Calgary & District Dental Society

Review of Cone Beam CT and 2D digital imaging in dentistry with cases

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OVERALL THOUGHTS ON IMAGE ENHANCEMENT

- Most image enhancements are applied to make the image more visually appealing (subjective enhancement) – in other words – does not improve accuracy of diagnosis[1]
- Indiscriminate use of enhancements/filters should be avoided – there is limited scientific evidence suggesting enhanced diagnosis[2-4]
- Enhancements are often task specific – what may benefit one diagnostic task may limit another[1]
- Mild Sharpening/Edge enhancement is probably the most likely alteration to improve diagnosis[5-8]
- Effectiveness of enhancement on diagnosis may depend on viewer preference/their individual visual system[1]

1. Mol A. Image processing tools for dental applications. Dent Clin North Am 2000;44(2):299-318
2. Wenzel A. A review of dentists' use of digital radiography and caries diagnosis with digital systems. Dentomaxillofac Radiol 2006;35(5):307-14.
3. Mallya SM, Tetradis S. Trends in Dentomaxillofacial Imaging. J Calif Dent Assoc 2015;43(9):500-2.
4. Mol A, Yoon DC. Guide to Digital Radiographic Imaging. J Calif Dent Assoc 2015;43(9):503-11.
5. Belem MD, Ambrosano GM, Tabchoury CP, Ferreira-Santos RI, Haiter-Neto F. Performance of digital radiography with enhancement filters for the diagnosis of proximal caries. Braz Oral Res 2013;27(3):245-51.
6. Baksi BG, Alpoz E, Sogur E, Mert A. Perception of anatomical structures in digitally filtered and conventional panoramic radiographs: a clinical evaluation. Dentomaxillofac Radiol 2010;39(7):424-30.
7. Nascimento HA, Ramos AC, Neves FS, de-Azevedo-Vaz SL, Freitas DQ. The 'Sharpen' filter improves the radiographic detection of vertical root fractures. Int Endod J 2015;48(5):428-34.
8. Choi JW, Han WJ, Kim EK. Image enhancement of digital periapical radiographs according to diagnostic tasks. Imaging Sci Dent 2014;44(1):31-5.

Guide to Confusing Periapical Radiopacities

Condition	Other names	Findings	Management
• Sclerosing Osteitis	• Condensing Osteitis	• Diffuse sclerosis typically centered on a root apex or occasionally accessory canal • Apical PDL commonly widened	• Endodontic evaluation of tooth
• Idiopathic Osteosclerosis	• Dense bone island • Enostosis	• Well-defined and mostly homogenous sclerotic bone • No peripheral lucent band • May or may not be associated with a root • Occasionally resorbs roots	• No treatment indicated
• Hypercementosis	• Bulbous roots	• Well defined but irregular shaped expansion of root size • Calcification confluent with root • Surrounded by normal thickness PDL and lamina dura	• No treatment indicated • Extractions may be difficult
• Cementoblastoma	• An osteoblastoma may appear similar (similar neoplasm)	• Rounded expansion of root • Calcification confluent with root • Surrounded by a thicker lucent band	• Surgical removal
• Periapical Osseous Dysplasia	• Focal osseous dysplasia • Florid osseous dysplasia • Periapical cemental/cemento-osseous dysplasia (old)	• Mixed density bony alterations in the periapical region of teeth • Calcifications typically appear granular • Almost always preservation of a vague and undulating peripheral lucent band • May also see hypercementosis or simple bone cavity formation	• No treatment indicated • Avoid biopsy

Sclerosing Osteitis	Enostosis (Idiopathic Osteosclerosis)
Nonvital tooth	Vital tooth
Symptomatic	Asymptomatic
Blending border	Well-defined border
Mixed density	Mostly uniform density
Extraction or endodontic therapy	No treatment needed
	Can resorb roots

Sclerosing Osteitis

Idiopathic Osteosclerosis

Most Common Errors on Panoramic Radiographs

Faults	*n*	%
Tongue not in contact with palate	1,298	71.6
Antero-posterior positioning errors	1,066	58.8
Absence of orientation (left/right) markers	642	35.4
Occlusal plane errors	568	31.3
Incorrect sagittal plane	508	28.0
Slumped position	267	14.7
Foreign objects/ghost shadows	164	9.0
Lower border of mandible off film	164	9.0
Poor film/screen contact	60	3.3
Overlap of upper and lower teeth	56	3.1
Movement artefact	35	2.0

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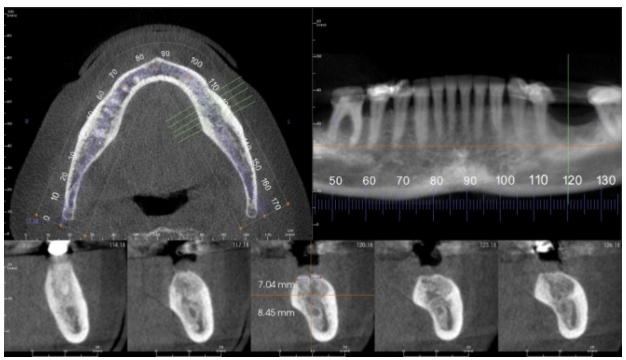
CBCT Basics

- Relatively low-dose acquisition of anatomic information in 3D
- Results in a 3D data set of voxels (3D pixels)
- Think stack of small cubes, each cube has its own grayscale value
- Dimensionally accurate, relatively high resolution imaging of hard tissues
- Good imaging of soft-tissue/air interfaces, but poor soft tissue differentiation (muscle vs fat vs fluid vs brain, etc.)
- Much more information (3D) than a pan (2D)
- Multiple ways to review of the information!

Ways to view CBCT scans

Three ways to view the volume of CBCT image data:



Slices

Volume Renderings

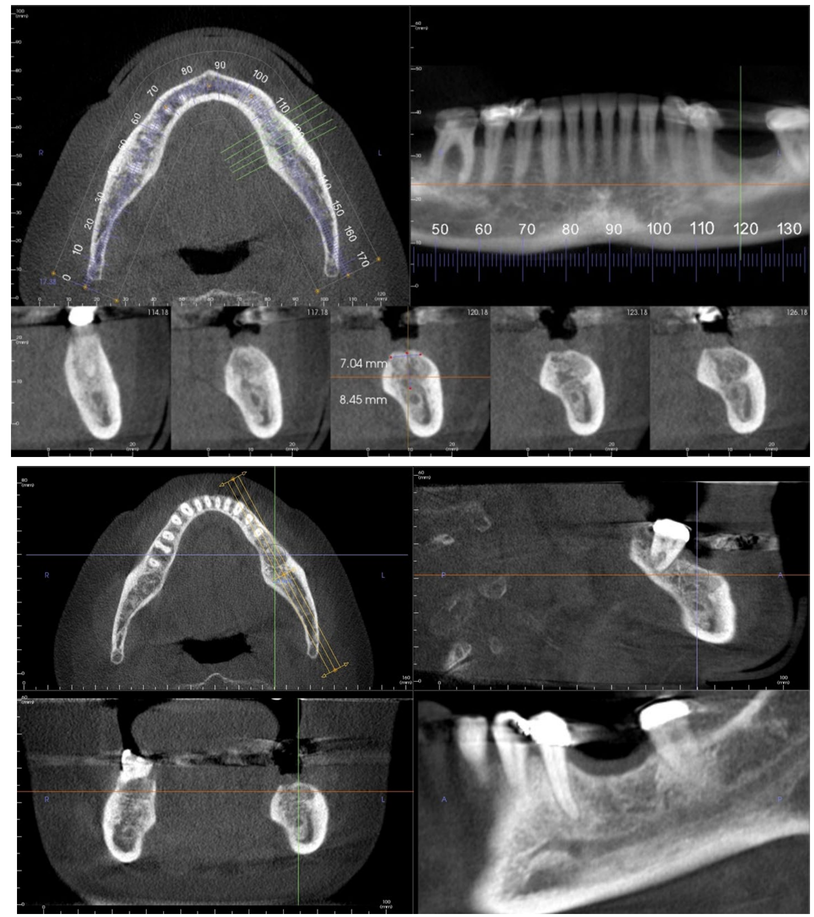
Reconstructed Radiographs

University of Minnesota

Ways to view CBCT scans

SLICES/SECTIONS

- Slices offer the most accurate and most detailed views of the CBCT data
- When lost, use the crosshairs or patient orientation identifiers
- Dimensionally accurate but beware of slice orientation



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Ways to view CBCT scans

VOLUME RENDERING

- Solid/Surface or semi-transparent rendering of the 3D information
- Great for assessment of spatial relationships of maxillofacial and dental structures
- Dimensionally accurate
- “Threshold” settings can significantly influence appearance of tissues
- Not reliable to assess fine details and bone quality
- Use slices to view details

Ways to view CBCT scans

RECONSTRUCTED RADIOGRAPHS

- Panoramic images
- Lateral cephs
- PA cephs

- Great for quick overviews and cephalometric analyses
- Not reliable to assess fine details – use the slices

Artifacts

IMAGE ARTIFACTS:

- Any distortion or corruption of image information that misrepresents reality

- Two main types of artifacts in CBCT: Patient motion and metal streak:

- Patient motion artifact:
- Recognizable as “double contours” or excessive streaking at osseous boundaries
- Typically controllable with patient education, stabilization, and selection of faster scan times

- Metal Streak artifact:
- Caused by x-ray’s inability to fully penetrate metal and other very dense materials
- Results in a combination of light/dark streaking artifacts surrounding dense objects
- Remove what metal you can
- Fortunately confined to axial planes of acquisition

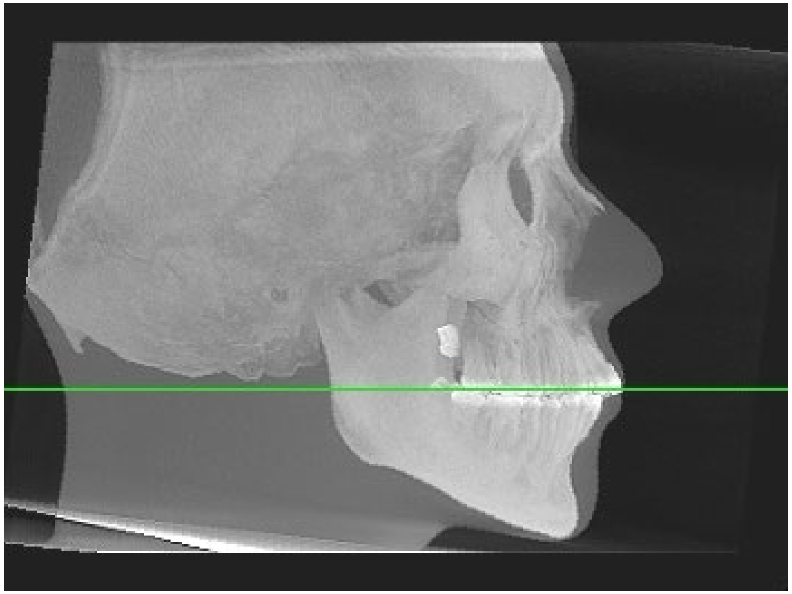
Dose

Patient exposure to ionizing radiation (dose) is intimately related to chosen scan factors:

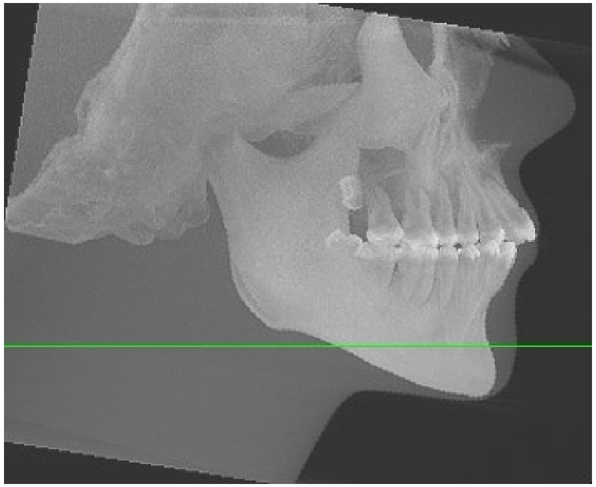
- FOV
- Resolution
- Noise

Field of View

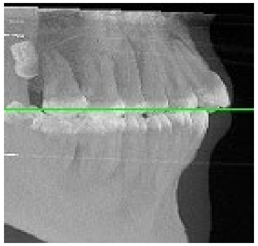
- Small (dental) FOV ~5x5cm
- Medium (dentoalveolar) FOV ~8x8cm to ~10x10cm
- Large (maxillofacial) FOV ~17x10cm to ~ 17x23cm and larger



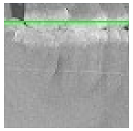
17x23cm



13x17cm



8x8cm



5x5cm

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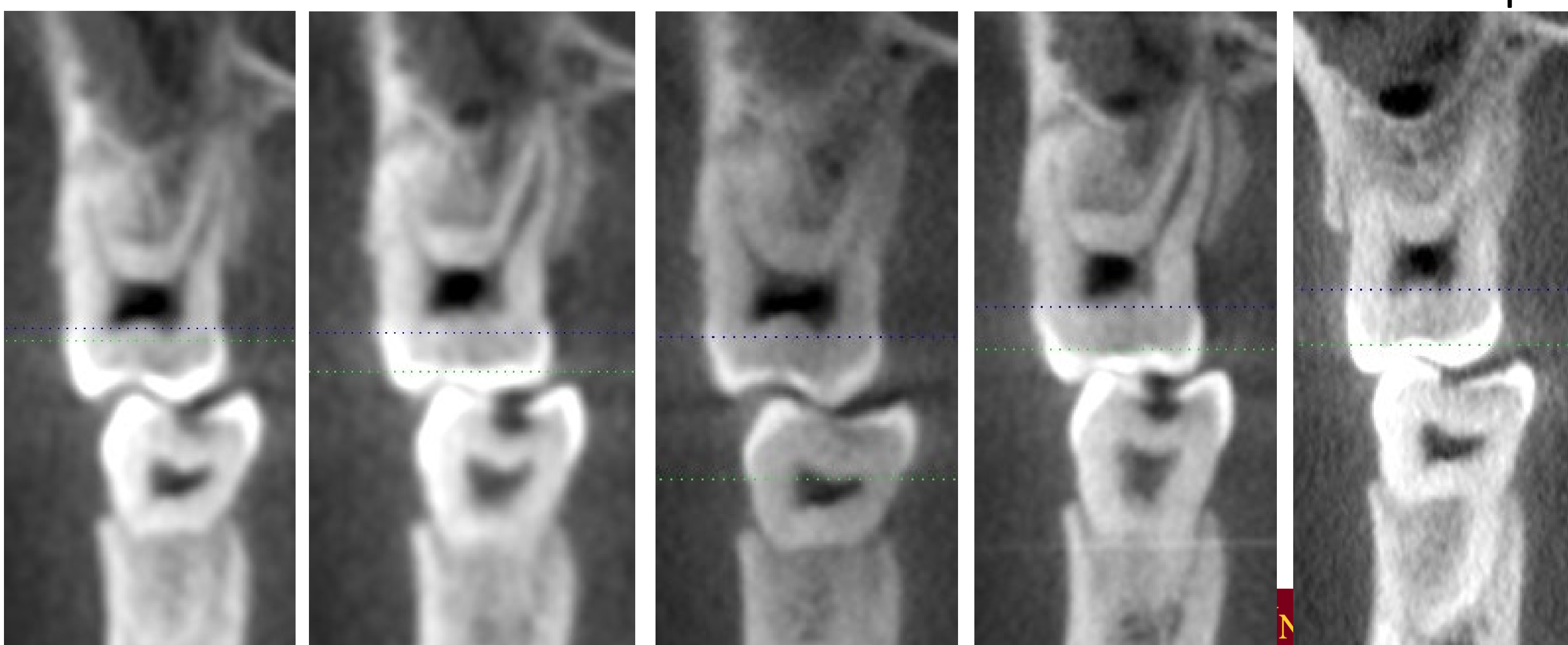
Resolution

- Measured in Voxels (a 3D pixel)
- 0.5mm to <0.1mm
- Typically the smaller the FOV, the smaller the allowed voxel size

0.4mm 0.3mm 0.25mm 0.2mm 0.2mm Sharpened



Noise

- Statistically random variation in voxel grayscale value
- Comes mostly from x-ray photons that scatter in the patient and accidentally hit the detector
- Unavoidable with current CBCT technology
- Relevant to dose

Noise

RELEVANCE:

- CBCT is unable to differentiate different soft tissue types and soft tissue versus fluid
- Grayscale values (even of bone) vary somewhat throughout the scan and are unreliable for anything more than an estimate
- Dictates that 3D renderings can be unreliable and sometimes look “bad”
- CBCT does a great job of relatively high-resolution, dimensionally accurate imaging of hard tissues and soft tissue-air interfaces

Noise

Noise is probably the most significant factor influencing perceived scan "quality", followed by resolution (voxel size)

- ↑ Noise, ↓ Scan quality = "bad looking scan"
- Desired scan quality must be dictated by your diagnostic goal, not the desire for a nice looking image
- For many machines, the level of noise can be controlled somewhat by scan time (seconds) or with high definition modes
- Longer scan or high definition scan = less noise = "nicer" looking scan

The catch is DOSE…

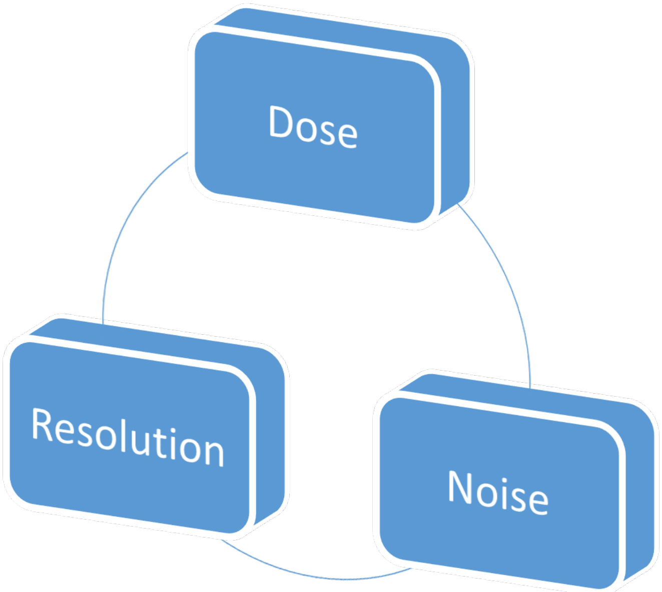
Dose and Scan Factors

- Dose is a measure of ionizing radiation imparted to the patient
- Dental dose levels result in additional risk for cancer later in life
- Dose is intimately related to scan FOV, Resolution, and Noise
- ↑ FOV ↑ Dose (scanning more tissue)

- For Resolution, Noise, and Dose, pick two:
  - High resolution, Low Noise (nice looking scan) High Dose
  - High resolution, High Noise (poor looking scan) Low Dose
  - Low resolution, Low Noise, (ok looking scan) Low Dose

Dose and Scan Factors

PICK TWO:

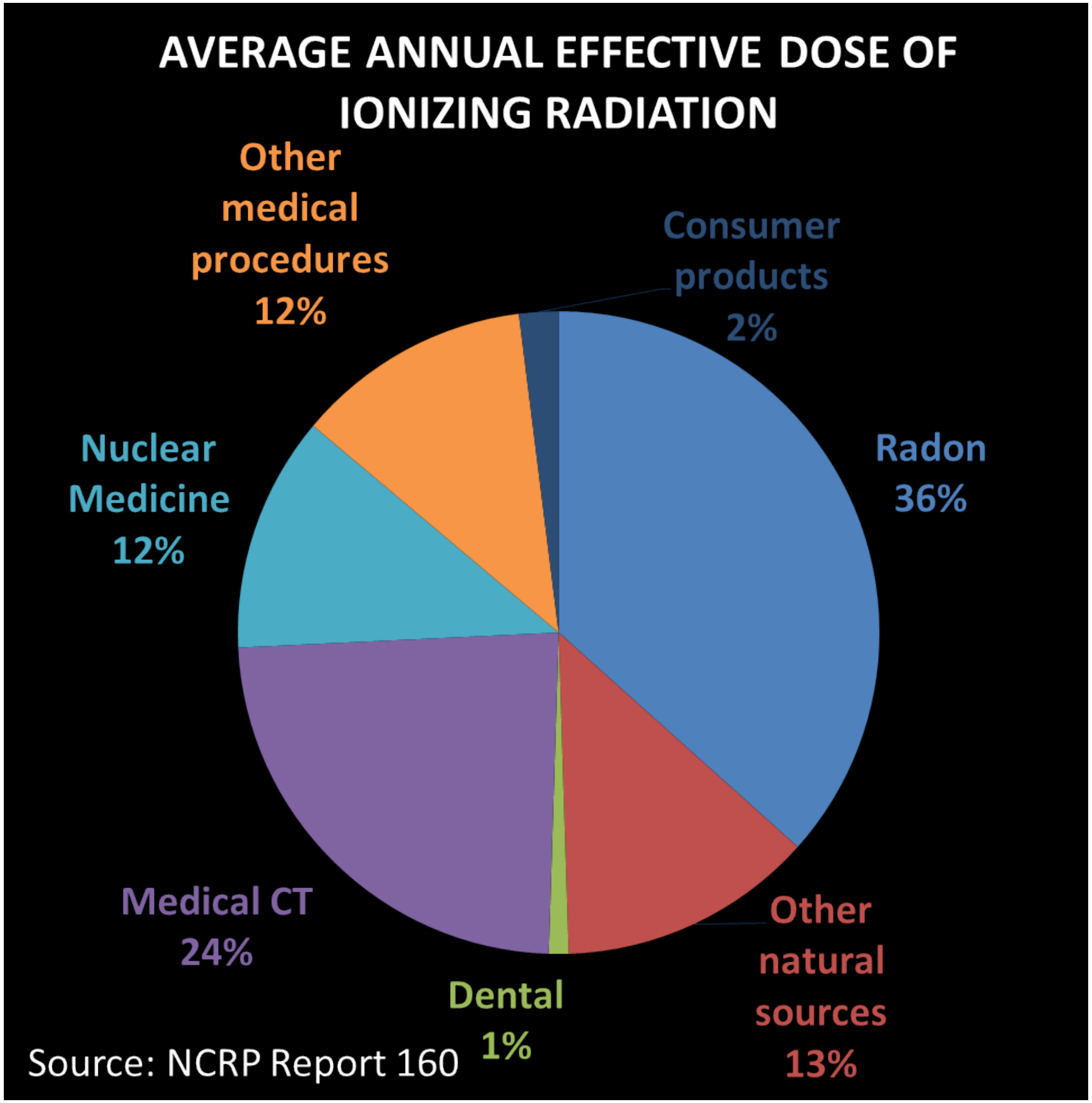


Dose in Context

For the average US citizen:

- Half of total annual exposure to ionizing radiation comes from natural sources (mostly Radon)
- The other half comes from manmade sources (almost half of manmade exposure comes from medical CT)
- Use of ionizing radiation (x-rays) in dentistry contributes at *most* a percent or two to total annual exposure

Dose in Context



Dose and Risk

For the average US citizen:

- The total lifetime cancer risk is 20-40%
- Total exposure to ionizing radiation contributes <1% to the 20-40% estimate
  - (Ionizing radiation is a relatively weak carcinogen)
- Remember dentistry contributes only a couple percent at most of the <1% added cancer risk...

Source: BEIR VII – Phase 2; 2006

BUT...

Dose and Risk

- We perform so many dental radiographic exams that our use of x-rays contributes to a real number of cancers
  - Best risk estimate: 0.055 additional cancers per Sievert of dose
- Excess and unnecessary cancers should be avoided
- Pediatric patients are 3-10x more sensitive to ionizing radiation than adults!

Source: ICRP 103, 60

Dose

- Dental dose numbers are typically reported in micro Sieverts (µSv), a measure of effective dose
- Effective dose reported in µSv is probably the most useful way to compare risk of cancer from different radiographic exams/machines

Dose

Dose and cancer risk from common intraoral dental radiographic exams		
Examination	**Effective Dose (µSv)**	**Probability of X in a million fatal cancer (adult)**
INTRAORAL		
Rectangular Collimation		
Posterior bitewings: PSP, F	**5**	**0.3**
Full Mouth Series: PSP, F	**35**	**2**
Full Mouth Series: CCD	**17**	**1**
Round Collimation		
Full Mouth Series: D	**388**	**23**
Full Mouth Series: PSP, F	**171**	**10**
Full Mouth Series: CCD	**85**	**5**

Dose and cancer risk from common extraoral radiographic exams		
Examination	**Effective Dose (µSv)**	**Probability of X in a million fatal cancer (adult)**
EXTRAORAL		
Panoramic	**9-24**	**1**
Cephalometric	**2-6**	**0.3**
CONE BEAM CT		
Large FOV	**68-1073**	**4-63**
Medium FOV	**45-860**	**3-50**
Small FOV	**19-652**	**1-40**
MULTISLICE CT		
Head conventional	**860-1500**	**50-88**
Head low-dose	**180-534**	**10-31**

- Ludlow JB, Davies-Ludlow LE, White SC. Patient risk related to common dental radiographic examinations: the impact of 2007 International Commission on Radiological Protection recommendations regarding dose calculation. Journal of the American Dental Association (1939) 2008 Sep;139(9):1237-43.
- Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. Oral surgery, oral medicine, oral pathology, oral radiology, and endodontics 2008 Jul;106(1):106-14.

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Dose

COMPARABLE ONE IN A MILLION RISK OF DYING BY ACTIVITY

Activity	Cause of Death
Smoking 1.4 cigarettes	cancer, heart disease
Drinking .5 liter of wine	cirrhosis of the liver
Spending 1 hour in a coal mine	black lung disease
Spending 3 hours in a coal mine	accident
Living 2 days in New York or Boston	air pollution
Traveling 6 minutes by canoe	accident
Traveling 10 miles by bicycle	accident
Traveling 300 miles by car	accident
Flying 1,000 miles by jet	accident
Flying 6,000 miles by jet	cancer caused by cosmic radiation
Living 2 months in Denver	cancer caused by cosmic radiation
Living 2 months in average stone or brick building	cancer caused by natural radioactivity
One chest X ray taken in a good hospital	cancer caused by radiation
Living 2 months with a cigarette smoker	cancer, heart disease
Living 5 years at site boundary of a typical nuclear power plant	cancer caused by radiation

Source: Adapted from Wilson, R., "Analyzing the Daily Risks of Life."
Technology Review, 81, 1979, pp. 40–46.

Old data, but reasonable estimates

Ordering

RELEVANCE:

- If there is a diagnostic need for 3D information, take the scan
- Prescribe radiographic exams with care
- Adjust scan FOV, resolution, and scan time to meet diagnostic needs
- Desired scan quality must be dictated by your diagnostic goal, not the desire for a nice looking image
- Pediatric patients need extra care (3-10x more sensitive)

When to acquire an image?

Does the radiographic exam:

- Change diagnosis?
- **<u>Change treatment plan?</u>**
- Change patient outcome?
- Benefit to society?

- Practitioner confidence?
- Patient education (patient expectation, satisfaction)?

The test must benefit the patient so much so that the dose, financial, and time costs (risk) are heavily outweighed by the benefits

Ordering

Useful CBCT approaches for implant planning:

- Medium FOV scan of single arch or both arches depending on prosthetic need of opposing arch information, graft site information, etc.
- Separate the teeth to reduce artifact and maintain occlusal information
- Remove any removable metal appliances to minimize artifact
- Stabilize patient to reduce motion!

Ordering

Useful CBCT technique for implant planning:

- Voxel size 0.2mm to 0.3mm
- Short to medium scan time for general visualization of anatomy (medium to high noise)
- Medium to long scan time/high dose scan for guided surgery planning (low to medium noise)
- Ideally, entire arch is visualized for graft and/or guided surgery planning

Scans for guided surgery serve as a final impression!

Ordering

Useful CBCT technique for endodontics:

- Smallest FOV to teeth of interest
- Voxel size as small as possible
- Long scan time/high dose scan for lowest noise levels, best visualization of anatomic details
- Consider medium scan time for patients who may have trouble staying still for a long duration
- If possible, remove obturation material to reduce artifacts…

Ordering

Useful CBCT technique for orthodontics:

- Large FOV for assessing bony and tooth spatial relationships:
  - Low resolution (0.3-0.5mm)
  - Short scan time
  - High noise but low dose

- Medium FOV for assessing impacted teeth/root resorption and other unique abnormalities/pathology:
  - High resolution (0.1-0.3mm)
  - Medium to long scan time
  - High resolution and low noise but higher dose

Ordering

Useful CBCT technique for pathology:

- Voxel size 0.2mm to 0.3mm
- Unless the pathology is very clearly localized, order a larger FOV (goal is to image the entire lesion)
- Scanning both sides of the arch/maxillofacial structures is helpful because is allows bilateral comparison
- Medium to long scan time/high dose scan for best visualization of pathologic and anatomic details (low to medium noise)

Ordering

Useful CBCT technique for TMD:

- Voxel size 0.25mm to 0.3mm
- Large FOV including TMDs and both jaws (approximately 13cm x 17cm)
- Scan patient in closed position (maximum intercuspation)
- CBCT scan of the TMJ region in an open position is of potentially limited value unless it directly addresses a clinical question
- If large FOV unavailable, acquire medium FOV scan that includes both joints, patient in closed position (approximately 16cm x 6cm)
- Two separate scans of TMJs is acceptable…but get both joints!
- Medium to long scan time/high dose scan for best visualization of anatomic details in joints (low to medium noise)

Every image must be interpreted

RADIOGRAPHIC INTERPRETATION:

Ability to recognize and understand what is revealed by diagnostic image

BEST DONE WITH A ROUTINE OR "STRUCTURED" SEARCH:

- Best chance at recognizing normal versus all abnormal findings primary and incidental (not miss anything)

- Caution with free/unstructured searches
- Caution with satisfaction of search

- Documentation of review and findings must be made in chart
- Interpretation must be accompanied by a decision process/algorithm for follow-up

Interpretation Fundamentals

FUNDAMENTAL PRINCIPLE OF INTERPRETATION:

Must be able to recognize normal from abnormal

HOW?

- Must be able to recognize normal anatomy and its variations
- Use symmetry to your advantage (axial and coronal slices)
  - Reorient your volume to establish symmetry!

- Use all three slice orientations to confirm findings

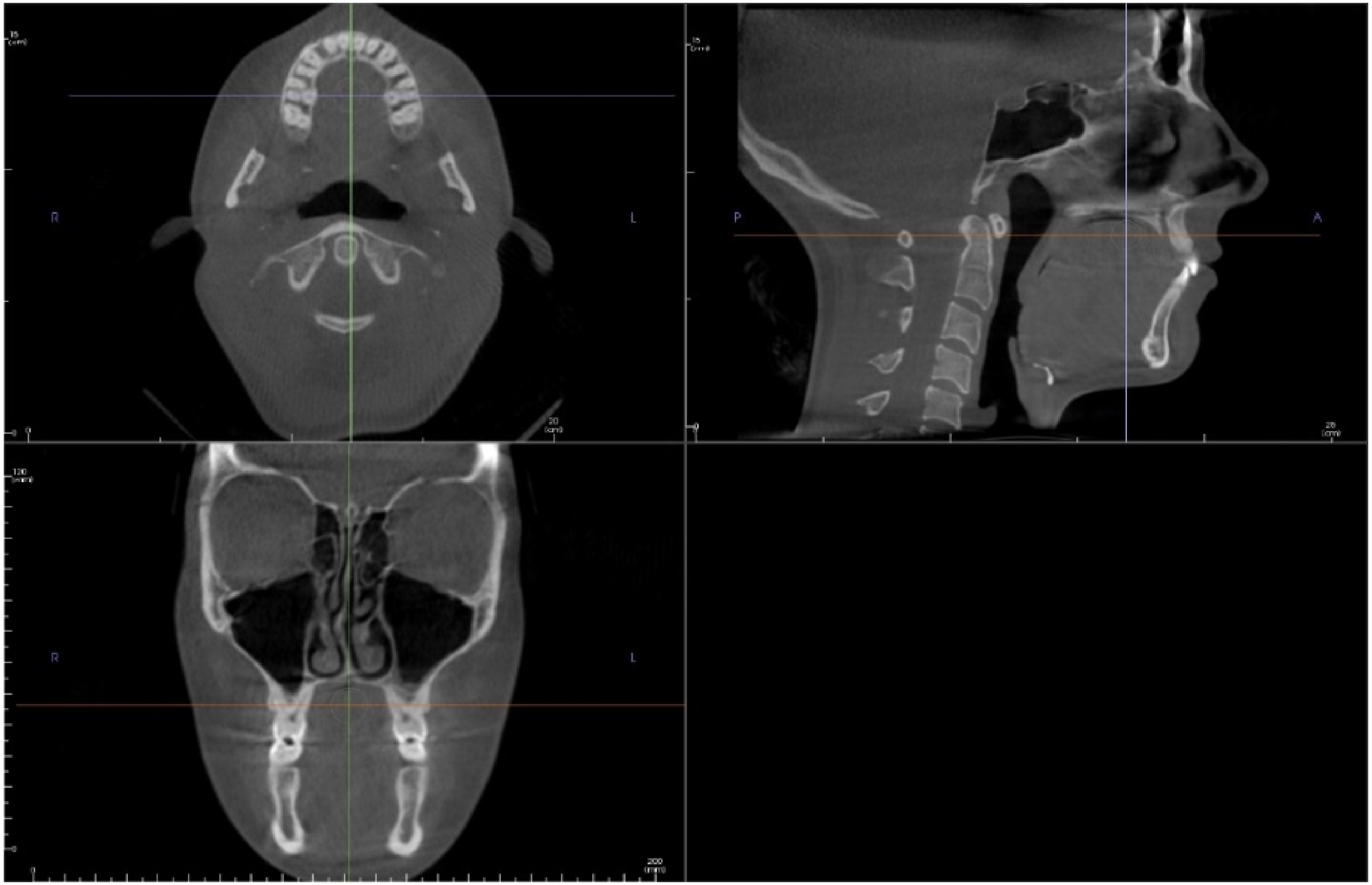
Interpretation Fundamentals

FUNDAMENTAL PRINCIPLE OF INTERPRETATION:

How do you learn and define normal?

- Know your anatomy!
- Practice - look at A LOT of cases to build a mental library of normal and its variations
- Study radiographic signs and radiographic images of pathology

Interpretation Fundamentals



Take advantage of symmetry in axial and coronal slices

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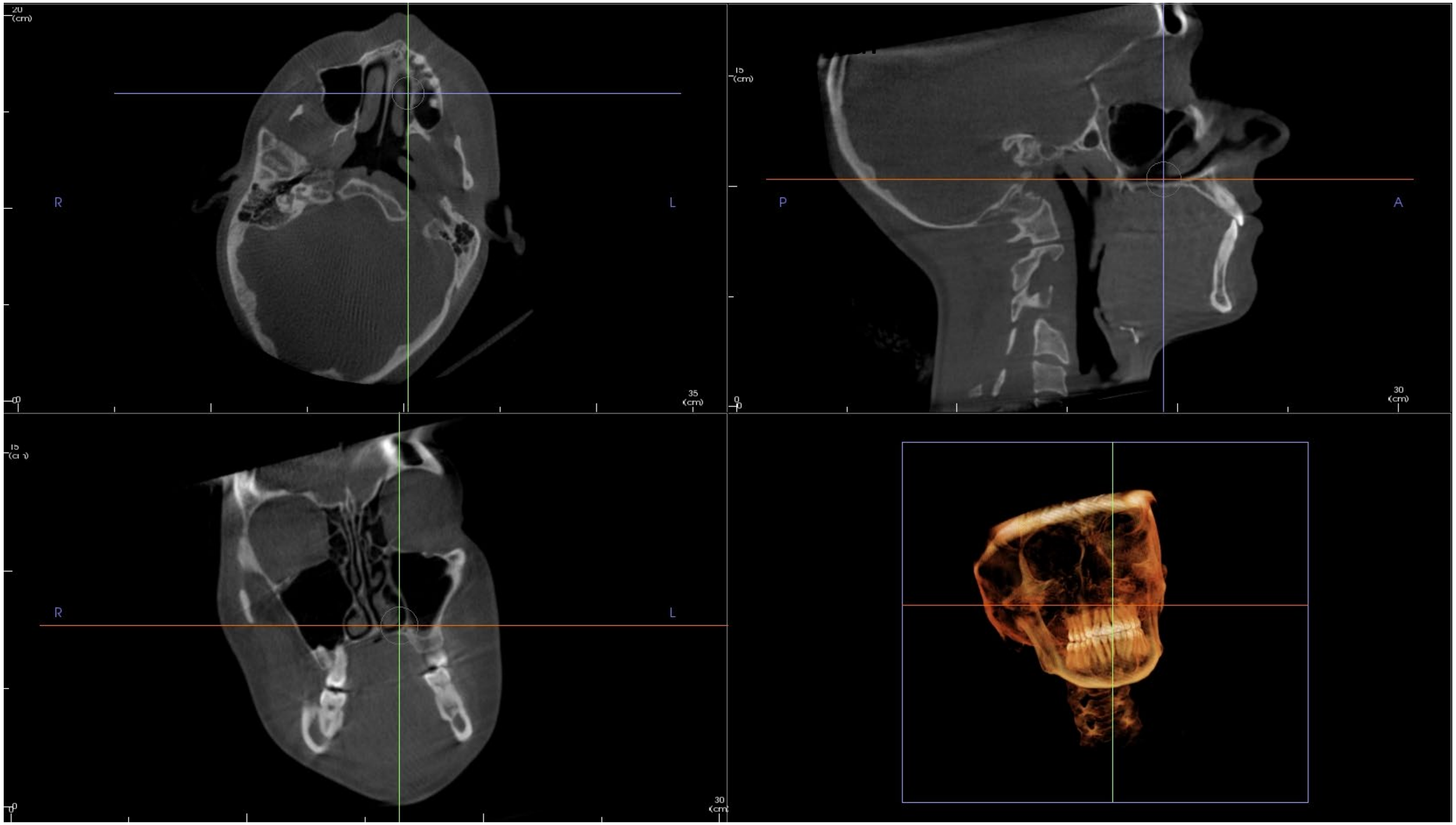
Interpretation Fundamentals



If necessary, reorient your volume prior to interpretation

Thank You!

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