Radiographic 3D Surfing: Catch the Waves of CBCT Diagnosis

CBCT: Applications and Interactive Interpretations

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Disclosure

I have no financial interests or relationships to disclose. Il have no actual or potential conflict of interest in relation to this presentation.

"Participants should be cautioned about the potential risks of using limited knowledge when integrating new techniques."

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Learning objectives

- CT has transformed the practice of dentistry. This course will address recent advances in CBCT imaging and how to incorporate these into the dental practice for optimal patient care. The technology as well as the practical uses of CBCT for improving diagnosis and treatment planning in various fields of dentistry will also be discussed. A case-based approach will be used to methodically review radiographic findings. The presentation will include 3-D illustrated case presentations, discussions, and interactive CBCT interpretations.
- Learning objectives:
  - Understand the basic principles and indications and dosimetry of CBCT imaging
  - Identify normal anatomical structures and incidental findings
  - Recognize applications of CBCT for implants, impacted teeth, TMD and lesions in the jaws, orthodontics and endodontics.
  - Understand the role of CBCT in airway analysis
  - Understand the medico-legal implications of CBCT imaging

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IDEAL IMAGING

- Imaging is used to reveal hidden anatomy
- The best image quality is achieved when the most appropriate modality is correctly used to solve a specific clinical problem
- The gold standard against which an imaging modality is compared is "anatomic truth" as it exists in vivo
- Accurate diagnosis and improves treatment outcomes

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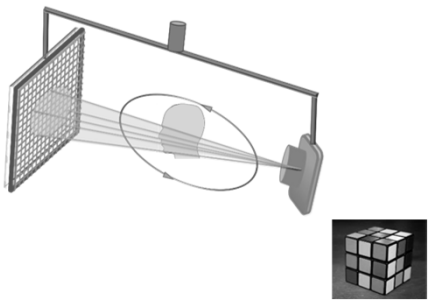

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Incidental Findings

- In 82% of the scans at least one incidental finding was found.
- More incidental findings were found in scans with large FOV (98% vs. 72%, OR = 22.39 large vs. small FOV, $p < 0.0001$).
- Further dental treatment due to incidental findings was needed in 31%.

Biel, P., Jurt, A., Chappuis, V. *et al.* Incidental findings in cone beam computed tomography (CBCT) scans for implant treatment planning: a retrospective study of 404 CBCT scans. *Oral Radiol* **40**, 207–218 (2024). https://doi.org/10.1007/s11282-023-00723-5

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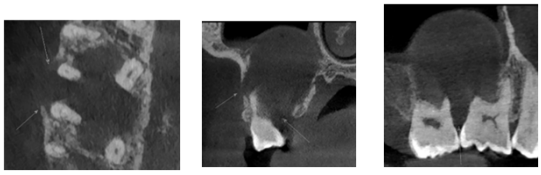
Case 1

History:	**10+ mm probings between teeth #2-3**
Indications:	Suppuration #2-3. Large cystic appearing lesion at R maxillary sinus. Perforation of B plate #2-3 sites.



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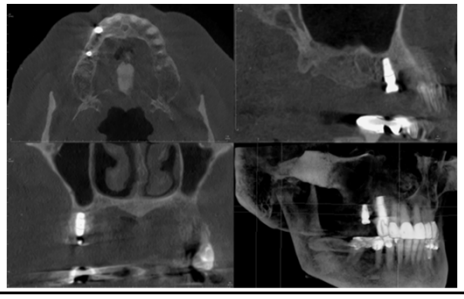
Stat Case 2

History:	**None noted**
Indications:	Pathology eval



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Case 3

- 63 yr old female
- Placement of implants in anterior area. Numbness and pain on right nasal and infraorbital area even after implant removal.
- Numbness right side nasal area and dysesthesia. Any obvious signs of nerve damage or other possible etiologies.

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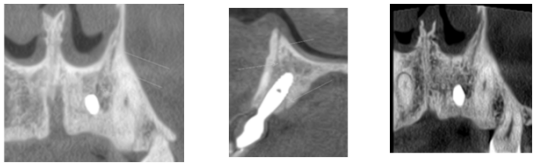
Case 3a

History:	**Extractions, implant placement**
Indications:	Pt has implant #10 placed and is experiencing sensitivity. General pathology review, evaluate implant #10



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Case 4

- Patient has had on and off pain for 12+ years, it has become worse within the last 14 months. There is facial swelling and pain. Clinically, there is firm submandibular nodule in the left vestibule in the area of the mental foramen, no numbness. Patient does not have a reported history of cancer or antiresorptive drugs.

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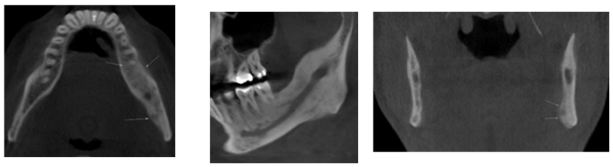

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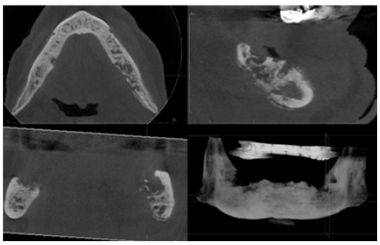
Case 5



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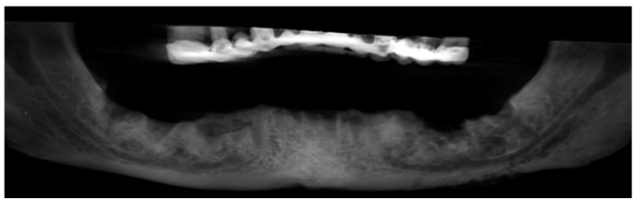

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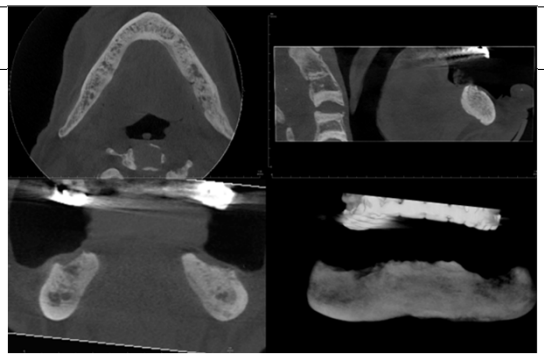

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Case 6

- **History:**
  - CBCT for read. Pain started as generalized through Max and mandible. Patient thought it was sinus. Med walk in clinic put him on antibiotic treatment twice and the pain got better both times as reported by the patient. He was told to see if this was coming from his teeth
- **Indications:**
  - Today the patient is wearing an upper full denture and lower partial denture with only teeth 24, 25, 26, and 27 remaining of his natural dentition. The patient is complaining of pain in the anterior mandible, submandibular area just behind the chin point bone inferior border. The pain is 8 to 9 with light touch to the mandible when you palpate the inferior border of the mandible in the midline and roll the finger into the submandibular and push upward on the insertion of the mylohyoid muscle. Significant decay is present in 24, 25, 26 but percussion of all teeth is 100% negative. The teeth probably need to be removed due to decay but I am not convinced the teeth are causing the pain. CBCT does not appear to show evidence of periapical pathology on any of the teeth in the mouth. It does however show some evidence of moth-eaten lingual cortical plate in the mandibular midline and just left of the midline. Please give me your diagnosis and thoughts and recommendations for treatment and/or follow-up.

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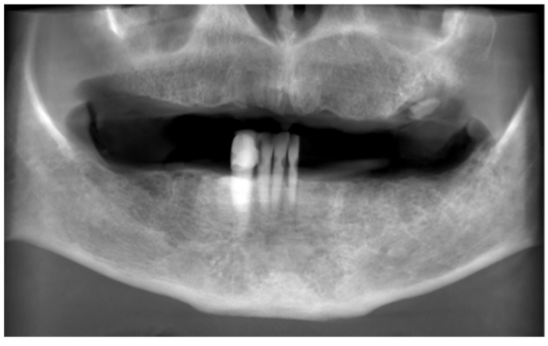

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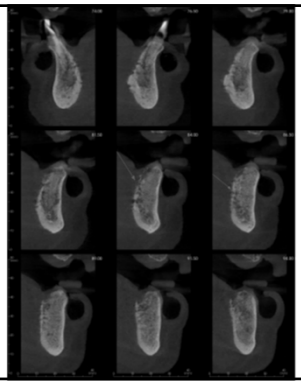

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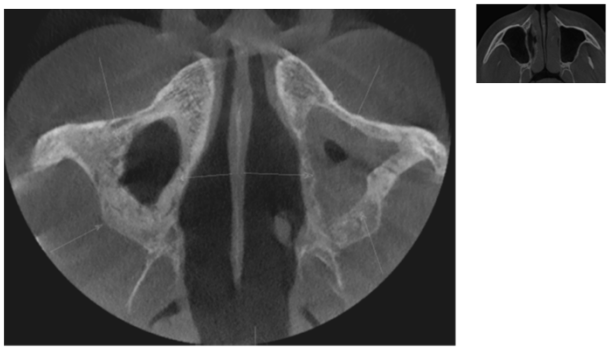

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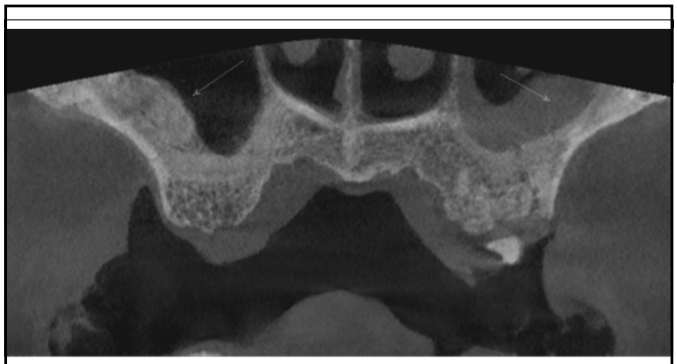

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The 2D Imaging Viewpoint

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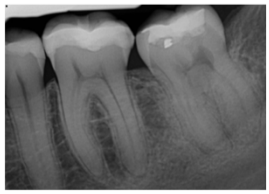
Interpretation Case 6



Endodontic Consult: #18
Chief complaint (CC): on/off throbbing with tooth and gum pimple and bleeds and drains unless I'm on antibiotics
HPI: Reports pain and H/C sensitivity in tooth, dentist replaced a filling in tooth April 2017.
2 months later blister formed that bleeds and has pus, has been taking Amox TID for past 3 days, prior to this course pt was on another 10 day course of Amox. Reports had 2nd opinion from general dentist to confirm tooth needs RCT.

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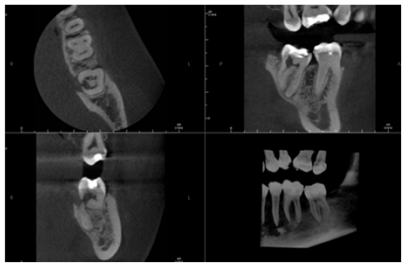
CBCT findings



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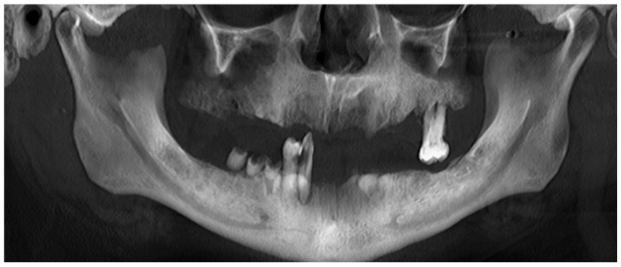
Case 7: 72-yr old male: a swelling in relation to her upper left back teeth and abscess for three months, associated with pain



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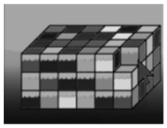
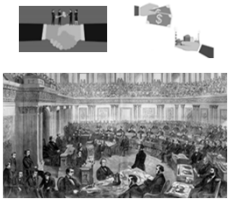
CBCT Image Formation

- Acquisition Stage
- Reconstruction
- Viewing the volume





Reconstruction | Definition, Summary, Timeline & Facts | Britannica

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CBCT Facts

Low Dose protocols = Increased noise, Low signal

Any filter = Altered image quality

CBCT image quality is not comparable across different scanners. There are approximately 50 commercially available CBCT models and scanners with variable image quality

Artifacts degrade image quality

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Voxel Size

- Current CBCT systems, the voxel size varies from 0.076 mm to 0.6 mm.
- In general, the smaller the voxel size, the higher the spatial resolution.
- Several other unit-specific parameters, such as reconstruction algorithms, also influence the signal-to-noise ratio and the spatial resolution.

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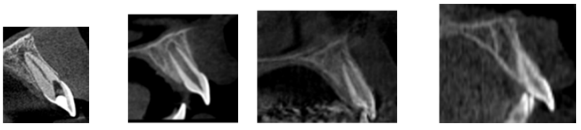
Voxel Size



0.09 mm .25 mm 0.4 mm 0.6 mm

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Voxel size recommendations

<0.125 mm:	Endodontic cases with limited FOV
0.2 mm:	Localization and evaluation of impacted teeth and associated teeth and structures with limited FOV
0.25 mm:	Implant and bone graft procedures with small to medium FOV
0.3 mm:	Large FOV procedures

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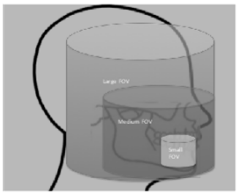
Field OF View (FOV)

- Collimating the primary x-ray beam limits radiation exposure to the ROI.
- This field size must be selected for each patient based on individual needs.
- This procedure reduces unnecessary exposure to the patient and produces the best images by minimizing scattered radiation, which degrades image quality.
- Select the smallest FOV that provides adequate anatomic coverage and adequate image resolution.



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Field of View: Recommendations

Small FOV	Medium FOV	Large FOV
Localization of an impacted tooth	Cleft palate	Orthognathic surgery
External/Internal resorption	Implants	Complex orthodontic cases
Root or root canal morphology	Assessment of osseous TMJ components	Sinus and airway analysis
Surgical endodontic procedures	Dental trauma	Facial reconstruction
Periapical assessment	Pathological lesions in the mandible/ maxilla	Trauma
Periodontal infra-bony and furcation assessment	Multiple impactions	Developmental anomalies/syndrome
Symptomatic post endo treatment/endodontic complications		
Suspected root fractures		
Single implants		

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CBCT Image Formation

- Acquisition Stage
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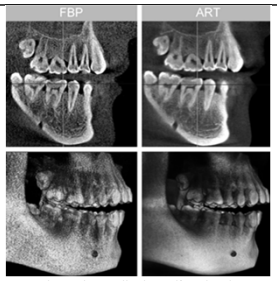
CBCT Image reconstruction

Comparison of image quality of sagittal and 3D renderings reconstructed using conventional Feldkamp back projection (FBP) and an iterative reconstruction called algebraic reconstruction technique (ART)

While ART requires greater computing power, it also reduces artifacts requiring fewer projections to conduct the reconstruction (equals less dose) and is less sensitive to common patient movement and metal artifacts.



Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin North Am. 2008 Oct;52(4):707-30, v. doi: 10.1016/j.cden.2008.05.005. PMID: 18805225.

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Artifacts In CBCT Images

- Inherent artifacts
  - Scatter
  - Partial volume averaging
  - Cone-beam effect
- Procedure-related artifacts
  - Undersampling
  - Scanner defects/calibrations
  - Misalignment of the x-ray source to detector
- Introduced artifacts
  - Beam hardening
    - Cupping
    - Extinction artifacts
  - Patient movement

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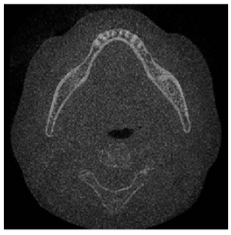
Scatter: Noise

- Scatter refers to the off-axis low-energy radiation that is generated in the patient during image acquisition.
- Low exposure levels
  - X-ray scatter
- Electronic noise from detector during data transmission
- Filtering during image reconstruction can either suppress or enhance noise



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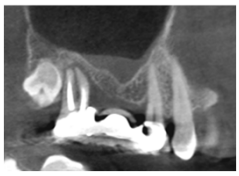
Scatter Correction Algorithms

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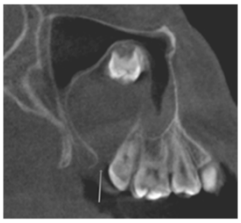
Partial Volume Averaging



Air Air

Air, soft tissue bone Bone

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Case 9: 17-year old female

- Asymptomatic
- Noted on routine radiograph taken for 3rd molars.

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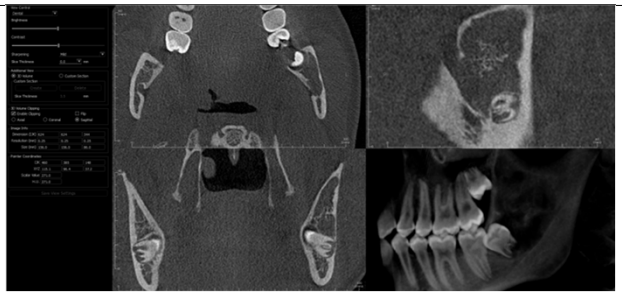
17-yr old female



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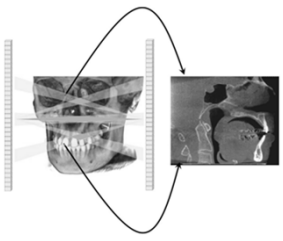
Cone-beam Effect

Peripheral portions of the scan volume.

Because of the divergence of the x-ray beam as it rotates around the patient in a horizontal plane, structures at the top or bottom of the image field are exposed only when the x-ray source is on the opposite side of the patient.

The result is image distortion, and greater peripheral noise.

Can be minimized by positioning the ROI in the horizontal plane of the x-ray beam.



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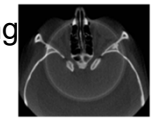
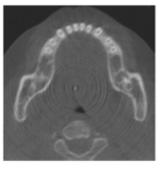
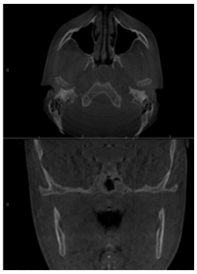
Ring

- Scanner–related artifacts:
  - Lack of calibration or imperfections in scanner detector
  - Recalibration of the machine often resolves the problem.

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Streak and beam hardening artifacts

When sharp changes in density are present, e.g. between bone and dense metals like amalgam

- A "starburst" artifact can form in which bright streaks emanate from the object for a short distance into nearby material

Beam hardening artifacts

- Metals can cause the low energy x-rays to be filtered out of the x-ray beam
- The mean energy becomes increases.
- Parts of the image appear darker.

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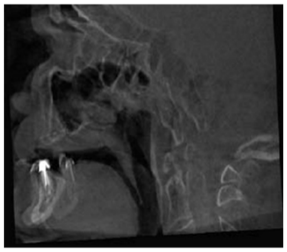
Patient movement

Another typical source of CBCT image deterioration in the clinical routine is related to the inability of the patient to remain perfectly still during the entire examination as a result of breathing and any movements.

This leads to motion artefacts, often seen as double contours and overall loss of image sharpness.

Recently, motion-artefact correction methods have been suggested, which track patient movement in real-time, or which estimate patient movement from the basis images, leading to corrected reconstructed volumes.



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- **Patient Stabilization mechanisms**
  - Helps prevent patient motion and positions them correctly for the scan
  - Positioning: bite fork, chin cup, T-Bar
  - Securing: Velcro head restraints, Stabilizing Prongs
  - Handle bars for patients to help stabilize themselves
- **Patient position:**
  - Sitting, standing or supine

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Motion-artefact reduction algorithms

- Motion-artefact correction systems enhanced image quality and interpretability for units with aligned detectors but were less effective for those with lateral-offset detectors.
- It sometimes resulted in non-interpretable images that were considered interpretable with the motion-artefact correction system turned off.

Santaella GM, Wenzel A, Haiter-Neto F, Rosalen PL, Spin-Neto R. Impact of movement and motion-artefact correction on image quality and interpretability in CBCT units with aligned and lateral-offset detectors. Dentomaxillofac Radiol. 2020;49(1):20190240.

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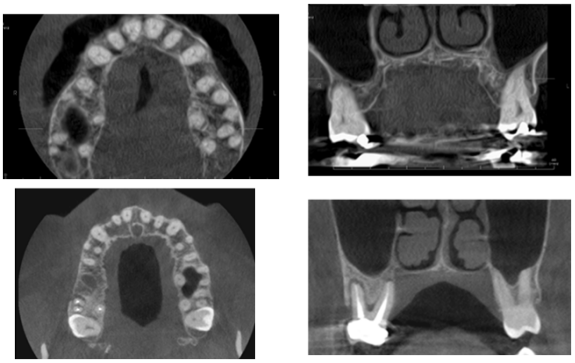

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Image Accuracy

- The size of these voxels determines the resolution of the image.
- In conventional CT, the voxels are anisotropic rectangular cubes.
  - Although CT voxel surfaces can be as small as 0.625 mm square, their depth is usually in the order of 1–2 mm.
- All CBCT units provide isotropic voxel resolutions
  - Produces resolution ranging from 0.4 mm to as low as 0.076 mm.

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Image accuracy

- By using a voxel size of 0.38 mm at 2 mA, CBCT alveolar bone height can be measured to an accuracy of about 0.6 mm
  - DOI: 10.1016/j.ajodo.2009.07.013
- All CBCT images performed similarly for the detection of simulated buccal marginal alveolar peri-implant defects. Depth, width and volume measurements of the defects from various CBCT images correlated highly with physical measurements.
  - doi: 10.1259/dmfr.20130332
- Accuracy of cone-beam CT measurements of various distances surrounding the mandibular canal was comparable to that of digital caliper measurements.
  - DOI: 10.1016/j.tripleo.2008.10.012
- The coefficient of repeatability, reproducibility and interoperator agreement were <0.5 mm. CBCT measurements were accurate; the mean of absolute differences between CBCT and real WL was 0.41 mm (99% CI 0.31-0.52 mm).
  - doi: 10.1259/dmfr/25500850

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CBCT Image Formation

- Acquisition Stage
- Reconstruction
- Viewing the volume

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Quality aspects of digital radiography

- Many general practice dentists had experienced several problems (65%).
- One of the weaker links in the technical chain of digital radiography appeared to be the monitor.
- The ambient light in the room was also found to affect the diagnostic outcome of low-contrast patterns in radiographs.
  - The ability to diagnose carious lesions was found to be significantly better in a room with lower ambient light.

Dentomaxillofac Radiol. 2007 Jul;36(5):249-55.
Digital radiography in general dental practice: a field study.
Hellén-Halme K, Nilsson M, Petersson A.

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Image Display

- Luminance
  - Monitor luminance is measured in Candelas per square meter).
  - Lmax in diagnostic monitors should be at least 350 cd/m2 for X-Ray, CT or MRI.
  - Formal hardware calibration to within 10% of Grayscale DICOM Diagnostic Function (GSDF) is required and must be maintained over the lifespan of the display.
  - The best diagnostic displays are self-calibrating and include all software and hardware required to perform this function.
  - The higher luminance offered by medical displays results in better image quality, making subtle lesions easier to detect.

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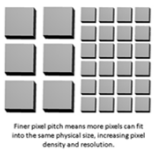
Pixel Pitch

- Have a small pixel pitch.
- The pixel pitch is the distance in millimeters from the center of a pixel to the center of the adjacent pixel.
- A smaller pixel pitch means there is less empty space between pixels; this equals higher pixel density and higher screen resolution. Pixel pitch in diagnostic monitors is usually no more than 0.21mm for digital images and CBCT images.



Finer pixel pitch means more pixels can fit into the same physical size, increasing pixel density and resolution.

https://www.planar.com/blog/2018/2/23/what-is-pixel-pitch-and-why-does-it-matter/

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Monitors

- Contrast ratio 1000:1

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Image display

- Display resolution:
- Lower quality have larger and more widely spaced pixel elements
- Displays with smaller picture elements are usually associated with high quality photographic and medical display devices.
- Have high resolution, which is at least 3 megapixels


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Image display

In comparison, the contrast ratio in LCD displays drops rapidly from the maximum to about 10:1 for a viewing angle of 85°

It is therefore recommended that the person viewing an image on a monitor should be seated directly, perpendicularly in front of the monitor.

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Diagnostic monitors

- High resolution: At least 3 megapixels
- Small pixel pitch: No more than 0.21mm
- High maximum luminance (Lmax): At least 350 cd/m2 for X-Ray, CT or MRI.

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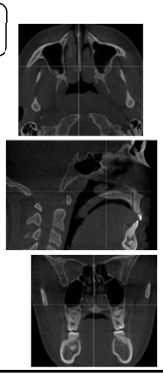
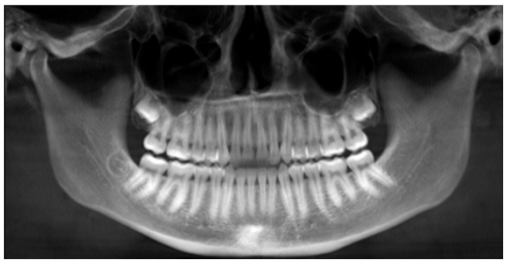
MPR

- **Axial Plane**
  - The axial plane is a **horizontal** plane. It is perpendicular to both the sagittal and coronal planes.
  - It divides the body into an upper (superior) section and a lower (inferior) section.
- **Sagittal Plane**
  - The sagittal plane is a vertical plane which passes through the body **longitudinally**. It divides the body into a left section and a right section.
  - A specific sagittal plane is the **median sagittal plane** – which passes down the midline of the body, separating it into equal halves.
- **Coronal Plane**
  - The coronal plane is a vertical plane which also passes through the body longitudinally – but **perpendicular** (at a right angle) to the sagittal plane.
  - It divides the body into a front (anterior) section and back (posterior) section.



58

Curved oblique view



59

Radiation and risk

Age Group (years)	Multiplication factor for risk
< 10	X 3
10-20	X 2
20-30	X 1.5
30-50	X 0.5
50-80	X 0.3
80+	Negligible risk
Multiplication factor at 30 years = 1	

- In radiology our patients and staff are exposed to low dose ionizing radiation.
- The potential effects of this low dose ionizing radiation exposure over many years are what are meant by late effects.
- The two most important concerns of late effects are carcinogenesis and genetic effects.
- Long term radiation effects:
  - Stochastic effects
    - Cancer and genetic mutation
    - Probability of cancer/genetic mutation increases with increasing the dose, but the severity does not depend on the amount of the dose
  - Deterministic effects (Non-stochastic effects)
    - Xerostomia, osteoradionecrosis, cataracts
    - Frequency of effect proportional to dose; the greater the dose, the greater the chance of having the effect

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Technique	Dose as multiple of typical panoramic dose, ICRP 2007	Days of per capita background, ICRP 2007	Probability of x in a million fatal cancer, ICRP 2007
Large FOV			
NewTom 3G large FOV	3	8	4
CB Mercuray maximum quality	44	131	59
CB Mercuray standard quality	23	69	31
Next Generation i-CAT portrait	3	9	4
Iluma standard	4	12	5
Iluma ultra	20	61	27
Medium FOV			
CB Mercuray panoramic FOV	23	68	31
Classic i-CAT standard scan	4	12	6
Next Generation i-CAT	4	11	5
Galileos default exposure	3	9	4
Galileos maximum exposure	5	16	7
Small FOV			
CB Mercuray I FOV maxillary	17	50	22
PreXion 3D standard exposure	8	23	10
PreXion 3D high resolution	16	47	21

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CBCT & Radiation Risks

- Wide dose range ~20 microSv to 400 microSv
- Main contributors: thyroid gland, salivary glands, remainder (oral mucosa, extrathoracic airways)
- Clear effect of FOV size & position on effective dose
- Other differences between doses: interplay with image quality
- Optimised (“customised”) patient dose: FOV selection based on region of interest + exposure selection based on image quality requirement

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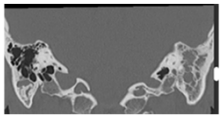
CBCT Scans Contain Findings Well Beyond Dentistry



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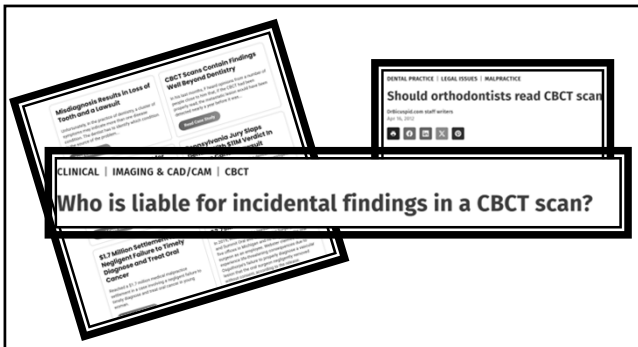
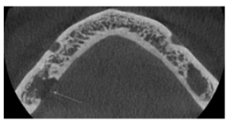


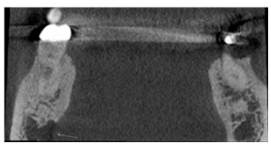
64

Case 10

- CC: None noted
  - General Pathology review

65





66

CBCT report

- A practitioner who performs or supervises CBCT examinations must hold a valid license.
- It is the responsibility of the practitioner obtaining the CBCT images to interpret the findings of the examination.
- An imaging report must accompany a CBCT scan.
- The entire dataset must be reviewed.

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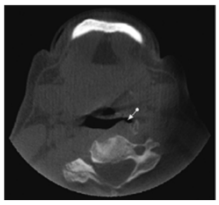
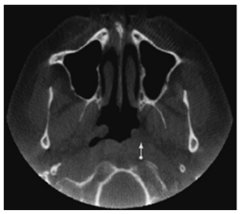
Soft tissue lesions





68

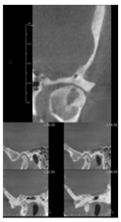
Standard of Care

- Dentists are liable for non-diagnosis of any abnormality on the CBCT scan.
- Dentists must possess the requisite standard of care when diagnosing and treating patients.
- This standard is normally stated as the level of knowledge, skill and care of a reasonable dentist.
- To meet this standard when using CBCT, dentists should use CBCT's full capabilities to obtain maximum diagnostic accuracy.
- https://medprodental.com/practice-more-safely/cbct-scans-contain-findings-well-beyond-dentistry

69

CBCT Interpretation

- Dentists who take their own scans or who use the services of facilities that perform them and do not include a report should be concerned about liability for reading the scan
- The dentist is responsible not only for reading the scan as it pertains to their area of practice or the particular reason for which the image was taken, but also for reading all of the anatomy—that is, the entire image volume contained in the scan



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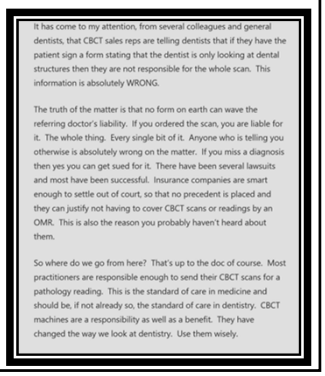
CBCT Reports

Some dentists have considered asking patients to sign a waiver of liability for the interpretation of the scans.

Dentists have also thought about giving patients the choice of whether to have the images read by a radiologist.

While patients may make treatment decisions, their choices are limited by the bounds of accepted standards of care, and it is not acceptable to give a patient a choice that is below the standard of care



It has come to my attention, from several colleagues and general dentists, that CBCT sales reps are telling dentists that if they have the patient sign a form stating that the dentist is only looking at dental structures then they are not responsible for the whole scan. This information is absolutely WRONG.

The truth of the matter is that no form on earth can wave the referring doctor's liability. If you ordered the scan, you are liable for it. The whole thing. Every single bit of it. Anyone who is telling you otherwise is absolutely wrong on the matter. If you miss a diagnosis then yes you can get sued for it. There have been several lawsuits and most have been successful. Insurance companies are smart enough to settle out of court, so that no precedent is placed and they can justify not having to cover CBCT scans or readings by an OMR. This is also the reason you probably haven't heard about them.

So where do we go from here? That's up to the doc of course. Most practitioners are responsible enough to send their CBCT scans for a pathology reading. This is the standard of care in medicine and should be, if not already so, the standard of care in dentistry. CBCT machines are a responsibility as well as a benefit. They have changed the way we look at dentistry. Use them wisely.

71

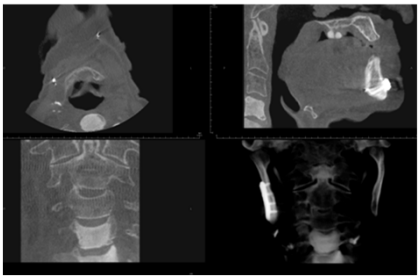
CBCT Reports

- Some dentists have considered asking patients to sign a waiver of liability for the interpretation of the scans.
- Dentists have also thought about giving patients the choice of whether to have the images read by a radiologist.
- While patients may make treatment decisions, their choices are limited by the bounds of accepted standards of care, and it is not acceptable to give a patient a choice that is below the standard of care

72

Case 11

- 72-year old male
- Incidental finding



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Systematic Review of CBCT Scans

The need to identify incidental findings is not based on the fear of liability and malpractice.

It is in the best interest of the patient as well as the provider to recognize these findings as many have the potential to change a treatment plan.

- Analyze the scan for artifacts or errors
  - Avoid interpreting low-quality scans if a retake is possible.
  - Document the presence of CBCT artifacts, such as beam hardening or motion artifacts.
- Report all their interpretation findings including incidental findings.
- Provide differential diagnosis for incidental and other findings.

74

Case 10

- 70 yr-old female
- Interested in implant-supported dentures
- Hypertension, high cholesterol, arthritis

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Systematic Review of CBCT Scans

Patient Name:
Date:
DOB:
ID#:

Date of Study:
Gender:
Referred By:

CLINICAL HISTORY:

IMAGING TECHNIQUE:

RADIOGRAPHIC FINDINGS: All imaged anatomic structures in this study have been evaluated. Significant findings include the following:

DENTAL FINDINGS:

SINUSES & NASAL FOSSA:

TMJ REGION:

CERVICAL VERTEBRAE:

OTHERS:

IMPRESSIONS:

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CBCT Study Reasons

- Impaction/ Localization
- TMD
- Orthodontics
- Pathosis
- Implants
- Endodontics
- Airway
- General report

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Impaction/Localization

- Location and orientation
- Supernumerary/normal teeth/Odontoma
- Any lesion
- Ankylosis (0.2 mm scan resolution)
- Root resorption/displacement in adjacent teeth
- Location of IAC or any other anatomical structure

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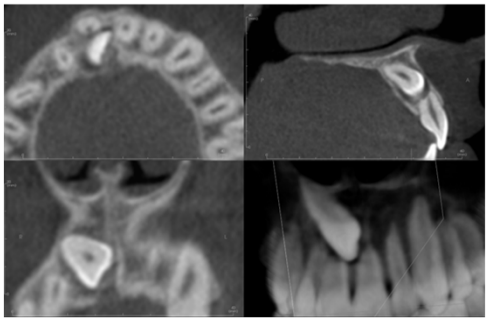
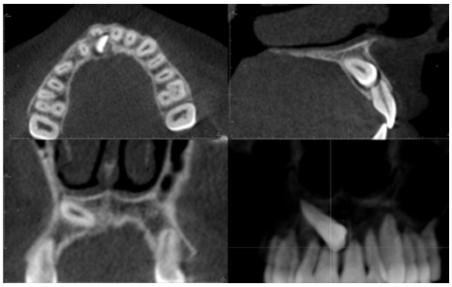


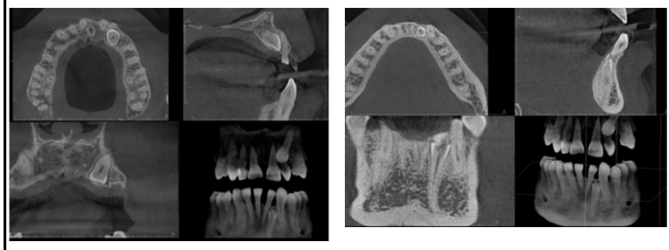
80

0.3 mm voxel



81

0.16 mm voxel



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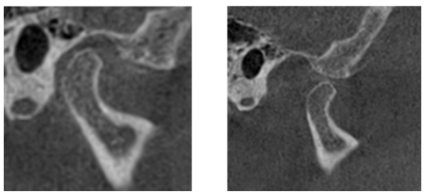
CBCT and TMJ evaluation

- Size, shape, quality and location of the condyle in the glenoid fossa
- Cortices, osteophyte formation, erosion
- Evaluation of glenoid fossa and articular eminence
- Closed and open mouth views
- Any lesion
- Scan resolution 0.25 or 0.3 closed mouth
  - Open mouth: low dose scan (0.4 mm)

83

TMJ Region Evaluation



84

Degenerative Joint Disease: Mandibular condyle

- Articular surface flattening
- Osteophytes
- Subcortical and generalized sclerosis
- Subchondral cysts
- Condylar surface erosion
- Reduction in joint space
- Loose bodies

85

Degenerative Joint Disease

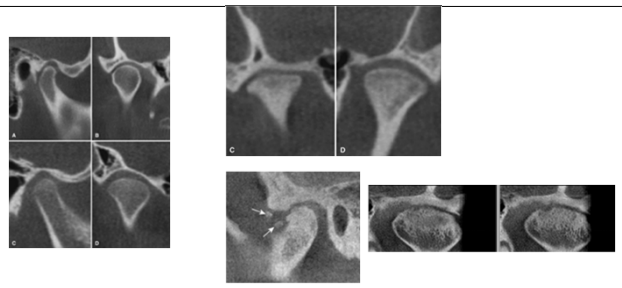
- Any age, incidence increases with age
- Female
- Asymptomatic or symptomatic
- Joint dysfunction
- Onset may be sudden or gradual

86

Remodeling

- Adaptive response to forces applied to the joint.
- Flattening and sclerosis.
- Abnormal only if accompanied by pain or dysfunction or if the degree of remodeling seen radiographically is severe.

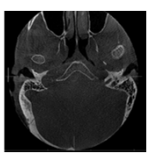
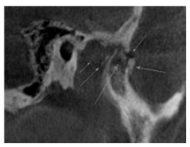
87



88

Case 14: TMJ: Septic arthritis

- L jaw pain for the past 10 months.


89

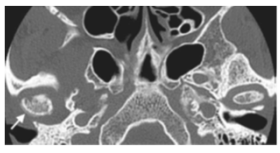
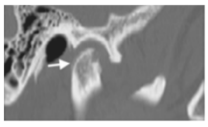
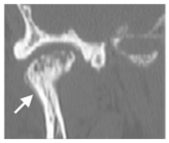
No radiographic findings in acute stage

Increased joint space

7-10 days after the clinical symptoms :

- Erosion of the articular surface, sequestrae and periosteal new bone formation
- Opacification of mastoid air cells, osteomyelitis and cellulitis of surrounding soft tissue

MRI findings - Muscle enlargement, edema and joint effusion

90

Septic arthritis

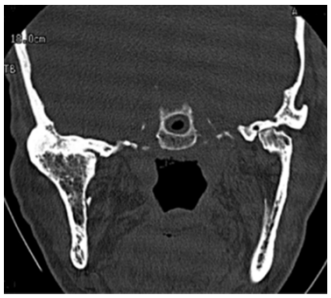
- Infection of a joint.
- Any age
- Usually unilateral
- Redness and swelling over joint, severe pain on opening, trismus, inability to occlude teeth, tender cervical lymph node, fever and malaise

91

Ankylosis

- Ankylosis is a condition in which condylar movement is restricted
- Bony or fibrous ankyloses
- Unilateral ankylosis are caused by in trauma or infection

92



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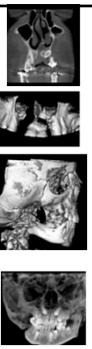
CBCT recommendations: Orthodontics

- Structural or eruption anomalies of teeth.
- Resorption related to impacted teeth.
- Evaluation of dental- alveolar boundaries.
- Assessment of craniofacial skeletal asymmetry.
- Assessment of skeletal discrepancies.
- TMJ evaluation.
- Assessment of airway morphology.
- Surgical treatment planning.
- Identifying optimal locations for temporary anchorage devices
- Quantitative assessment of skeletal and dental changes produced by maxillary expanders.



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Guidelines for CBCT in Orthodontics

- Image appropriately according to clinical condition
- Assess the radiation dose risk
- Minimize patient radiation exposure
- Maintain professional competency in performing and interpreting CBCT studies

95

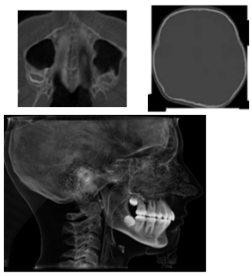
CBCT and Children

- Children are 2 -10 times more sensitive to radiation-induced cancer than adults.
- Risk-benefit analysis is more complex
- No high-quality evidence to support the benefits of routine CBCT imaging in orthodontics.

96

Orthodontic Practice CBCT Scans

- An orthodontist we'll call "Dr. X" bought a practice that only had a CBCT unit. All new patients were imaged with a large FOV, 0.3 voxel, low dose protocol, CBCT scan.
- Radiation exposure is typically 2-4 times higher with a CBCT vs panoramic and lateral cephalometric.
- There was a backlog of older scans, none of which had imaging findings or reports.
- "Dr. X" sent all the old scans for evaluation near the end of 2022.
- We've completed over 1000 reports to this point with many more to go.



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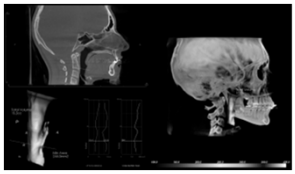
Orthodontic Practice CBCT Scans

- What have we found in this specific population (average ages from 6-20)?
  - Approximately 4 out of every 10 scans have some actionable finding beyond the reason they were taken or typical dental findings.
  - There have been a broad range of additional findings…
    - Systemic diseases
    - Developmental disorders
    - Para-nasal sinus disorders
    - Cervical spine abnormalities
    - Degenerative changes in the TMJ
    - Pathology in the maxillofacial skeleton including the skull base
    - Airway constriction (not included in the 10% because it is so common)
- Unfortunately, all relevant findings are over two years old at this point.

98

Airway Analysis via CBCT

- Obstructive sleep apnea (OSA) is a common health issue in both adults and children. Approximately 3 % of children are estimated to have it.
- Weight is a significant predictor of OSA in adults while enlarged lymphatic tissues and craniofacial anomalies are major predictors in children.
- Medium to large FOV CBCT often captures the airway and can be used to determine airway volumes.
- Patients with obstructive sleep apnea have significantly lower airway volumes as measured by CBCT than those who do not have sleep apnea.
- Sleep apnea is associated with multiple co-morbidities in both adults and children and treatment can help reduce these risks.



Chang SJ, Chae KY. Obstructive sleep apnea syndrome in children: Epidemiology, pathophysiology, diagnosis and sequelae. Korean J Pediatr. 2010.

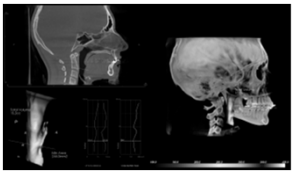
Zhang W, Phillips A, Wang BY. Correlation Analysis between Airway Volume and Risk of Sleep Apnea/Periodontitis. J Oral Maxillofac Res. 2022.

Buchanan A, Cohen R, Looney S, Kalathingal S, De Rossi S. Cone-beam CT analysis of patients with obstructive sleep apnea compared to normal controls. Imaging Sci Dent. 2016.

99

Airway Analysis via CBCT

- We use InVivo software for airway analysis.
- The primarily focus is the minimum cross-sectional area of the airway.
  - < 52 mm^2 is considered high risk.
  - 52-100 mm^2 is considered medium risk.
  - >110 mm^2 is considered low risk.
  - > 155 mm^2 is normal
  - In addition to airway analysis, we also look at the tonsils, adenoids, TMJ, sinuses, and shape of the mandible.
- This analysis allows us to determine risk, not make a diagnosis of OSA.



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Buchanan A, Cohen R, Looney S, Kalathingal S, De Rossi S. Cone-beam CT analysis of patients with obstructive sleep apnea compared to normal controls. Imaging Sci Dent. 2016.

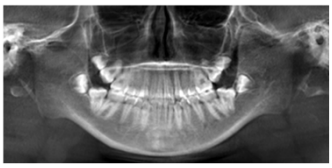
100

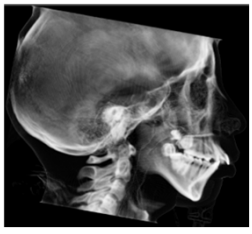
Case 12

Patient: JW

Age: 16 y/o female at time of imaging

Reason for imaging: Initial orthodontic records





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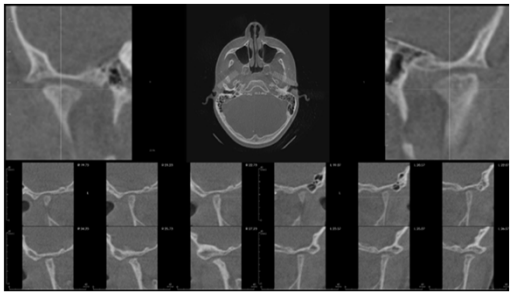
Case 12:



102

Progressive Condylar Resorption (PCR)

- Anterosuperior surfaces of condyles and occasionally articular eminence
- Flattening of the mandibular condyle with posterior inclination of the condylar head and neck
- Secondary hypoplasia of the ipsilateral mandible with shortening of the ramus and deepening of the antegonial notch
- Loss in condylar volume, complete resorption of the condyle in some cases
- Anterior open bite – condylar height is lost and the mandible counter-rotates

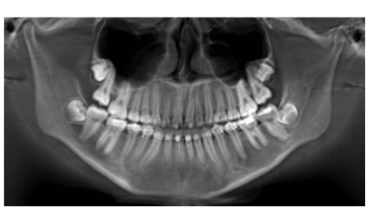
103

Case 13

Patient: LH

Age: 17 y/o female at time of imaging

Reason for imaging: Progress records



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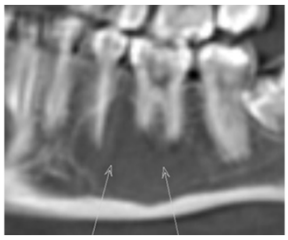
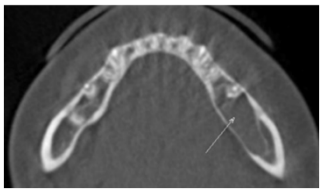




105

Case 14:

Patient: JL

Age: 19 y/o male at time of imaging

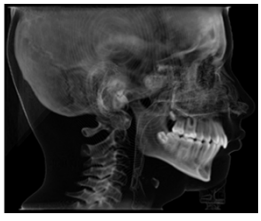
106

Case 15:

Patient: SF

Age: 11 y/o male at time of imaging

Reason for imaging: Initial records



107

Case 16:

Patient: JL

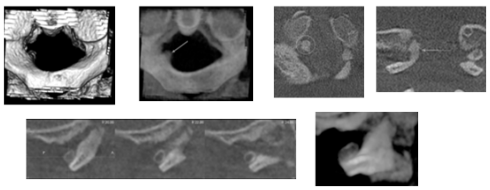
Age: 19 y/o male at time of imaging

Reason for imaging: Initial orthodontic records

108

Case 17

History:	**None noted**
Indications:	Any pathology? Abnormality?



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Significance

- These cases are just a small number of the many different conditions we're evaluating for on a CBCT.
- Important findings don't always just jump out at you.
- Any imaging study must be read systematically. We go through it system by system so we don't miss anything.
  - Study type, errors, and artifacts
  - Skeletal anatomy
  - TMJ
  - Cervical spine
  - Paranasal sinuses
  - Airway
  - And only at the very end… dental findings

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If there are actionable findings in approximately 4 out of every 10 patients in a private orthodontic practice population, what can we expect for older and less healthy populations?

- Actionable findings for older adults tend to be different and often more severe than what we see in the pediatric to young adult population. We regularly see evidence of the following on "routine" scans taken for dental treatment…
  - Intracranial arterial rim calcifications
  - Benign cysts and tumors that require surgical intervention
  - Malignant lesions, both primary and metastatic
  - Systemic diseases such as CKD or early stage multiple myeloma
  - Chronic sinus disease
  - Degenerative diseases
  - Osteomyelitis

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Endodontics

- **Pre-RCT evaluation**
  - Identify or rule out periapical or periodontal pathosis
  - Identify dental anomalies
  - Identify accessory/ anomalous canals
  - Identify root fracture
  - Identify root resorption
  - Identify pulp calcification/ stones
  - Determine proximity to and condition of vital structures
- **Post RCT evaluation**
  - Recurrence/ persistence of inflammatory disease
  - Root or crown fractures
  - Access/ Instrumentation/ obturation evaluation
  - Periodontal condition
  - Determine proximity to and condition of vital structures

< 0.1 mm scan

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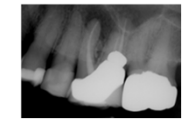
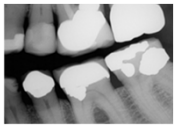
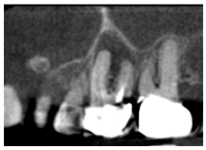
Case 12

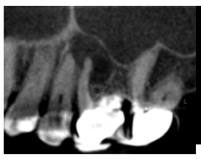




- Emerg ex. cc: " pain upper left" - points to #14. Pain x 4 days, constant throb/ache, worse when eating. Denied temperature sensation.
- No significant probe depths noted on B and MB.
- Recommended retreat, apico or ext.

113





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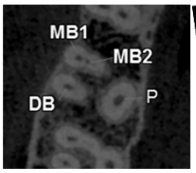
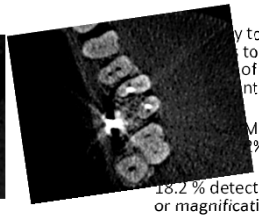
MB canal





y to locate the MB2
to the highest
of endodontic failure
nt maxillary first

MB2 canal was found
% of the maxillary

18.2 % detection without CBCT or magnification.

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Initial Treatment

- Preoperative
  - Recommendation 3: Limited FOV CBCT should be considered the imaging modality of choice for initial treatment of teeth with the potential for extra canals and suspected complex morphology,such as mandibular anterior teeth, and maxillary and mandibular premolars and molars, and dental anomalies.
- Intraoperative
  - Recommendation 4: If a preoperative CBCT has not been taken, limited FOV CBCT should be considered as the imaging modality of choice for intra-appointment identification and localization of calcified canals.
- Postoperative
  - Recommendation 5: Intraoral radiographs should be considered the imaging modality of choice for immediate postoperative imaging.

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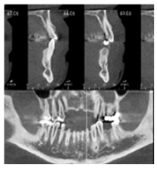

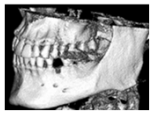

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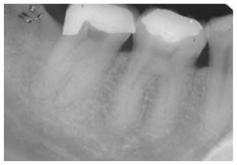

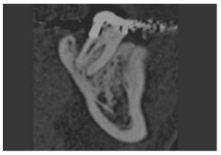

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Use of CBCT in Endodontics

- Voxel resolution of 0.3 mm or less for external root resorption
- > 90% accuracy of detection of mesiobuccal canals in maxillary molars with a voxel resolution of 0.12 mm (compared to 60% at 0.4mm resolution).
- Initial stages of apical periodontitis at least 0.2 mm scan
- With CBCT, 100% of lesions were identified, while only 60-75% are identified with plane/digital images.

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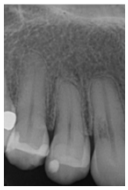

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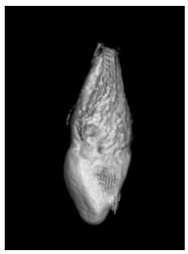
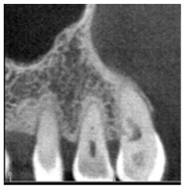

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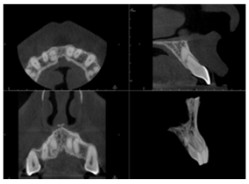
Invasive Cervical Resorption

- Invasive cervical resorption is defined as ‘a localized resorptive process that commences on the surface of root below the epithelial attachment and the coronal aspect of the supporting alveolar process.
- Progressive and usually destructive loss of tooth structure.
- This resorbed structure is replaced by highly vascular tissue which may become visible as pinkish discoloured tooth.

122

Root Fracture

- Radiographic diagnosis of root fractures: a systematic review, meta-analyses and sources of heterogeneity. Salineiro FCS *et al.,* Dentomaxillofac Radiol. 2017 Dec;46(8):20170400.
  - CBCT was the imaging exam that rendered a higher diagnostic accuracy for root fractures.
- Detection accuracy of root fractures in cone-beam computed tomography images: a systematic review and meta-analysis. Ma RH *et al.* Int Endod J. 2016 Jul;49(7):646-54.
  - CBCT images are accurate for the detection of root fractures in nonendodontically treated teeth.
  - The diagnostic accuracy of root fractures in root filled teeth or teeth with posts still needs further investigation.
  - Voxel size does not impact on the diagnostic accuracy of root fracture in nonroot filled teeth.



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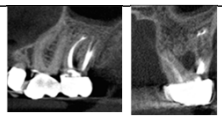
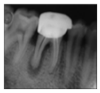
Radiographic features of vertical root fracture

- Widening of periodontal ligament
- Vertical bone loss
- Separation of root fragments
- Furcation radiolucency
- Presence of ‘radiographic halo’ has been shown as a major finding in cases of vertical root fractures.

Khasnis SA, Kidiyoor KH, Patil AB, Kenganal SB. Vertical root fractures and their management. J Conserv Dent. 2014 Mar;17(2):103-10.

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Incidental Findings in Small Field of View Cone-beam Computed Tomography Scans

David G Oser [1], Brett R Henson [1], Elaine Y Shiang [1], Matthew D Finkelman [1], Robert B Amato [2]

Affiliations + expand

PMID: 28359665 DOI: 10.1016/j.joen.2017.01.033

Abstract

Introduction: The use of cone-beam computed tomography (CBCT) in endodontics has increased in recent years. In clinical application of small field of view (FOV) CBCTs, these scans are not reviewed routinely by a radiologist. Studies of large FOV CBCT scans show the prevalence of incidental findings to be greater than 90%. The purpose of this study was to evaluate the prevalence of missed findings by endodontic residents as compared with a radiologist on small FOV CBCT scans.

Methods: Two hundred three small FOV CBCTs obtained for endodontic purposes were analyzed by an endodontic resident and a medical radiologist. The reported findings of each practitioner were compared to evaluate for missed incidental findings by the endodontic resident.

Results: The radiologist reported abnormalities in 176 of the 203 subjects (87%), with a total of 310 abnormalities reported. The endodontic resident reported abnormalities in 102 of the 203 subjects (50%), with a total of 126 abnormalities reported. The percentage of scans with any abnormality reported by the radiologist was significantly greater than the endodontic resident ($P < .001$). There was no significant difference between jaw locations in percentage of missed findings for the 3 most common types of finding-rarefying osteitis, sinusitis/mucosal lining thickening, and excess restorative material in the periapical area. Rarefying osteitis was missed significantly less than the other 2 types of findings ($P < .001$).

Conclusions: A radiologist is significantly more likely to identify incidental findings in small FOV CBCT scans than an endodontic resident. Scan location had no significant association with the rate of missed findings.

Table 1. Number and Percentage of Missed Findings by Type of Finding (n=203 Total Scans)

Type of finding	Number of findings by radiologist	Number (%) missed findings by endodontic resident
Rarefying osteitis	133	39 (29)
Sinusitis/mucosal lining thickening	78	70 (90)
Excess restorative material in periapical area	64	48 (75)
Mucous retention pseudocysts	9	9 (100)
Impactions	7	5 (71)
Root resorption--external or internal	7	4 (57)
Sclerosing osteitis	4	4 (100)
Nasopalatine duct cyst	2	2 (100)
Retained root tips	1	1 (100)
Idiopathic osteosclerosis/enostosis	1	1 (100)
Cemento-osseous dysplasia	0	0 (N/A)
Fibrous dysplasia	0	0 (N/A)
Other	4	1 (25)

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Case 18

- Pt had previous intraoral and extraoral swelling in LR quadrant, seen by endodontist. RCT at #29 was completed 12/01/2022.
- Endodontist concerned with ongoing swelling in the area that has not fully resolved since RCT. Endodontist attempted two rounds of Clindamycin, one round Doxycycline, and one round Medrol Dose Pack with minimal resolution of intraoral swelling.
- Pt was also experiencing paresthesia prior to RCT. Endodontist referred to our practice hoping surgical therapy could save the tooth.

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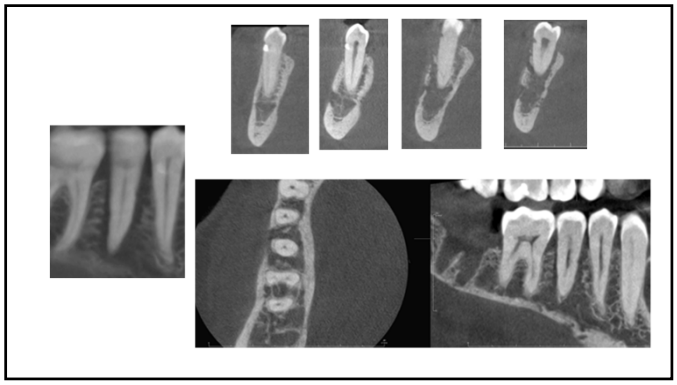

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Case 18A

- 56-yr old male
- Endo clinic
  - Numbness of chin right.
  - Lesion in premolar

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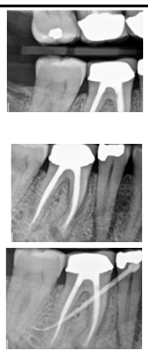
- CC: "Pain on lower right side of the mouth. Took 800mg and was given antibiotics a month ago. That is when it started. pain now and again History of numbness on jaw since the infection. (up to the right half of the lip) "
- #28 :Cold (++), Palp (-), Perc (-)
- #29 :Cold (-), Palp (-), Perc (-) Patient states he feels numb upon testing of #29
- #30:Cold (-), Palp (-), Perc (-) Sinus tract present buccal to #30, located in alveolar mucosa, apically positioned
- #31:Cold (++), Palp (-), Perc (-)
- Palpation of buccal surface from #29 towards the anterior, the patient stated, he could not feel the sense of touch. Patient also stated that extraoral palpation of mandible in the area of #29 caused a sharp/electric feeling in the right side of his lip. Patient states that root canal was done in the 90s.



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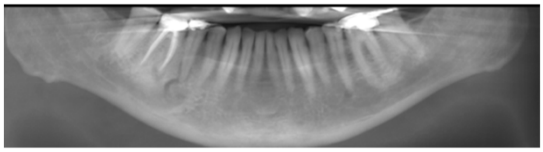

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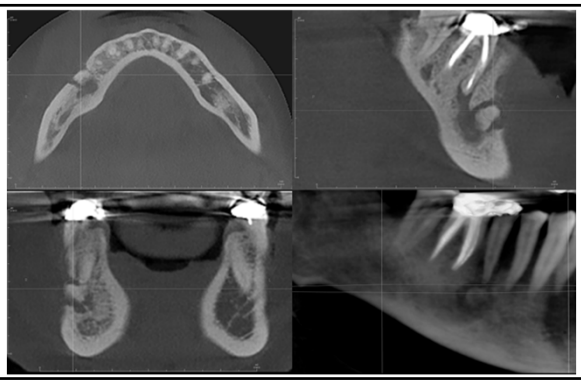

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NUMB chin syndrome

Causes:

- Malignancy
- Dental and traumatic injury
- Infection /Inflammation
- Sickle cell disease
- Cerebral ischemia

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INFLAMMATORY DISEASES OF THE SINSUSES:

- Mucositis
- Mucus Retention Pseudocyst
- Sinonasal Mucocele
- Sinonasal Polyposis
- Acute Rhinosinusitis
- Chronic Rhinosinusitis
- Odontogenic Sinusitis
- Allergic Fungal Sinusitis
- Invasive Fungal Sinusitis

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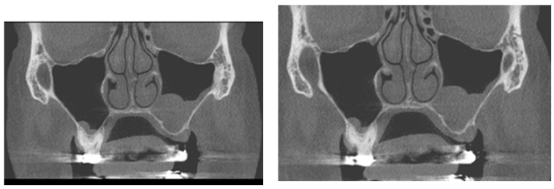
Mucosal thickening



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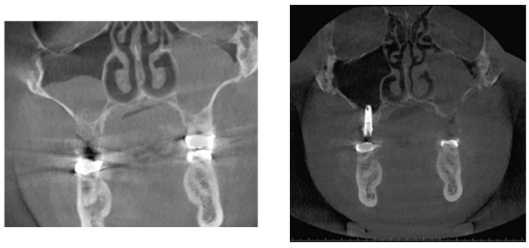
Mucous retention pseudocyst



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MRP

- Incidental finding
- Is a benign and self-limiting lesion resulting from the outflow of mucus within the sinus mucosa due to ductal obstruction
  - allergic reactions, trauma, smoking, and alteration of air temperature and humidity may be important etiological factors

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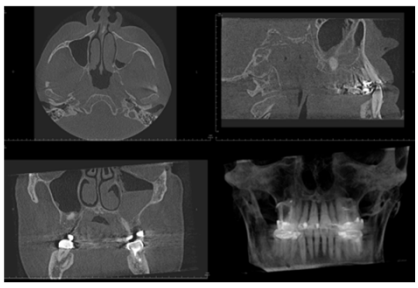
Acute sinusitis



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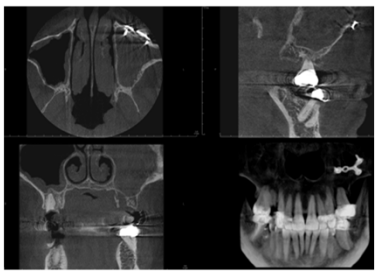
Chronic sinusitis



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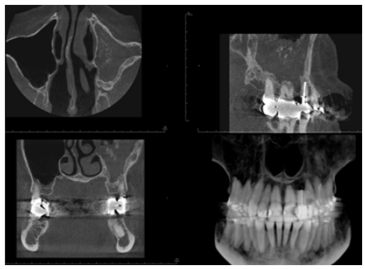
Fungal sinusitis



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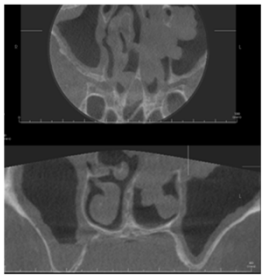
Case 30

- 45-yr old female
- General pathology review



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Antrochoanal polyp

- Antrochoanal polyps (ACP) are benign lesions that arise from the mucosa of the maxillary sinus, grow into the maxillary sinus and reach the choana, and nasal obstruction being their main symptom
- Benign inflammatory lesions
  - Widening of the maxillary ostium and extending into the nasopharynx
  - No associated bony destruction but rather smooth enlargement of the sinus
- Classic treatment is intranasal polypectomy.

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Sinonasal Inverted Papilloma

- Inverted papilloma is a benign tumor that generates a lot of attention due to it being notoriously known to be locally aggressive, high recurrence rate and risk of malignant transformation.
- Fifth to sixth decade
- Men > women
- Maxillary and ethmoid sinuses. May also appear as an isolated polyp in the nose or sinus
- Unilateral nasal obstruction
- 10% incidence of associated carcinoma
- Nonspecific imaging features (histopathologic examination required)
- Homogenous radiopaque mass, soft tissue density
- May cause pressure erosion

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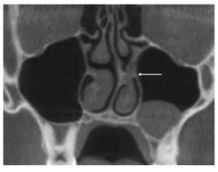
Deviated Nasal Septum

- Common finding, occurs when the nasal septum is displaced toward one side of the nasal cavity, can be congenital or secondary to trauma.



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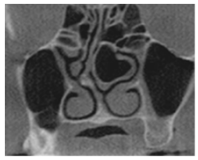
Concha Bullosa

- Pneumatization of the concha most commonly seen in the middle turbinate and may be unilateral or bilateral, they are in most cases an anatomical variation and asymptomatic.



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Sleep Apnea

- Sleep-related breathing disorders
  - Abnormal respiration during sleep and include primary central sleep apneas, obstructive sleep apneas and sleep-related hypoventilation and hypoxemia.
- Obstructive sleep apnea (OSA)
  - Obstruction in the upper airway results in increased breathing effort and inadequate ventilation.
- OSA is characterized by partial to complete obstruction of the pharyngeal airway during sleep

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Obstructive Sleep Apnea (OSA)

- Symptom: Excessive daytime sleepiness, impaired cognitive function and fatigue.
- OSA may be a risk factor for cardiac arrhythmias, hypertension, coronary artery disease, type II diabetes mellitus and mood and anxiety disorders.
- OSA prevalence:
  - 3% - 7% in men
  - 2% - 5% in women.
  - 41%- 78% in obese and overweight individuals.

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SIGNS & SYMPTOMS

- Thorough clinical evaluation.:
  - Snoring, mouth breathing
  - facial profile
  - Droopy eyes
- Intraoral findings:
  - High palatal vault
  - Narrowed transverse dimensions of the maxillary and/or mandibular dentition

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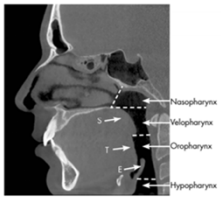
AIRWAY



- Nasopharynx:
  - Posterior of the nasal cavity to the level of the hard palate.
- Velopharynx:
  - horizontal plane of the hard palate caudally to the tip of the uvula.
- Oropharynx:
  - uvula to the base of the epiglottis.

White, S. M., Huang, C. J., Huang, S. C., Sun, Z., Eldredge, J. D., & Mallya, S. M. (2015). Evaluation of the Upper Airway Morphology: The Role of Cone Beam Computed Tomography. *Journal of the California Dental Association*, *43*(9), 531–539. https://doi.org/10.1080/19424396.2015.12222893

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CBCT and OSA

- Nasal Septum Deformities
- Turbinates
- Tonsils
- Soft palate
- High palatal vault
- Narrow dental arches
- TMJ
- Mandibular retrognathia
- Mandibular and palatal tori

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Airway area and OSA probability

< 52 mm^2	high risk for obstructive sleep apnea
52- 110 mm^2	intermediate risk for obstructive sleep apnea
> 110 mm^2	low risk for obstructive sleep apnea.

White, S. M., Huang, C. J., Huang, S. C., Sun, Z., Eldredge, J. D., & Mallya, S. M. (2015). Evaluation of the Upper Airway Morphology: The Role of Cone Beam Computed Tomography. *Journal of the California Dental Association*, *43*(9), 531–539. https://doi.org/10.1080/19424396.2015.12222893

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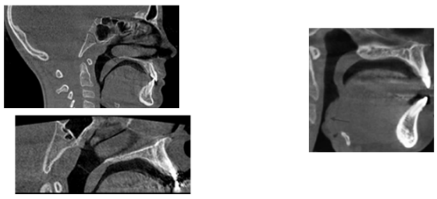
Soft Tissue Encroachments



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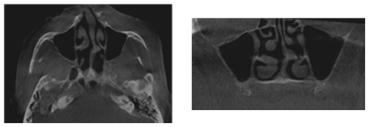
DNS & Septal Spur



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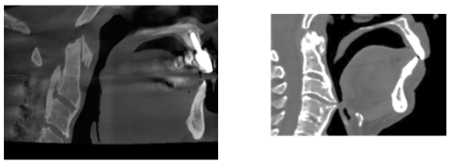

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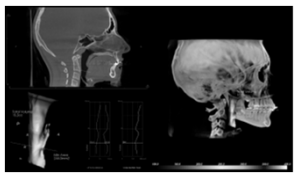
Airway Analysis via CBCT

- Obstructive sleep apnea (OSA) is a common health issue in both adults and children. Approximately 3 % of children are estimated to have it.
- Weight is a significant predictor of OSA in adults while enlarged lymphatic tissues and craniofacial anomalies are major predictors in children.
- Medium to large FOV CBCT often captures the airway and can be used to determine airway volumes.
- Patients with obstructive sleep apnea have significantly lower airway volumes as measured by CBCT than those who do not have sleep apnea.
- Sleep apnea is associated with multiple co-morbidities in both adults and children and treatment can help reduce these risks.



Chang SJ, Chae KY. Obstructive sleep apnea syndrome in children: Epidemiology, pathophysiology, diagnosis and sequelae. Korean J Pediatr. 2010.

Zhang W, Phillips A, Wang BY. Correlation Analysis between Airway Volume and Risk of Sleep Apnea/Periodontitis. J Oral Maxillofac Res. 2022.

Buchanan A, Cohen R, Looney S, Kalathingal S, De Rossi S. Cone-beam CT analysis of patients with obstructive sleep apnea compared to normal controls. Imaging Sci Dent. 2016.

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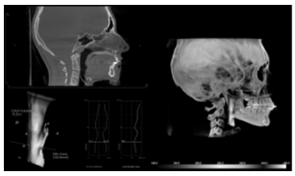
Airway Analysis via CBCT

- We use InVivo software for airway analysis.
- The primarily focus is the minimum cross-sectional area of the airway.
  - < 52 mm^2 is considered high risk.
  - 52-100 mm^2 is considered medium risk.
  - >110 mm^2 is considered low risk.
  - > 155 mm^2 is normal
  - In addition to airway analysis, we also look at the tonsils, adenoids, TMJ, sinuses, and shape of the mandible.
- This analysis allows us to determine risk, not make a diagnosis of OSA.



Chang SJ, Chae KY. Obstructive sleep apnea syndrome in children: Epidemiology, pathophysiology, diagnosis and sequelae. Korean J Pediatr. 2010.

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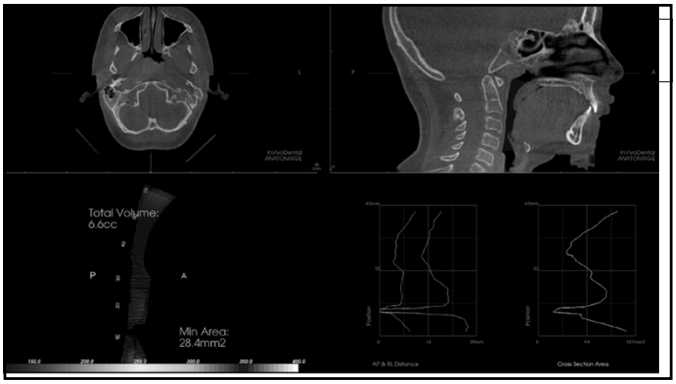

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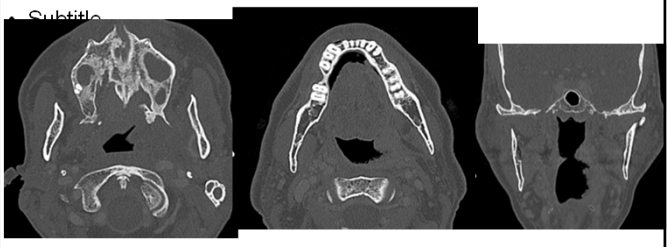
Case 27a

- Subtitle



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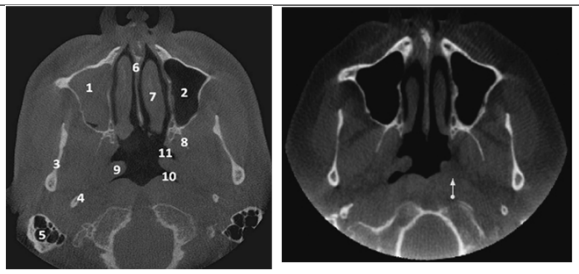

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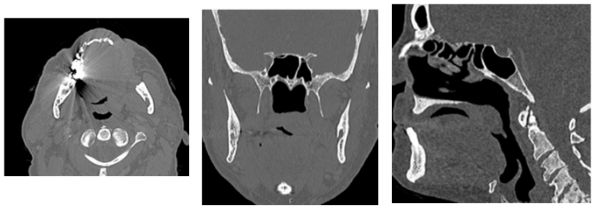

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Unknown cases

- Cases 1-8

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Radiology interpretation challenge

Win up to 1,000 points per answer

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" You only see what you look for… and you only diagnose what you know!"

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