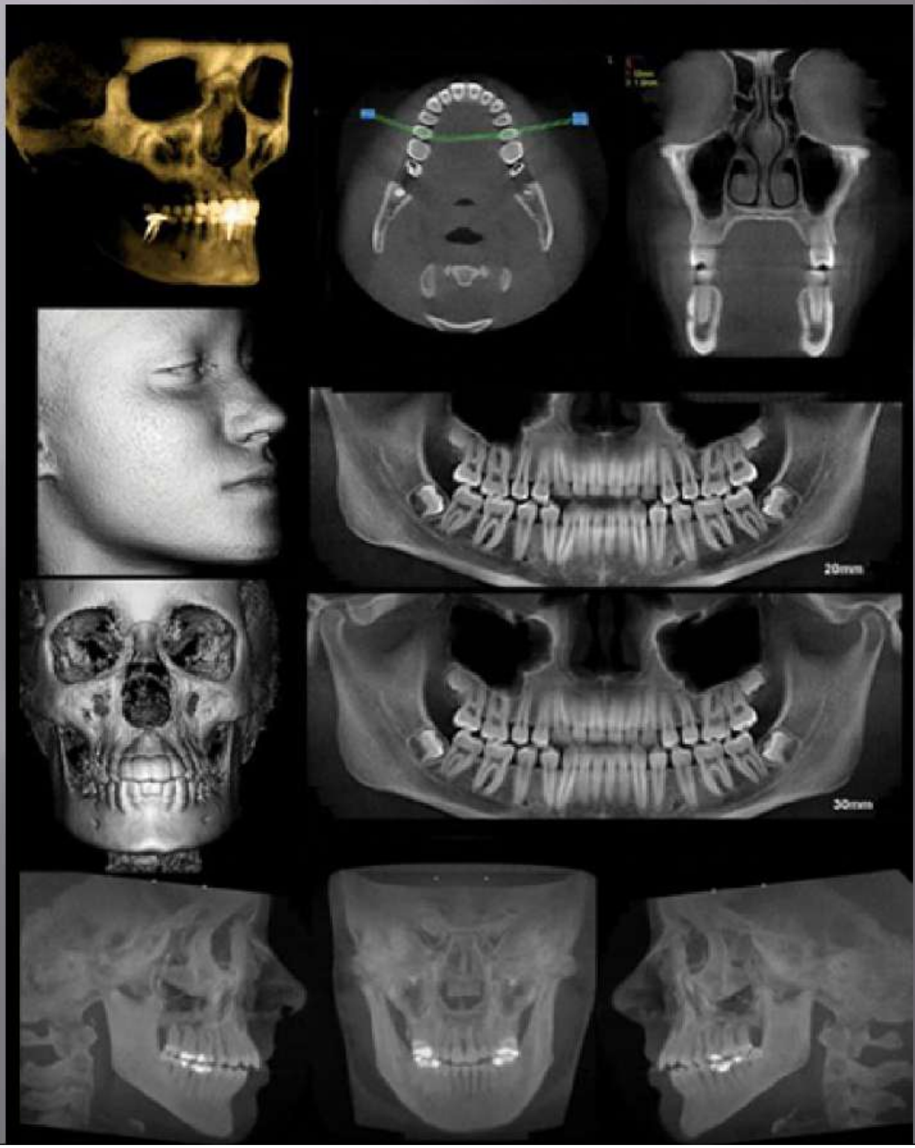
IN THE NAME OF GOD

Cone-Beam Computed Tomography



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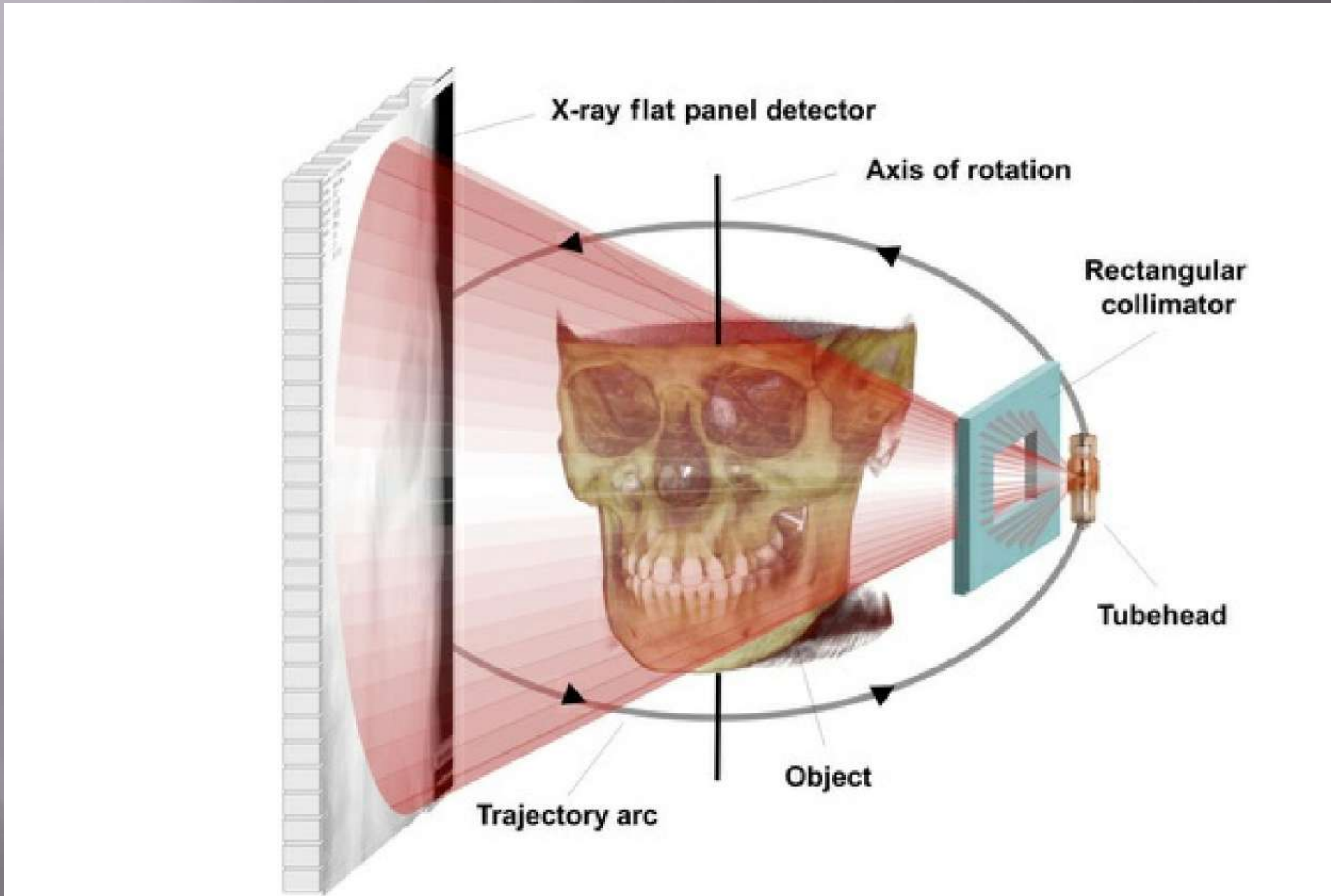
- *Hamadan Dental school*

CBCT

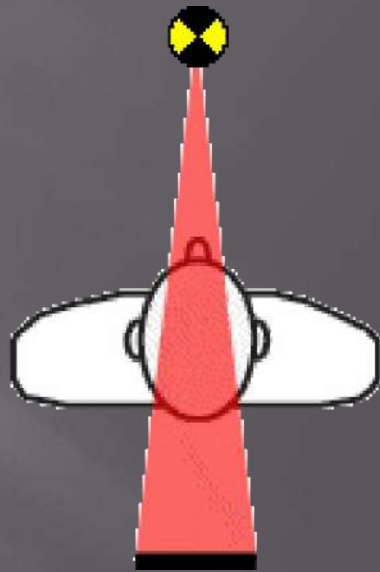
- **A divergent or "cone" shaped source of ionizing radiation**
- **Two – dimensional area detector fixed on a rotating gantry**
- **Acquire multiple sequential projection images in one complete scan**

(exceeding 180 degrees)


X-ray flat panel detector
Axis of rotation
Rectangular collimator
Tubehead
Object
Trajectory arc

- single projection images known as basis images
- Similar to lateral cephalometric radiographic images each slightly offset from one another
- Software programs including back- filtered projection applied to generate a 3D volumetric data in three orthogonal planes (axial ,sagittal and coronal)

Scanning in Cone Beam CT



Components Of Image Production

X-ray generation

- **X-ray detection**
- **Image reconstruction**

Patient positioning

In three possible position : sitting , standing and supine

Seated units are the most comfortable

With all systems it is important to immobilize the patient


i-CAT

X-Ray Generator

- May be continuous or pulsed coincide with the detector activation
-
- CBCT exposure factors adjusted basis of patient size

✓ automatic exposure control

Exposure Parameters and pulsed x ray beam and size of image field determination patient exposure

Scan Volume or Field of View

- detector size and shape,
- beam projection geometry
- ability to collimate the beam.
- ✓ cylindrical or spherical
- ➤ Collimating :limits x radiation exposure to the ROI
- ↓unnecessary exposure to the patient
- best images →↓ scattered radiation

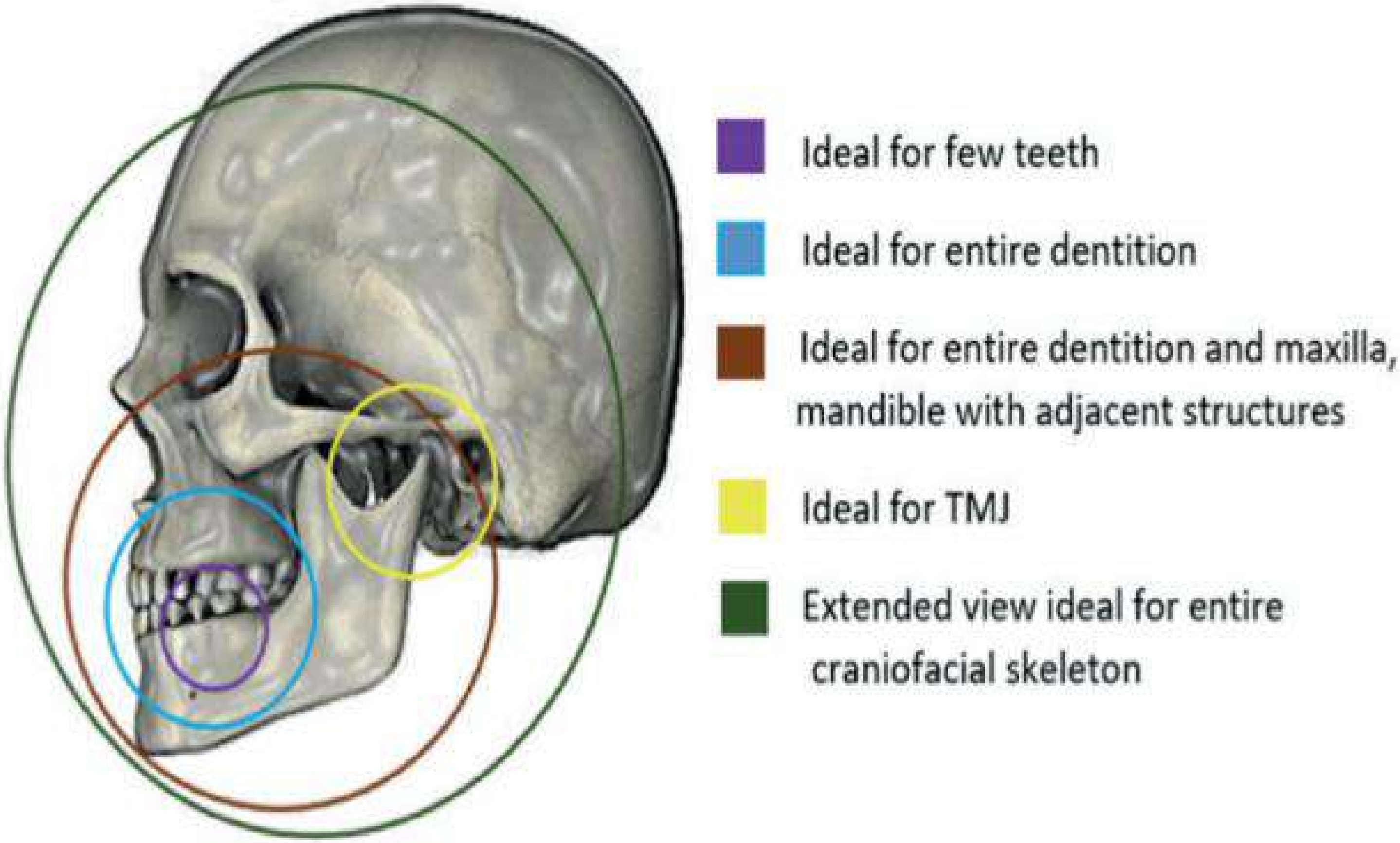
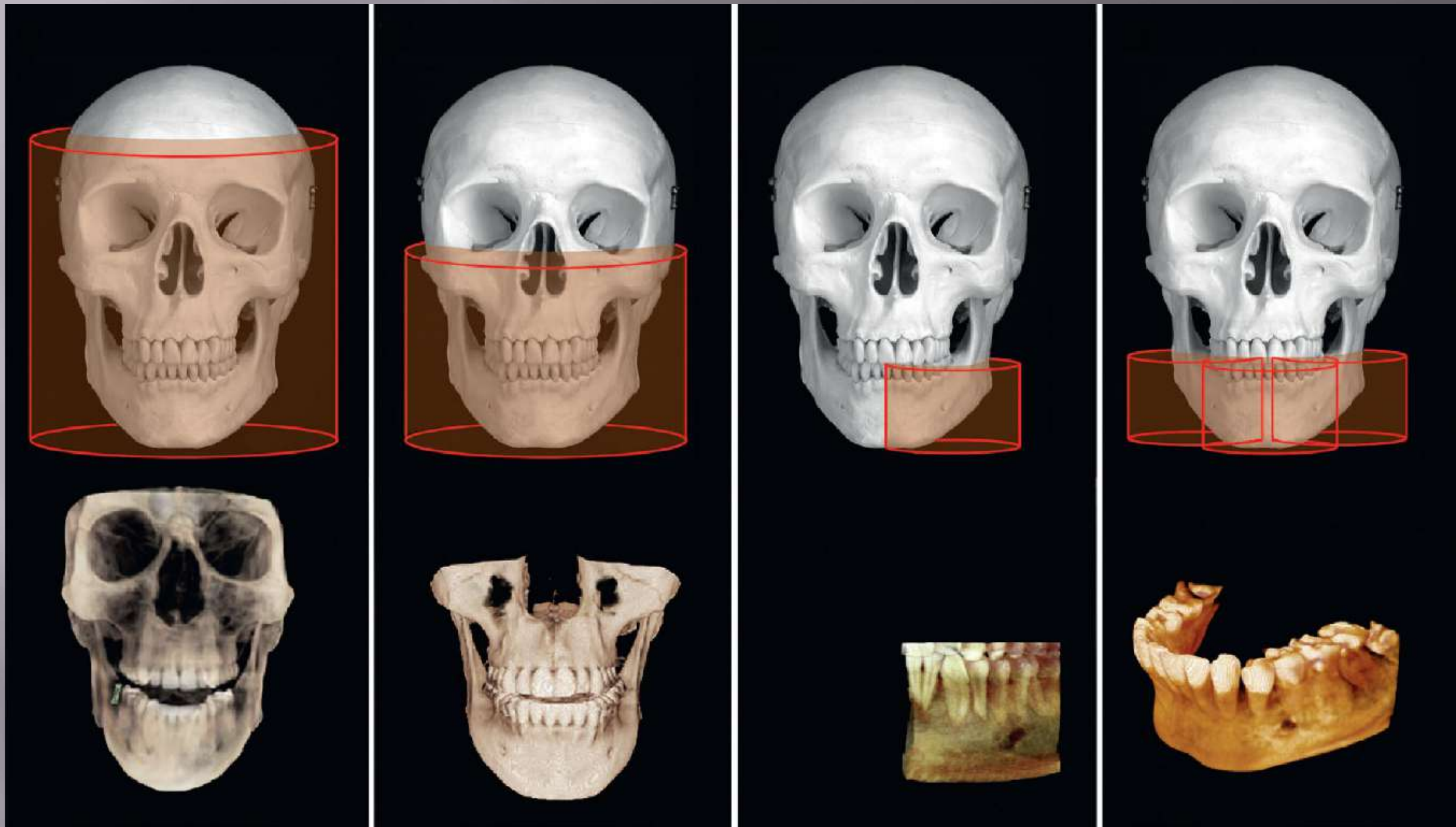
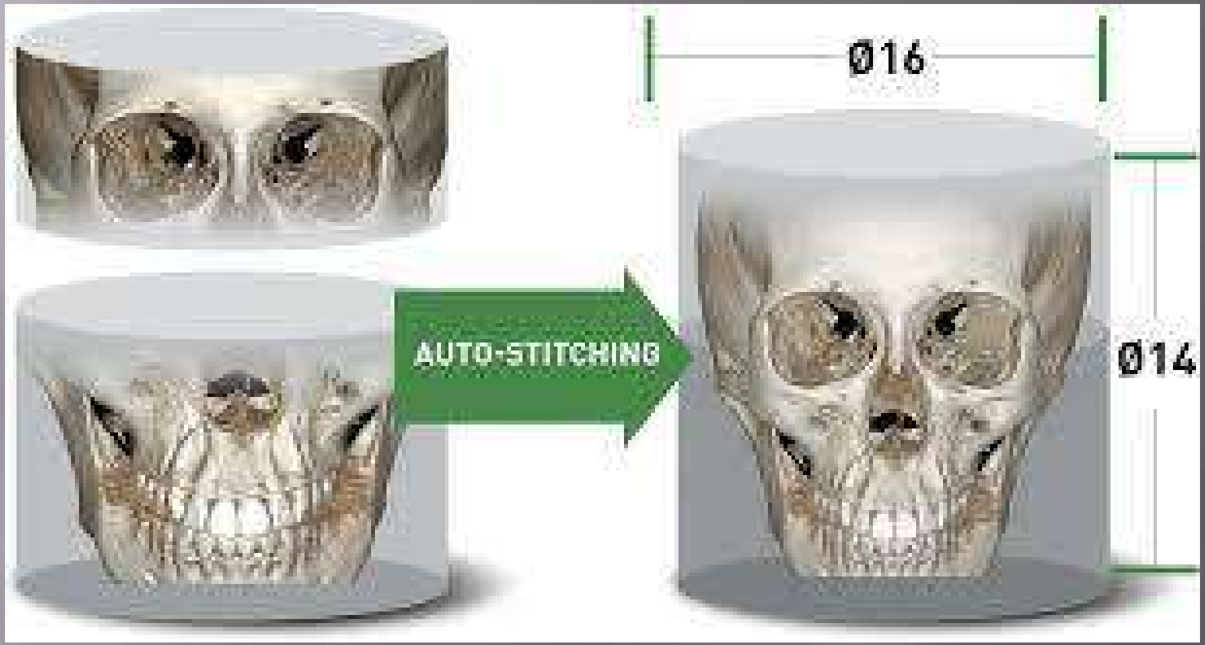


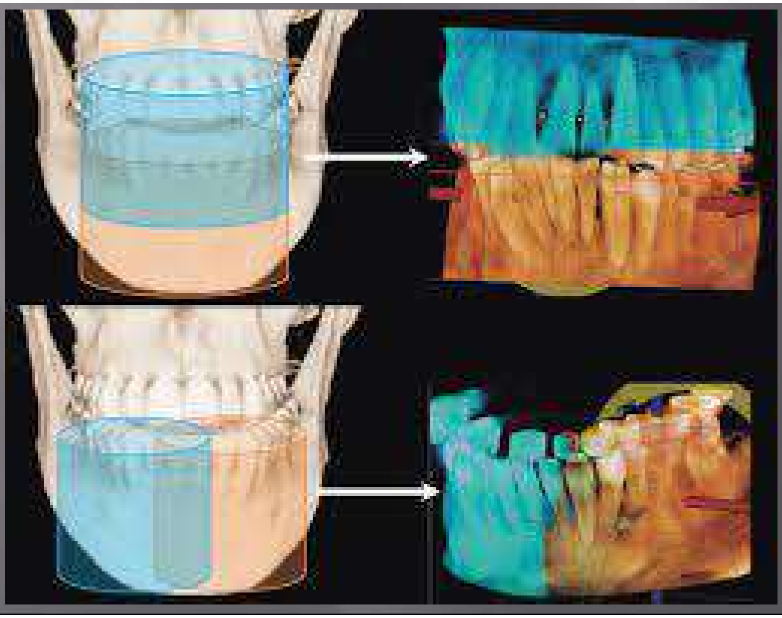
Figure 4. *Showing the capability of CBCT machines to collimate (select FOV's) the X-ray beam to suit the needs of individual clinical situations.*



Classification of CBCT units according to the FOV. **A, Large FOV scans provide images of the entire craniofacial** skeleton, enabling cephalometric analysis. **B, Medium FOV scans image the maxilla or mandible or both. C, Focused or restricted FOV** scans provide high-resolution images of limited regions. **D, Stitched scans from multiple focused FOV scans provide larger regions of interest** to be imaged from superimposition of multiple scans.

Blending or Stitching





Scan Factors

Frame Rate

Signal to Noise ratio

Metal Artifacts

Scan Time

Radiation Dose

Primary reconstruction Time

Image Detectors

- Image Intensifier tube/charge –coupled device (II/CCD)

- Flat panel detectors(FPDs)
- ✓ Cesium iodide scintillatore applied to amorphous silicon

Voxel Size

- Determined spatial resolution
- Isotropic equal in all three dimensions
- Motion during exposure and the type of scintillator and image reconstruction algorithms influenc image resolution

Images Artifacts

- **Any distortion or error in the image that is unrelated to the subject being studied.**
- **CBCT images inherently have more artifacts than MDCT images.**
- Inherent Artifacts
- Procedure-Related Artifacts
- Introduced Artifacts
- Patient Motion Artifacts

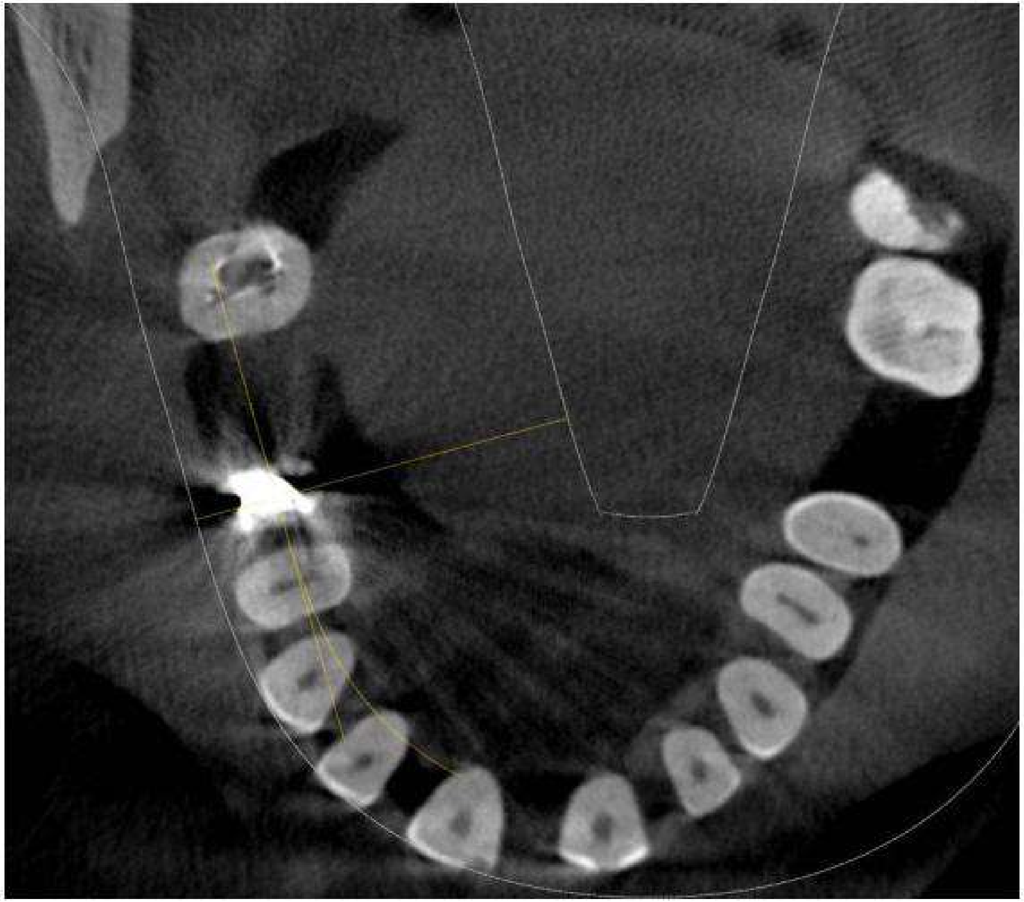


Figure 1. Artefact causing image degradation.

Figure 2. Noise reducing image contrast.

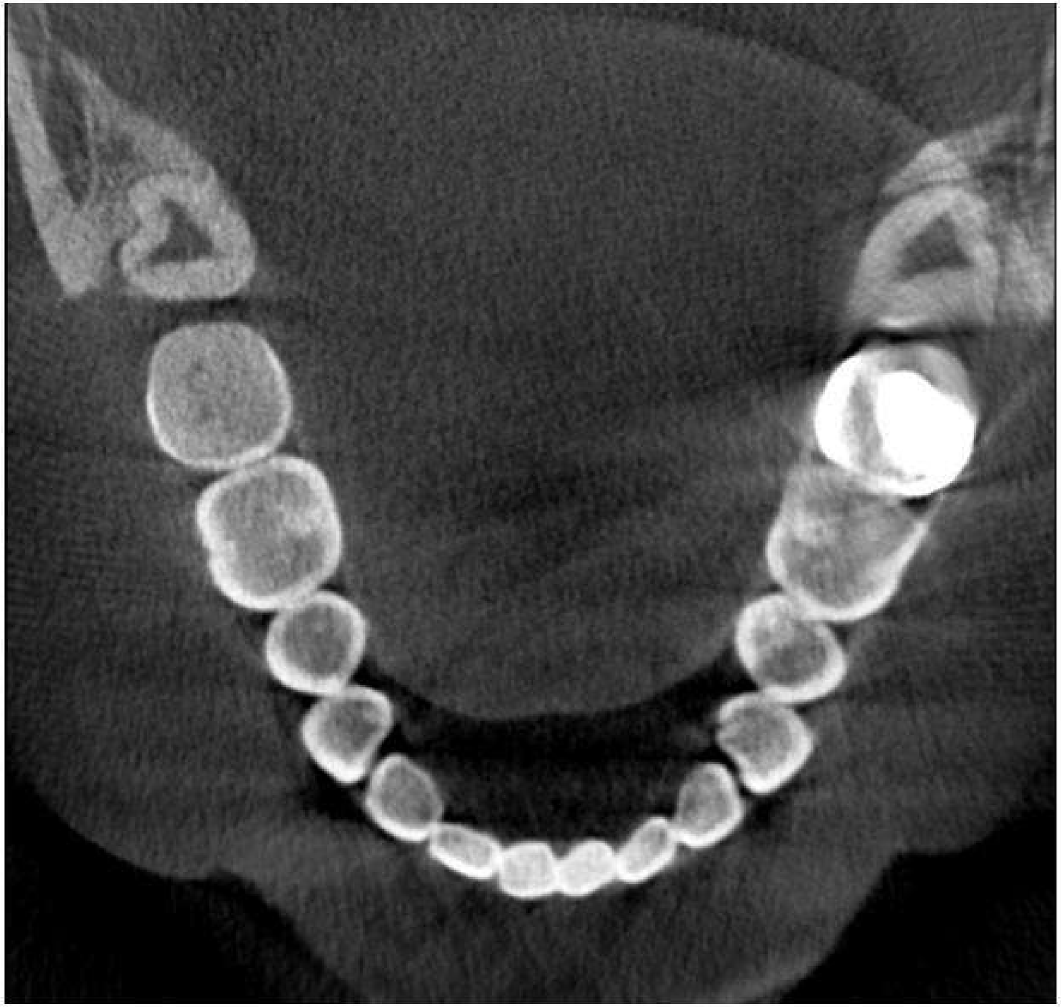
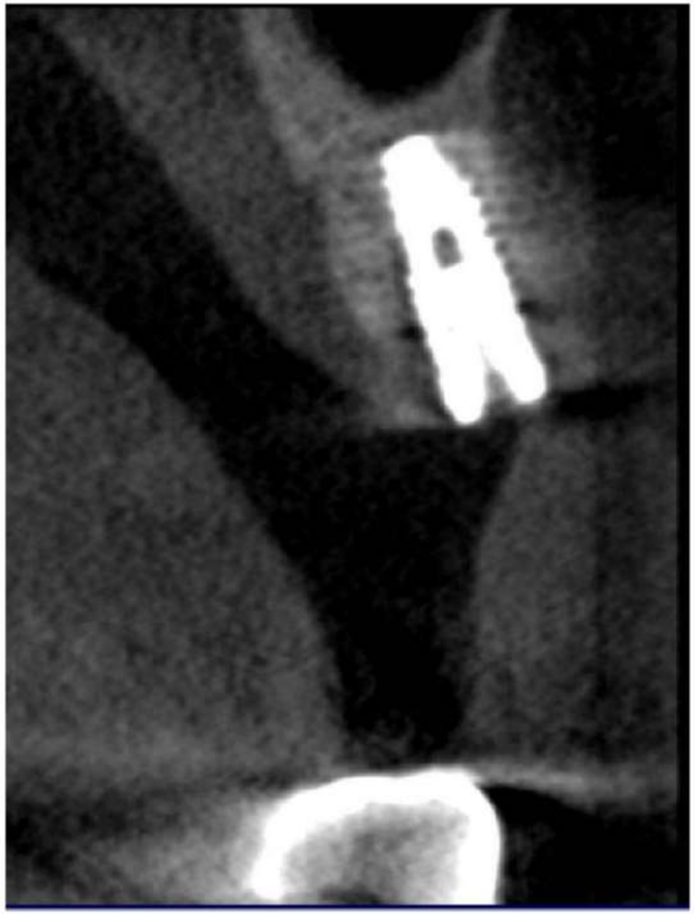


Figure 3. Metal restoration artefact seen on axial image.



(a)

(b)

Figure 4. Implant artefact on axial and cross sectional image.

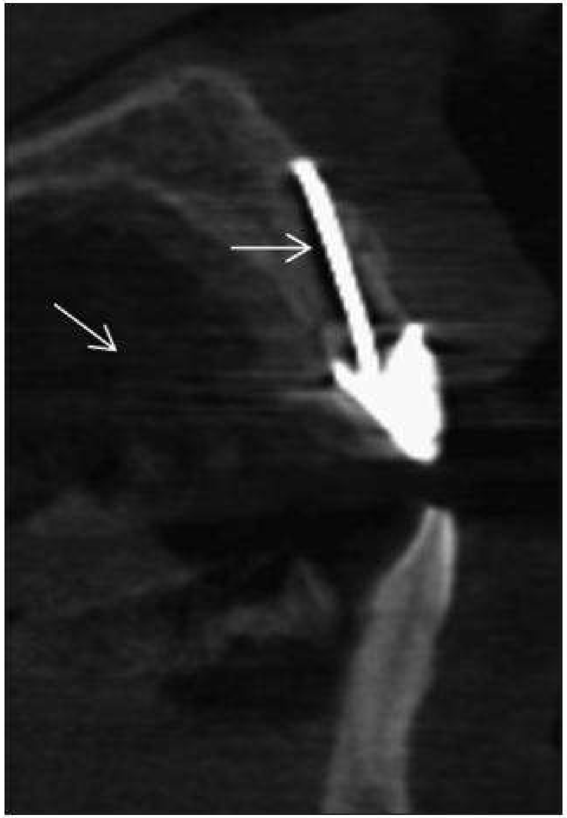


Figure 2: Beam hardening artifact adjacent to a silver point and metal artifact streaks from the metal coping

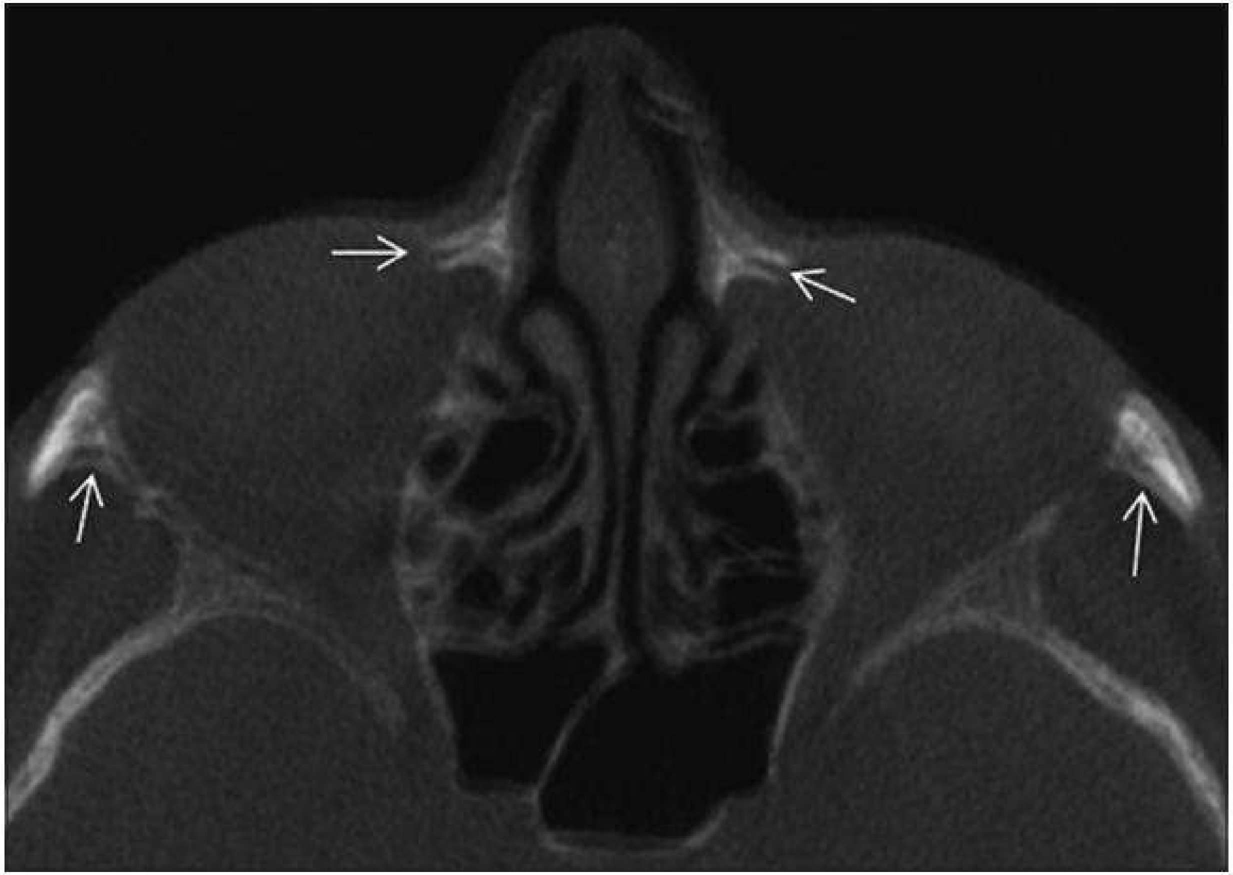


Figure 3: Blurring and double cortices caused by motion artifact

Figure 4: Ring artifact caused by calibration error

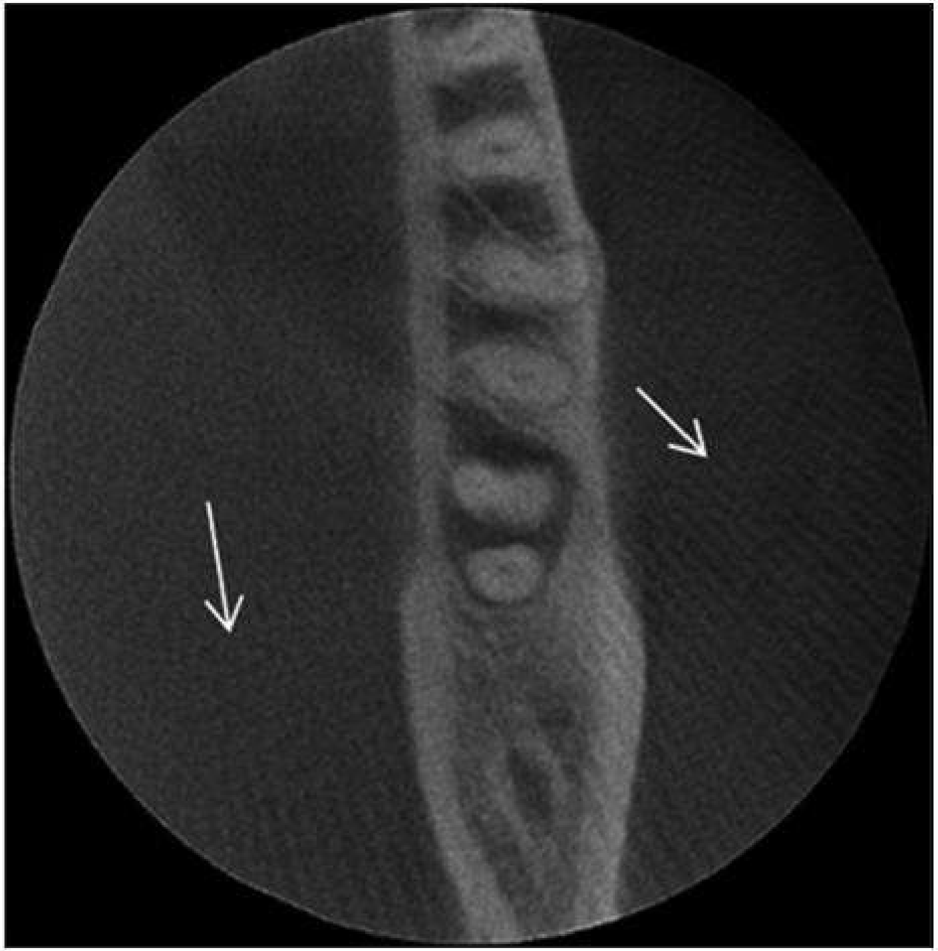


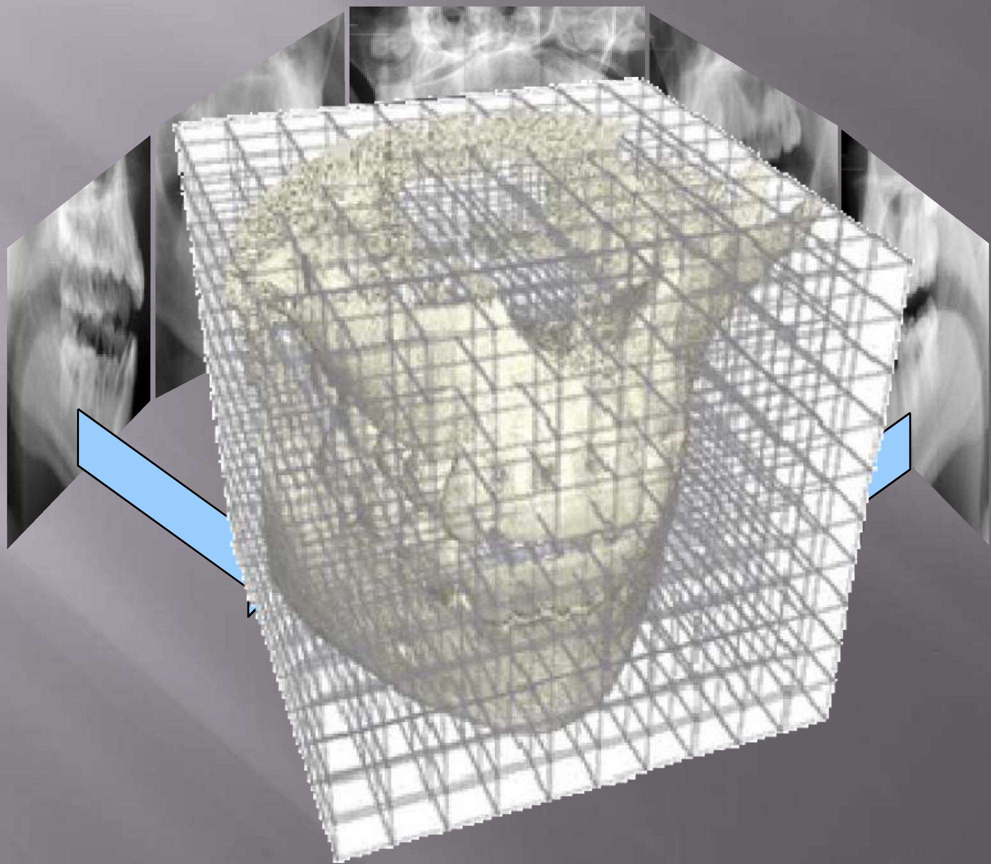
Figure 6: Aliasing pattern artifact

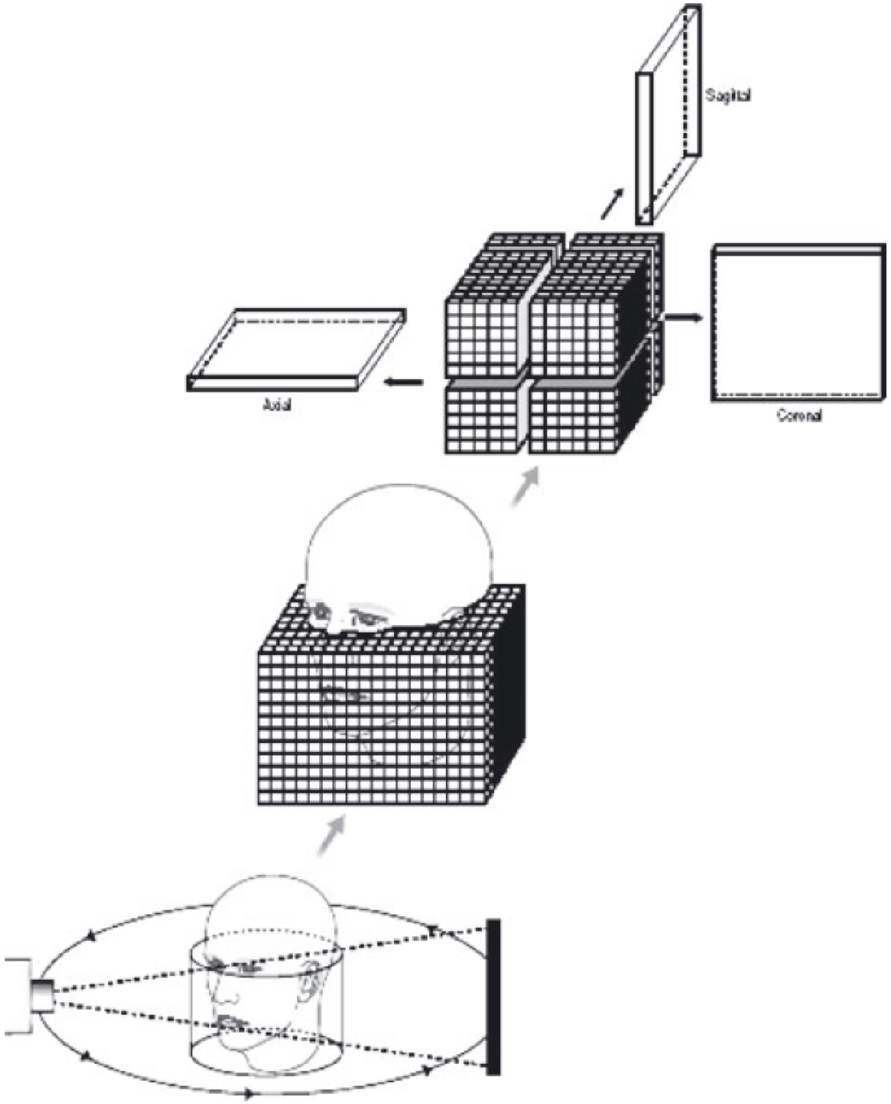
Partial Volume Averaging

- Both MDCT and CBCT imaging

- The selected voxel size of the scan is larger than the size of the object being imaged.

Reconstruction in CBCT

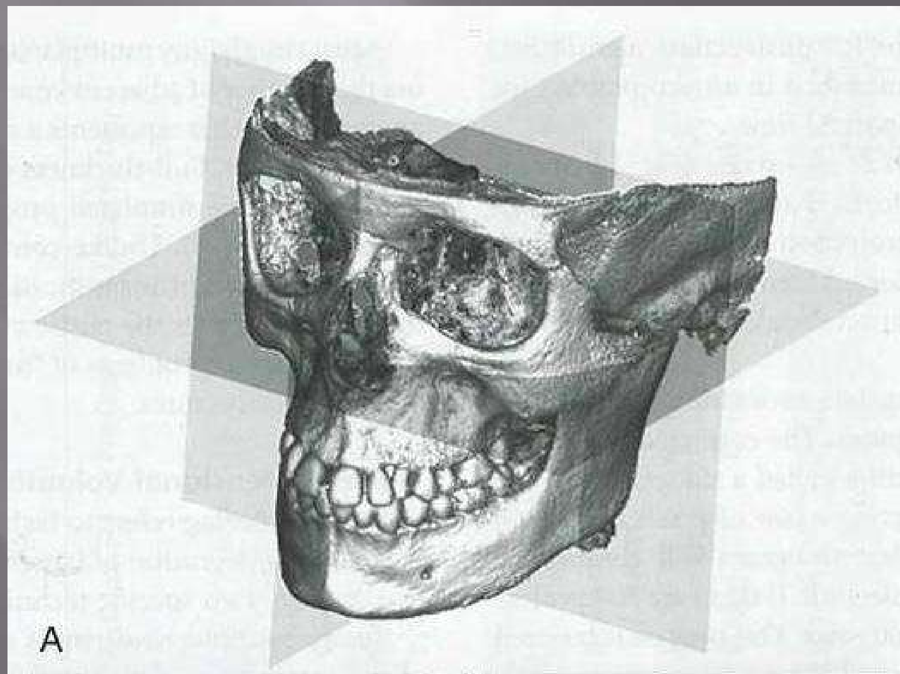


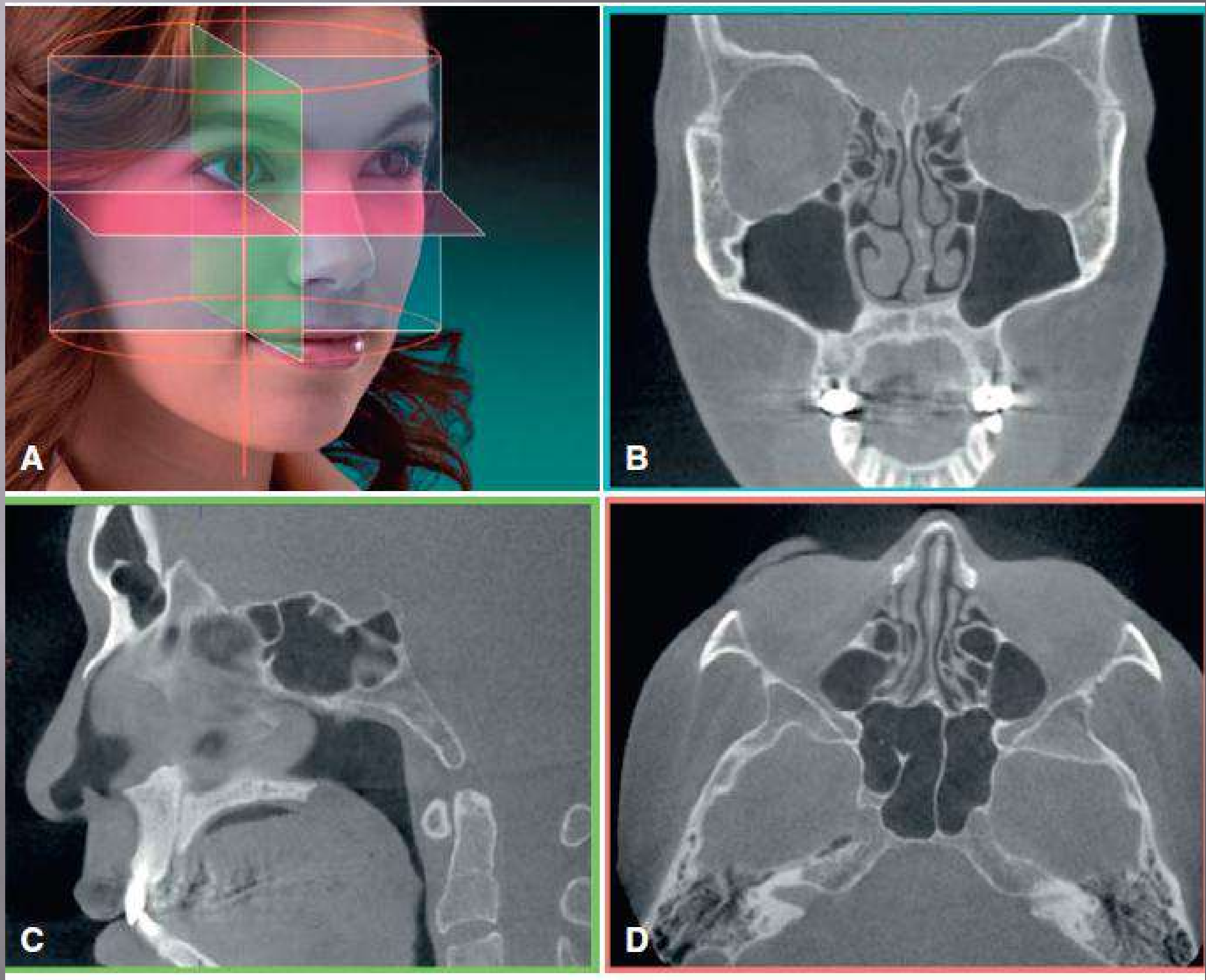

Sagittal
Axial
Coronal

Display

Reconstructed images in three orthogonal planes :

axial ,sagittal and coronal

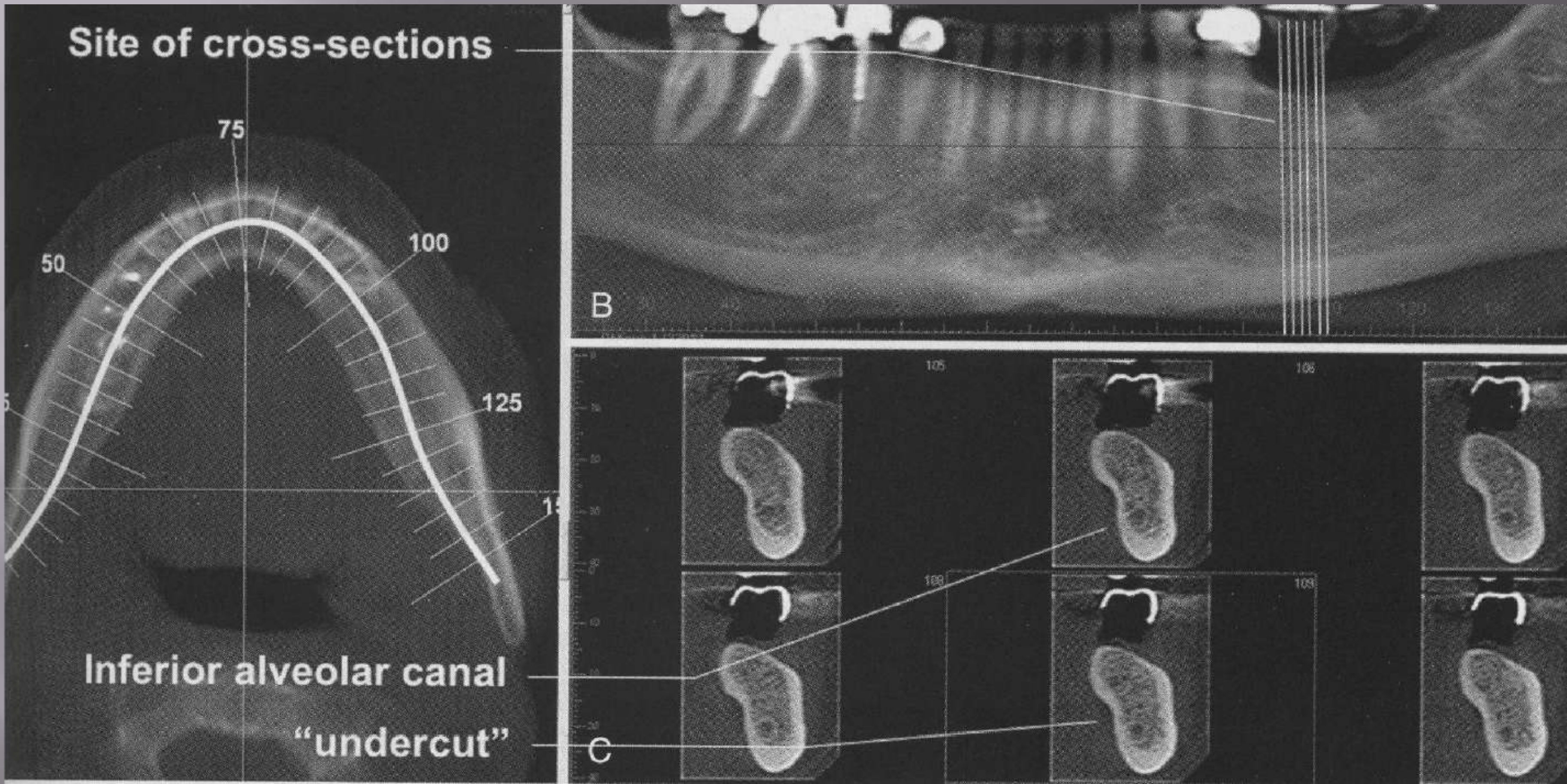



A
B
C
D

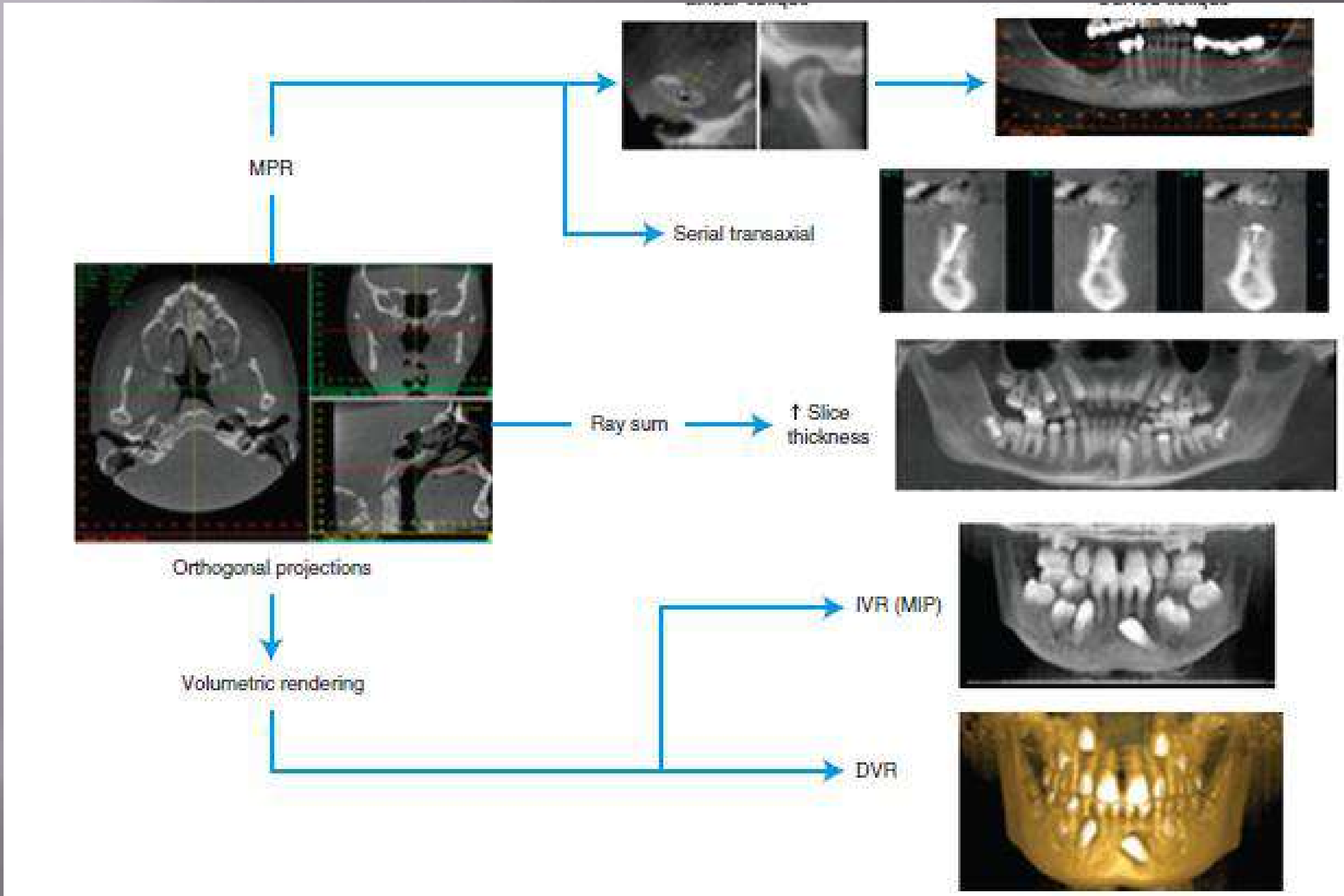
Multiplanar reformation

Because of the isotropic nature of acquisition the volumetric data set can be sectioned non orthogonally to provide nonaxial two-dimentional images referred to **multiplanar reformation:**

1. oblique ,curved planar reformation
2. serial transplanar reformation (serial cross-sectional)



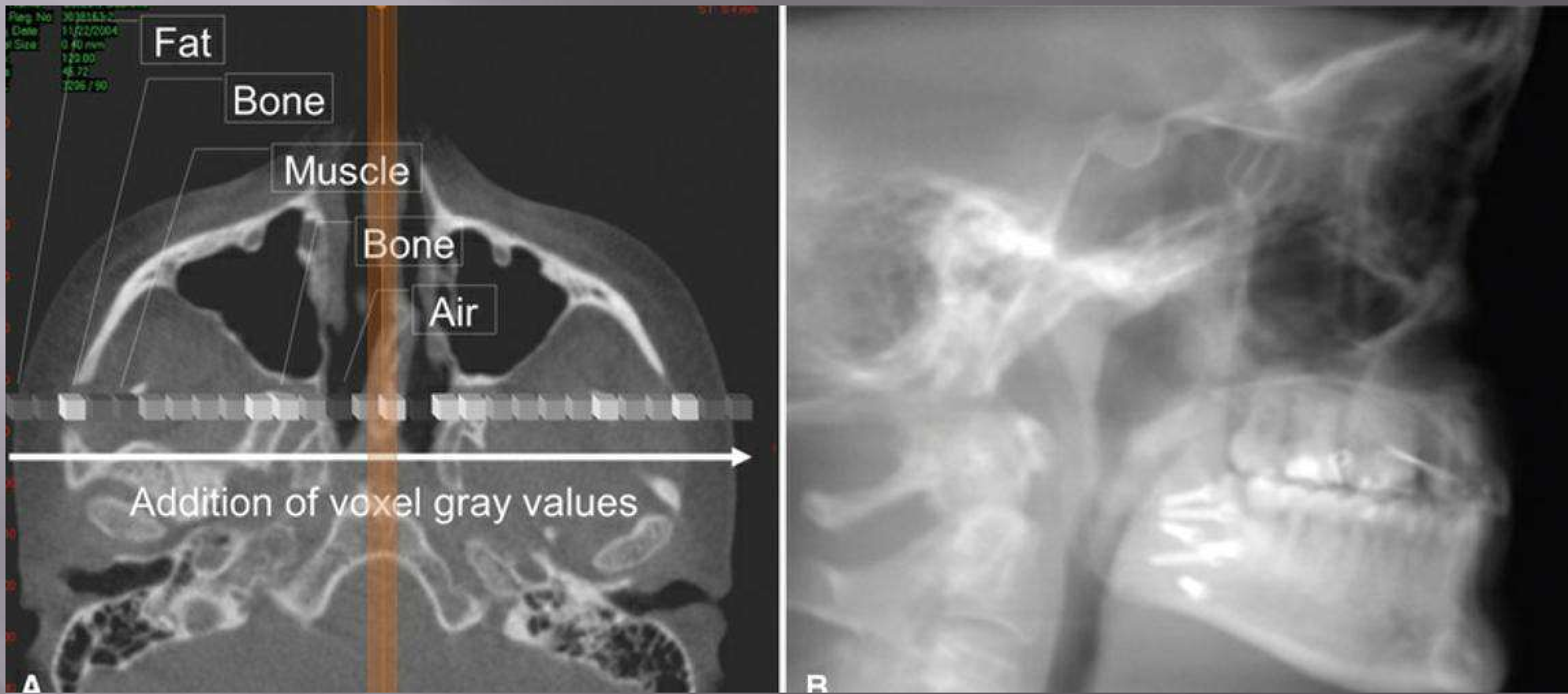
Site of cross-sections
75
50
100
125
B
Inferior alveolar canal
"undercut"
C



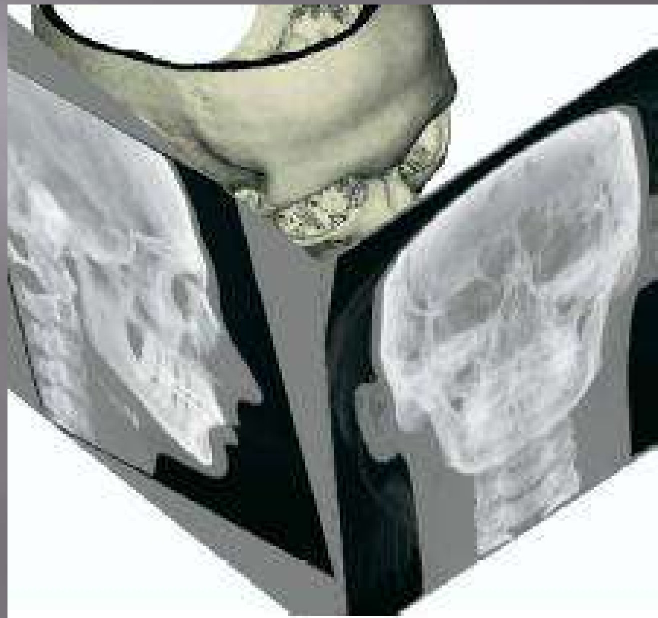
MPR
Serial transaxial
Ray sum
↑ Slice thickness
Orthogonal projections
Volumetric rendering
IVR (MIP)
DVR

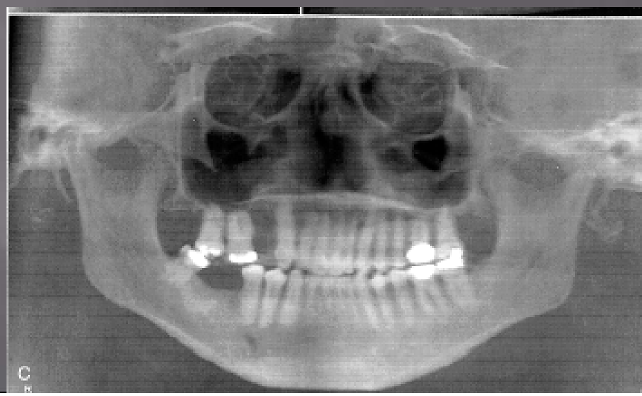
Ray sum reformation

- Slice of orthogonal or MPR images can thick ened by increasing the number of adjacent voxels creates image slab referred as ray sum
- Full thickness ray sum similar to cephalometric images
- Without magnification and parallax distortion
- Affected by anatomic noise and superimposition of multiple structures


Fat
Bone
Muscle
Bone
Air
Addition of voxel gray values

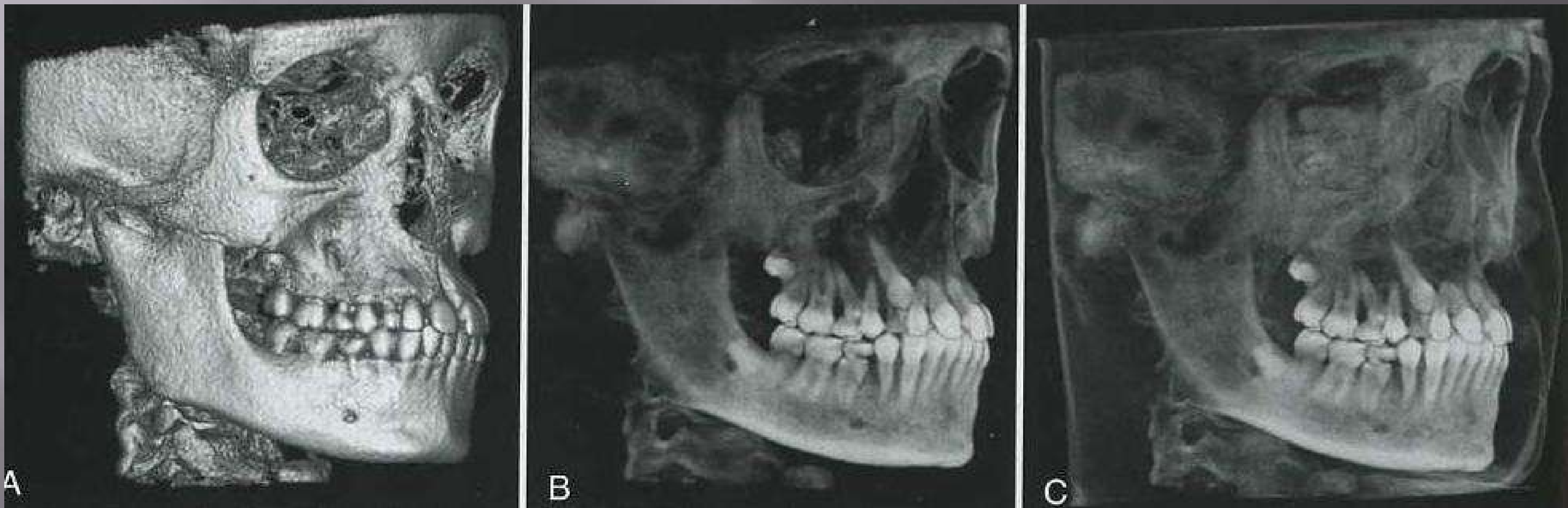
Ray sum reformation





Three – Dimentional Volume Rendering

Techniques that allow the visualization of 3D data

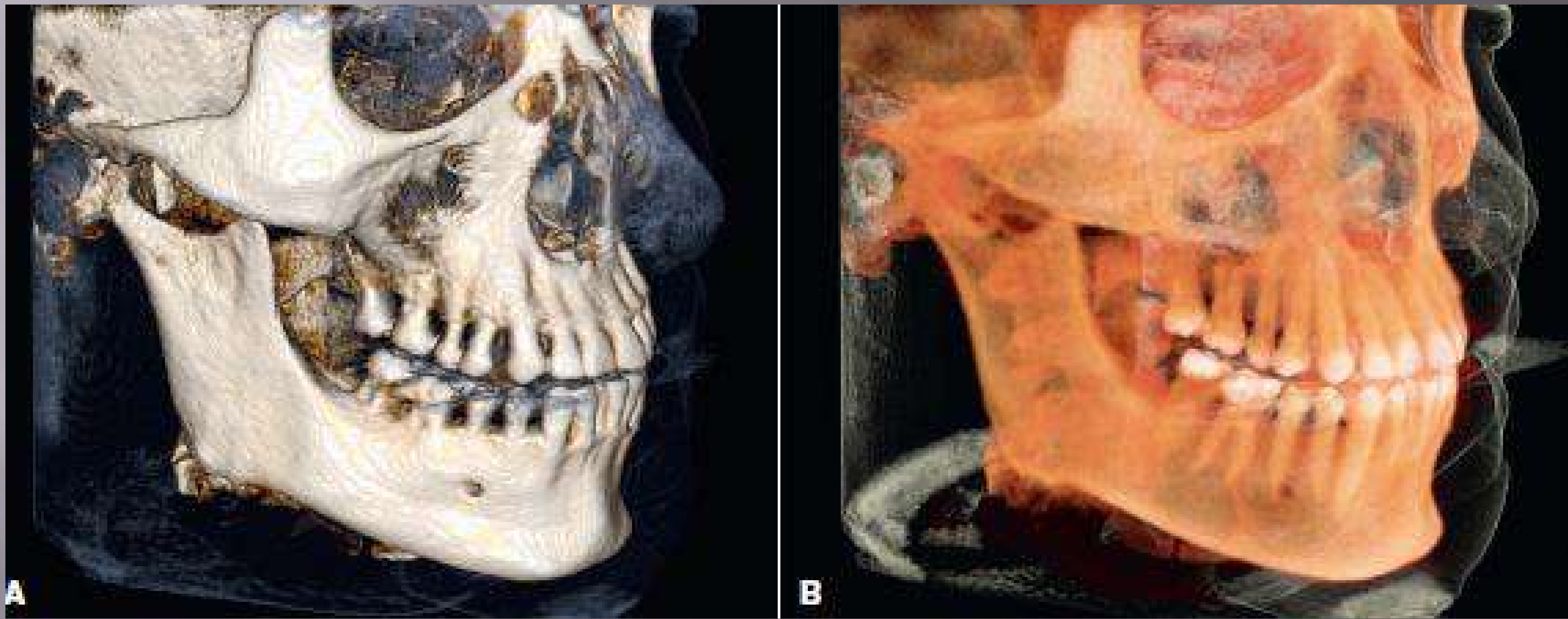


Indirect volume rendering or segmentation

- selection of range of intensity values and provides a volumetric surface reconstruction with depth
- Requiring specific software
- Two types of views:

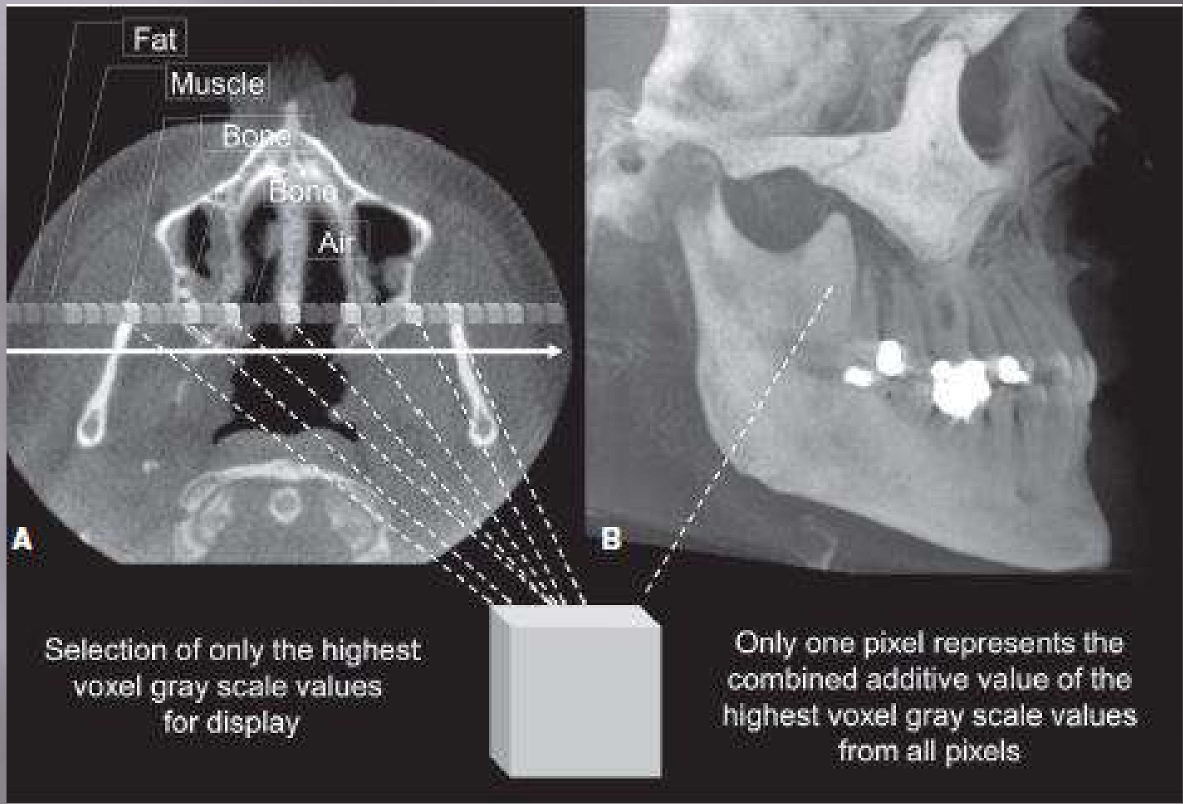
Solid or surface rendering

Transparent or volumetric rendering

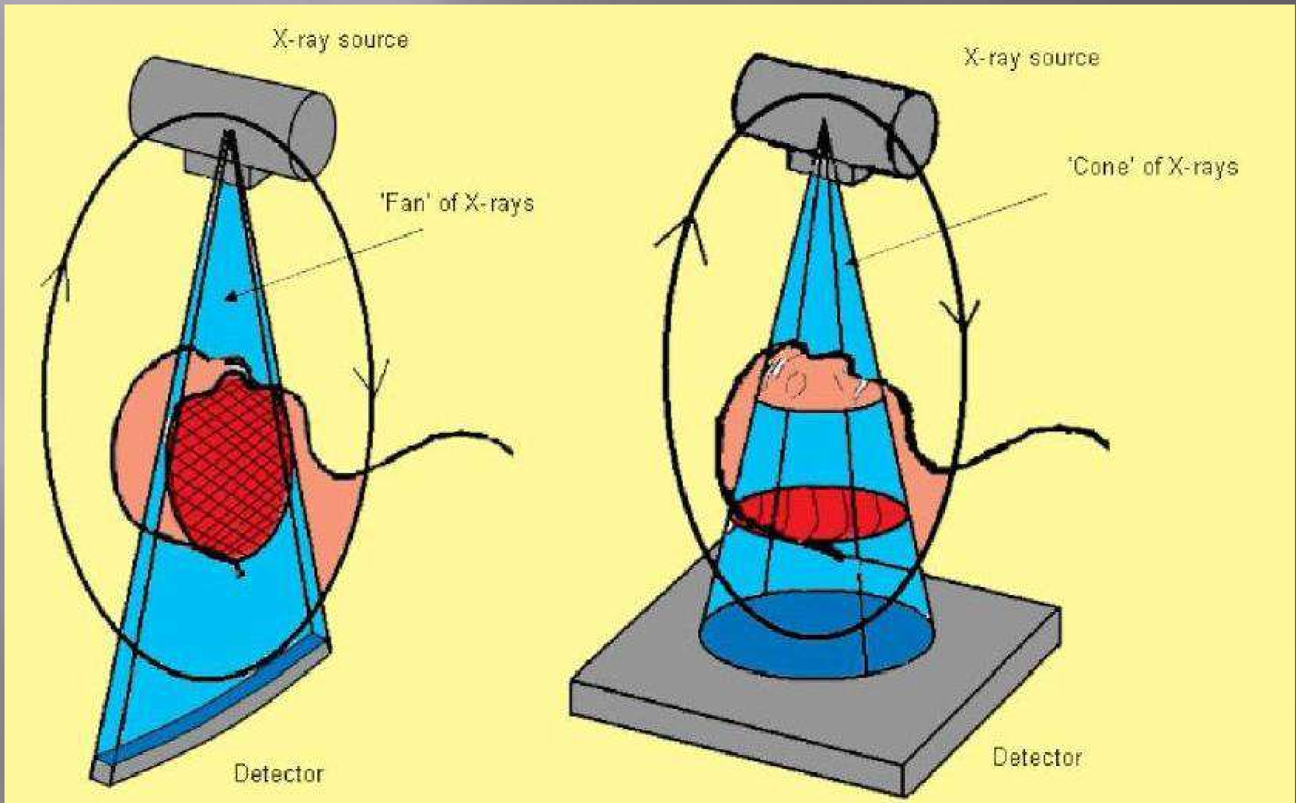

A
B

Direct volume rendering

- Much simpler process
- Selection of arbitrary threshold of voxel intensities
- Most commonly maximum intensity projectin (MIP)
- Application: licatin of impacted teeth ,TMJ,fractures,surgical follow up,soft tissue dystrophic calcification


Fat
Muscle
Bone
Bone
Air
A
B
Selection of only the highest voxel gray scale values for display
Only one pixel represents the combined additive value of the highest voxel gray scale values from all pixels

Comparison between CBCT and CT



Rapid scan time

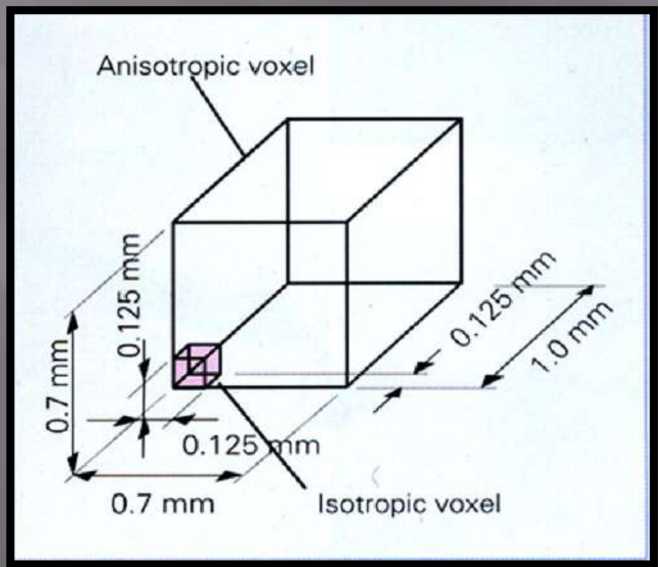
- Because Cone Beam CT acquires all basis images in a single rotation, scan time is rapid (less than 30 seconds) and comparable with that of medical spiral MDCT systems , where several fan beam rotations are required to complete the imaging of an object

Patient radiation dose

- Published reports indicate that the effective dose for various CBCT devices ranges from 5 to 1073 microsievert [μSv]) depending on the type and model
- Approximately 3 to 123 days equivalent per capita backradiation dose
- Approximately equivalent to 1 to 42 digital panoramic
- Dose reduction compared with “conventional” fan-beam CT systems

Submillimeter Resolution

- In conventional CT, the voxels are anisotropic
- All CBCT units provide voxel resolutions that are isotropic equal in all 3 dimensions
- Subsequent MPR of CBCT has the same resolution as basis projection (applicable for maxillofacial applications)



Intractive Analysis

- Access and interaction with medical CT data are not possible as workstations are required.

- Reconstruction of CBCT data is performed natively by a personal computer.

Size and cost

- ✓ Greatly reduced size and physical footprint compared with conventional CT
- ✓ Approximately one fourth to one fifth the cost

Reduced image artifact

- With manufacturers' artifact suppression algorithms and increasing number of projections, Cone Beam CT images can result in a low level of metal artifact, particularly in secondary reconstructions designed for viewing the teeth and jaws

limitations

- **Image noise**

  area beam and higher compton scattered radiation

  variations in hemogeneity(quantum mottle)

  added noise of the detector system

- **Poor soft tissue contrast**

  scattered radiation

  numerous inherent detector-based artifacts

Specific Application in Dentistry

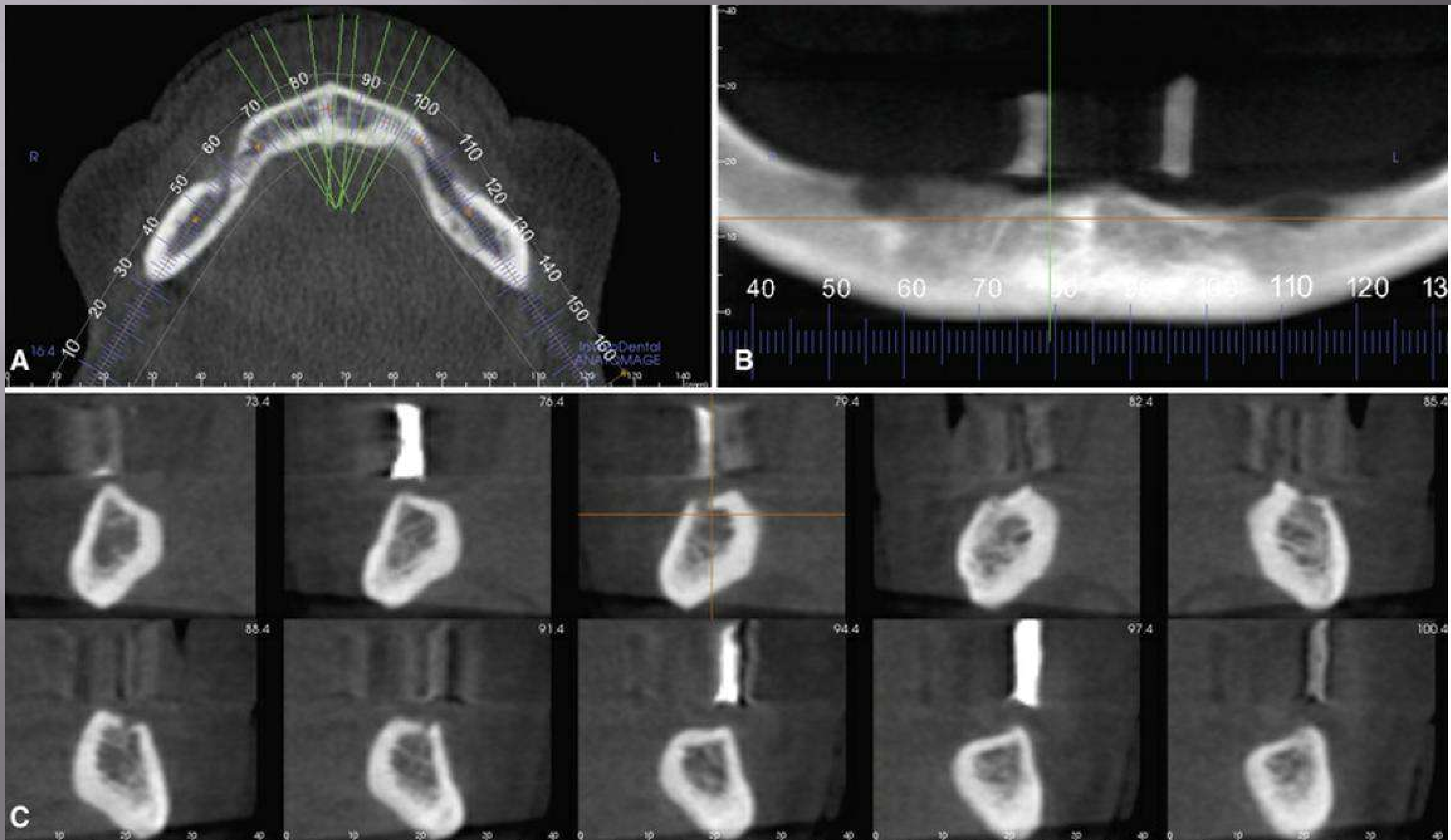
- **Not be considered a replacement for panoramic or conventional projection radiographic application but rather as a complementary modality for specific application**

Implant site assessment

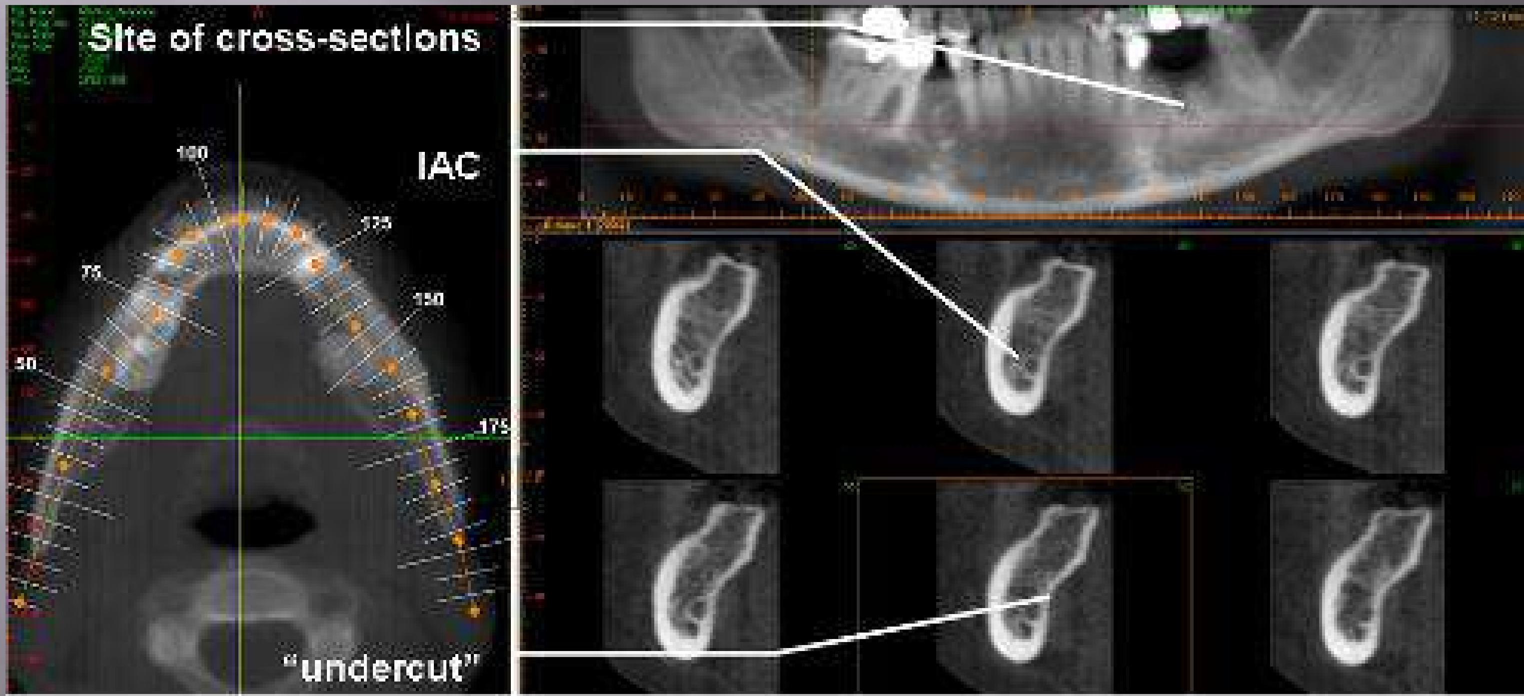
- Greatest impact
- Cross-sectional images of the alveolar bone height ,width ,and angulation
- Accurately depicts vital structures such as the inferior alveolar canal in the mandible or sinus in the maxilla
- Most useful series of images : axial , reformatted panoramic ,serial transplanar images

30
25
20
B
15
16
17
11.5
12.1
9.0

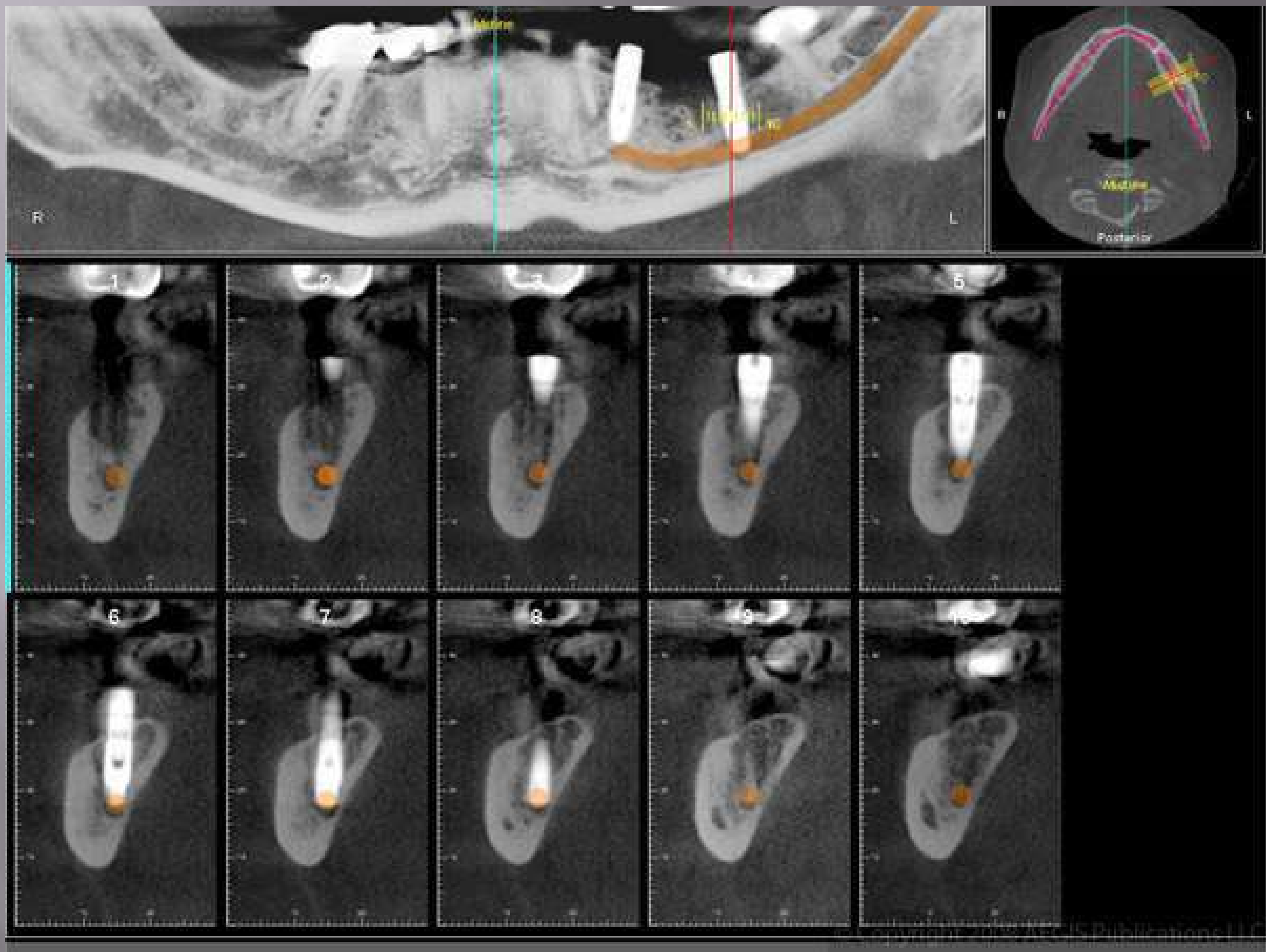
Radiographic template with hyperdense markers provides a precise reference of the location of the proposed implants



assessment of a potential implant site in the lower left jaw (mandible) of a patient with a recent extraction



A occlusal (left), panoramic (upper right) and serial cross-sectional 1mm thick images (lower right) of a potential implant site of the lower left mandible. The occlusal and panoramic images show the location whereas the cross-sectional images demonstrate the amount of undercut and location of the inferior alveolar canal (IAC) carrying the artery and nerve.


Midline
R
L
Posterior
1
2
3
4
5
6
7
8
9
10

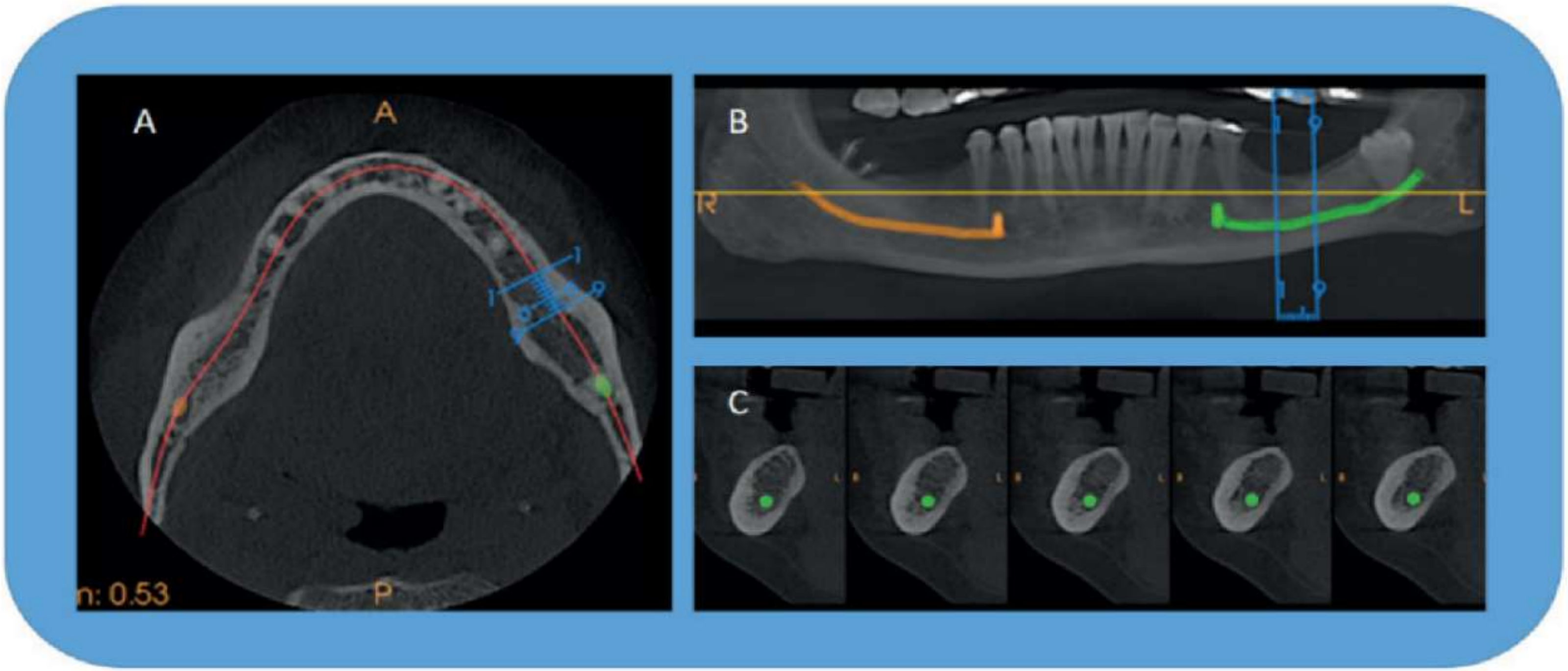


Figure 6. *CBCT scan– MPR showing axial view* ***(A)*** *with curved line (red solid line) for "panoramic" view* ***(B)*** *and set of cross-sections, 1-mm-thick images* ***(C)*** *of a potential implant site in the lower left mandible. Blue lines on the axial and panoramic images indicate the location of the cross-sections. Apart from information of bone quality and dimensions, the cross-sections reveal the amount of lingual undercut and location of the inferior alveolar canal (green).*

Endodontics

- nonspecific clinical signs and symptoms associated with previously endodontically treated teeth
- teeth with extra canals and suspected complex morphology
- identification and localization of calcified canals
- detection of vertical root fracture
- evaluating the nonhealing of previous endodontic treatment to help determine further treatment, such as nonsurgical, surgical, or extraction

Endodontics

- complications, such as overextended root canal obturation material, separated endodontic instruments, and localization of perforations
- presurgical treatment planning to localize root apex/apices and to evaluate the proximity to adjacent anatomical structures
- For diagnosis and management of limited dentoalveolar trauma, root fractures, luxation, and/or displacement of teeth, and localized alveolar fractures
- localization and differentiation of external and internal resorptive defects

Endodontics

- periapical conditions (A)
- periodontal, periapical, and sinus disease (B)
- root fracture and associated alveolar bone loss (C)

- (b) axial, (c) sagittal and (d) coronal views of a patient with internal resorption of the maxillary right incisor and external cervical resorption of the maxillary left incisor teeth

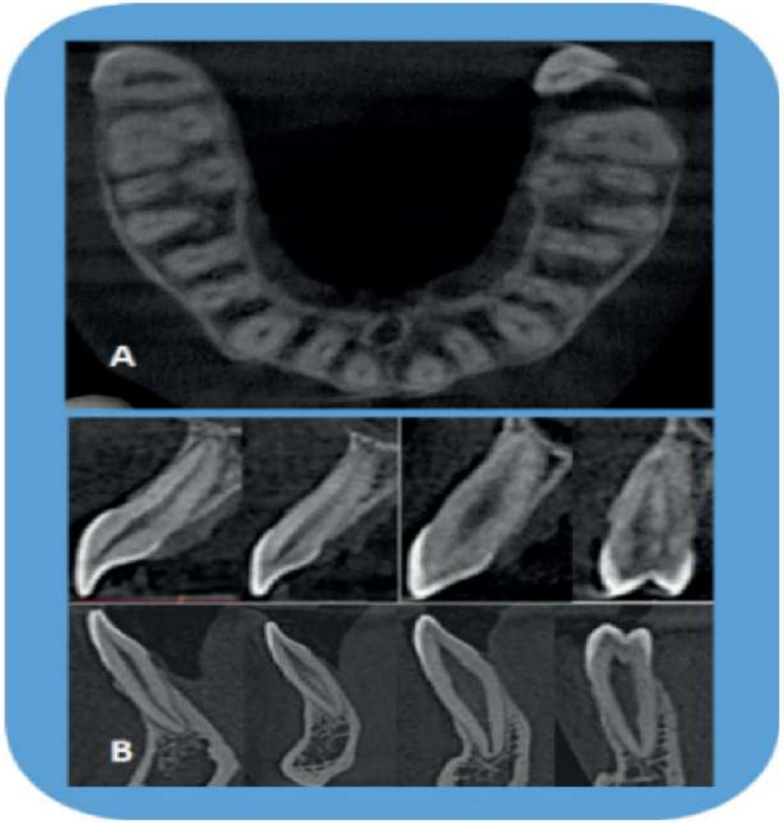


Figure 21. *CBCT images (axial and crossections) are indispensable in endodontics for the evaluation of morphology of the tooth including location and number of canals, pulp chamber size and degree of calcification, root structure, direction and curvature, fractures, iatrogenic defects, and the extent of dental caries. The images also allow measurements free from distortion and magnification.*

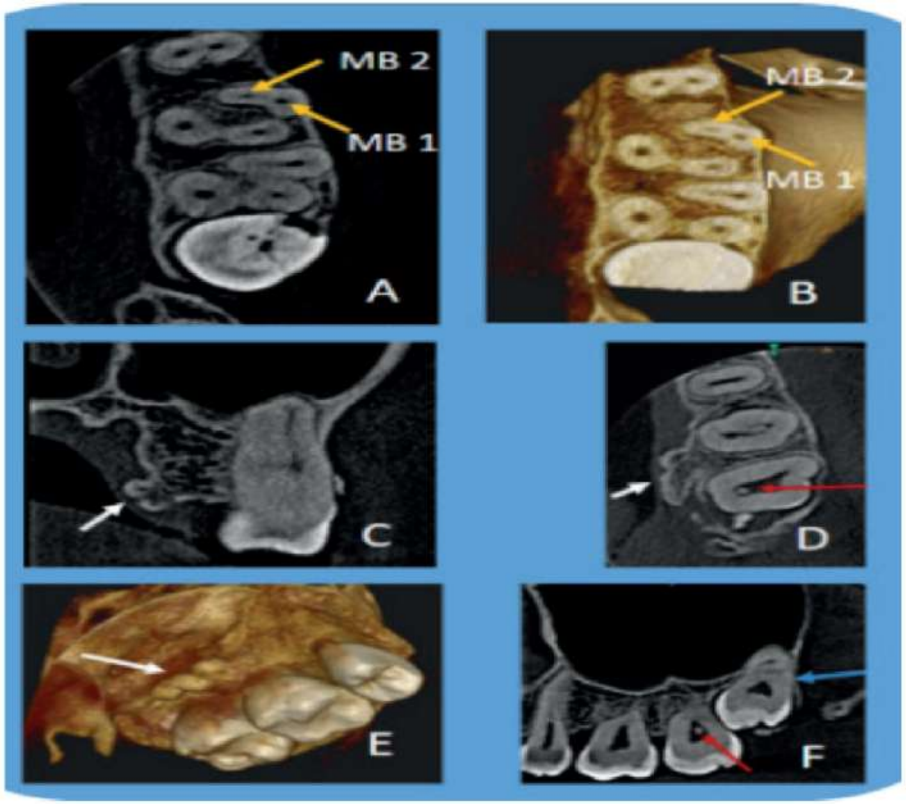


Figure 22. *Small FOV, CBCT scan of left posterior maxilla showing MB2 canal in first molar* ***(A, B)****, exostosis* ***(C,D,E)****, pulp stone in second molar (D,F), third molar relationship with sinus* ***(F)****, and the sinus devoid of any pathology.*

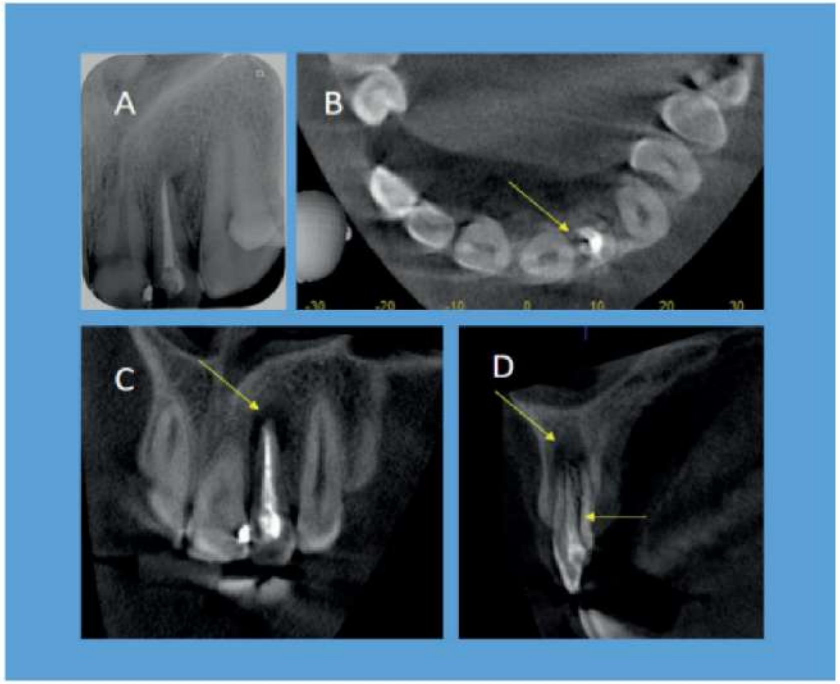


Figure 23. *Periapical radiograph **(A)** showing root canal treated maxillary left lateral incisor without any significant changes. In the CBCT, axial **(B)**, coronal **(C)** and sagittal **(D)** view showing periapical lesion with vertical root fracture (Yellow arrow).*

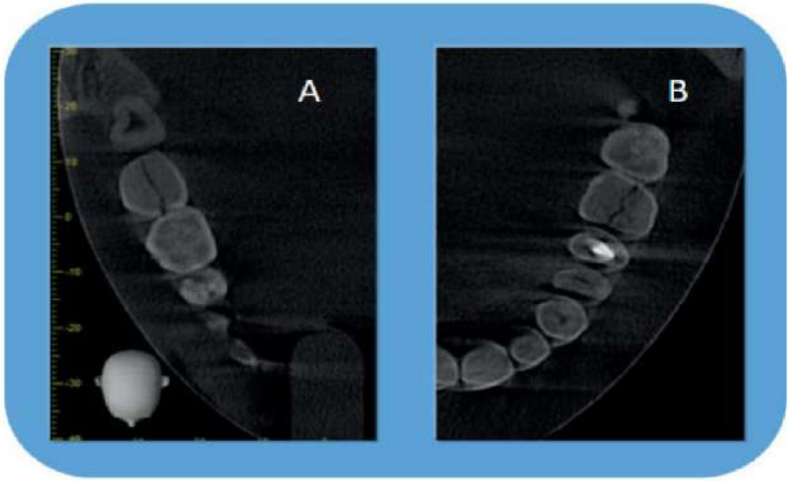


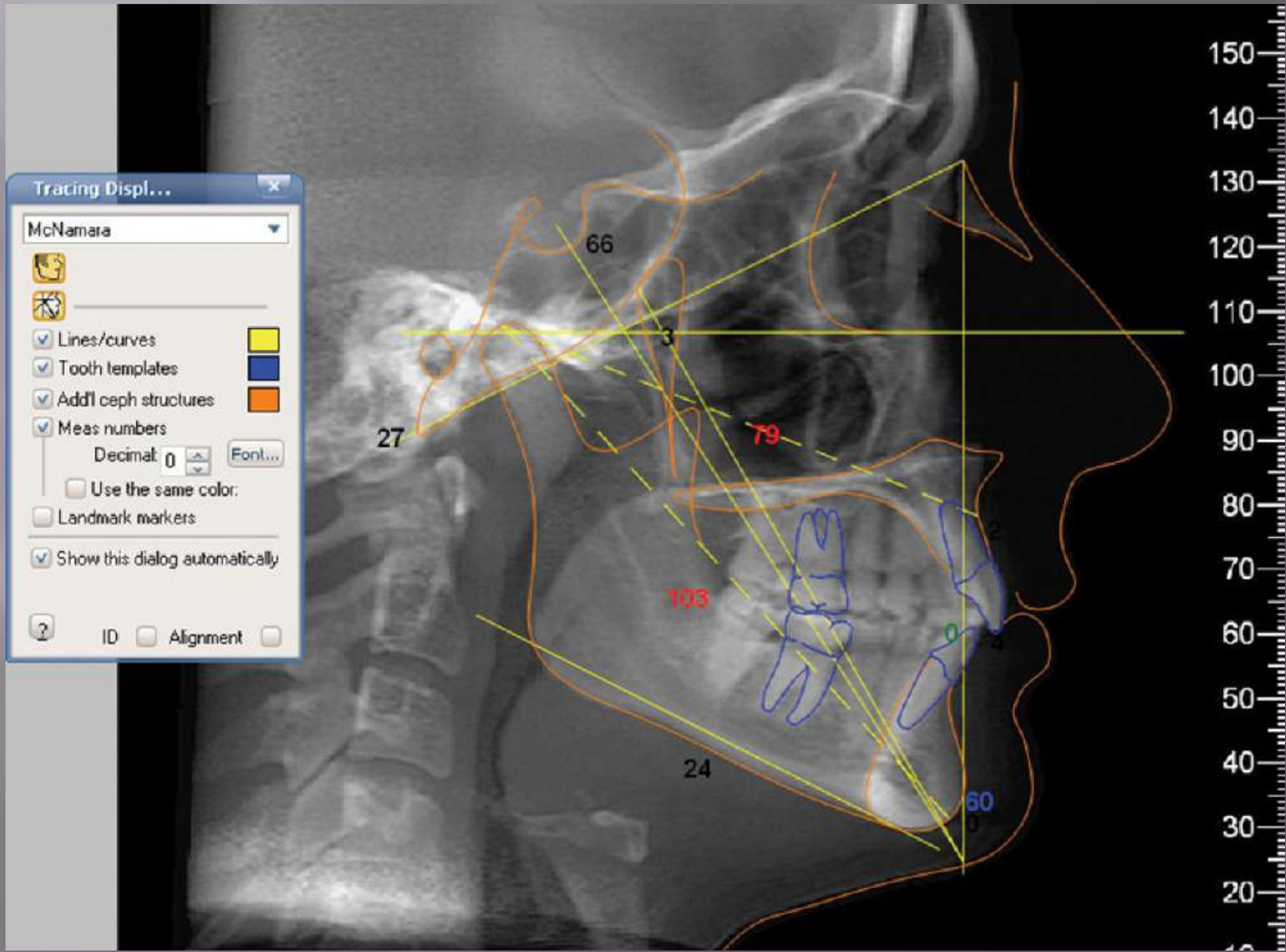
Figure 24. *Axial views of two CBCT scans reveal vertical fracture in left lower second molar **(A)** & left maxillary first molar **(B)**.*

Orthodontics

most common useful:root resorption, position of impacted and supernumerary teeth and their relationship to adjucent structure

- ✓ Palatal morphlogy and dimensions
- ✓ Tooth inclination and torque
- ✓ Alveolar bone width for buccolingual movement
- ✓ TMJ and pharyngeal airway space

Numerous linear images currently used in orthodontic diagnosis, cephalometric analysis, and treatment planning can be created from a single CBCT scan



Create two-dimensional radiographic images from 3D volume dataset in the lateral, panoramic, frontal and SMV views

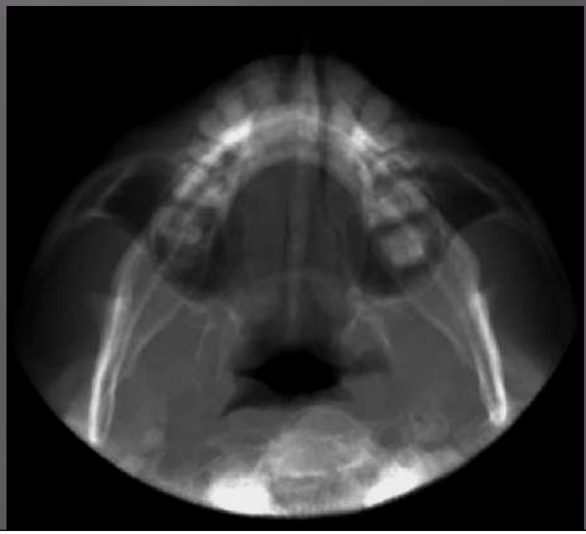


Figure 2. CBCT volume rendering.

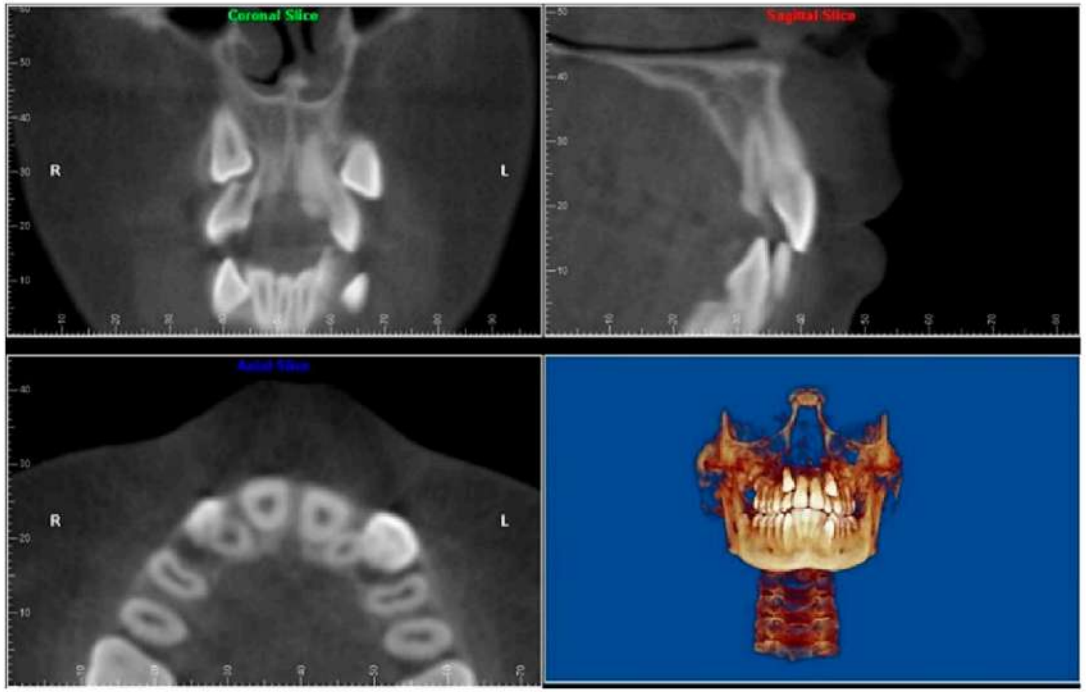


Figure 3. Coronal, sagittal, axial and volume rendering views.

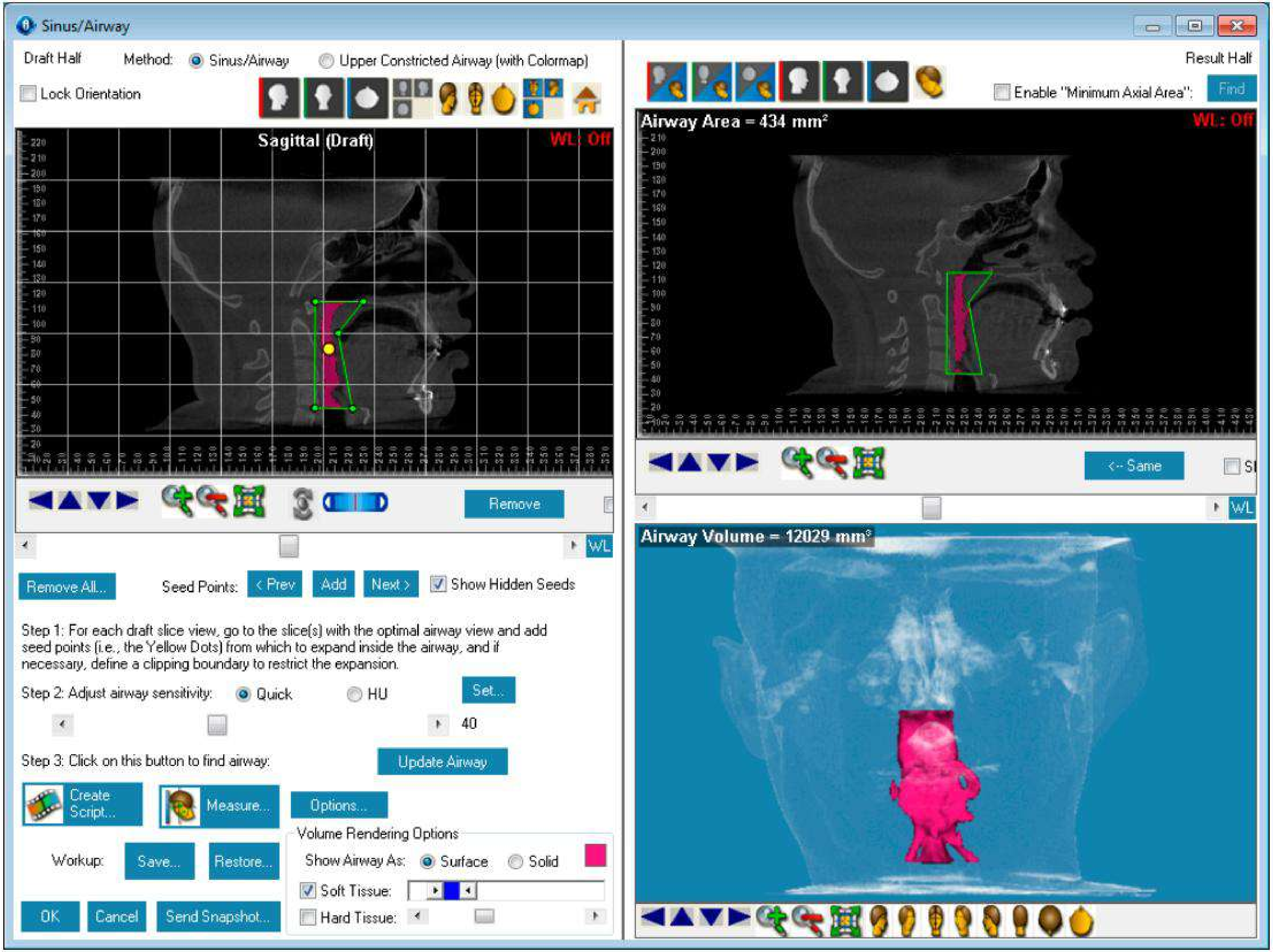


Figure 15. Example of a measurement of the oropharyngeal airway volume and area.

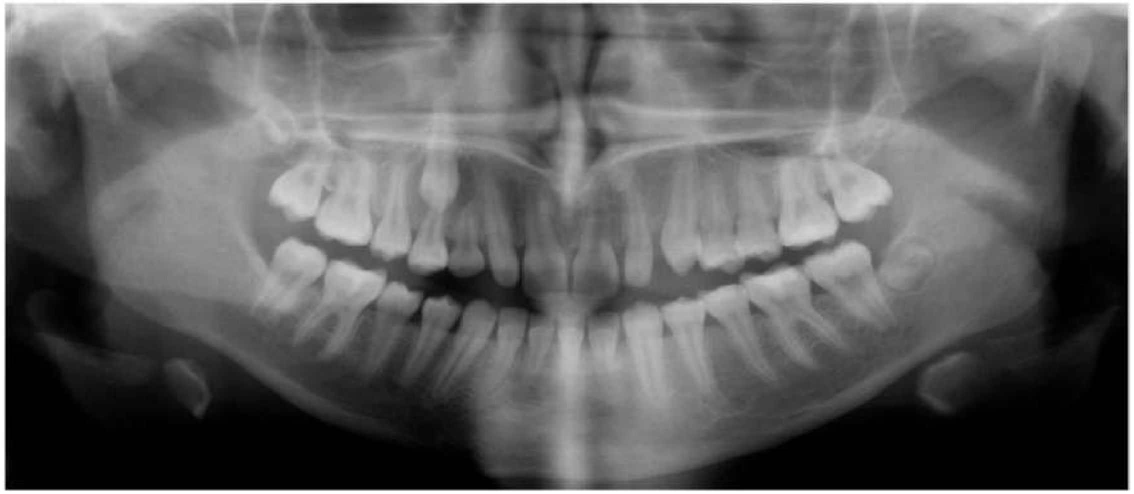


Figure 20. A conventional 2D panoramic radiograph that did not depict accurate status of the canine and first premolar.

Figure 21. Coronal, sagittal, axial views, and volume rendering showing the impacted canine and its relationship to adjacent structures.

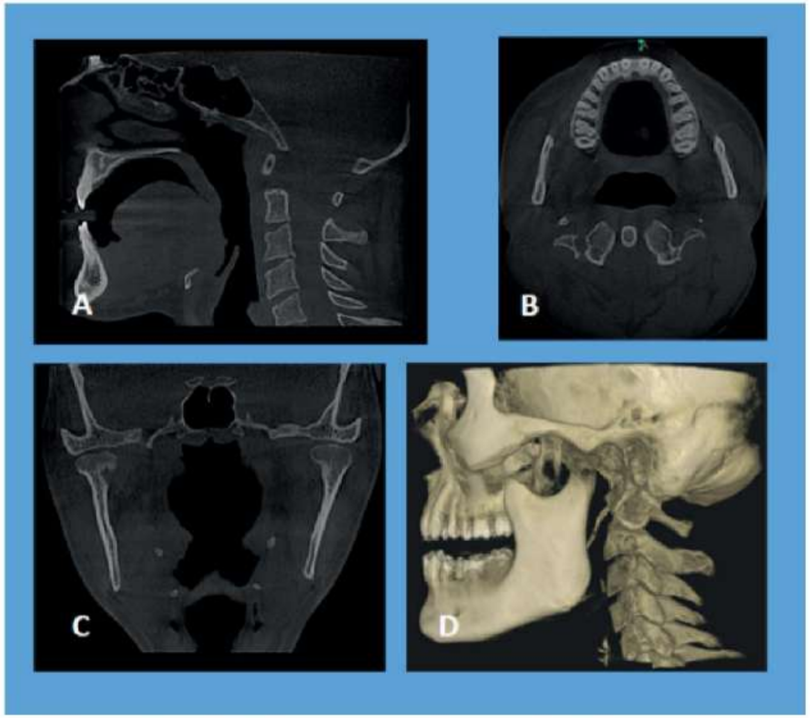


Figure 15. *CBCT scans - Extended FOV for Orthodontic and Airway analysis.*

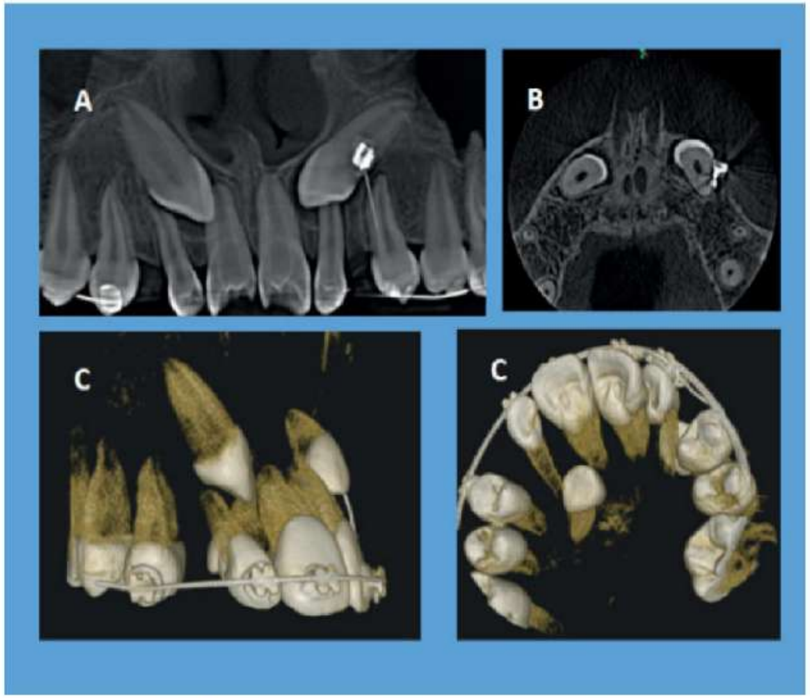


Figure 16.*Orthodontic applications revealing evaluation of impacted canine by CBCT.*

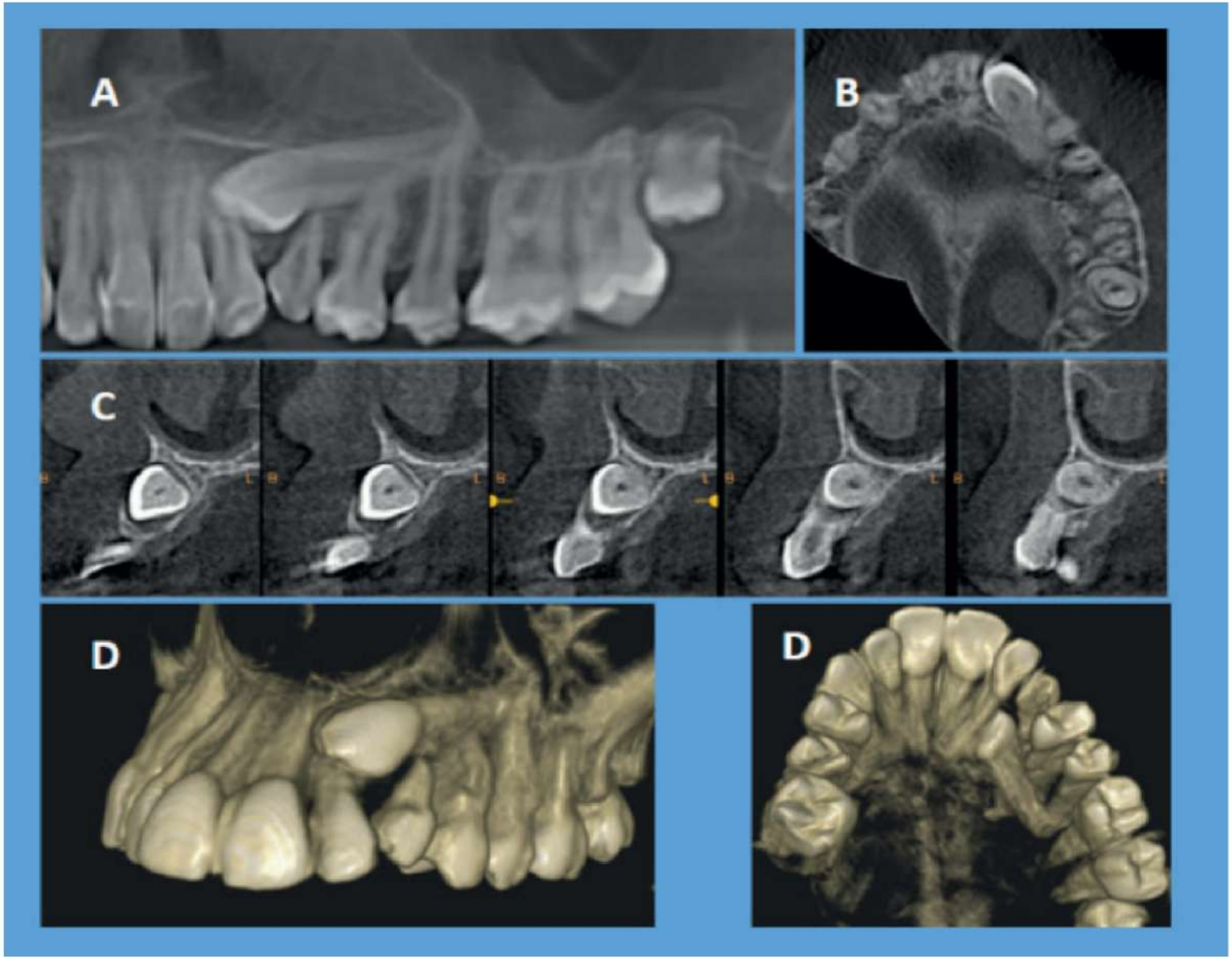
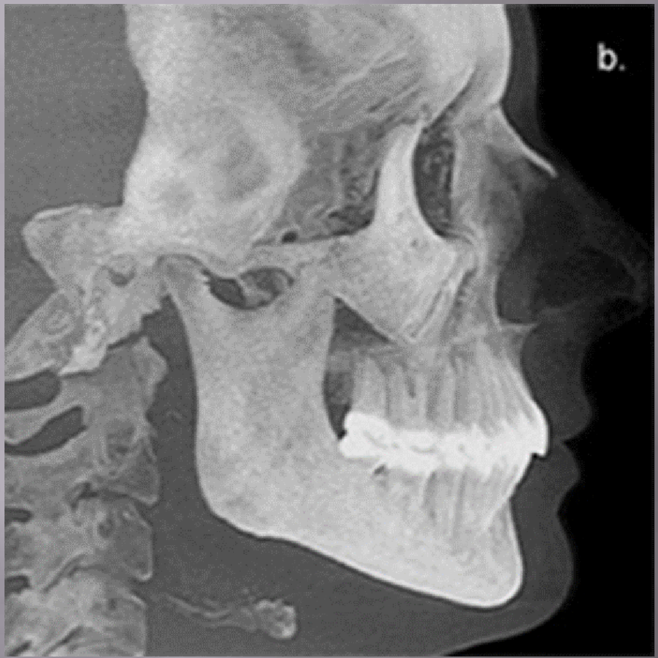


Figure 17. *CBCT images used for assessment of orthodontic treatment involving impacted canines.*

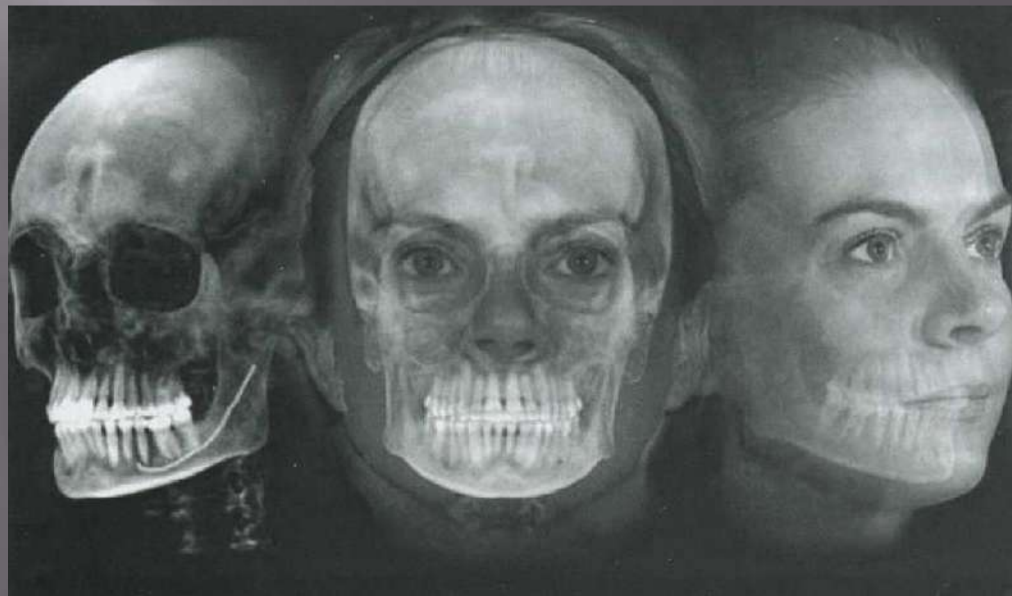
Three-Dimentional cephalometry



Benefits to 3D cephalometry include :

- demonstrating and characterizing asymmetry and dentoskeletal discrepancies
- incorporating the soft tissue integument
- potential for assessment of growth and development

fusion

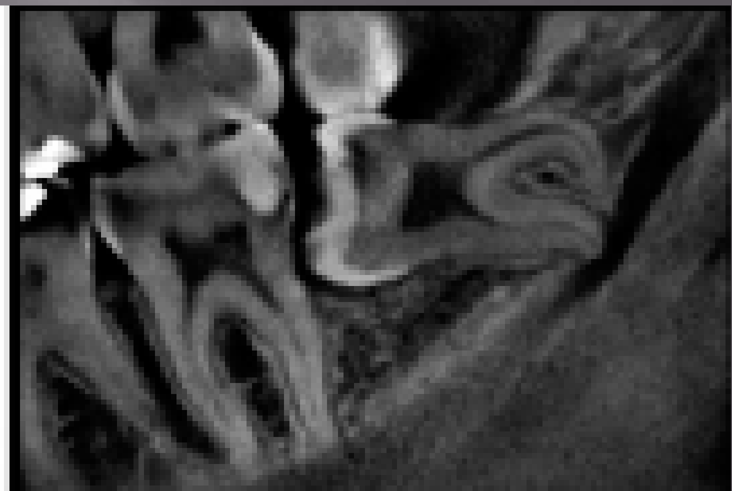


Asymmetry

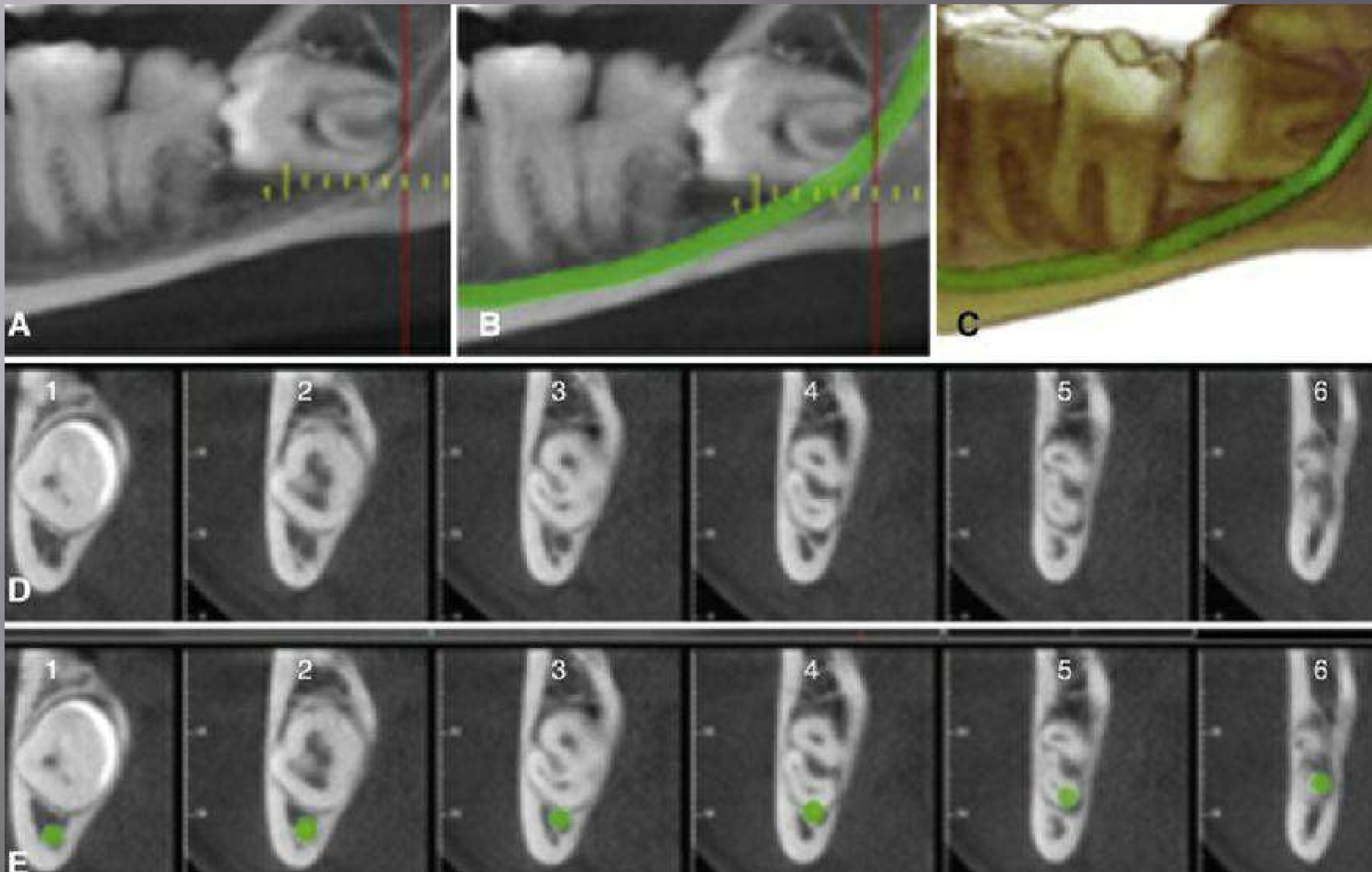
Mandibular third molar position

- Localization of the inferior alveolar canal
- Panoramic imaging adequate when the third molar is clear of the canal
- Use of a CBCT imaging in case of radiographic superimposition



cross-sectional images at 1-mm intervals. Cross-sectional slices with the IAC traced i demonstrate the close proximity of the IAC in relation to the root of the left mandibular third molar



Tempromandibular joint

- Provides multiplanar and potentially 3D images of condyle and surrounding structures
- CBCT can depicts:

  features of degenerative joint disease
  anomalies of the condyle
  ankylosis
  rhomatoid arthritic disease
- Appropriate imaging protocols include:

  reformatted panoramic
  axial images
  corrected parasagittal
  paracoronal transerial slices
- 3D reconstruction in case of asymmetry or surgery

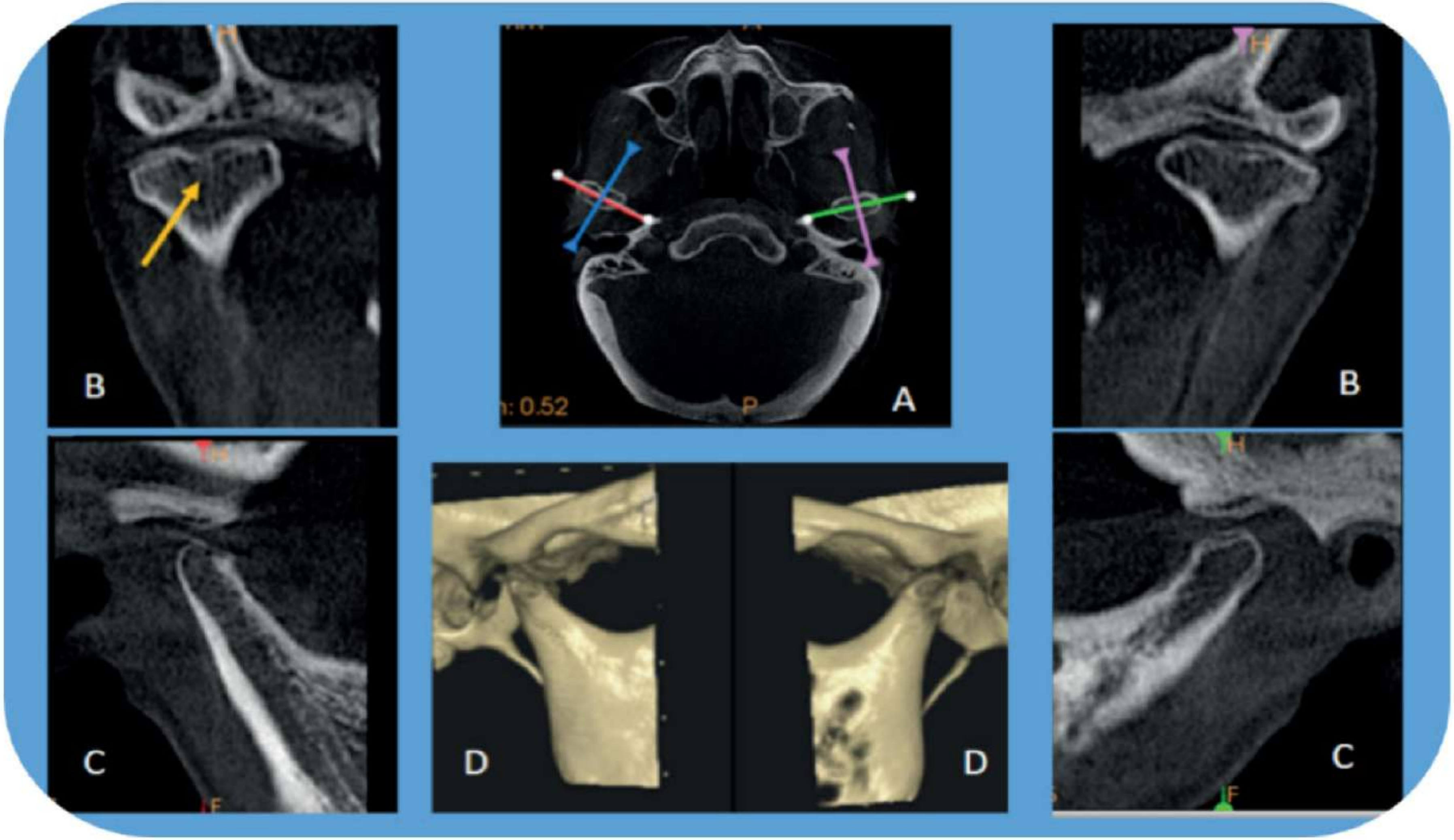
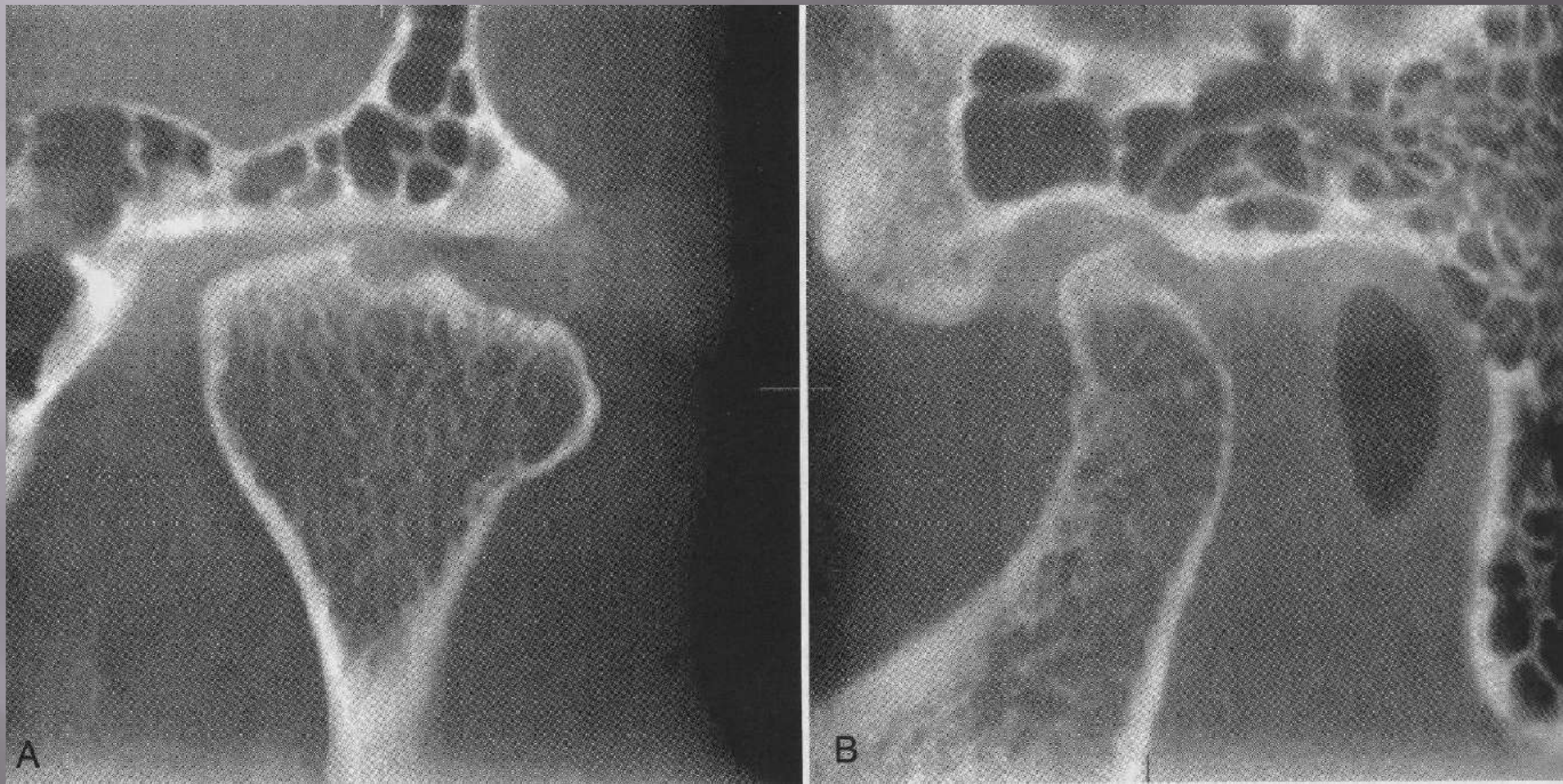
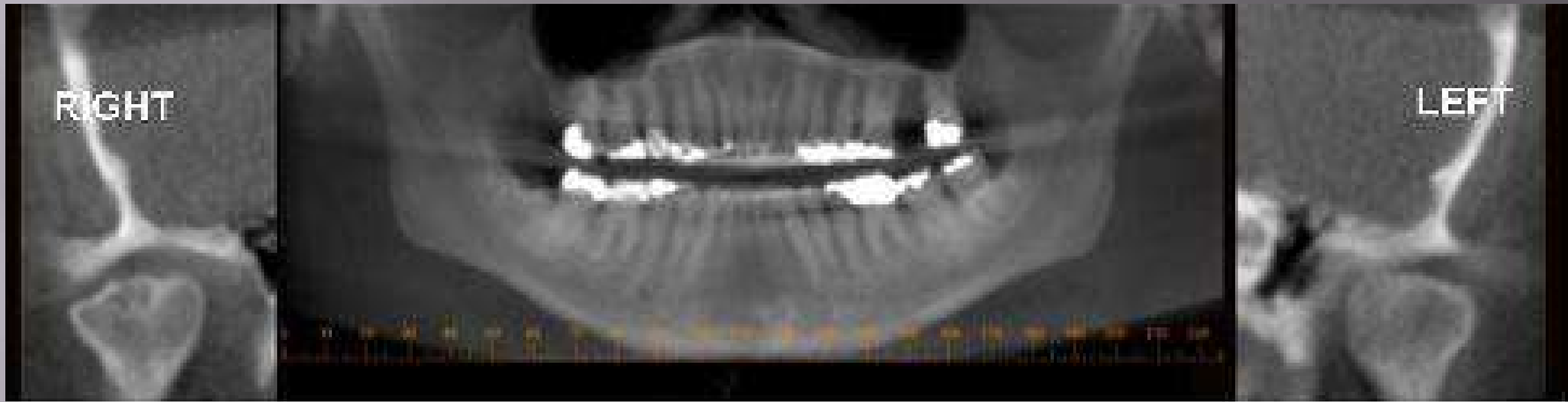


Figure 18. *CBCT showing TMJ; Bilateral oblique MPR through lateral and medial poles of the condyle on the axial image showing coronal **(B)**, sagittal view **(C)** and IVR **(D)** with right side showing bifid condyle (yellow arrow).*

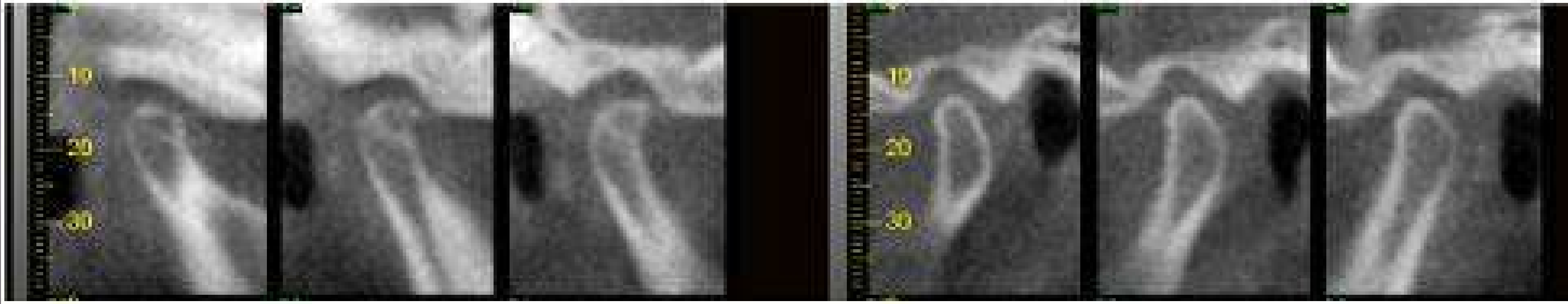

A
B

patient (below) presented with slow progressive changes in the bite of the teeth and was assessed prior to jaw (orthognathic) surgery. The changes in the TMJ are suggestive of active degenerative joint disease – an importantconsideration before such surgery



"Panoramic" (center) image and frontal (para-coronal) thin cut images of the left and right mandibular condyle reconstructed from CBCT data of showing "bubbling" just below the surface compared to normal left

.



Cropped reformatted images from the side (para-sagittal) from CBCT clearly showing defects in surface of right condyle (cyst) = **ACTIVE OSTEOARTHTITIS**

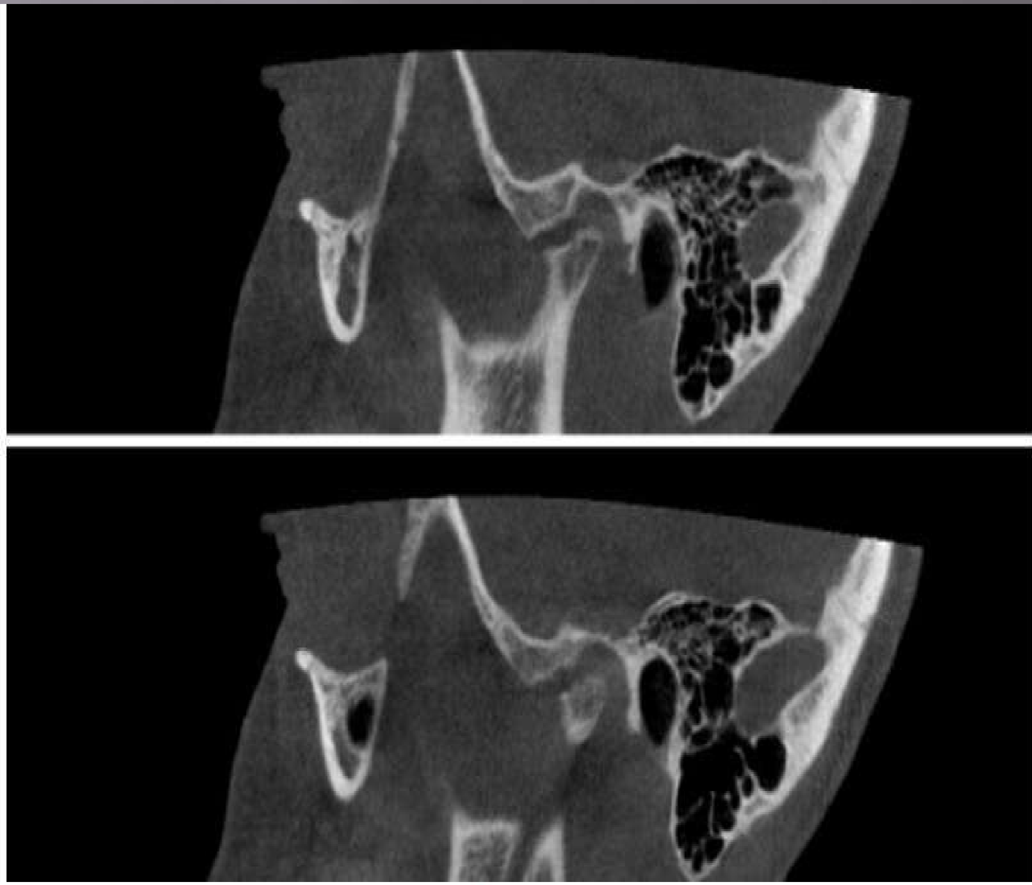
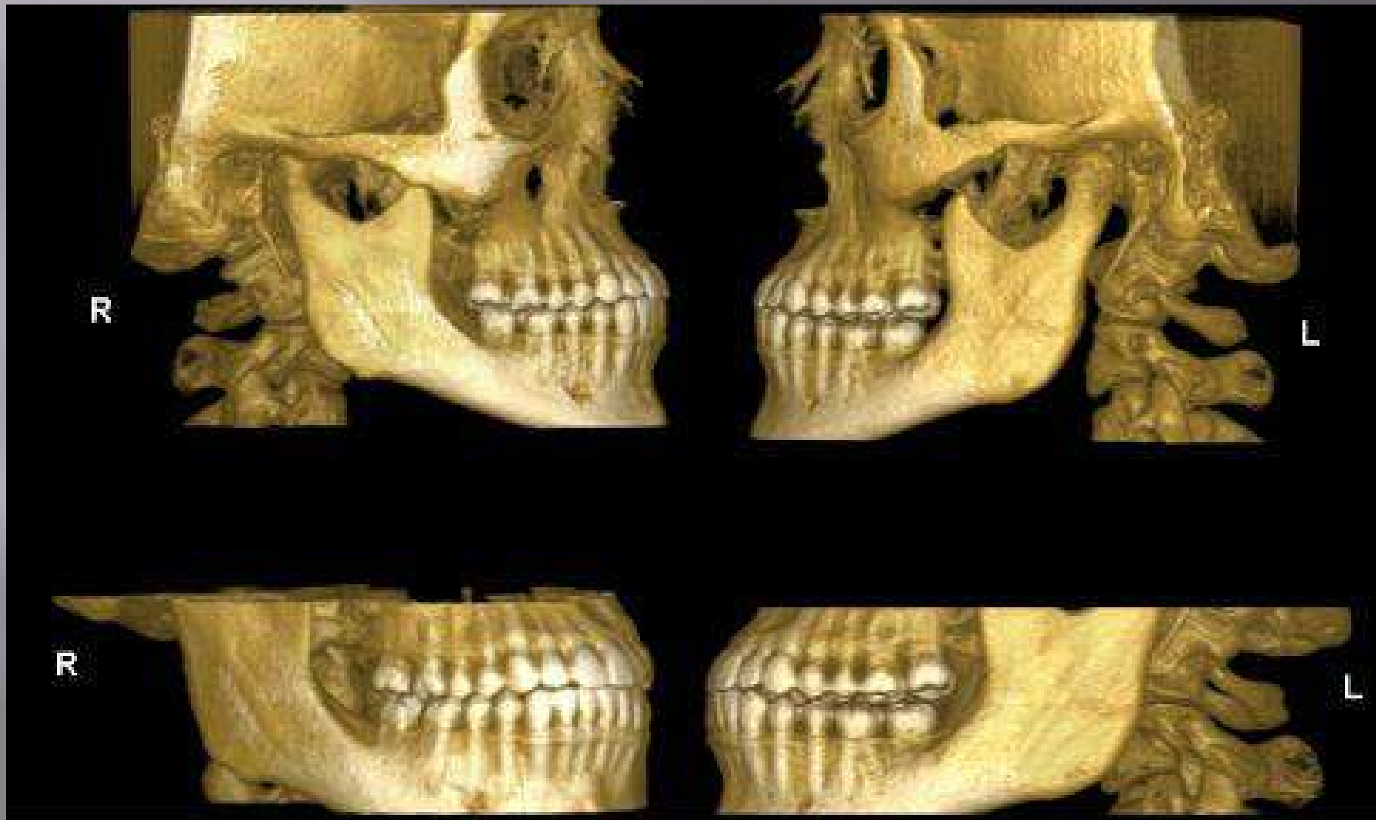


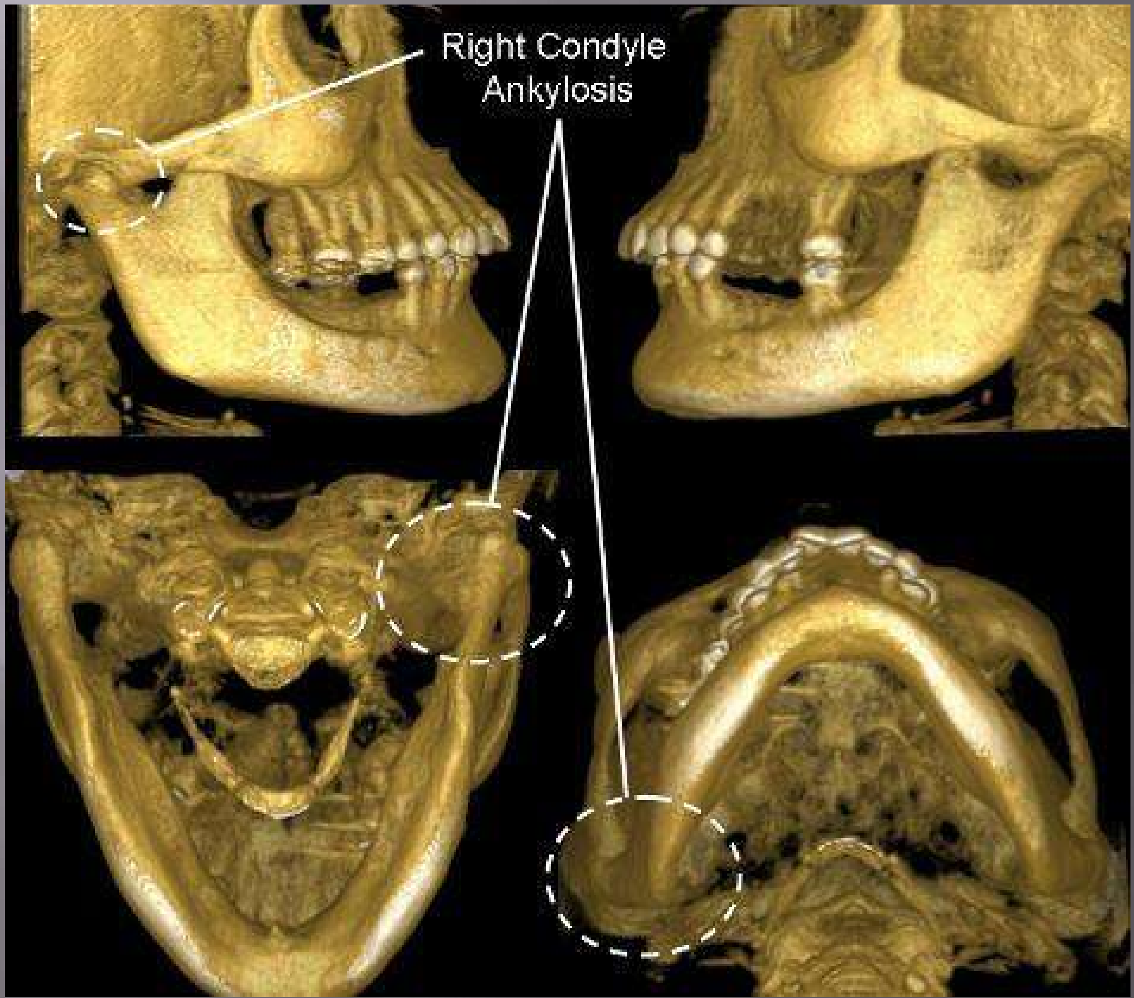
Figure 8 CBCT of juvenile idiopathic arthritis: deformed (remodelled) joint with surface erosions: flattened condyle with enlarged anteroposterior dimension and double contour. Articular eminence also flattened (female, 16 years).

This patient presented with a changing bite located on the right after orthodontic treatment. The cause for this is easily determined by 3D reconstructed volumetric renderings showing substantial left condylar hyperplasia



Multiple 3D volumetric reconstructions demonstrating left hyperplasia of the mandibular condyle and effects on left sided occlusion

This patient presented with progressing limited opening of the jaw. CBCT 3D volumetric reconstructions demonstrate a deformity on the right consistent with fusion (ankylosis) of the condyle to the skull



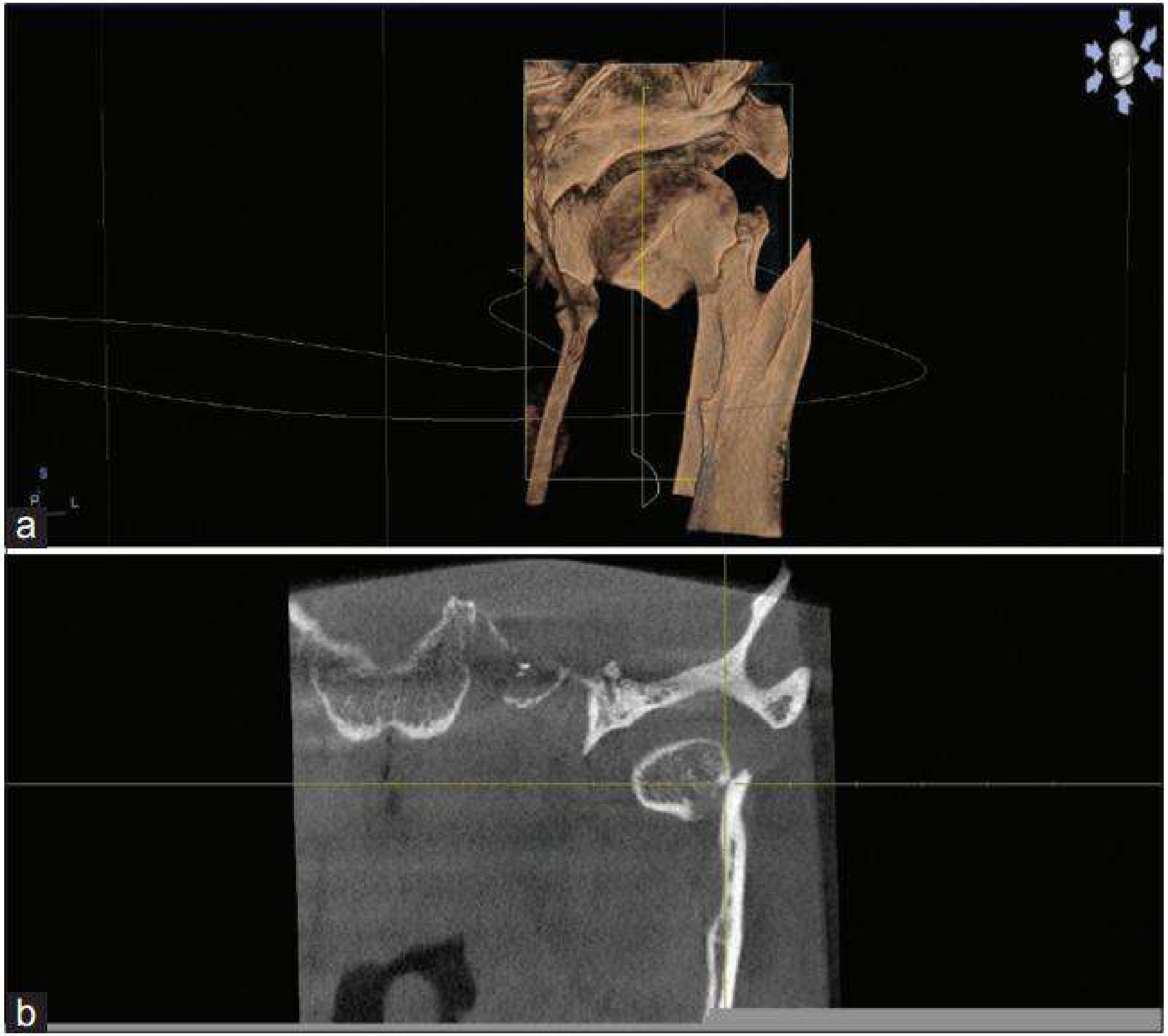
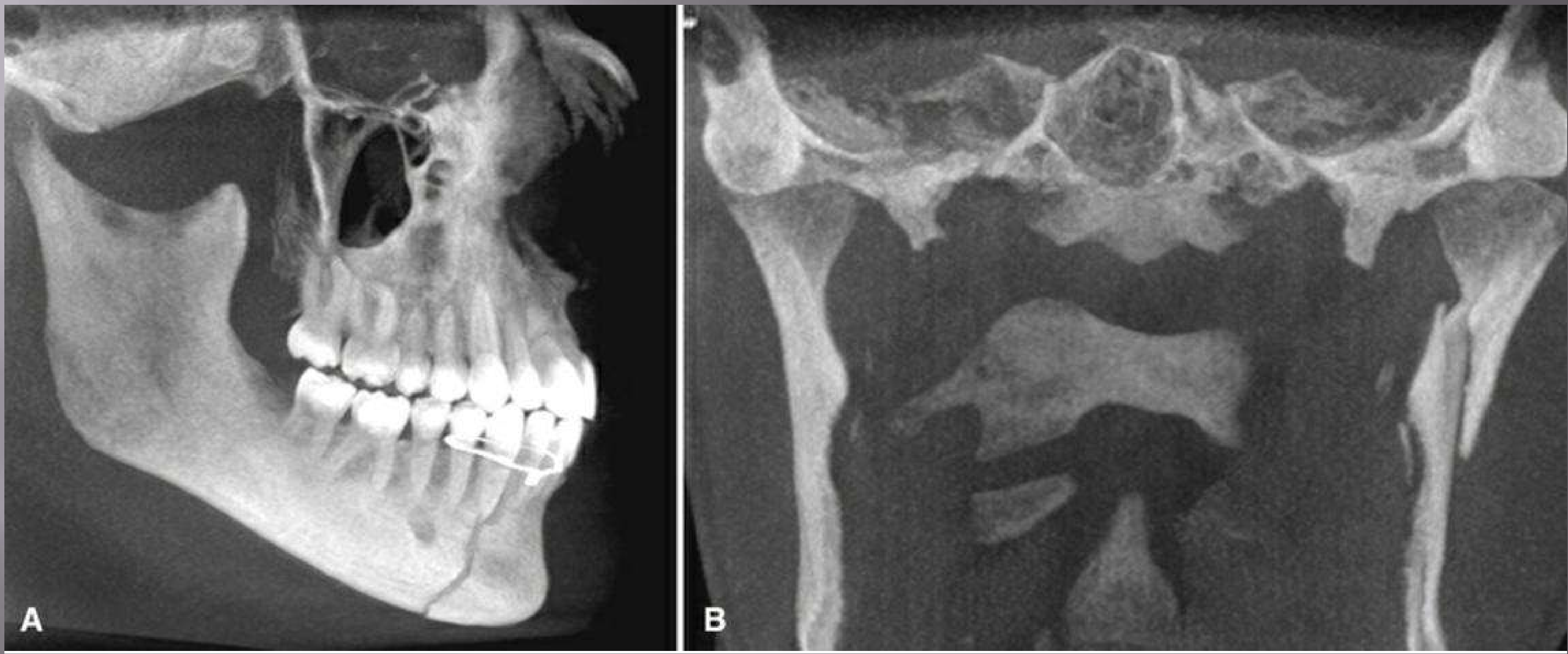


Figure 2: (a) Three-dimensional view of the fractured head of a condyle. The image also demonstrates the glenoid fossa, styloid process, and medial aspect of the mandibular ramus. (b) Cross-sectional view of the fractured condylar head

Maxillofacial Pathoses

- impacted and supernumerary teeth
- fractured or split teeth,
- periapical lesions
- periodontal disease
- Benign calcifications:tonsilloliths, lymph nodes, salivary gland stones
- extent of paranasal soft tissue lesions :mucous extravasation cyst
- assessment of trauma
- extent and degree of involvement of cysts and tumors and osteomyelitis

MIP application demonstrates (A)simple, slightly displaced fracture of the right parasymphyseal region. (B) left subcondylar neck fracture



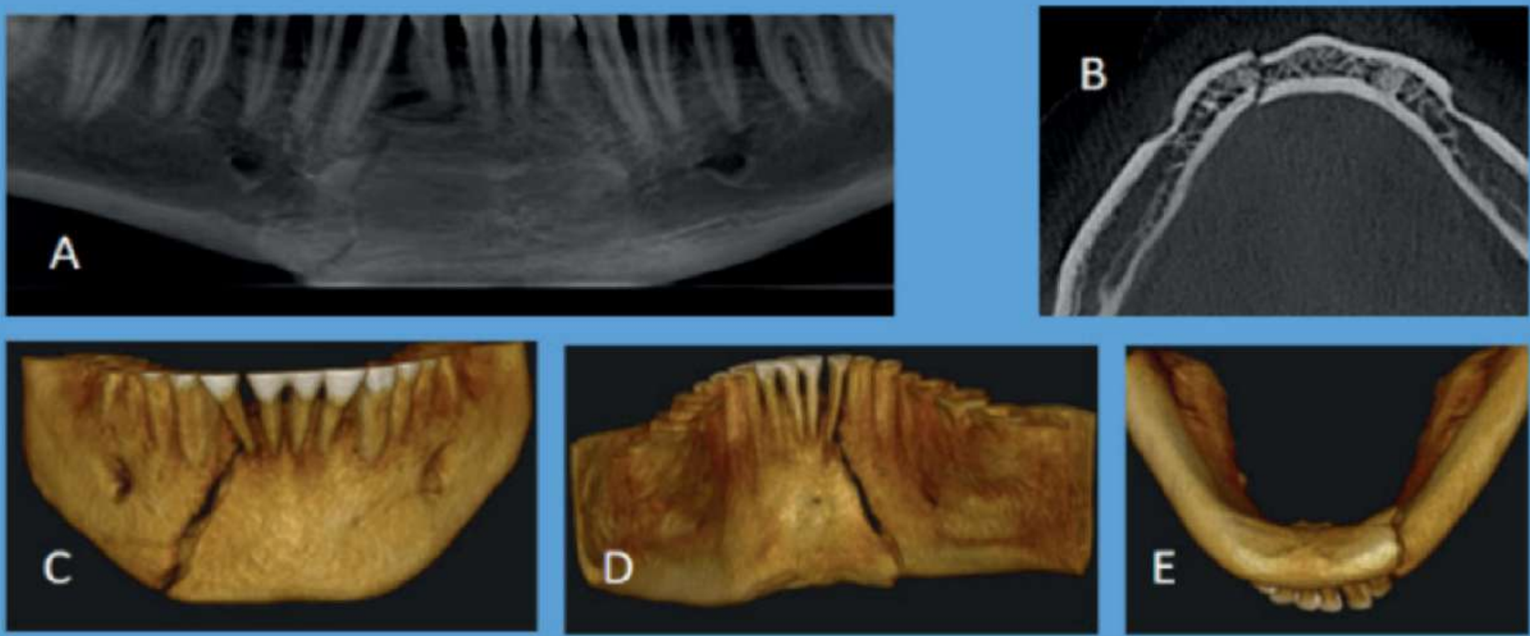


Figure 7. *Three Dimensional visualization of right parasymphysis fracture of mandible on CBCT scan – Panoramic view **(A)**, Axial view **(B)** and IVR **(C, D, E)**.*

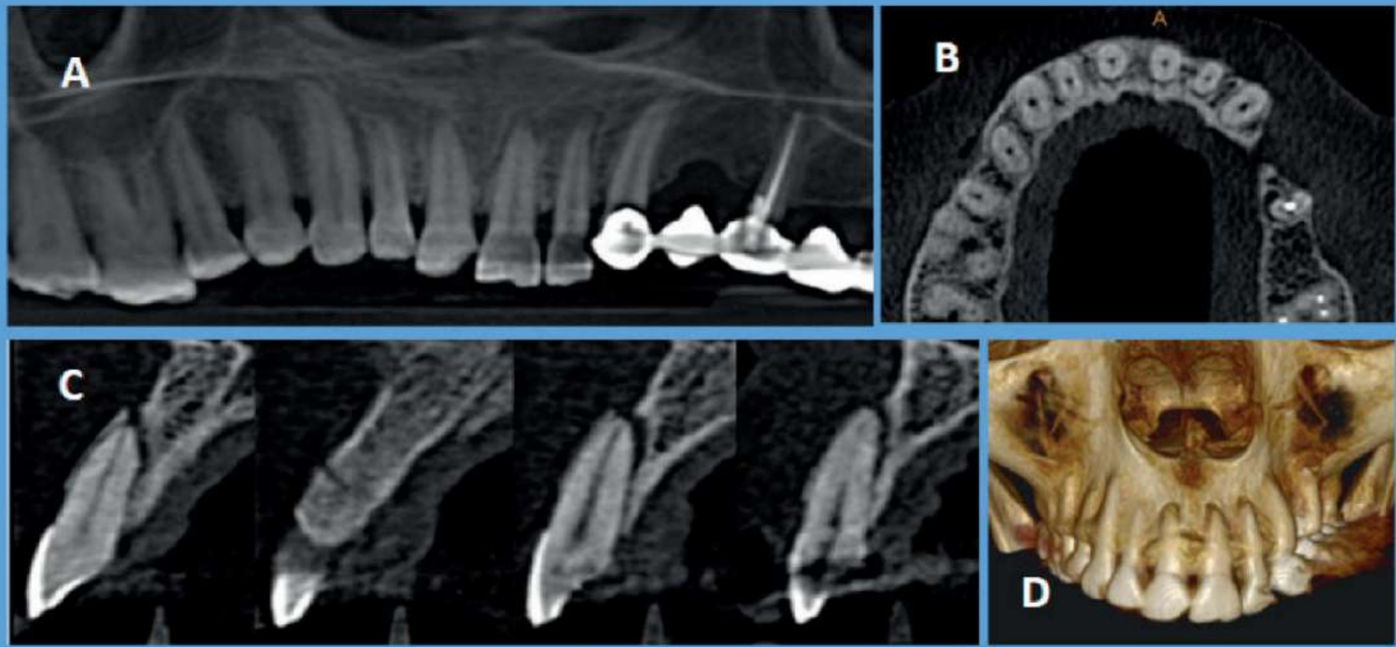
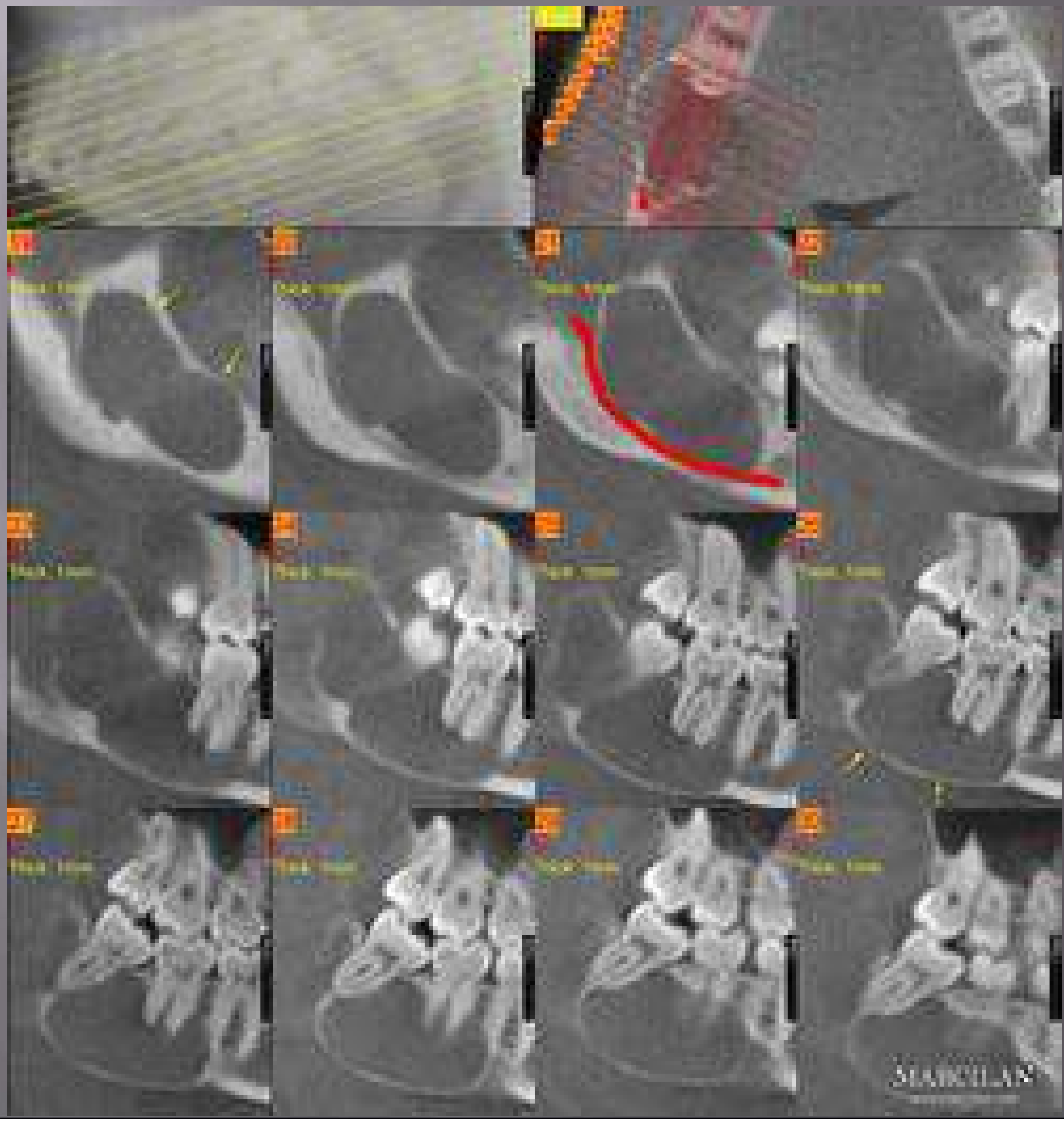


Figure 8. *MPR is very useful in evaluating dentoalveolar fractures, which are easily missed on 2D imaging. The present CBCT scan reveals dentoalveolar fracture associated with maxillary anterior teeth in different display modes.*

Ameloblastoma

There is a well-defined radiolucent lesion in the right posterior mandible. The lesion starts from the distal aspect of root for tooth #30 and extends posteriorly and superiorly to involve the ramus area. There appears to be slight root resorption associated with tooth #31. The right mandibular canal is displaced inferiorly and facially. The lesion is expansile and there is thinning of cortical borders



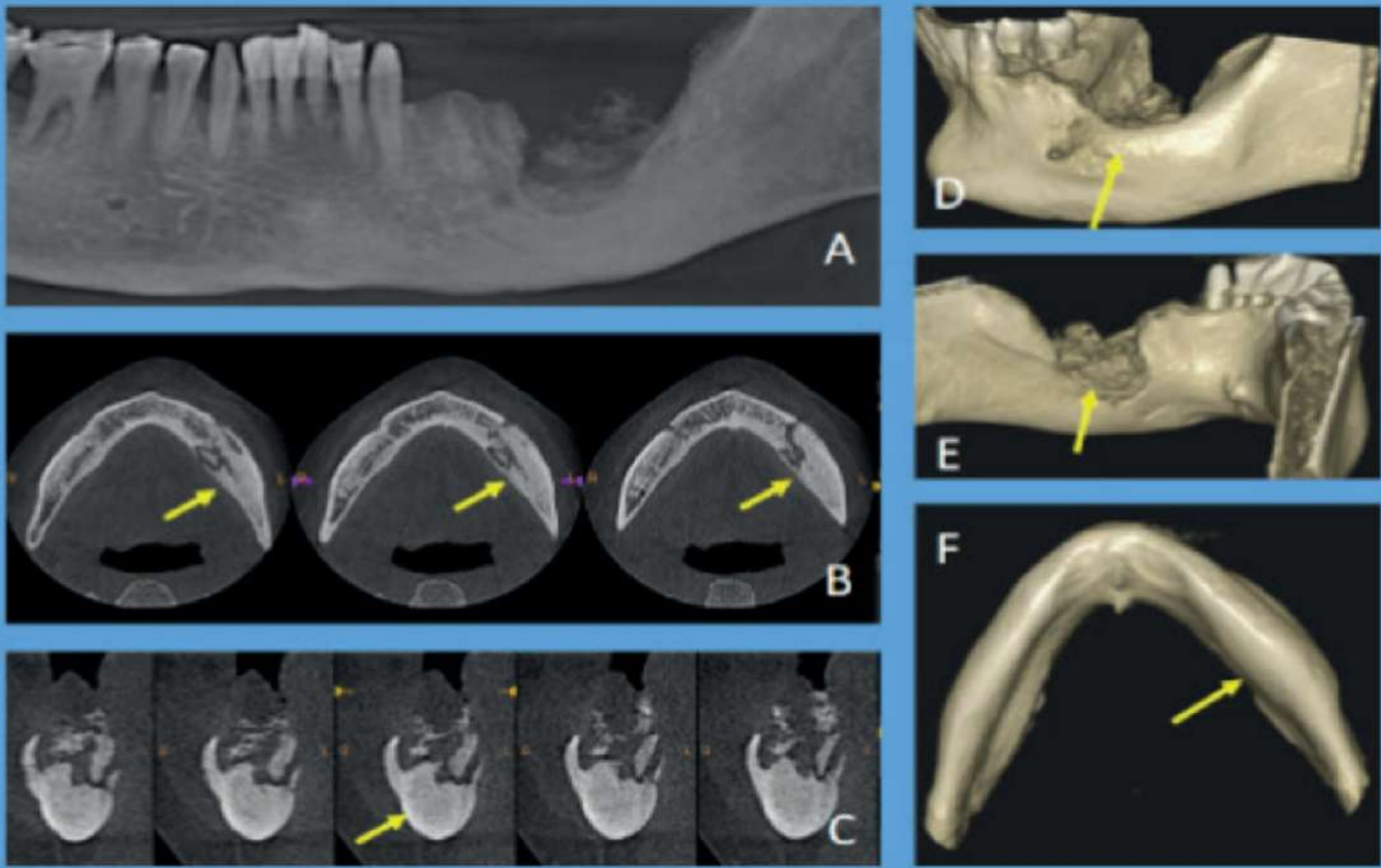


Figure 11. *CBCT scan- Panoramic view **(A)**, Axial views **(B)**, crossections **(C)** and IVR reveal radiographic features (sequestration, altered density of trabecular bone, cortical expansion, compression of the mandibular canal) of a case of chronic osteomyelitis.*

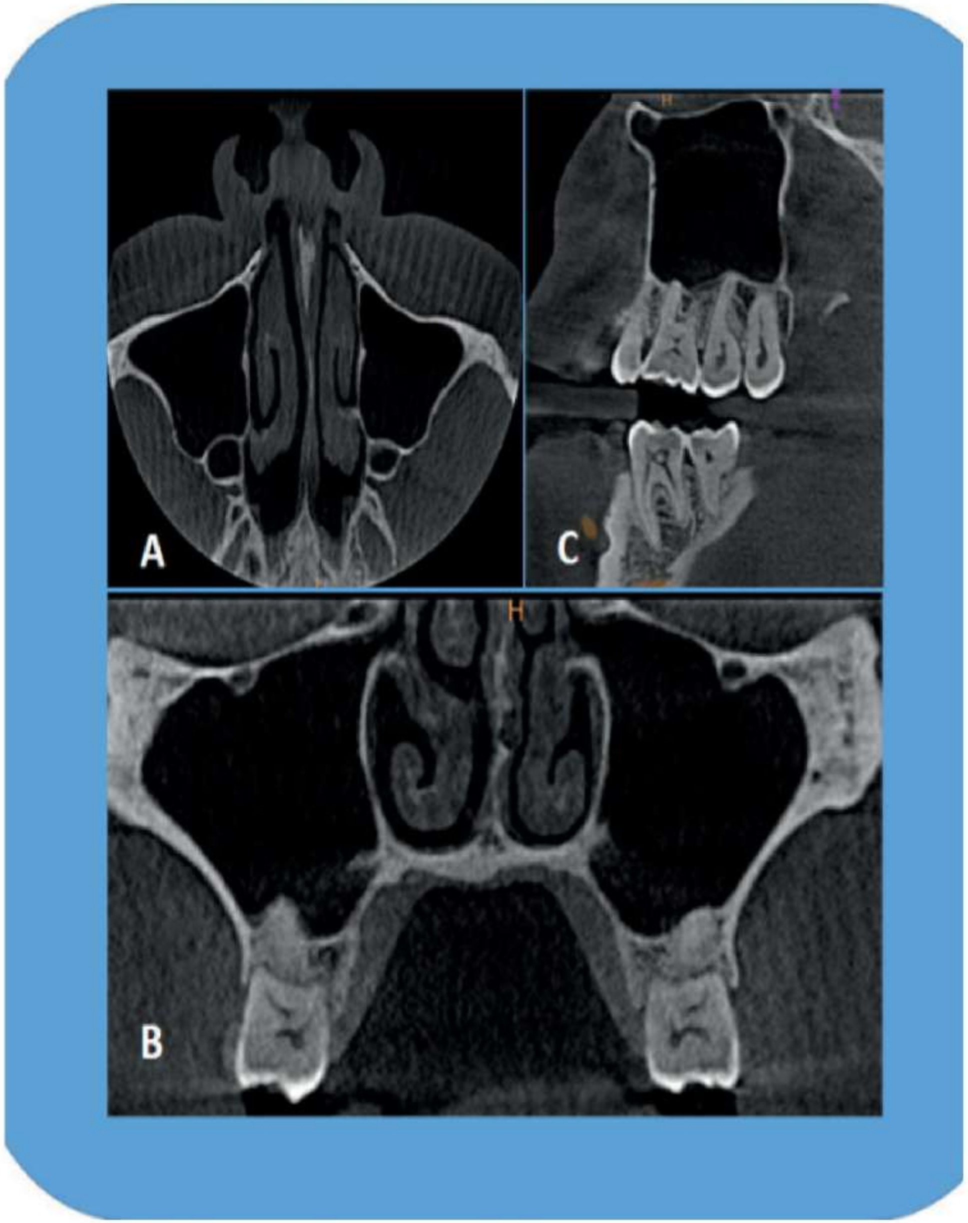


Figure 26. *ENT applications of CBCT: MPR can be used for evaluation of paranasal air sinuses. Mild deviation of the nasal septum towards left side can be appreciated in the present scan along with other features of maxillary sinus*


THANKS