Interpretation Basics of Cone Beam Computed Tomography
Introduction

This chapter will cover basics of cone beam computed tomography including comparison to traditional computed tomography, common uses, artifacts frequently seen, and views created with a cone beam computed tomography dataset.

Conventional Computed Tomography (CT)

General Information

Computed tomography (CT) is credited to Godfrey Hounsfield, who in 1967 wrote first about the technology and then created a unit in 1972. He was awarded the Nobel Prize in Physiology/Medicine in 1979. Conventional CT units are both hard-tissue and soft-tissue imaging modalities. The first CT, first generation, had a scan time of 10+ minutes depending on how much of the body was being imaged. The processing time would take 2½ hours or longer. All first-generation CT units were only a single slice. This means that one fan of radiation exposed the patient and would have to circle around the patient several times to cover the area of concern. Current CT units are fifth generation, or helical/spiral. The scan times have gone down to 20–60 seconds with a processing time of 2–20 minutes. The number of slices available is up to 64, 128, and 256. The more slices available makes it possible to scan more of the patient in one circle, hence the lower scan times. Conventional CT units work with the patient lying down on a table while being scanned. The table
moves in and out of the bore to cover the area of concern. Once all the data are received, they are compiled to create a dataset. This dataset can be manipulated to look at the information in many different angles.

**Cone Beam Computed Tomography (CBCT)**

**General Information**

Cone beam computed tomography (CBCT) was discovered in Italy in 1997. The first unit created was the NewTom. The NewTom was similar to conventional CT having the patient lying down with an open bore where the radiation exposes the patient. Instead of a fan of radiation (used in conventional CT units), a cone of radiation is used to expose the patient, hence the name cone beam computed tomography. As new CBCT units were created, companies started using seated or standing options. With continued updates to the units, the sizes have become smaller, with many needing only as much space as a pantomograph machine.

**Conventional CT Versus Cone Beam CT**

**Voxels**

Voxels are three-dimensional data blocks that representing a specific x-ray absorption. CBCT units capture isotropic voxels. An isotropic voxel is equal in all three dimensions (x, y, and z planes) producing higher resolution images compared to conventional CT units. Conventional CT unit voxels are nonisotropic with two sides equal but the third side (z-plane) different. The voxel sizes currently available in CBCT units range from 0.076 mm to 0.4 mm. The voxel sizes currently available in conventional CT units range from 1.25 mm to 5.0 mm. Resolution of the final image is determined by the unit’s voxel size. The smaller the voxel size the higher the resolution. However, the higher the resolution, the higher the radiation dose to the patient as well.

**Field of View**

Field of view (FOV) is the area of the patient irradiated. CBCT units vary, with some units having a fixed FOV and some having changeable FOVs. The ranges of FOVs are from 5 cm × 3.8 cm, commonly referred to as a small FOV, to 23 cm × 26 cm, commonly referred to as a large FOV (Figures 1.1 to 1.3).

**Radiation Doses**

Radiation doses with CBCT units are as varied as the field of view options. CBCT units have approximate radiation dose ranges of 12 microSieverts to 1073 microSieverts. Conventional CT units have much higher radiation doses due to their soft tissue capabilities with doses of 1200 microSieverts and higher per each scan, depending on the selected scan field.
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Figure 1.1. (a) 3D rendering of a small FOV of 5 cm × 8 cm from an anteroposterior (AP) view; (b) 3D rendering of a small FOV of 5 cm × 8 cm from a lateral view.

Figure 1.2. (a) 3D rendering of a medium FOV of 8 cm × 8 cm from an anteroposterior (AP) view; (b) 3D rendering of a medium FOV of 8 cm × 8 cm from a lateral view.

Figure 1.3. (a) 3D rendering of a large FOV of 16 cm × 16 cm from an anteroposterior (AP) view; (b) 3D rendering of a large FOV of 16 cm × 16 cm from a lateral view.
Viewing CBCT Data

**Multiplanar Reformation (MPR)**

Multiplanar reformation, or MPR, is a view frequently of three different directional 2D images (axial, coronal, and sagittal planes) (Figure 1.4). Within this view, the images may be manipulated in the thickness of data, and direction of viewing can be altered. Reconstructed pantomographs and lateral cephalometric skulls (Figures 1.5 and 1.6) are possible without distortion from standard 2D radiography. The dataset may also be manipulated to create cross-sectional (orthogonal) views of the jaws and condyles (Figures 1.7 and 1.8).

**3D Rendering**

The most common form of 3D rendering offered in CBCT software is indirect volume rendering, which determines the grays of the voxels to create a 3D image (Figure 1.9). Another form of 3D rendering is referred to as direct volume rendering, or maximum intensity projection (MIP) (Figure 1.10).
Figure 1.5. Sample reconstructed pantomograph with 3D view on bottom left, focal trough bottom middle, and preview on bottom right.

Figure 1.6. Sample reconstructed lateral cephalometric skull.
Figure 1.7. Sample cross-sectional slices with axial view and reconstructed pantomograph.

Figure 1.8. Sample temporomandibular joint view with cross-sectional slices.
Artifacts

Streak Artifacts/Undersampling

Streak artifacts occur when an object with high density (such as metallic restorations) creates areas of undersampling where no viable information is recorded (Figure 1.11). Care should be taken not to interpret anything in the streak. Aliasing is another form of undersampling, when too few images are acquired and appear as small lines throughout a scan (Figure 1.12).
Figure 1.11. (a) Axial view showing streak artifact due to metallic restorations in a linear pattern radiating out from the restorations; (b) Coronal view showing streak artifact due to metallic restorations as multiple horizontal lines obscuring the image at the level of the restorations.

Figure 1.12. Axial view with metallic streak artifact and aliasing of scan as linear radiolucent lines throughout the entire image.
Motion Artifacts

Motion artifacts occur due to either normal pathophysiological movement or when the patient moves during a scan. This presents as ill-defined edges ranging from a blurring of the edge of an object to multiple visible edges evident (Figure 1.13). This can be minimized by restraining the patient’s head and using as short a scan time as possible.

Ring Artifacts

Ring artifacts present as white or black circular artifacts. They typically indicate poor calibrations and imperfections in the scanner detection (Figure 1.14).
Common Uses

Developing Dentition

Cleft Palate and Bone Graft Assessment

CBCT imaging has shown limited research that scans are reliable when determining the bony dimensions of a cleft palate (Figure 1.15). Cleft palate cases are recommended for CBCT imaging, as 2D radiographs cannot show facial-lingual dimensions of a defect. This additional information is helpful to a surgeon especially prior to bone grafting and helpful to an orthodontist prior to movement of teeth near the defect. Axial views are recommended to determine the bone quantity surrounding roots of teeth adjacent to the cleft. The FOV recommended is one large enough to see the entire cleft and portions of the nasal cavity for the surgeon to have all the information necessary. The recommended voxel size is 0.3 mm or larger, so as to reduce the overall radiation exposure since these scans are typically made on growing children.

Localization of Impacted Teeth

The most commonly impacted teeth are third molars and maxillary canines. CBCT imaging provides additional information about third molar location in relation to either the maxillary sinus or mandibular canal (Figures 1.16 and 1.17). CBCT imaging provides exact locations of impacted canines and the presence or absence of external root resorption of adjacent teeth (Figures 1.18 and 1.19). Cross-sectional views are recommended to determine exact facial-lingual width and
Figure 1.16. (a) Reconstructed pantomograph showing impacted mandibular third molars and mandibular canal noted in gray (b) Cross-sectional slices with 1.0 mm spacing showing location of impacted mandibular left third molar in relation to the mandibular canal (gray circle).
Figure 1.17. Reconstructed pantomograph and cross-sectional slices showing location of impacted maxillary left third molar (black arrow) in relation to the maxillary sinus.

Figure 1.18. Reconstructed pantomograph and cross-sectional slices showing location of an impacted maxillary canine (black arrow).
effect on adjacent teeth. The FOV recommended is one large enough to capture the tooth or teeth in question and surrounding bone and anatomical structures. A voxel size of 0.3 mm is recommended to produce a quality scan with overall low radiation doses to the patient.

**Restoring the Dentition**

**Periapical Pathosis**

CBCT imaging has increased sensitivity in the detection of periapical pathosis (Figure 1.20) compared to 2D radiographs. In the presence of clinical signs with the absence of 2D radiographic findings, a CBCT may be recommended to rule out or rule in possible periapical pathosis. It is important to thoroughly check all the teeth on a scan as early periapical pathosis has been noted on CBCT prior to detection on 2D radiographs. Sagittal and cross-sectional views are the recommended views for detecting periapical pathosis. The FOV recommended is dependent on how many teeth you want to evaluate. A single tooth only needs a small FOV; however multiple teeth throughout both jaws will need a medium FOV or larger. A voxel size of 0.2 mm or less is recommended.
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Root Fractures

Vertical root fractures are difficult to diagnose on 2D radiographs, typically presenting as a J-shaped lesion around the root with the fracture. CBCT imaging has shown increased sensitivity in detecting vertical and horizontal root fractures (Figures 1.21 and 1.22). One large concern when evaluating for fractures is teeth that have been endodontically treated, as the filling material can cause artifacts leading to small fractures to be obscured. Coronal, sagittal, and cross-sectional views are the recommended views for detecting vertical root fractures. Axial views are the recommended views for detecting horizontal root fractures. The FOV recommended is a small one to include the tooth in question. If more than one tooth is in question and both cannot be visualized on a single small FOV scan, a larger FOV should be used. A voxel size of 0.2 mm or less is recommended.

Surgical Applications

Bony Pathosis

There are various bony lesions that present throughout the jaws (Figures 1.23 and 1.24). CBCT imaging provides additional information about the exact location and possible nature of a bony lesion prior to removal or biopsy. All views (axial, coronal, sagittal, and cross-sectional) are recommended to completely grasp the size, position, and nature of a lesion. The FOV recommended is one large enough to capture the area in question. A voxel size of 0.3 mm is recommended to keep radiation doses to the patient low.

Implants

Quantity of bone, alveolar ridge morphology, maxillary sinus location, and mandibular canal location are important information prior to placing an implant. Standard 2D radiographs can provide the height of bone available but does not show whether there are ridge defects or concavities (Figures 1.25 and 1.26). CBCT imaging provides...
Figure 1.21. (a) Pantomograph and (b) periapical radiographs showing impacted first premolar and canine with a dentigerous cyst; (c) Cross-sectional slices showing a vertical root fracture on the maxillary right second premolar (black arrow) and dentigerous cyst associated with impacted canine (white arrow).
Figure 1.22. Cross-sectional slices (a,b) showing horizontal root fractures (black arrows).

Figure 1.23. (a) Periapical and (b) pantomograph radiographs showing an odontogenic myxoma in the anterior mandible.
(c) Axial (A), sagittal (S), and coronal (C) views showing extent of bone loss (black arrows); (d) Reconstructed pantomograph and cross-sectional slices showing width of odontogenic myxoma. Bone discontinuity on the facial from a prior incisional biopsy (black arrow).
Figure 1.24. (a) Bitewing radiographs and (b) pantomograph showing bone loss with impacted mandibular right third molar consistent with a dentigerous cyst (white arrow); (c) Axial (A), sagittal (S), and coronal (C) views showing extent of bone loss (white arrows).
(d) Reconstructed pantomograph and cross-sectional slices showing width of dentigerous cyst.

Figure 1.25. Reconstructed pantomograph and cross-sectional slices showing lingual concavity in posterior mandible (white arrow) and mandibular canal noted in gray.
information on these things to ensure implant placement within the bone and not surrounding soft tissues. Cross-sectional views are recommended to view the facial-lingual width and morphology of the alveolar ridge. A voxel size of 0.3 mm is recommended to keep the radiation doses to the patient low.

References

Conventional Computed Tomography and Cone Beam Computed Tomography


**Viewing CBCT Data**


**Artifacts**


**Common Uses**


