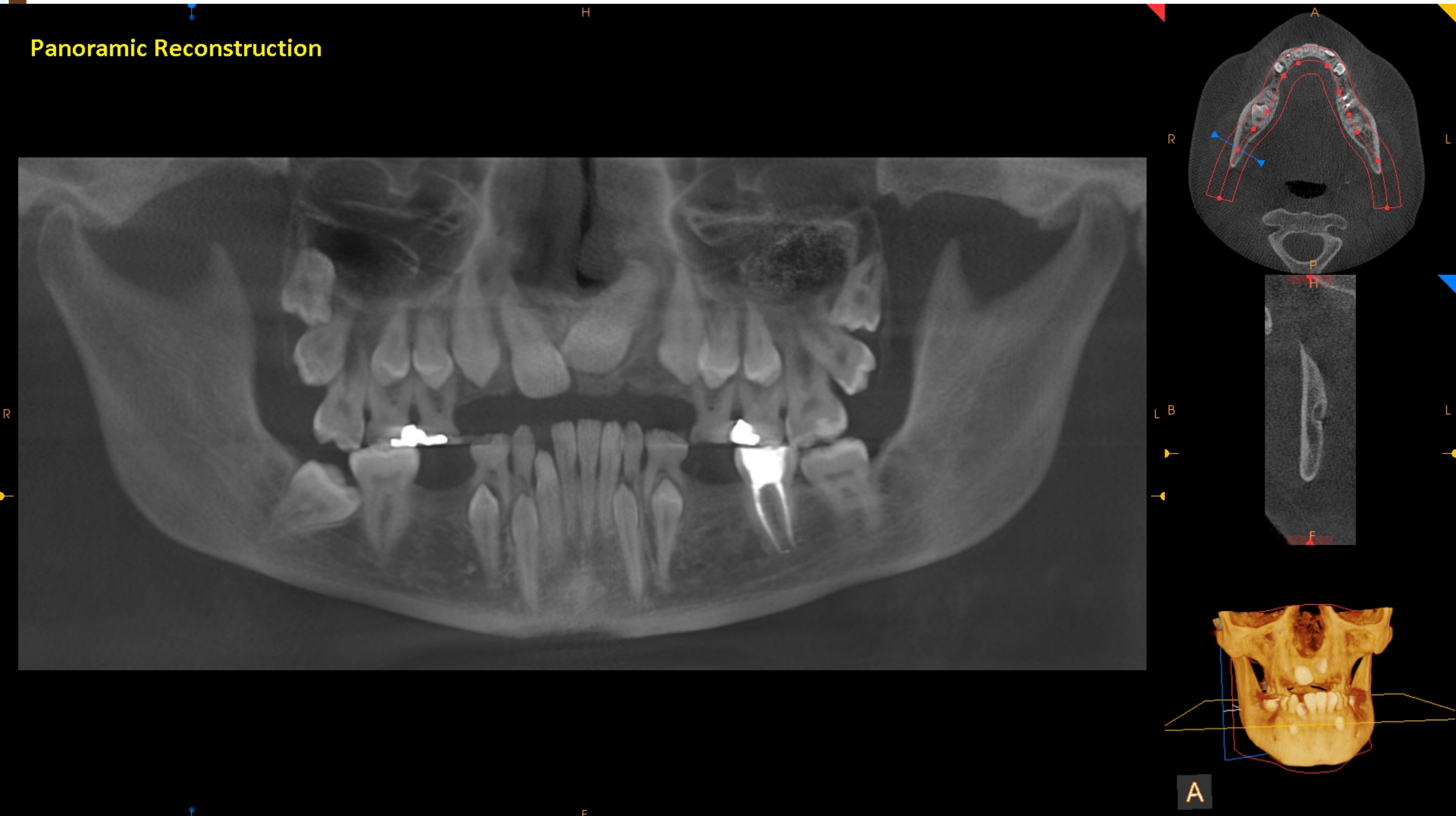


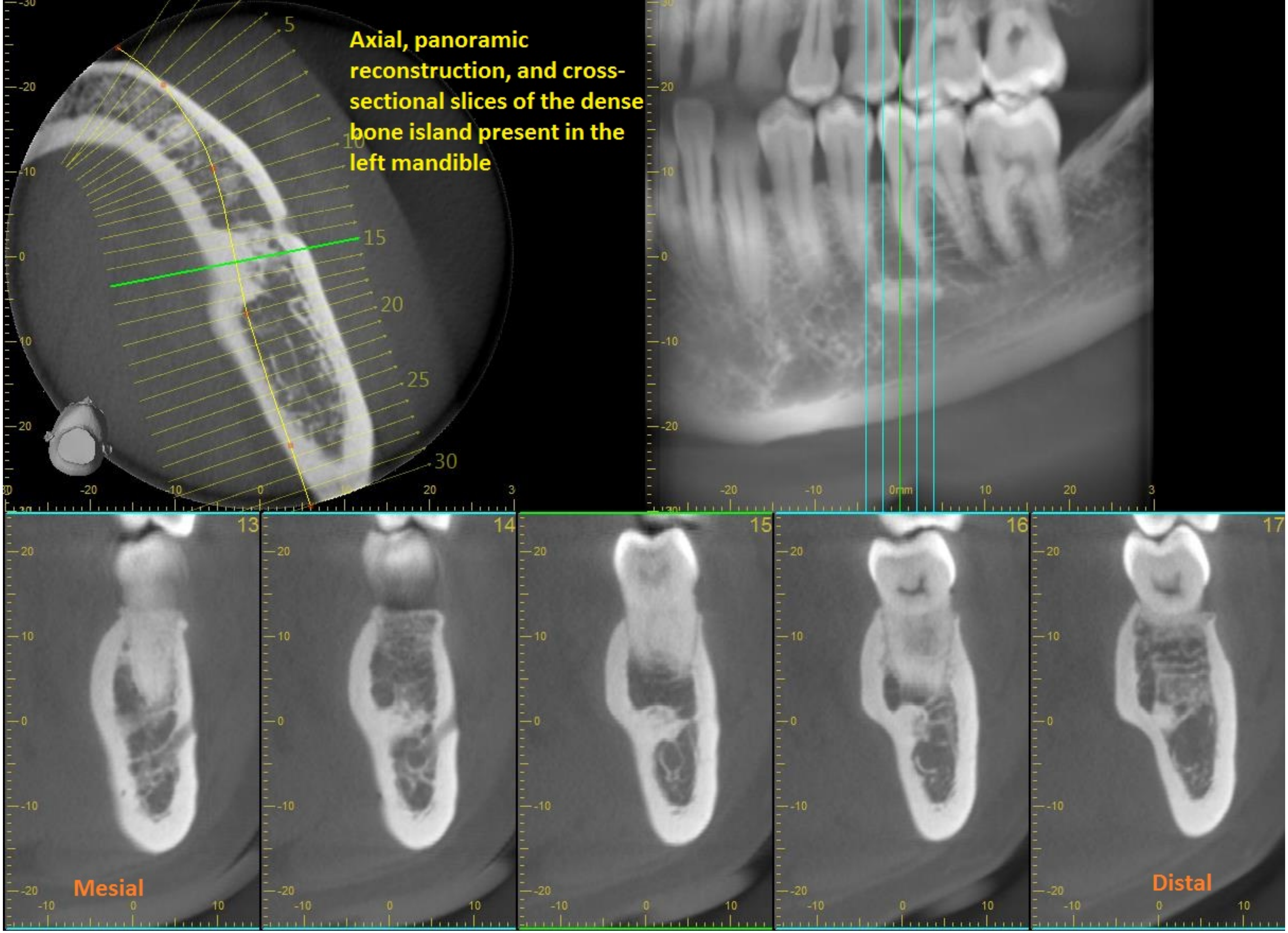
Fig. 8-11. White and Pharoah

CBCT Image Reconstruction

- Reconstruction Stage:
  - Radon Transformation: basis images are converted into a sinogram, a composite image of sine waves, detailing the number of rays at the detector (horizontal) and projection angles (vertical)
  - Filtered back-projection algorithm: most CBCTs use Feldkamp algorithm



Source: Dr. M. Brownlee



Source: Dr. M. Brownlee

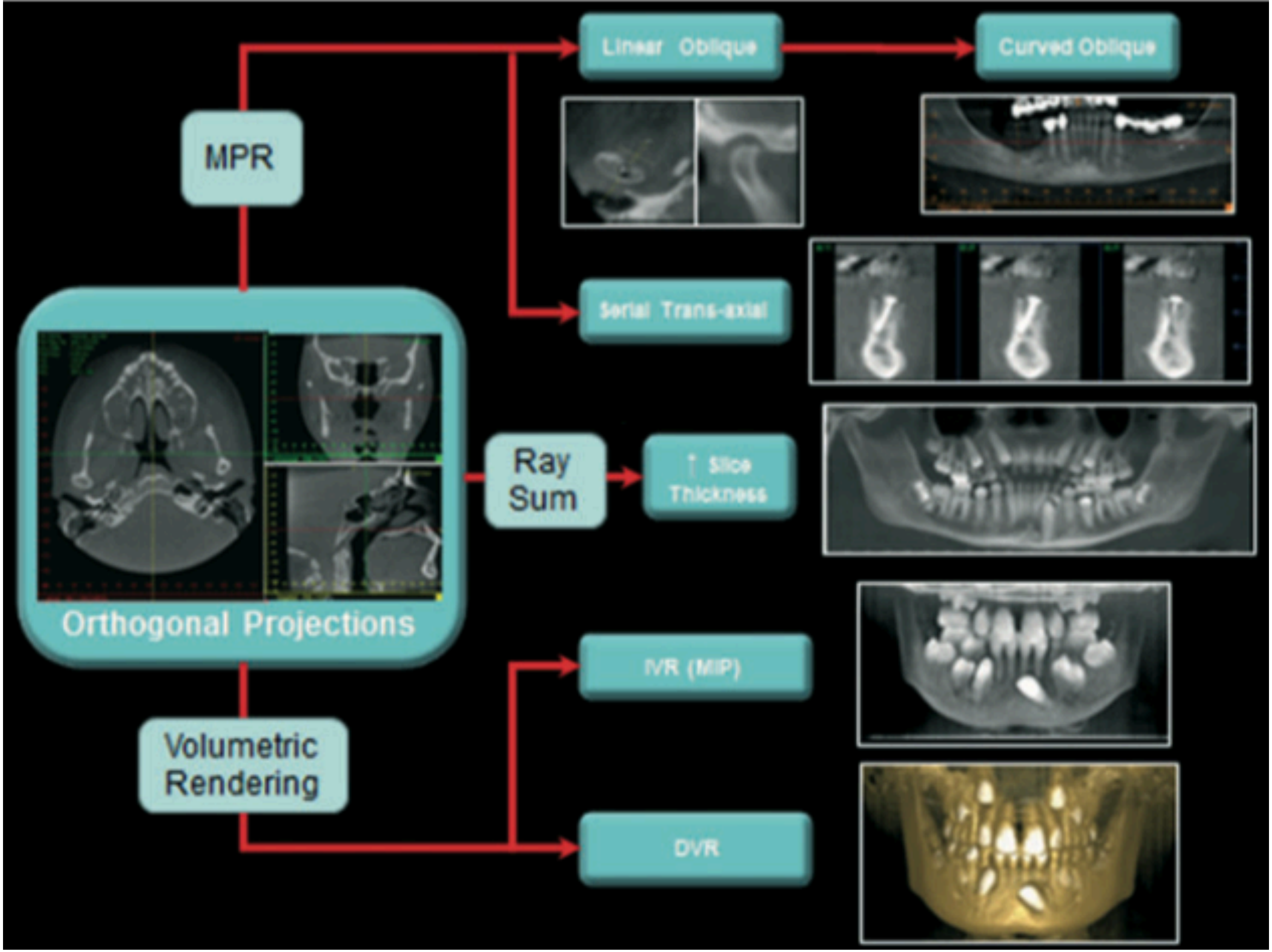


Fig. 8 Scarfe et. al. 2012

CBCT Strengths

- Size: smaller footprint than MDCT
- Cost: 20-25% of the cost of MDCT
- Fast acquisition: usually > 30 sec.
- Submillimeter resolution: 0.076mm and greater voxel resolution => great spatial resolution
- Relatively low patient dose, dependent on many factors
- Interactive analysis utilizing a personal computer; software programs with various functions

CBCT Limitations

- CBCT does not have the contrast necessary to differentiate soft tissues, as MSCT or MRI do
- Increased scattered photons compared to MSCT, thus increased image noise
- Increased heel effect: increased divergence of X-ray beam over the detector, thus increased non-uniformity of the X-ray beam through the patient tissues and non-uniformity in absorption (greater SNR from the cathode side to the anode side of the image)

Questions?

- All images in this lecture are sourced and/or credited to Dr. Meredith Brownlee, unless otherwise noted

References:

- White SC, Pharoah MJ (2014). Oral Radiology: Principles and Interpretation, 7th Ed. CV Mosby, St. Louis.
- Scarfe WC, Li Z, Aboelmaaty W, Scott SA, Farman AG. Maxillofacial cone beam computed tomography: essence, elements and steps to interpretation. Aus Dent J 2012; 57(1 Suppl): 46-60.