ใช้โคนบีมซีทีอย่างไรให้ปัง

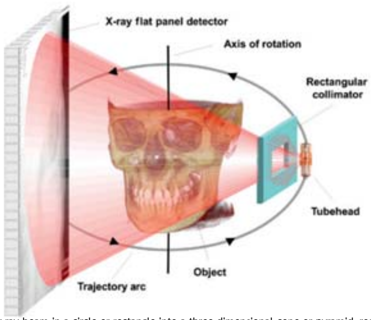
รศ.ทพ.ดร. สุนทรา พันธ์มีเกียรติ

24 กุมภาพันธ์ 2564 13:00-14:30 น.

Cone-beam Computed Tomography

- Cone-beam CT, CBCT (Cone-beam Computed Tomography)
- Volumetric Computed Tomography (VCT)
- Ortho-CT
- Micro-CT
- CBVT (Cone-beam Volume Tomography)
- DVT (Digital Volume Tomography) (German-speaking regions)
- DVT (Dental Volumetric Tomography)

Cone Beam Imaging Geometry



Collimated divergent x-ray beam in a circle or rectangle into a three-dimensional cone or pyramid, respectively. The x-ray projection is directed through the patient onto a detector (either solid-state flat panel detector or II/charge-coupled device).After a single two-dimensional projection is acquired by the detector, the x-ray source and detector rotate a small distance around a trajectory arc. At this second angular position, another basis projection image or frame is captured. This sequence continues around the object for the entire 360 degrees (full trajectory) or along a reduced or partial trajectory capturing hundreds of individual images.

Origin: Mallya SM and Lam EWN. White and Pharoah's Oral Radiology Principles and Interpretation, 2019, 8th edn

- Introduced to dentistry in the late 1990s
- from 1996 to 2019, 279 CBCT models (143 CBCT series) from 47 manufacturers in 12 countries (Brazil, China, Denmark, Finland, France, Germany, Italy, Japan, Republic of Korea, Slovakia, Thailand, and USA)

Gaêta-Araujo et al. Dentomaxillofac Radiol 2020; 49: 20200145.

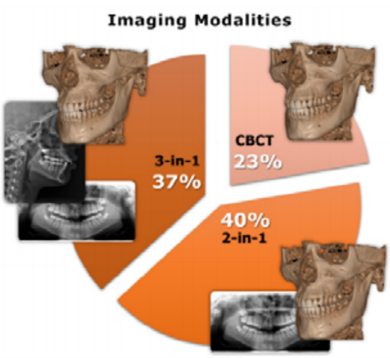
Categorized according to

Functionality

- Dedicated unit
- Hybrid unit with

- panoramic

- panoramic and cephalometric



Gaêta-Araujo et al. Dentomaxillofac Radiol 2020; 49: 20200145.

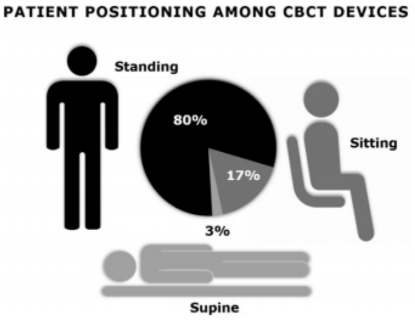
Manufacturer	Model	Availability on the market	Imaging modalities CBCT	PANO	CEPH	Maximum dimensions (width x depth x height) in meters	Maximum weight in kilograms	Patient position	Software
MyRay (Italy)	SkyView	No	x			1.5 × 2.5 x 1.8	360	Supine	SkyView
	Hyperion X5 3D/2D	Yes	x	x		0.9 × 1.1 x 2.3	90	Standing	iRYS
	Hyperion X5 3D/2D CEPH	Yes	x	x	x	1.8 × 1.1 x 2.3	115	Standing	iRYS
	Hyperion X9 Full FOV	Yes	x	x		1.3 × 1.5 x 2.5	170	Standing	iRYS
	Hyperion X9 Full FOV CEPH	Yes	x	x	x	1.8 × 1.5 x 2.5	190	Standing	iRYS
	Hyperion X9 Extended FOV	Yes	x	x		1.3 × 1.5 x 2.5	170	Standing	iRYS
	Hyperion X9 Extended FOV CEPH	Yes	x	x	x	1.8 × 1.5 x 2.5	190	Standing	iRYS
	Hyperion X9 Pro 10 × 8 version	Yes	x	x		1.3 × 1.5 x 2.5	155	Standing	iRYS
	Hyperion X9 Pro CEPH 10 × 8 version	Yes	x	x	x	1.8 × 1.5 x 2.5	175	Standing	iRYS
	Hyperion X9 Pro 13 × 16 version	Yes	x	x		1.3 × 1.5 x 2.5	155	Standing	iRYS
	Hyperion X9 Pro CEPH 13 × 16 version	Yes	x	x	x	1.8 × 1.5 x 2.5	175	Standing	iRYS
Meyer (China)	SS-91010D Pro-3D	Yes	x	x		1.1 × 1.4 x 2.5	?	Standing	DCTViewer
	SS-91010D Pro-3De	Yes	x	x	x	1.9 × 1.4 x 2.5	?	Standing	DCTViewer
	X12008D Pro-3D	Yes	x			1.5 × 1.7 x 2	350	Sitting	DCTViewer
PiXAMED (Thailand)	DentiiScan 2.0	Yes	x			1 × 1.3 x 2.4	190	Standing	In house software
Owandy (France)	I-MAX 3D	Yes	x	x		1 × 1.1 x 2.2	66	Standing	QuickVision
	I-MAX 3D Touch	Yes	x	x		1.2 × 1.3 x 2.5	161	Standing	QuickVision
	I-MAX 3D Touch CEPH	Yes	x	x	x	2 × 1.3 x 2.5	186	Standing	QuickVision
Osstem (Republic of Korea)	Osstem Implant CBCT T1	Yes	x	x	x	1.9 × 1.2 x 2.3	210	Standing	Oneclinic
Planmeca (Finland)	ProMax 3D Classic	Yes	x	x		1.2 × 1.3 x 2.4	113	Standing	Romexis
	ProMax 3D Classic (Ceph)	Yes	x	x	x	2 × 1.3 x 2.4	128	Standing	Romexis
	ProMax 3D S	Yes	x	x		1.2 × 1.3 x 2.4	113	Standing	Romexis
	ProMax 3D S (Ceph)	Yes	x	x	x	2 × 1.3 x 2.4	128	Standing	Romexis
	ProMax 3D Plus	Yes	x	x		1.2 × 1.4 x 2.4	131	Standing	Romexis

Gaêta-Araujo et al. Dentomaxillofac Radiol 2020; 49: 20200145.

Categorized according to

Patient position

- Seated
- Standing
- Supine



Gaêta-Araujo et al. Dentomaxillofac Radiol 2020; 49: 20200145.

(A) Seated (e.g., 3D Accuitomo 170, J Morita Corp., Osaka, Japan).

(B) (e.g., X-Mind trium Pan 3D, Acteon North America, Mt. Laurel, NJ) and (C) (e.g. Rayscan Alpha 3D, LED Medical Diagnostics Inc., Atlanta, GA), Standing.

(D) Supine (e.g., Newtom 5G, QR srl, Verona, Italy).

According to function, CBCT devices can also be categorized according to functionality and considered a dedicated unit (A and D) or a hybrid unit with panoramic (B) or panoramic and cephalometric capability (C).

Origin: Mallya SM and Lam EWN. White and Pharoah's Oral Radiology Principles and Interpretation, 2019, 8th edn

wide variation in technical characteristics and clinical diagnostic performance

- kV
- mA
- Focal spot
- Detector type
- Detector gray scale
- FOV (small, medium, large)
- FOV stitching
- Voxel size
- Scan time
- Reconstruction time
- Pulsed beam

Gaêta-Araujo et al. Dentomaxillofac Radiol 2020; 49: 20200145.

Practitioners and operators using CBCT must have a thorough understanding of

- the operational parameters
- the effects of these parameters on image quality and radiation safety

Wait a minute!

X-ray: an ionizing radiation

minimized radiation

for

acceptable image quality

Minimized radiation by

1) Justification (การให้เหตุผล)
2) Optimization (การใช้ความเหมาะสมที่สุด)
3) Dose limitation (การจำกัดปริมาณรังสี)

Origin: IAEA. Radiation protection and safety in medical uses of ionizing radiation. 2018.

Justification (การให้เหตุผล)

Prescribing imaging after

- thorough medical and dental history
- clinical examination
- prior radiographs if any
- then does patient need imaging?

Costs

- Financial (CBCT > conventional)
- Health

- deterministic (tissue reaction)
- stochastic
  - carcinogenic
  - heritable

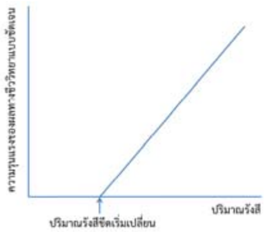
Benefits

Will the imaging

- change diagnosis?
- change treatment plan?
- effect treatment outcome?

Deterministic effects (Tissue reactions) (ผลทางชีววิทยาแบบชัดเจน)

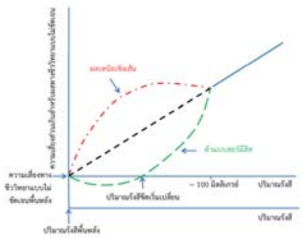
- Mucositis, cataracts, osteoradionecrosis
- Threshold dose



- CBCT doses below threshold dose

Stochastic effects (ผลทางชีววิทยาแบบไม่ชัดเจน)

- Cancer induction



- Linear no-threshold (LNT) hypothesis
- It is prudent to assume that risk is proportional to dose and that there is no safe threshold.

Radiation-induced cancer from diagnostic maxillofacial radiography

Leukemia

- highest risks in children
- peak at ~ 7 years
- cease after ~ 30 years

Radiation-induced cancer from diagnostic maxillofacial radiography

Thyroid cancer

- higher in children than adult
- Females are 2 to 3 times more susceptible than males to radiogenic and spontaneous thyroid cancers.

Radiation-induced cancer from diagnostic maxillofacial radiography

Salivary gland tumors

- mostly, Warthin tumor
- an association between salivary gland tumors and dental radiography
- This association is likely a consequence of more dental radiographs made to investigate the symptoms of an existing tumor, rather than dental radiation doses inducing tumors.

Radiation-induced cancer from diagnostic maxillofacial radiography

Breast cancers

- Female breast is highly sensitive.
- Risk is significantly higher when exposed before age 20.

Radiation-induced cancer from diagnostic maxillofacial radiography

Brain and nervous system cancers

- association between intracranial meningiomas and previous medical or dental radiography
- This association is likely due to more dental radiographs that were made in response to facial pain referred from the tumor rather than radiation causing more meningiomas.

Stochastic effects

- Heritable effects (genetic effects)

- consequence of DNA damage in germ cells
- congenital abnormality seen in offspring of irradiated individuals
- Dental radiation does not usually involve the reproductive organs.
- limited chance of heritable effects
- Risks from CBCT is negligible.

(White SC. 1992 Dentomaxillofac Radiol 1992; 21: 118-126. doi: 10.1259/dmfr.21.3.1397466)
(EC, European Commission. Radiation protection 172. 2012; pp 27, 39-88, 113. http://www.sedentexct.eu/files/radiation_protection_172)

Risks = carcinogenesis

Broad estimate of risk of a fatal radiation-induced malignancy from dental and medical X-ray examinations in a standard 30-year-old patient

X-ray examination	Estimated risk
• Bitewing/periapical radiograph (70 kV, round collimation, D-speed film)	1 in 1,000,000
• Bitewing/periapical radiograph (70 kV, rectangular collimation, F-speed film)	1 in 10,000,000
• Panoramic radiograph (average)	1 in 1,000,000
• Upper standard occlusal	1 in 2,500,000
• Lateral cephalometric radiograph	1 in 5,000,000
• Skull radiograph (PA)	1 in 1,000,000
• Skull radiograph (lateral)	1 in 1,250,000

Broad estimate of risk of a fatal radiation-induced malignancy from dental and medical X-ray examinations in a standard 30-year-old patient

X-ray examination	Estimated risk
Chest (PA)	1 in 1,430,000
Chest (lateral)	1 in 540,000
CT head	1 in 14,300
CT chest	1 in 3000
CT abdomen	1 in 3500
CT mandible and maxilla	1 in 80,000 to 1 in 14,300
Barium swallow	1 in 13,300
Barium enema	1 in 9100
Dento-alveolar cone beam CT	1 in 2,000,000 to 1 in 30,000
Craniofacial cone beam CT	1 in 670,000 to 1 in 18,200

European Guidelines on Radiation Protection in Dental Radiology (2004)

Age group (yr)	Multiplication factor for risk
<10	×3
10–20	×2
20–30	×1.5
30–50	×0.5
50–80	×0.3
80+	Negligible risk

TABLE 3.2 Typical Effective Dose From Radiographic Examinations

Examination	Median Effective Dose	Equivalent Background Exposure[a]
Intraoral[b]		
Rectangular collimation		
Posterior bite-wings: PSP or F-speed film	5 µSv	0.6 day
Full-mouth: PSP or F-speed film	40 µSv	5 days
Full-mouth: CCD sensor (estimated)	20 µSv	2.5 days
Round collimation		
Full-mouth: D-speed film	400 µSv	48 days
Full-mouth: PSP or F-speed film	200 µSv	24 days
Full-mouth: CCD sensor (estimated)	100 µSv	12 days
Extraoral		
Panoramic[b]	20 µSv	2.5 days
Cephalometric[b]	5 µSv	0.6 day
Chest[c]	100 µSv	12 days
Cone beam CT[b]		
Small field of view (<6 cm)	50 µSv	6 days
Medium field of view (dentoalveolar, full arch)	100 µSv	12 days
Large field of view (craniofacial)	120 µSv	15 days
Multidetector CT		
Maxillofacial[b]	650 µSv	2 months
Head[c]	2 mSv	8 months
Chest[c]	7 mSv	2 years
Abdomen and pelvis, with and without contrast[c]	20 mSv	7 years

[a]Approximate equivalent background exposure is calculated based on an estimated background radiation dose of 3.1 mSv/year. Exposures more than the equivalent of 3 days are rounded off to the nearest day, month, or year.
[b]Median dose from dentomaxillofacial radiography with typical exposure protocols is calculated from data collated from multiple published studies. Doses in the range of 10–1000 µSv are rounded off to the nearest multiple of 10.
[c]American College of Radiology, https://www.acr.org/~/media/ACR/Images/Quality-Safety/eNews/2015-September/Dose_chart.png?la=en
CCD, Charge-coupled device; *CT*, computed tomography; *PSP*, photostimulable phosphor.

Origin: Mallya SM and Lam EWN. White and Pharoah's Oral Radiology Principles and Interpretation, 2019, 8th edn

Cancer induction

International Commission on Radiological Protection (ICRP) suggest a 1 in 20,000 chance of developing a fatal cancer for every 1 mSv of effective dose

Justification and Referral Criteria

Three fundamental approaches to guideline development

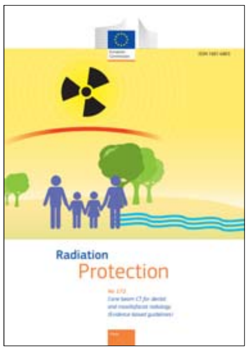
1. Opinion of an expert panel
2. Consensus method
3. Evidence-based method

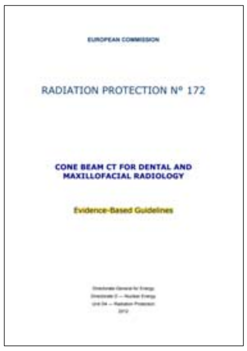
↓

referral criteria

selection criteria

appropriateness criteria





Origin: European Commission. Radiation Protection no 172, Cone beam CT for dental and maxillofacial radiology. Evidence-Based Guidelines. 2012. Available from: https://ec.europa.eu/energy/sites/ener/ files/documents/172.pdf

CONTENTS

The "Basic Principles"

1) CBCT examinations must not be carried out unless a history and clinical examination have been performed

2) CBCT examinations must be justified for each patient to demonstrate that the benefits outweigh the risks

3) CBCT examinations should potentially add new information to aid the patient's management

4) CBCT should not be repeated 'routinely' on a patient without a new risk/benefit assessment having been performed

5) When accepting referrals from other dentists for CBCT examinations, the referring dentist must supply sufficient clinical information (results of a history and examination) to allow the CBCT Practitioner to perform the Justification process

The "Basic Principles"

6) CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) radiography

7) CBCT images must undergo a thorough clinical evaluation ('radiological report') of the entire image dataset

8) Where it is likely that evaluation of soft tissues will be required as part of the patient's radiological assessment, the appropriate imaging should be conventional medical CT or MR, rather than CBCT

9) CBCT equipment should offer a choice of volume sizes and examinations must use the smallest that is compatible with the clinical situation if this provides less radiation dose to the patient

10) Where CBCT equipment offers a choice of resolution, the resolution compatible with adequate diagnosis and the lowest achievable dose should be used

The "Basic Principles"

11) A quality assurance programme must be established and implemented for each CBCT facility, including equipment, techniques and quality control procedures

12) Aids to accurate positioning (light beam markers) must always be used

13) All new installations of CBCT equipment should undergo a critical examination and detailed acceptance tests before use to ensure that radiation protection for staff, members of the public and patient are optimal

14) CBCT equipment should undergo regular routine tests to ensure that radiation protection, for both practice/facility users and patients, has not significantly deteriorated

The "Basic Principles"

15) For staff protection from CBCT equipment, the guidelines detailed in Section 6 of the European Commission document 'Radiation Protection 136. European Guidelines on Radiation Protection in Dental Radiology' should be followed

16) All those involved with CBCT must have received adequate theoretical and practical training for the purpose of radiological practices and relevant competence in radiation protection

17) Continuing education and training after qualification are required, particularly when new CBCT equipment or techniques are adopted

The "Basic Principles"

18) Dentists responsible for CBCT facilities who have not previously received 'adequate theoretical and practical training' should undergo a period of additional theoretical and practical training that has been validated by an academic institution (University or equivalent). Where national specialist qualifications in DMFR exist, the design and delivery of CBCT training programmes should involve a DMF Radiologist

19) For dento-alveolar CBCT images of the teeth, their supporting structures, the mandible and the maxilla up to the floor of the nose (e.g. 8cm x 8cm or smaller fields of view), clinical evaluation ('radiological report') should be made by a specially trained DMF Radiologist or, where this is impracticable, an adequately trained general dental practitioner

The "Basic Principles"

20) For non-dento-alveolar small fields of view (e.g. temporal bone) and all craniofacial CBCT images (fields of view extending beyond the teeth, their supporting structures, the mandible, including the TMJ, and the maxilla up to the floor of the nose), clinical evaluation ('radiological report') should be made by a specially trained DMF Radiologist or by a Clinical Radiologist (Medical Radiologist)

Origin: European Commission. Radiation protection no. 172. Cone beam CT for dental and maxillofacial radiology (evidence based guidelines) a report prepared by the sedentexct project. 2012. Available at: http://www. sedentexct.eu/files/radiation_protection_172.pd

Selection criteria Clinical recommendations

- Tyndall DA, Price JB, Tetradis S, et al. Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol 2012;113(6):817–26.
- American Academy of Oral and Maxillofacial Radiology. Clinical recommendations regarding use of cone beam computed tomography in orthodontics [corrected]. Position statement by the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol 2013;116(2):238–57.
- Fayad MI, Nair M, Levin MD, et al, Special Committee to Revise the Joint AAE/AAOMR Position Statement on Use of CBCT in Endodontics. AAE and AAOMR joint position statement: use of cone beam computed tomography in endodontics 2015 update. Oral Surg Oral Med Oral Pathol Oral Radiol 2015;120(4):508–12.
- Patel S, Brown J, Semper M, et al. European Society of Endodontology position statement: use of cone beam computed tomography in Endodontics: European Society of Endodontology (ESE) developed by Int Endod J 2019;52:1675e8.
- Matzen LH, Berkhout E. Cone beam CT imaging of the mandibular third molar: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR). Dentomaxillofac Radiol 2019; 48: 20190039.

CBCT

- As adjunctive diagnostic imaging
- Not as screening procedure

Optimization by ALARA principle

(การใช้ความเหมาะสมที่สุด)

- Continuous or pulsed beam

- Exposure time of pulsed beam is substantially less than scanning time .

- Pulsed beam considrably reduce patient radiation dose.

Optimization by ALARA principle

(การใช้ความเหมาะสมที่สุด)

- Adjust exposure factors according to
- patient size
- specific diagnostic task
- Adjust exposure factors
- mA
- kVp
- exposure time
  - faster scans: fewer basis images

Primary determinants of patient exposure

- mA
- kVp
- exposure time
- pulsed x-ray beam
- size of FOV (field of view)

Optimization by ALARA principle

(การใช้ความเหมาะสมที่สุด)

- Effective dose clinically varies according to
  - FOV
  - kV
  - mA
  - exposure time
  - machine specificity

FOV (scan volume)

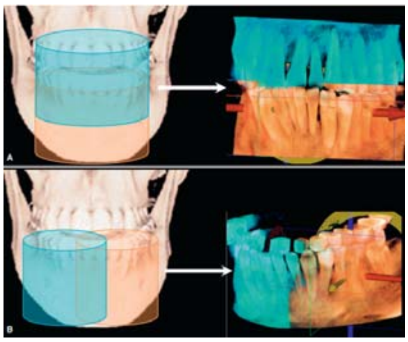
- Depend on detector size and shape
- Round collimator: spherical
- Rectangular collimator: cylindrical
- Smallest volume to

- reduce unnecessary exposure to the patient

- render best images by minimizing scattered radiation

Scan ROI greater than FOV of detector

1) Stitching or blending



(KODAK CS 9000 Carestream Dental, Atlanta, GA) stitched manually using proprietary software (InVivoDental software; Anatomage, San Jose, CA).

Disadvantage: double radiation dose to the overlapped regions

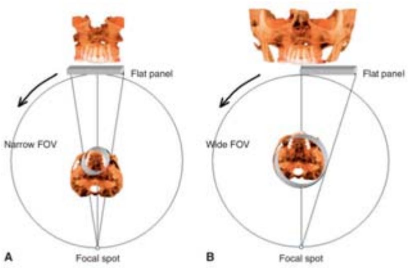
Origin: Mallya SM and Lam EWN. White and Pharoah's Oral Radiology Principles and Interpretation, 2019, 8th edn

Scan ROI greater than FOV of detector

2) Offset detector position

Collimate the beam asymmetrically

Scan only half of the ROI in each of the two offset scans



(Adapted courtesy of SOREDEX, Tuusula, Finland.)

Origin: Mallya SM and Lam EWN. White and Pharoah's Oral Radiology Principles and Interpretation, 2019, 8th edn

Scan factors (detector frame rate)

- Number of basis images depends on

- detector frame rate (number of images acquired per second)

- completeness of trajectory arc (180^{0} to 360^{0})

- rotation speed of the source and detector

- Number of basis images may be fixed or variable.

Scan factors (detector frame rate)

- Higher frame rates
- increasing signal-to-noise ratio (less noise)
- reducing metal artifacts
- However, higher frame rates
- higher patient radiation dose
- increasing primary reconstruction time

Scan factors (detector frame rate)

- In contrast, some “quick-scan” or “fast-scan” protocols use
- markedly lower frame rates
- considerably reduced patient radiation dose.
- However, image resolution may not be adequate for all diagnostic tasks.

Scan factors (rotation angles)

- mostly, fixed arc
- A full 360° or partial trajectory arc
- 78% of CBCT units are based on panoramic platform.
- Therefore, less than 360° scan arcs
- reduced scan time (reduced motion artifact)
- reduced patient radiation dose
- greater noise
- greater reconstruction interpolation artifacts

Scan factors (rotation angles)

- Decreasing scan time to reduce motion artifact by
- increased detector frame rate (give highest quality images)
- reduced number of projections (increasing image noise)
- reduced scan arc (increasing image noise)

Image detectors (voxel size)

- Isotropic voxel
- Nominal voxel size in a CBCT image is principally determined by matrix and pixel size of detector.
- Detectors with smaller pixels
- capture fewer x-ray photons per voxel
- result in more image noise
- to obtain higher resolution (smaller pixels), use higher dosage to achieve a reasonable signal-to-noise ratio for improved diagnostic image quality

Spatial resolution

- Degree of geometric unsharpness (a limiting factor in spatial resolution) is determined by
- focal spot size (the smaller, the sharper image, the more cost)
- geometric configuration of x-ray source
- Reducing object-to-detector distance and increasing source-to-object distance minimizes geometric unsharpness.

Additional factors influencing image resolution

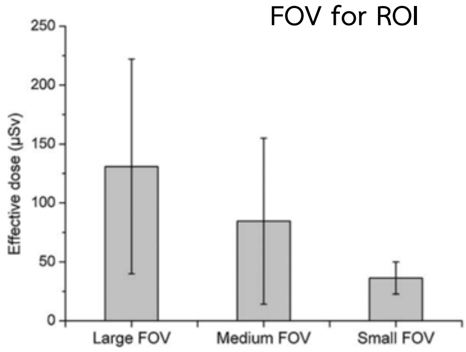
- motion of patient's head during exposure
- type of scintillator used in detector
- image reconstruction algorithms

Grayscale

- bit depth (2^x) (bit depth = x)
- All currently available CBCT units use detectors capable of recording grayscale differences of 12 bits (2^{12} = 4096 shades) or greater.
- More bits, more computational time, larger file size

FOV

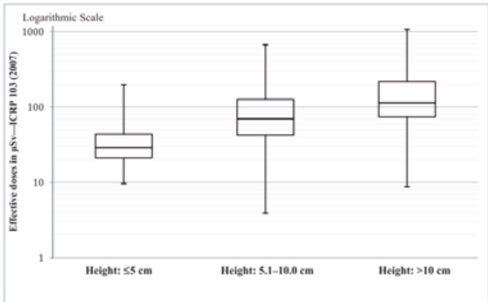
Choose the smallest FOV for ROI



The average doses for large, medium and small FOVs were 131, 88 and 34 μSv respectively.

Pauwels et al., 2012

FOV



Effective dose (μSv)	Height: ≤5 cm	Height: 5.1–10.0 cm	Height: >10 cm
Minimum	9.7	3.9	8.8
Median	28.5	69.9	114.0
Maximum	197.0	674.0	1073.0

Al-okshi et al., 2015

kVp

- Currently, 90 kVp, the best image quality (Pauwels et al, 2014; Pauwels et al, 2017 Eur Radiol; Panmekiate et al, 2018)
- kVp > 90 waiting for investigation

mA

- mA reduction is possible depending on diagnostic task (Lofthag-Hansen et al, 2011; Pauwels et al, 2015; Choi, 2016; Goulston et al. 2016; Panmekiate et al, 2018)

Exposure time (arc of rotation)

- 180^0 vs 360^0 (promising results)
  - Periapical bone loss (in vitro) (Lennon et al, 2011)
  - Implant (in vivo) (Dawood et al, 2012)
  - Anthropomorphic phantom (Pauwels et al, 2014)
  - TMJ (in vitro) (Yadav et al, 2015)
  - Periodontium (in vitro) (Panmekiate et al, 2018)

Patient preparation (lead shielding)

- Current guidelines do not recommend application of lead aprons (European commission. 2012 http://www.sedentexct.eu/files/radiation_protection_172.pdf ; Harris et al. E.A.O. Guidelines for the use of diagnostic imaging in implant dentistry 2011. Clin Oral Implant. Res 012;23:1243e53; HPA Working Party on Dental Cone Beam CT Equipment. Guidance notes for dental practitioners on the safe use of dental cone beam computed tomography (CBCT) equipment. Chilton, Didcot: HPA. 2010 (HPA-CRCE-010).), although it has been shown recently that the skin dose, particularly in the female breast region, can be reduced by >90% if a lead apron is applied (Schulze et al. Health Phys 2017;113:129e34).

Patient preparation (lead shielding)

- It is recommended that at least a leaded torso apron be applied correctly (above the collar) to the patient. (White and Pharoah's Oral Radiology Principles and Interpretation, 2019)
- particularly advisable for pregnant patients and for children (White and Pharoah's Oral Radiology Principles and Interpretation, 2019)
- Thyroid shields is highly recommended with a caution not to interfere with the scan causing artifacts or interfere with the AEC. (White and Pharoah's Oral Radiology Principles and Interpretation, 2019)

Patient preparation

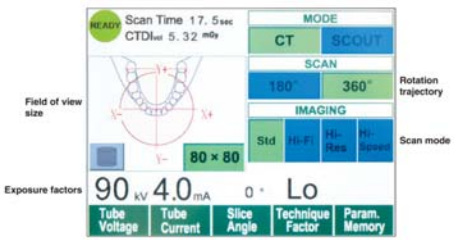
- Head stabilization: chin cup, posterior and lateral head support, head restraint
- Occlusal plane in horizontal plane
- Upper and lower teeth separated by cotton rolls to reduce scatter from metallic restoration in opposing arch
- Inform the patient to

- remain as still as possible
- breathe slowly through the nose
- close the eyes

Imaging protocol

- A set of technical exposure parameters
- Optimal quality with least amount of radiation exposure (ALARA)
- Exposure parameters should be based on patient size and diagnostic task

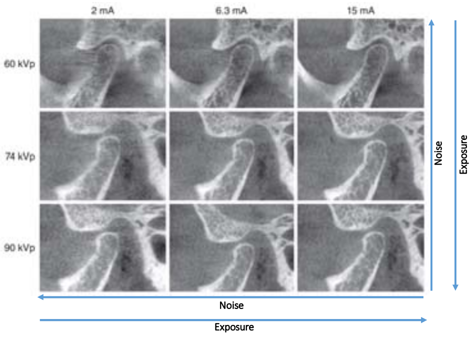
Imaging protocol



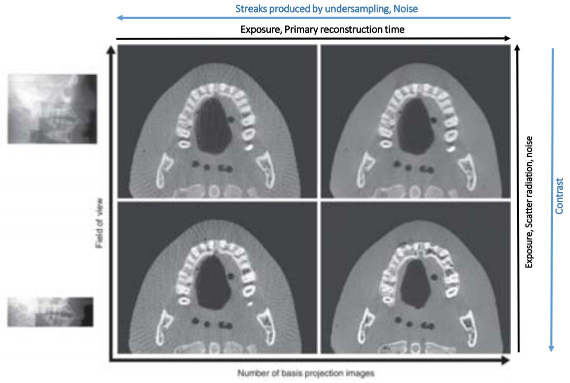
Operators should be knowledgeable of the effects of all parameters on image quality and patient radiation dose when selecting imaging protocols to fulfill ALARA principle

Origin: Mallya SM and Lam EWN. White and Pharoah's Oral Radiology Principles and Interpretation, 2019, 8th edn

Effect of exposure parameters (kVp, mA) on image quality for cortical and cancellous bone

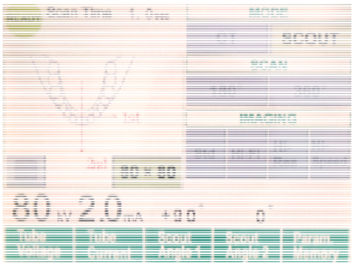


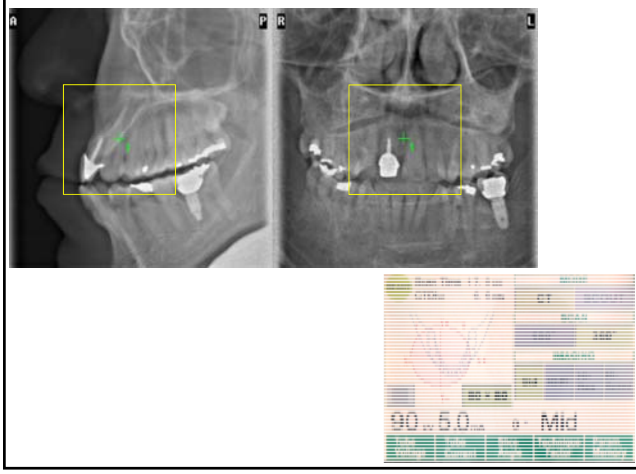
Modified from Fig. 10.10 from Mallya SM and Lam EWN. White and Pharoah's Oral Radiology Principles and Interpretation, 2019, 8th edn



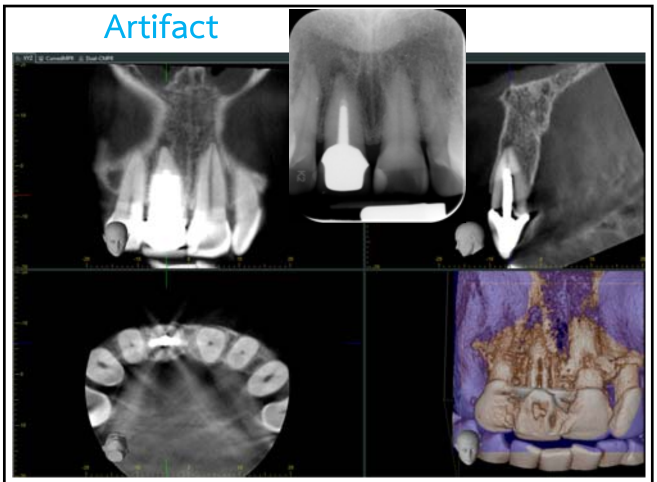
Modified from Fig. 10.11 from Mallya SM and Lam EWN. White and Pharoah's Oral Radiology Principles and Interpretation, 2019, 8th edn

For apical surgery of tooth 11

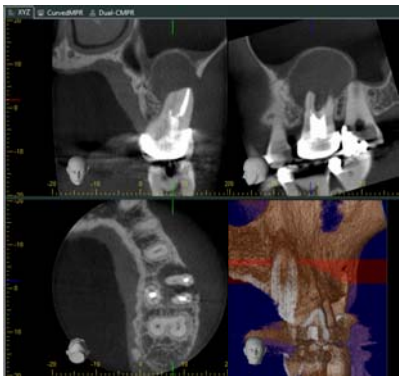




Artifact

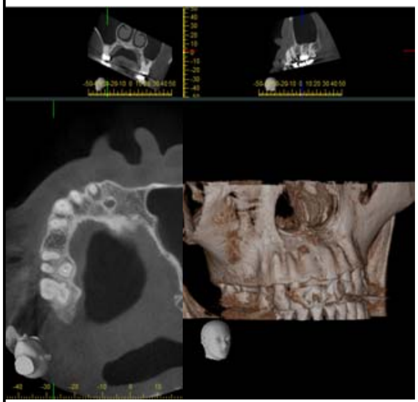


Missed MB2



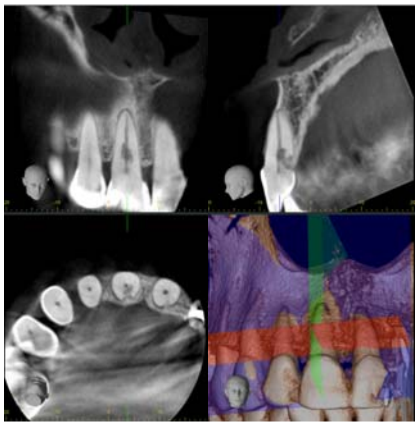
Reslicing (zoom reconstruction)

Tooth 16 FOV 10x5 cm Voxel size 0.25mm



Tooth 16 FOV 4x4 cm Voxel size 0.08mm

Root resorption



Root fracture

Pre-operative implant site assessment

The European Association for Osseointegration suggests CBCT (2012)

1) where clinical examination and conventional radiography have failed to demonstrate the relevant anatomy
2) to help reduce the risk to important anatomical structures
3) in borderline situations where there is limited bone available to place dental implants
4) where implant positioning can be improved to optimize biomechanical, functional, and aesthetic results

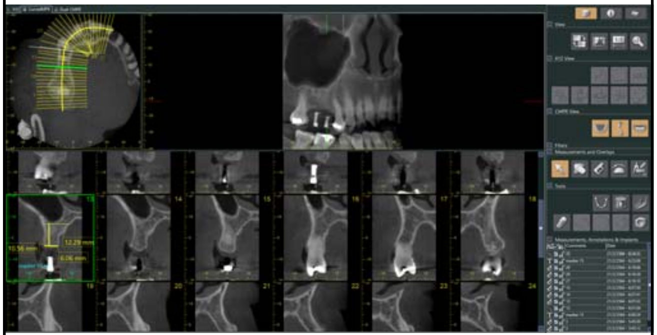
Pre-operative implant site assessment

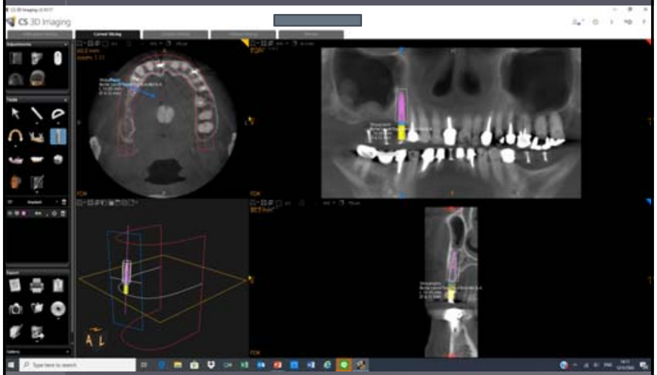
The American Academy of Oral and Maxillofacial Radiology's position statement suggests (2012)

1) panoramic and intraoral imaging should be performed as the initial imaging method
2) preoperative planning should also include cross-sectional imaging

Pre-op implant 15 and 16 (MPR)

Cross-sectional view (transaxial view)





Computer-Assisted Implant Surgery (CAIS)

Static

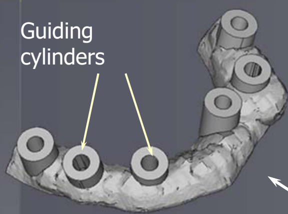
- CT scan ➡ DICOM
- ⬇
- Software ➡ Virtual implant
- ⬇
- CAD/CAM ➡ SurgiGuide
- ➡ Prototype
- ➡ Provisional prosthesis

Dynamic

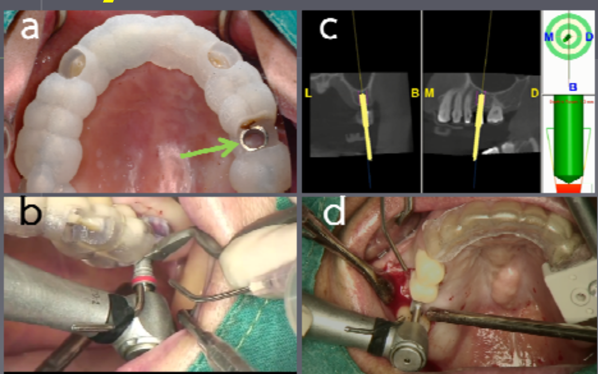
- CT scan ➡ DICOM
- ⬇
- Software ➡ Virtual implant
- ⬇
- Optical tracking ➡ Realtime installation

SurgiGuide Design : Based on SimPlant Plan

The SurgiGuide indicates:
- Position
- Angle



Dynamic CAIS



ภาพด้วยความอนุเคราะห์จาก รศ. ทพ. ดร.อาทิพันธุ์ พิมพ์ขาวขำ

Dynamic CAIS

- Not used in most cases
- Insufficient evidence to justify routine use

Misch Classification of Bone Density

Classification Type	Radiographic Appearance	Typical Anatomic Location	MDCT Density Range (HU)
D1	Primarily composed of dense cortical bone Marrow spaces are hardly visible	Occasionally in anterior mandible Rarely in posterior mandible	>1250
D2	Thick outer layer of porous cortical bone Coarse trabecular bone pattern	Commonly in anterior and posterior mandible Occasionally in anterior maxilla	850–1250
D3	Thinner layer of porous cortical bone Fine trabecular bone pattern	Commonly in anterior maxilla, posterior maxilla, and posterior mandible Occasionally in anterior mandible	350–850
D4	Faint to imperceptible outline of thin cortical bone Alveolar process is primarily composed of fine trabecular bone	Commonly in posterior maxilla Rarely in anterior maxilla	150–350

HU, Hounsfield units; *MDCT*, multidetector computed tomography.

Modified from Misch CE. *Contemporary Implant Dentistry.* 3rd ed. St. Louis: Mosby; 2008.

Chang E. Dental implants. In: Mallya SM, Lam EWN. (eds). White and Pharoah's Oral Radiology, Principles and Interpretation (8th edn). St. Louis: Elsevier, 2019, p 259.

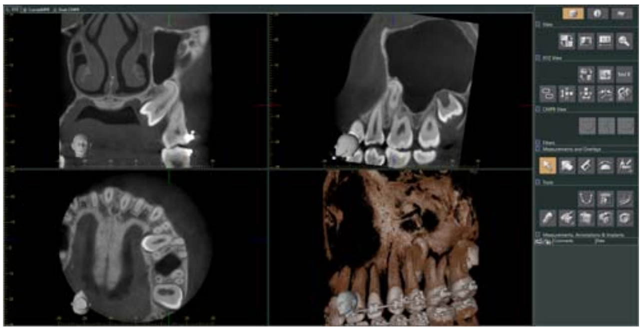
Bone density in CBCT

- Hounsfield units????
- From experimental and clinical research, great variability of gray values can exist on CBCT images
- Gray values in CBCT should be generally avoided at this time.

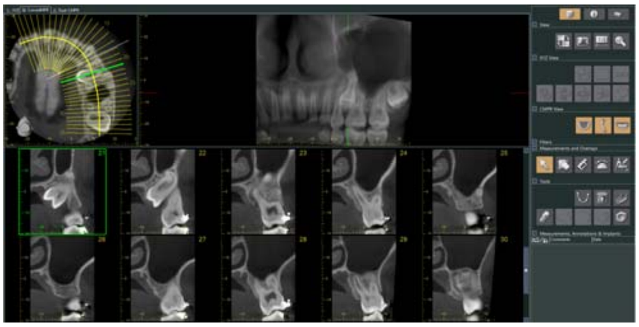
Origin: Pauwels et al. CBCT-based bone quality assessment: are Hounsfield units applicable? Dentomaxillofac Radiol 2015; 44: 20140238.

Embedded tooth 25:

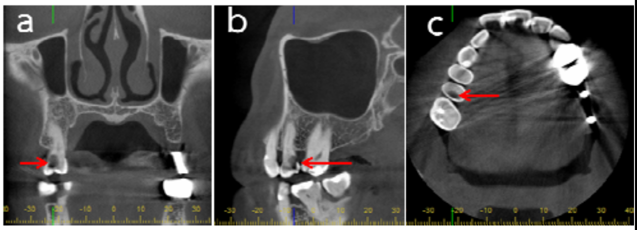
root dilaceration, external root resorption



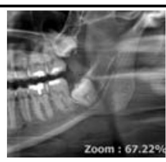
Cross-sectional view (transaxial view)

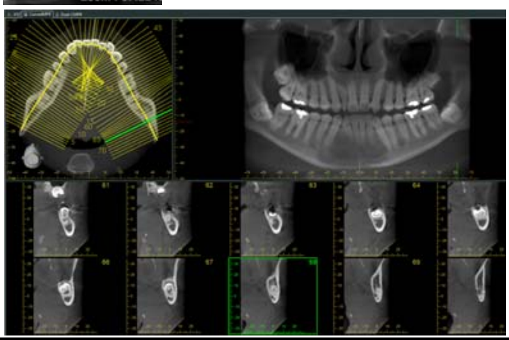


Caries (incidental finding)



Impacted third molar





Mandibular Third Molar Removal

Grade C recommendation:

´´where conventional radiographs suggest a direct interrelationship between a mandibular third molar and the mandibular canal, and when a decision to perform surgical removal has been made, CBCT may be indicated´´

Origin: European Commission. Radiation Protection no 172, Cone beam CT for dental and maxillofacial radiology. Evidence-Based Guidelines. 2012. Available from: https://ec.europa.eu/energy/sites/ener/ files/documents/172.pdf

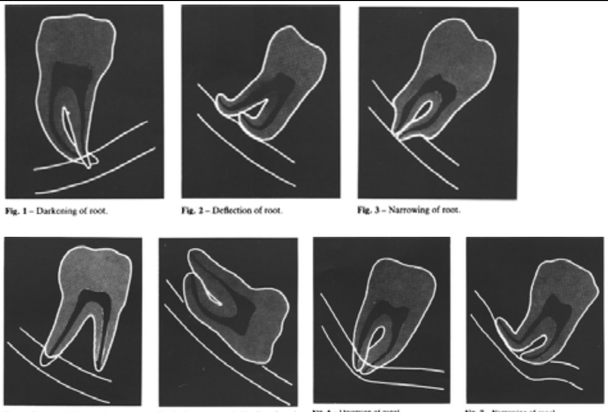


Fig. 1 – Darkening of root. Fig. 2 – Deflection of root. Fig. 3 – Narrowing of root.

Fig. 4 – Dark and bifid apex of root. Fig. 5 – Interruption of white line of canal. Fig. 6 – Diversion of canal. Fig. 7 – Narrowing of canal.

Origin: Rood JP, Shehab BA. The radiological prediction of inferior alveolar nerve injury during third molar surgery. Br J Oral Maxillofac Surg 1990; 28: 20–5. doi: https://doi.org/10.1016/0266-4356(90) 90005-6

Literature review

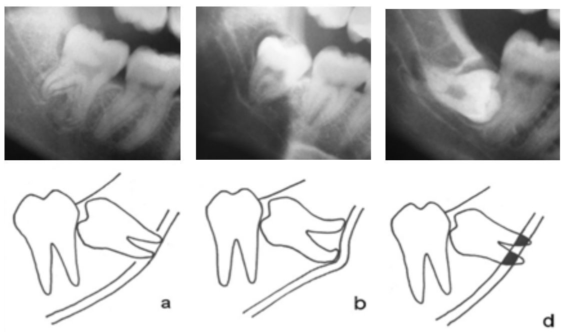
Table 2. Relationship between LTM and alveolar canal on OPG and CT.

Author	Year	N° Patients	N° LTM	CT: N° of cases with absense of cortical in IAC	Radiographic signs on OPG related with absence of IAC cortical bone on CT			
					Canal			LTM root
					Interrup-tion	Diversion	Narrowing	Darkening
Monaco et al. (4)	2004	44	73	50	+	-	+	+
Nakawaga et al. (11)	2007	65	73	56	+	...	...	...
Nakamori et al. (12)	2008	443	119	48	-	+	+	+
Jhamb et al. (5)	2009	29	31	9	+	-	+	+

IAC: Inferior alveolar canal
... Not evaluated
\+ Statistically significant (p<0.05)
\- Not statistically significant (p>0.05)

Origin: Palma-Carrió C, García-Mira B, Larrazabal-Morón C, Peñarrocha-Diago MA. Radiographic signs associated with inferior alveolar nerve damage following lower third molar extraction. Med Oral Patol Oral Cir Bucal. 2010 Nov 1;15 (6):e886-90. http://www.medicinaoral.com/medoralfree01/v15i6/medoralv15i6p886.pdf

3 signs significantly associated with IAN paresthesia



interruption of superior cortex of canal wall — diversion of the canal — darkening of the root

Szalma J, Lempel E, Jeges S, Szabó G, Olasz L. The prognostic value of panoramic radiography of inferior alveolar nerve damage after mandibular third molar removal: retrospective study of 400 cases. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;109:294-302

Cone beam CT imaging of the mandibular third molar: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR)

1) Does CBCT change the treatment of the patient?

Answer:

- For the majority of patients, the treatment is the same based on panoramic radiographs and CBCT.
- For the minority of patients, the treatment changed from full removal to coronectomy and vice versa.

Origin: Matzen LH, Berkhout E. Cone beam CT imaging of the mandibular third molar: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR). Dentomaxillofac Radiol 2019; 48: 20190039.

Cone beam CT imaging of the mandibular third molar: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR)

2) Does CBCT reduce the number of post-operative sensory disturbances of the IAN?

Answer: The overall conclusion of a meta-analysis is that CBCT does not reduce the number of post-operative sensory disturbances of IAN after full removal of a mandibular third molar. (Clé-Ovejero et al. J Am Dent Assoc 2017; 148: 575–83. doi: https://doi.org/10.1016/j.adaj.2017. 04.001)

Origin: Matzen LH, Berkhout E. Cone beam CT imaging of the mandibular third molar: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR). Dentomaxillofac Radiol 2019; 48: 20190039.

Cone beam CT imaging of the mandibular third molar: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR)

2) Does CBCT reduce the number of post-operative sensory disturbances of the IAN?

Additionally, CBCT did not reduce the operation time, number of pain-relieving analgesics, or complications leading to contact with the surgeon. (Petersen et al. Dentomaxillofac Radiol 2014; 43.20140001. doi: https://doi.org/ 10.1259/dmfr.20140001)

Origin: Matzen LH, Berkhout E. Cone beam CT imaging of the mandibular third molar: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR). Dentomaxillofac Radiol 2019; 48: 20190039.

Cone beam CT imaging of the mandibular third molar: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR)

2) Does CBCT reduce the number of post-operative sensory disturbances of the IAN?

Answer: An epidemiological study in Finland showed that despite the increased use of CBCT the number of permanent injuries to the IAN did not decrease. (Suomalainen et al. Acta Odontol Scand 2013; 71: 151–6. doi: https://doi.org/10.3109/00016357.2011. 654254)

Origin: Matzen LH, Berkhout E. Cone beam CT imaging of the mandibular third molar: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR). Dentomaxillofac Radiol 2019; 48: 20190039.

Cone beam CT imaging of the mandibular third molar: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR)

3) Can CBCT predict the risk for a post-operative sensory disturbance of the IAN?

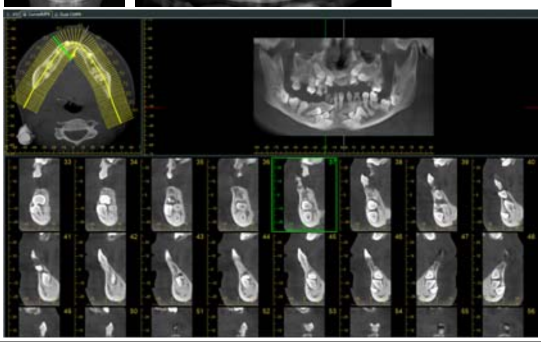
Answer:
- Radiographic signs observed in CBCT are not more valid as predictors for a sensory disturbance of IAN compared to signs seen in panoramic radiographs.
- Particularly, the sign "no bony separation between roots of third molar and mandibular canal" seen in CBCT had a low positive predictive value.

Origin: Matzen LH, Berkhout E. Cone beam CT imaging of the mandibular third molar: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology (EADMFR). Dentomaxillofac Radiol 2019; 48: 20190039.

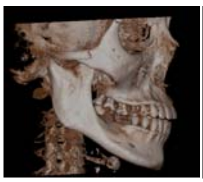
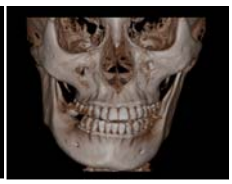
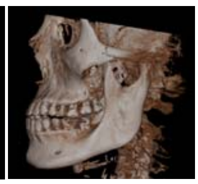
Recommendations from European Academy of DentoMaxilloFacial Radiology (EADMFR)

1) CBCT should not be used routinely when assessing mandibular third molars for extraction (Grade A) or coronectomy (Grade C).
2) Panoramic imaging in most cases leads to the same patient outcome, with lower costs and radiation dose.
3) CBCT should only be applied when surgeon has a very specific clinical question in an individual patient case that cannot be answered by conventional (panoramic and/or intraoral) imaging.


Cleidocranial dysostosis



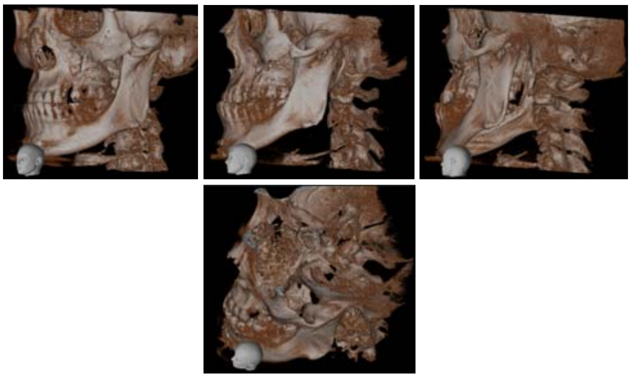
Orthognathic surgery

TMJ ankylosis

Coronoid fused to temporal bone

Coronoid fused to temporal bone



Coronoid fused to temporal bone

Bilateral osteoarthrosis

TMJ arthritis

- There is a poor correlation between the severity of arthritis on CBCT and symptoms of the disease. (Petersson Journal of Oral Rehabilitation 2010; 37: 771–778)
- One study has shown CBCT imaging led to changes in primary diagnosis and management in more than half the patients with TMJ disorders. (de Boer EWJ et al Br J Oral Maxillofac Surg 2014; 52: 241-6)