Cone Beam CT in Endodontics

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Abstract

Cone Beam CT (CBCT) is an excellent tool in endodontic diagnosis and treatment planning. This course defines CBCT, compares the types of devices available, and discusses which ones are best in endodontics. It lists the advantages and disadvantages of CBCT. It shows how much radiation a patient receives compared to other medical and dental X-rays.

The types of endodontic cases where a CBCT is indicated are listed. Several cases are presented where CBCT more clearly revealed the cause of the problem than conventional two-dimensional X-rays. CBCT sometimes prevents subjecting patients to exploratory surgery or endodontic access on hopeless teeth. Like the operating microscope, clinicians who utilize CBCT would not want to practice without it.

Educational Objectives

At the end of this program, participants will be able to:
1. Define cone beam CT and then describe the types of machines available.
2. Understand the amount of radiation a patient receives from CBCT compared to other types of medical and dental X-rays.
3. Describe when taking a CBCT is appropriate in endodontics.
4. Compare the advantages and disadvantages of CBCT over conventional 2D radiography.
5. Understand the limitations of CBCT with regard to artifacts.
6. Explain who is responsible for detecting and reporting potential pathology on CBCT scans.
Two-dimensional X-rays have been an integral part of endodontic diagnosis and treatment planning for over a century but they have limitations. Three-dimensional cone beam computed tomography (sometimes called cone beam volumetric tomography), or CBCT, now allows viewing the anatomy and pathology of the teeth and bone in all three dimensions in thin slices at any angle, and accurate measurement of the teeth and other structures.

What is Cone Beam CT?

In CBCT a cone-shaped X-ray beam is rotated around the head of the patient, exposing a sensor to multiple views of the teeth and jaws. A computer then renders those scans into a volume of images of the region of interest (ROI) that are then reconstructed to allow viewing slices at any angle or thickness. More importantly, CBCT allows viewing anterior teeth in the sagittal (anterior to posterior) plane and posterior teeth in the coronal plane (from the mesial and distal) as well as slicing them axially (at right angles to the long axis of the teeth); these views are essentially unobtainable in periapical radiography. CBCT also displays bone, defects or lesions in bone, as well as anatomic structures to be avoided in surgery like the inferior alveolar nerve, the mental foramen and the maxillary sinus. Because of the dimensional accuracy of the scan, teeth and bone can be measured in sub-millimeter distances.

CBCT differs from spiral (fan) beamed medical CT in that it is lower in cost and in the amount of radiation exposure to the patient. CBCT devices are classified by the size of the area imaged called the field of view (FOV). Large FOV machines image the entire skull; medium FOV machines image both jaws; and small or limited FOV image one quadrant or one jaw. The minimum cube of data displayed is called voxel (volumetric pixel) and is analogous to the square pixel in digital photography. The voxel size also represents the minimum slice thickness achievable by the scan.

In general, the larger the field of view, the greater the absorbed radiation dosage to the patient and the larger the voxel size. Because endodontic diagnosis and treatment planning is usually concerned with imaging one quadrant of teeth and with fine detail, small FOV machines are most appropriate in endodontics. When looking for cracks and periapical lesions, the smallest voxel size is best. Although new machines are constantly becoming available, 76 microns (0.076mm) is the smallest voxel size currently on the market. The average width of the periodontal ligament space and the diameter of the tip of a size 20-K file currently on the market is 200 microns (0.20mm).

CBCT is a valuable aid in endodontics in the following situations:

- Difficult endodontic diagnosis where suspected apical lesions are not seen on periapical X-rays (PA) and the clinical exam is inconclusive.
- Difficult root and canal anatomy to help determine the number, shape, curvature and length of roots and canals.
- Endodontic retreatment cases where cause of failure is unclear.
- Locating suspected cracks in roots or bone loss caused by them.
- Procedural accidents (perforations, file separations).
- Internal and external tooth/root resorption.
- Traumatic injuries to teeth and bone.
- Measuring the length of teeth, the width of bone and the distance from anatomic structures like the inferior alveolar canal and maxillary sinus to the apex when planning endodontic surgery.

ALARA – “As Low As Reasonably Achievable” – is the guiding principle in all radiology. Due to the slightly higher radiation, CBCT should only be used when the clinical exam and conventional radiographs don’t demonstrate enough information for adequate diagnosis and treatment planning. Young patients are much more susceptible to the effects of radiation than adults who are more susceptible than senior citizens.

Anyone who orders or takes a CBCT is responsible for all pathology visible on the scan. All slices in all three-dimensions should be carefully reviewed for pathology, not just the region of interest. Just as those who perform oral surgery or endodontics are held to the standard of care of a specialist, those who take or order a CBCT are held to the standard of care of an oral maxillofacial radiologist. Until one becomes proficient in reading CBCT scans, they should also be reviewed by someone who is.

The AAOMR (http://www.aaomr.org/) presents courses in CBCT interpretation that are quite good.

How Much Radiation Does a Patient Receive from CBCT?

Effective radiation dosage can be expressed a number of ways. Micro Sievert (μSV) is the unit most cited in current literature. The most meaningful to the patient is probably days of normal background radiation.

Chart 1 was created from Ludlow1 and White & Pharoah.2 It illustrates the various dosages of different brands of CBCT machines and traditional X-rays. Note that a cross-country airline trip exposes a patient to radiation dosages higher than some dental CBCT scans and that radiation from medical CT is much higher than most dental CBCT machines, especially the small FOV.

Advantages of CBCT over 2D X-rays

Maxillary posterior teeth are sometimes difficult to visualize due to anatomic overlap of the zygomatic arch, buccal roots, maxillary sinus, palatal roots and palatal bone. They are more easily visualized on CBCT than with conventional PA. Multiple

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continued on page 86
periapical X-rays taken at different angles will sometimes show the anatomy but small FOV CBCT scans of the maxilla expose the patient to radiation doses similar to two to three periapical X-rays and more clearly displays the anatomy and pathology.

Seltzer & Bender in 1961 demonstrated that defects created in the cancellous portion of the jaw were not visible with 2D X-rays unless they invaded the cortical plate. By displaying a thin slice at any angle through both the cancellous and cortical bone, CBCT often shows bone loss from apical periodontitis that is not visible on 2D intraoral periapical radiography.

Lofthag & Hansen in 2007 concluded “…in selected cases, e.g., when there is no detectable pathology in periapical radiographs although clinical tests indicate so, or when endodontic surgery is planned for multi-rooted teeth, additional radiographic examination using a 3D technique… should be considered.” Estrela et al. in 2008 concluded that detection of apical periodontitis was significantly better with CBCT than with periapical or panoramic radiography.

Fig. 1 shows two cases demonstrating that principle. The PA didn’t clearly show the periapical lesions but the CBCTs did.

Fig. 2 illustrates the value of CBCT in making a diagnosis. The clinical exam didn’t differentiate which tooth was causing the patients symptoms. The PA didn’t show an obvious periapical lesion. CBCT

clearly shows a lesion at the apex of #15 on both the sagittal and coronal slices.

The PA (Fig. 3) doesn’t show a lesion but the CBCT (Fig. 4) clearly shows not only a lesion on the mesial buccal root but also that the cause is probably a previously untreated MB2 canal.

Nurbakhsh et al.\textsuperscript{6} reported using CBCT to study maxillary sinus mucositis adjacent to teeth with apical periodontitis. Maxillary sinusitis can sometimes be confused with endodontic periapical pathology and visa versa. Fig. 5 is a case where the patient was diagnosed by his ENT with a sinus infection. The PA didn’t show which tooth was the cause but the CBCT clearly showed that the abscessed upper first molar was the cause of the sinus infection.

Lower molars sometimes have three distinct roots.\textsuperscript{7} Figs. 6 and 7 show a case where the CBCT clearly shows that to be the case but the PA does not.

Maxillary incisors very rarely have more than one root. Fig. 8 is a case where the periapical X-ray didn’t show that but the CBCT did.

Figs. 9 and 10 are a case where the tooth remained symptomatic after root canal treatment. The PA didn’t reveal the cause of the


problem but the CBCT did. Note that only two of the four canals were located and treated.

The mesial roots of lower molars sometimes have three canals. Fig. 11 shows how CBCT shows three canals in the mesial root of a lower second molar; the periapical doesn’t.

Patel et al.\(^8\) concluded that “the advent of cone beam computed tomography has considerably enhanced the clinician’s capability of diagnosing internal root resorption.” Root resorption is sometimes difficult to see clearly on PA. Fig. 12 is a case where CBCT much more clearly shows the extent of the internal resorptive defect on the palatal root of an upper first molar that is not evident on the PA.

Cracked teeth and roots are notoriously difficult to diagnose and treatment plan. Bernardes et al.\(^9\) concluded that “cone-beam volumetric tomography was better than conventional radiography in the diagnosis of root fractures.”

Kajan & Taromsari\(^10\) concluded “CBCT can be an ideal alternative in the diagnosis of root fracture in the field of endodontics.” CBCT can only reveal cracks that are at least twice as wide as the minimum voxel size of the scan according to the Nyquist Theorem. Even if the crack is too small to be seen on a CBCT, the bone loss caused by the bacteria contained in cracks is often easier to demonstrate on CBCT than on periapical radiographs.

Fig. 13 is a case where the bone loss caused by a crack on the distal of the lower second molar is visible on the CBCT but not on the periapical. Note that the crack in the root is not visible on the CBCT so it must be narrower than twice the 76 micron voxel size of the scan, or about the diameter of the tip of an ISO size 15/02 endodontic file.

Fig. 14 is an upper canine where the crack in the root can clearly be seen on the axial view of the CBCT, so it must be wider than twice the voxel size. Notice that the crack and the bone loss are also seen on the periapical X-ray.

The vertical bitewing suggests a short root canal filling in the mesial buccal root of the upper first molar might be the cause of the problem and that retreatment or apical surgery might be indicated. Cone beam CT clearly shows the palatal root has a vertical fracture, making the prognosis hopeless (Fig. 15).

The results of traumatic injuries to teeth and bone are often easier to see on CBCT than on conventional periapical X-rays. Fig. 16 is a case of two lower incisors re-implanted by an emergency room physician that look OK on the PA. CBCT clearly shows that they were not re-implanted in the sockets but rather between the alveolus and the soft tissue.

Kovisto et al.\(^11\) concluded “the CBCT scan is an accurate, non-invasive method to evaluate the position of the mandibular canal.” CBCT allows tracing and accurate measurement of the inferior alveolar nerve. This case (Fig. 17) shows that the nerve is over 6mm from the apex of the lower first molar’s mesial root.

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making periapical surgery less risky than if the nerve was nearer the apices.

In Fig. 18 the apices of the lower molars are touching the inferior alveolar nerve, increasing the risk of paraesthesia caused by apical surgery.

Fig. 19 demonstrates the various artifacts on CBCT than can be confused with pathology. Metal restorations and radiopaque root canal fillings cause beam hardening and streak artifacts due to photon starvation that appear like decay in the crowns of teeth and cracks in the roots. One must be careful when first interpreting CBCT scans not to misinterpret these as pathology.

Procedural accidents like root perforations and file separation are better visualized by CBCT than periapical X-rays. Fig. 20 is a case where the cause of non-healing is not apparent on the PA but a post perforation to the buccal mid root is clearly visible on the CBCT.

Although Cone Beam CT is being utilized by more than one-third of the endodontists in the U.S., it is not yet the standard of care. It should not be used for routine screening of all patients or taken on all cases.12

Summary

CBCT is a valuable tool in endodontics in cases where the clinical exam and traditional two-dimensional radiographs fail to produce a diagnosis; in retreatment cases; where unusual anatomy, cracks, trauma and resorptive defects are present or suspected; or where apical surgery is planned. A CBCT will sometimes prevent subjecting patients to needless operative or surgical procedures to make a diagnosis and treatment plan of hopeless teeth. Like the operating microscope, clinicians who utilize CBCT would not want to practice without it.

Post-test

1. Which size field of view (FOV) scan is most appropriate in endodontics?
   a. Small or limited FOV.
   b. Medium FOV.
   c. Large FOV.
   d. Medical CT.

2. What is the number of days of natural background radiation a patient receives from a single limited FOV Kodak 9000 CBCT scan?
   a. Zero to one.
   b. One to five.
   c. Five to 10.
   d. Ten to 20.

3. What is the ability to see periapical lesions in cancellous bone on cone beam CT scans compared to periapical X-rays?
   a. Less.
   b. About the same.
   c. More.
   d. It depends on the size of the lesion.

4. An axial slice on a cone beam CT is:
   a. Parallel to the floor.
   b. From ear to ear.
   c. From front to back.
   d. At an oblique angle.

5. The distance from the apex of a lower tooth to the inferior alveolar canal can be measured accurately to within a tenth of a millimeter on cone beam CT.
   a. True
   b. False

6. Dental decay can easily be identified by a CBCT on teeth where there are several large metal restorations on other teeth in the quadrant.
   a. True
   b. False

7. Which statement about detecting cracks in teeth and roots is not true about cone beam CT scans?
   a. They might only be visible if they are wider than twice the minimum voxel size of the scan.
   b. They will be visible even if there are metal posts or radiopaque fillings in the root canals.
   c. The bone loss adjacent to the cracks in roots is often visible on scans even if the cracks themselves aren’t.
   d. They are more easily visualized on CBCT than on periapical X-rays.

8. Who is responsible for detecting and reporting to the patient any pathology visible on a cone beam CT scan?
   a. An oral maxillofacial radiologist.
   b. The practitioner who orders the scan.
   c. The owner of the facility that takes the scan.
   d. All of the above.

9. As a person ages from a child to an adult to a senior citizen, which is true about their susceptibility to any potential adverse effects of radiation?
   a. Less susceptible.
   b. More susceptible.
   c. About the same.
   d. Depends on the weight of the patient.

10. Cone beam CT is now the standard of care in endodontics, and if available in the office should be taken on all cases.
    a. Both parts of the statement are true.
    b. The first part is true but the second false.
    c. The first part is false but the second true.
    d. Both parts of the statement are false.

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