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Basics Of CBCT

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Abstract

Nothing has captured the dental profession's imagination in the past few years like the introduction of CBCT which has gained importance in clinical practice. CBCT is the most exciting advance in dental imaging which has revolutionized the field of diagnostic radiology. Being a 3D imaging modality, it makes the radiographic image crystal clear and there is little scope for misinterpretation and misdiagnosis. This imaging modality is a boon to dentistry due to its advantages over conventional 2D techniques and medical computed tomography. This article provides an overview of the basics of CBCT technology.

Keywords: CBCT, 3D imaging, Diagnostic radiology

Introduction

CBCT is a recent 3D imaging technology that was initially developed for angiography in 1982. Further, it was also applied in maxillofacial imaging. This 3D imaging technology has been given several names: cone-beam volumetric tomography, dental computed tomography, dental volumetric tomography, etc. The most commonly used term is cone-beam computed tomography as it is a digital-analog of film tomography. The principal feature of CBCT is that multiple planer projections are acquired by rotational scan to produce a volumetric data set from which inter-relational images can be generated.

Principle of CBCT:

Basis, frame, or raw images:

The patient is positioned and the field of view (foV) is fixed based on the region of interest. The x-ray source and detector rotate around a rotation center fixed within the center of the region of interest (180-360°). During the rotation, multiple sequential planar projections are obtained which **constitute the raw primary data** and are known as a basis, frame, or raw images.

Projection data:

There are usually several hundred two dimensional basis images from which the image volume is calculated and constructed. The complete series of images is known as projection data.

Primary Reconstruction:

After the basis projection frames are acquired, volumetric data set is created. This process is called primary reconstruction. The procedure of reconstruction comprises of two stages:

1.) Pre-processing Stage

2.) Reconstruction Stage

Both these stages require two different computers. Pre-processing stage is performed at the acquisition computer while the reconstruction stage is performed on the reconstruction computer. Both computers are connected with an Ethernet connection.

1.) **Pre-processing Stage:**

After the multiplanar projection images are acquired, these images may be corrected for inherent pixel imperfection, variations in sensitivity across the detector, and uneven exposure. This correction requires "*Image Calibration*".

2.) **Reconstruction Stage:**

The corrected images are transformed into a distinct presentation called a Sinogram. Sinogram is a conglomerate image developed from multiple projection images. The process of generating a sinogram is known as Radon transformation. The two-axis of the sinogram is the horizontal axis and the vertical axis.

The horizontal axis of a sinogram represents individual rays at the detector, whereas the vertical axis represents projection angles. The resulting image comprises multiple size waves of different amplitude, as individual objects are projected onto the detector at continuously varying angles. With a filtered back-projection algorithm the final image is reconstructed from the sinogram. The most widely used algorithm is the field kamp algorithm. This process of final image formation is known as Inverse Radon transformation.

X-ray Generation:

The different parameters considered in x-ray generation are as follows:

1.) **Patient Positioning:**

CBCT scans are often performed with the patient in three possible positions:

a.) Sitting

b.) Standing

c.) Supine

2.) **X-ray Generator:**

During the CBCT scan, each projection image is made by sequential single image capture of the remnant x-ray beam of the detector. Using a constant beam of radiation during the rotation is the easiest method of exposing the patient. This also allows the x-ray detector to sample the attenuated beam in its trajectory. This results in continuous radiation exposure to the patient, much of which does not contribute to the formation of the image. X-ray generation may be continuous or pulsed. It is desirable to pulse the x-ray beam to coincide with the detector sampling. This means that the actual exposure time is markedly less than the scanning time. Patient radiation dose is reduced considerably by this technique.

It is of utmost importance to adhere to the ALARA principle of radiation protection which necessitates that CBCT exposure factors should be adjusted based on patient size. This can be achieved by appropriate selection of either tube current (mA), tube voltage (kVp), or both. Although both kVp and mA are fixed in certain CBCT machines, they are automatically modulated in near real-time by a feedback mechanism detecting the intensity of the transmitted beam, a process known as automatic exposure control.

On others machines, the initial scout exposure automatically determines the exposure settings. This feature is preferred mostly because it is operator-independent. It is recommended that for each clinical indication maximum kVp should be used as it gives the best contrast. However, radiation exposure can be kept to a minimum by reducing mA up to 2-4 mA. If feasible, the equipment which provides pulsed exposure should be used as it reduces the exposure to a considerable extent. CBCT equipment provided with automatic exposure control is desirable.

Field of View/Scan Volume:

The dimensions of the field of view or scan volume primarily depend on the detector size or shape and the ability to collimate the beam. The FoV can be either cylindrical or spherical in shape.

Depending on the clinical need, the smallest FoV should be selected. FoV can be classified as:

1.) Small or localized FoV i.e 5x5 cm or less.

2.) Medium FoV i.e 8x8 cm, 10x5 cm, 10x10 cm

3.) Large FoV i.e 17x11 cm, 17x 13.5 cm.

Small or localized FoV can be used for dentoalveolar, temporomandibular joint, endodontia, single implant placements, disimpactions, or any other treatment requiring a high level of detail.

Medium FoV can be used for single arch (for maxilla or mandible), inter-arch (for multiple implant placements, complicated disimpactions) and

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pathologies involving both dental arches and single temporomandibular joint assessments.

Large FoV can be used for complex treatment planning, pathologies extending from lower border of mandible upto the vertex of the head, sinus and airway analysis, orthodontia, orthognathic surgery, facial reconstruction, maxillofacial trauma and bilateral TMJ assesements.

In the case of the protocol using stitched images, two or more segments are exposed separately and the data obtained are stitched by using the software. In this process, the margins of the constituents FoV may be exposed twice, thereby adding to the radiation dose. Hence it is recommended to avoid stitched images from the radiation protection viewpoint.

Scan factors:

The frame rate is the speed with which individual images are acquired and measured in frames, projected images, per second. Most CBCT imaging systems use a complex circular trajectory or a scanning arc of 360 degrees to acquire projection data which is necessary for 3D reconstruction. Also, CBCT scan times should be reduced to minimum as possible to avoid motion artifact resulting from subject movement.

Image Detection:

Current CBCT units are divided into 2 groups:

1.) Based on detector type image intensifier tube or charged couple device combinations.
2.) Flat panel imager.

The flat-panel imager is more preferred over image intensifier due to more accurate volume rendering, higher spatial and contrast resolution. It consists of a cesium iodide scintillator applied to a thin film transistor made of amorphous silicon.

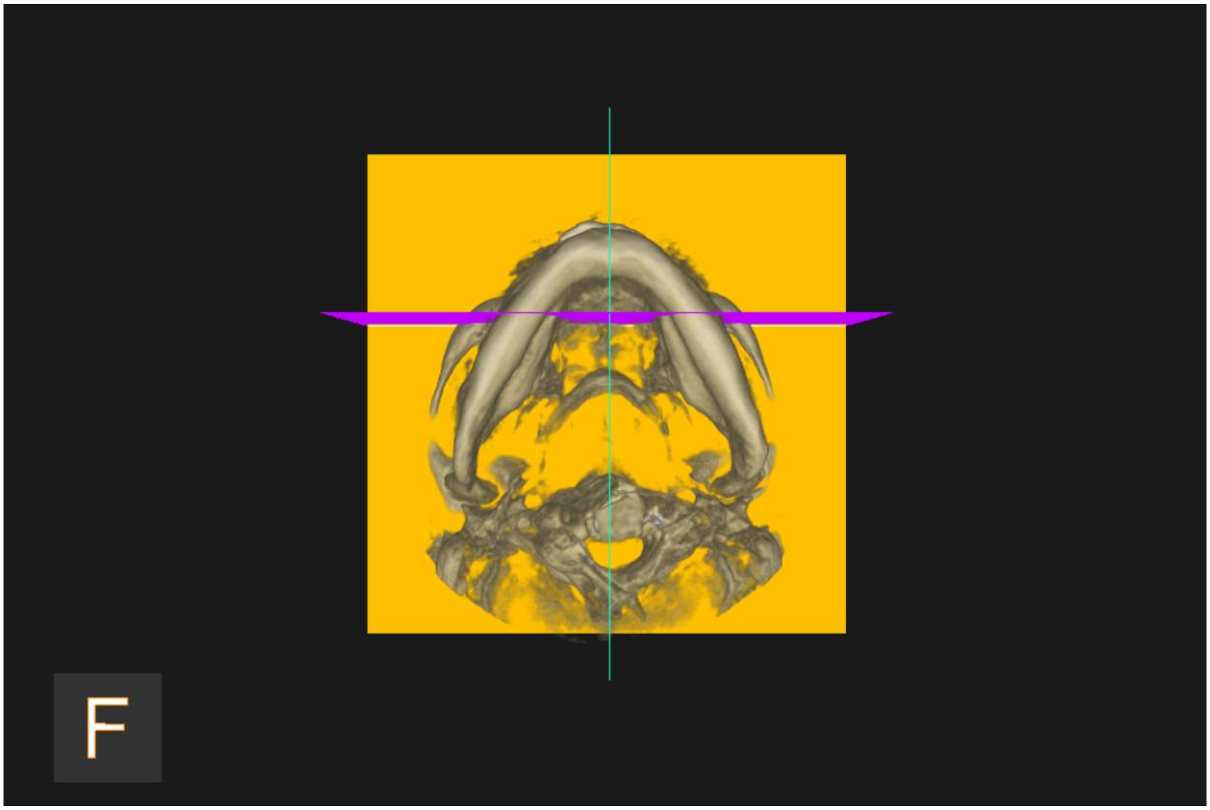
Voxel Size:

The spatial resolution and therefore the detail of the CBCT image is determined by individual volume element (voxel) produced in formatting the volumetric data set. CBCT units provide isotropic (i.e equal in all 3 dimensions) voxel resolutions. The voxel size of CBCT equipment range from 0.075 to 0.6mm. Higher resolution can be obtained by a smaller voxel size. Therefore, when a high level of detail is required smaller voxel sizes are preferred. E.g., For endodontic purposes. A voxel sizes up to 0.150 nm^3 is found to be suitable for the detection of periodontal defects. For detection of external root resorption, 300µm voxel size can be used with adequate efficacy. The optimal resolution CBCT imaging system used in endodontics is suggested not to exceed 200µm and a voxel size of 0.3 to 0.4 mm is considered adequate to provide CBCT images of acceptable diagnostic quality for implant treatment planning.

Image display (Multiplanar Reformation)

The volumetric data is presented to the clinician on the screen as secondary reconstructed images in three orthogonal planes i.e., axial, sagittal, and coronal.

Axial orientation: The image is displayed looking from the patient's head or feet.



Axial Slice: Axial means horizontal cut slices.

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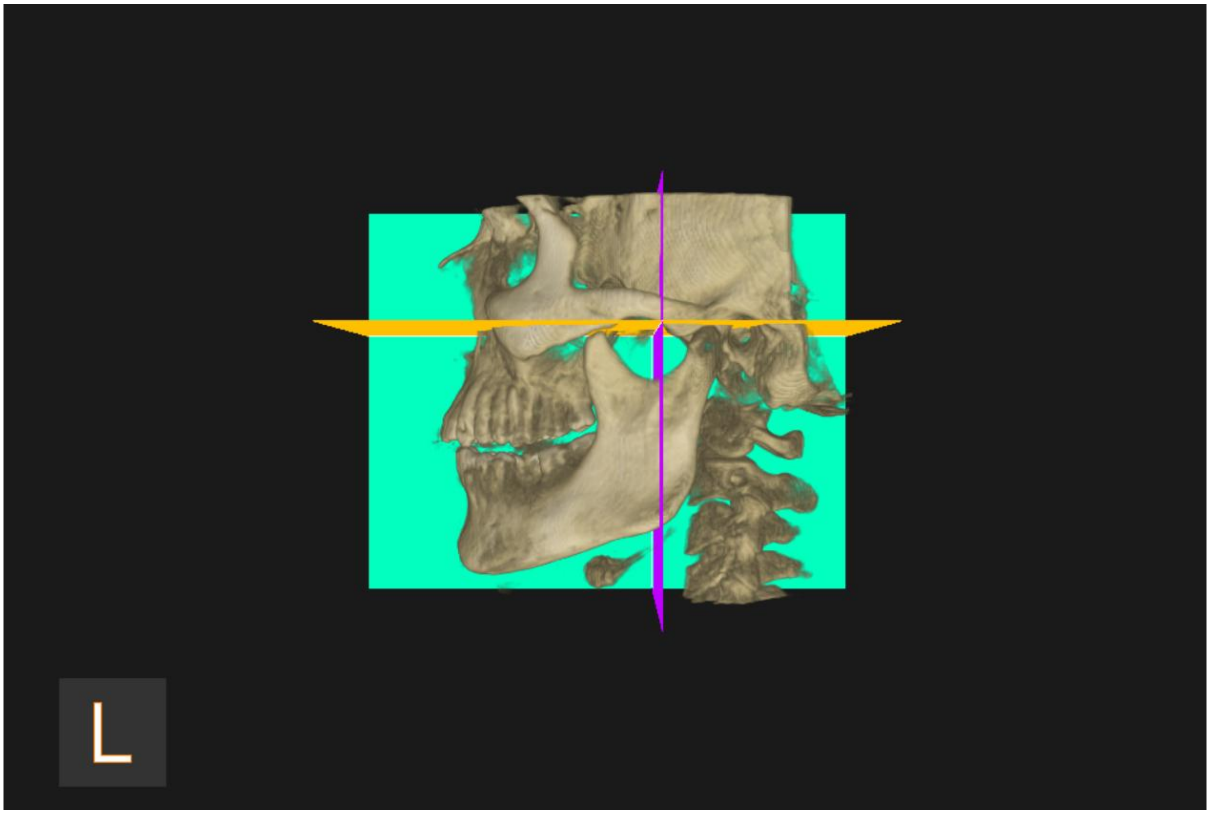
Sagittal Orientation: The image is displayed looking at the patient's left side



Sagittal Slice: Sagittal means vertical slices from front to back

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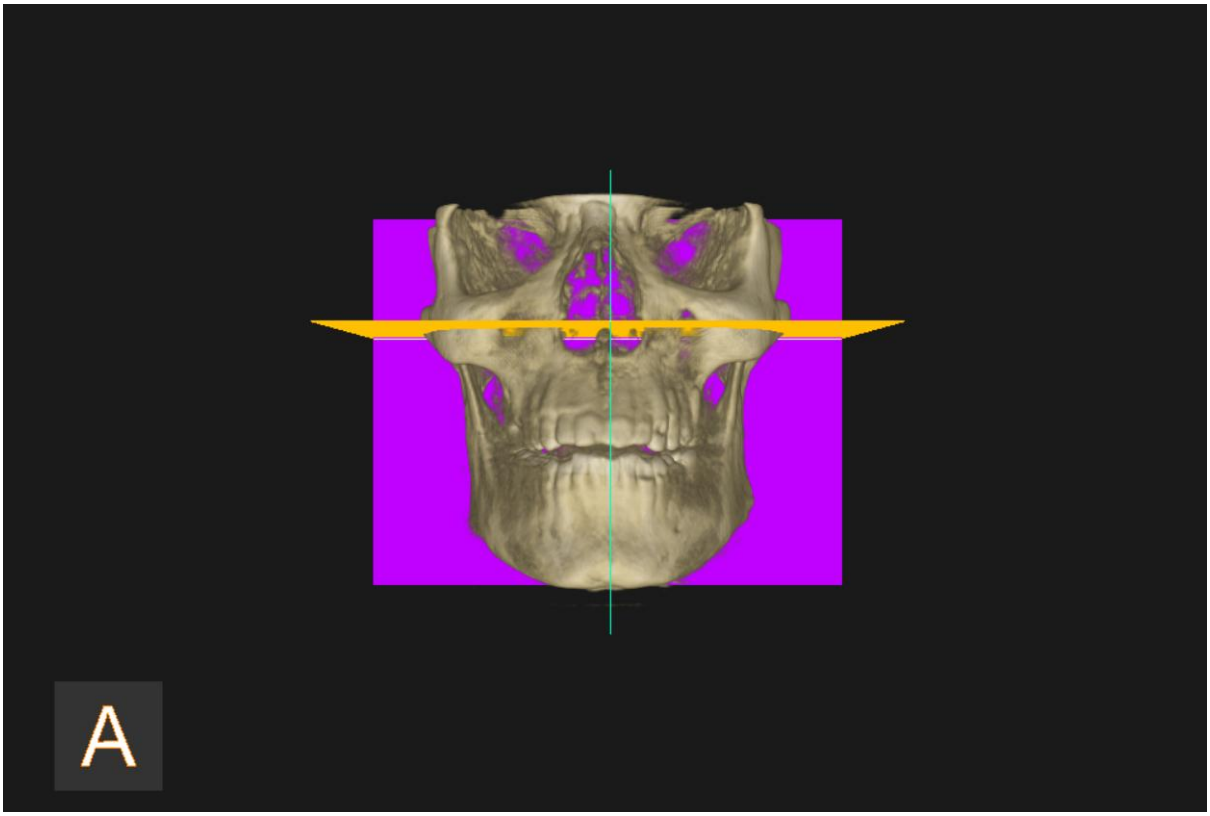
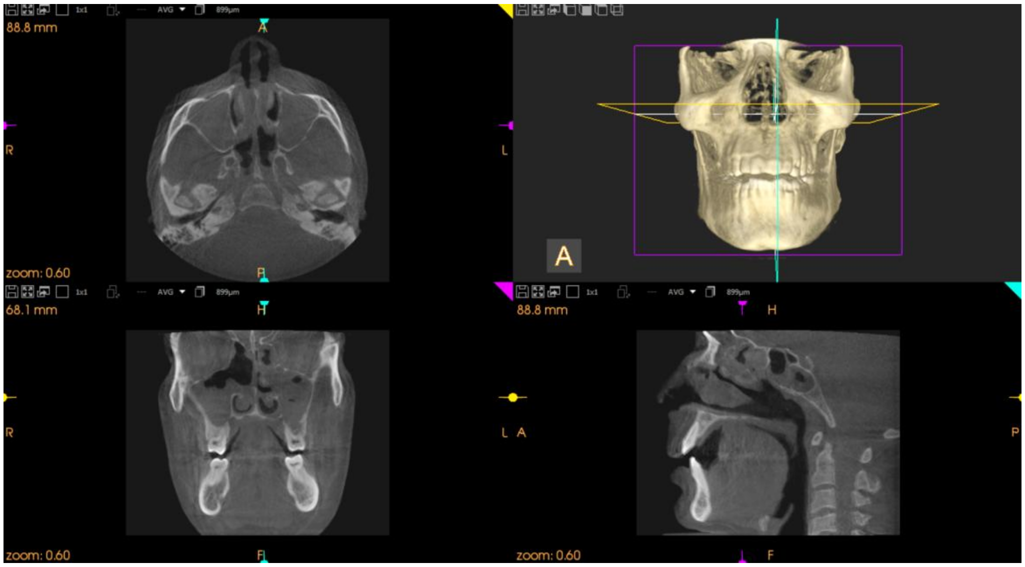
Coronal Orientation: The image is displayed looking at the patient anterior



Coronal Slice: Coronal means vertical slices from side to side

Multiplanar reformation (MPR):

MPR is a two-dimensional presentation of three-dimensional data in multiple projection planes.



Ways of viewing and analyzing

Four different mode tabs are identified by the type of slicing represented in them

1.) Orthogonal Slicing

2.) Curved Slicing

3.) Custom Slicing

4.) Oblique Slicing

Orthogonal Slicing:

- The main View Screens are displayed on the Orthogonal Slicing Tab, and are described below:
- 3D view
- Multi-planar Reformatting (MPR) View Screens:
  - Axial Slice
  - Coronal Slice
  - Sagittal Slice
- Each mpr view screen has a colored triangular tag in the top right corner. These colours are important because the position of the mpr slice is shown in the other two mpr views by grab handles of the same color.

Curved Slicing

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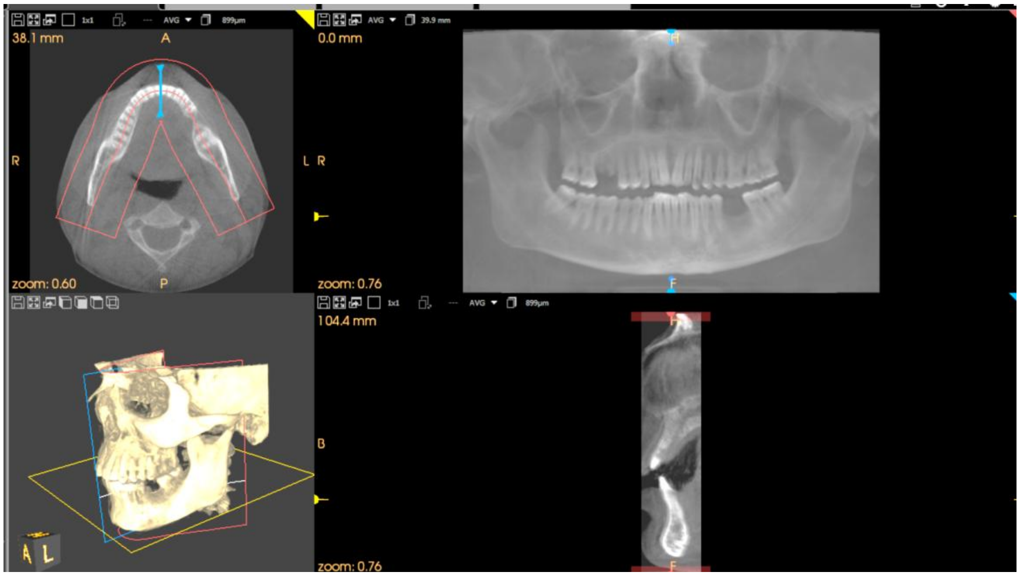
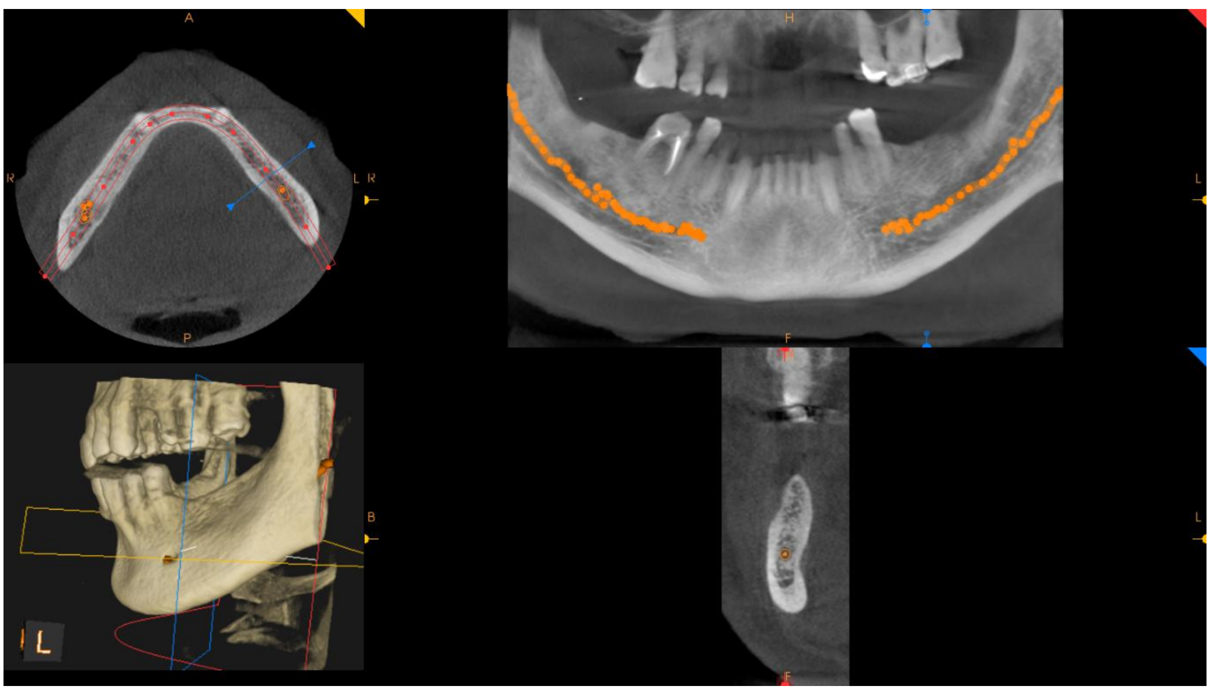


- Curved slicing tab enables to examine 3D volume in more depth. The view screens in the curved slicing tab are:
- Axial view screen – displays horizontal slices.
- Reconstructed panoramic image view displayed after a curve is drawn in the axial plane.
- Temporal bone view screen.
- 3D view screen

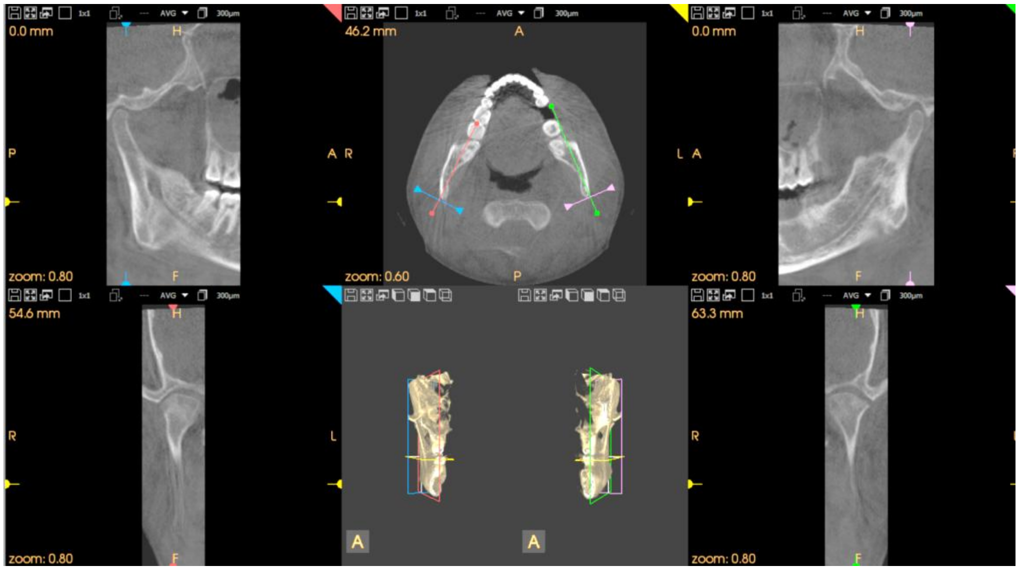
Nerve canal tracing:



Nerve canal tracing can be done in a curved slicing tab

- Create a reconstructed panoramic image.
- Activate the nerve canal tool.
- Identify the mental foramen in sagittal view and trace the canal from mental foramen to mandibular foramen.

Custom Slicing



- The **Custom Slicing** tab provides tools to help you examine specific areas of interest in depth. The views you see in this tab depend on the field of view and the area of interest.
- The Custom Slicing tab contains the following View Screens:

— Axial Slice View Screen – Horizontal slices.

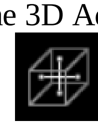
— Custom View Screen (s) – One or more views, to the left or the right of the Axial view; these are empty the first time you use the tab. They are filled by custom views you create in this tab.

— Trans-axial or cross-section View Screen (s) – One or more views that are displayed after an area of interest is drawn onto the axial plane. They show the trans-axial, or cross-section, view of the area of interest. When appropriate, they show symmetrical left and right-side views. They are created by a 90° cut through the lines drawn onto the axial plane. They are located in the bottom half of the workspace, typically in one or both far corners.

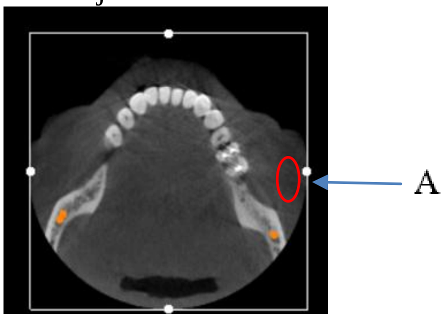
— 3D View Screen (s)- One or two 3D scenes, next to the trans-axial plane (s) in the lower half of the workspace.

— When there are two 3D scenes, they are identical the first time you use the tab. When an area of interest has been drawn onto the axial plane, these views change to show the symmetrical 3D scenes defined by left and right areas of interest.

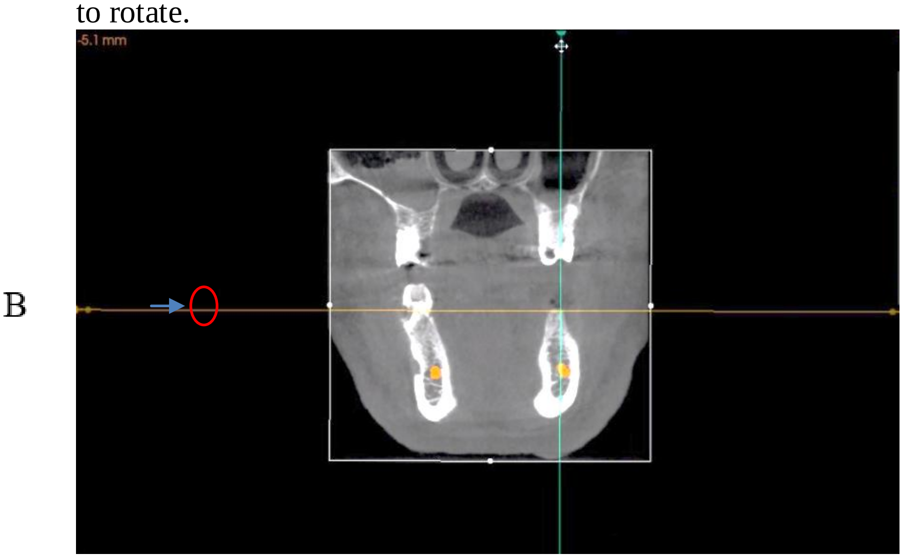
Oblique Slicing

- Oblique slicing tab enables to isolate and examine 360 degrees around an area of interest.
- It provides the same view as the orthogonal slicing tab but with additional tools to facilitate this function.
- To use the Oblique Slicing tab, follow these steps:
    1. On the Oblique Slicing tab, adjust your axial, coronal, and sagittal slices to display your region of interest.
    2. Click  to display the 3D Adjustment tools in the Tools panel.
    3. In the Tools panel, Click  A cube is displayed around the 3D scene, and corresponding selection boxes are displayed in the MPR windows.

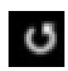
4. To adjust the visible 3D area, click and drag any of the white grab handles (A).



5. Use the mouse wheel to zoom the 3D scene so that your new anatomy selection fills the space.
6. After you isolate the area of interest, you can rotate the planes of the MPR views to see 360 degrees around the area. To rotate a plane, click and drag on the round grab handle (B) of the plane you want to rotate.



(Note: Each of the MPR planes can be rotated independently.)

7. To reset the MPR views and the 3D scene, click  beneath the planes tools in the tools panel

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