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Research Article

# NEW DIMENSION IN ENDODONTIC IMAGING – CONE BEAM COMPUTED TOMOGRAPHY

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A B S T R A C T

Cone beam computed tomography (CBCT) has proven to be an important as well as essential tool for successful diagnosis, treatment planning as well as post procedure monitoring in all fields of dentistry including endodontics. It is a modern, radiological imaging system which is designed so as to produce undistorted three-dimensional image of the maxillofacial skeleton, teeth and the surrounding tissues that overcomes the limitations of conventional radiograph. CBCT allows as well as confirms a more precise and accurate diagnosis of any periapical lesions (true size, extent, nature and position), root fractures(specially vertical), root canal anatomy(location and number of canals, pulp chamber size, direction and curvature of root morphology), true nature of the alveolar bone topography around teeth, external and internal resorptions, degree of calcification, inflammatory lesions and defects. The relationship of anatomical structures such as the maxillary sinus and inferior dental nerve to the root apices may also be clearly visualized. The purpose of this article is to assess the functionality of CBCT as a high resolution imaging technique and its potential Implementations in the diagnosis and treatment of various endodontic conditions.



## INTRODUCTION

Throughout many decades, endodontic treatments count on effective imaging techniques for diagnosing tooth anatomy and its surrounding structures and tissues during treatment planning. Conventional (both chemical and digital) radiography (introduced in the 1980s by French dentist Francis Mouyen) renders a 3-D anatomical structure in 2-D. They give information about the tooth, including pulp chamber, its contents, number, patency, curvature and length of the canals. They also help in identifying canal perforations, broken implants, obturation failure, surgical failures and number of pathological conditions. But on the other side, they have some limitations too. Conventional radiograph shows a number of errors like geometric distortion, magnification, anatomical overlapping or combination of the factors. Moreover, they require multiple exposures, and occasionally fail to provide complete and accurate information. For example, a single radiograph may indicate an apparently successful treatment, whereas a second or third viewpoint may reveal an unnoticed yet important discrepancy. Also, in many incidences, it becomes a matter of guesswork even to the experienced doctor, like in the case of relationship of the maxillary molars with the maxillary sinus. These limitations can be avoided by the use of CBCT.

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CBCT was first introduced in the European market in 1996 by QR s.r.l. (NewTom 9000) and into the US market in 2001. CBCT is accomplished by using a rotating gantry to which an x-ray source and detector are fixed. A divergent pyramidal source of ionizing radiations is directed through the middle of the area of interest onto an area x-ray detector on the opposite side of the patient. The x-ray source and detector rotate around a fixed fulcrum within the region of interest. During the exposure sequence, hundreds of planar projection images are acquired of the FOV in an arc of at least 180°.Unlike medical CT, which captures the image in slices, CBCT data are captured in a 3-D pixel unit called voxel. As these voxels are isotropic, the object is accurately measured in different directions. The image so prepared can then be rotated as well as color-contrasted. The slices can be isolated too and further analyzed — even down to a single voxel size of 76 microns in thickness. Anatomic structures like nerve canals can also be traced and highlighted for easy recognition.

### *Limitations of 2d Imaging*

Intraoral radiography is based on the principle of transmission, attenuation, and then recording the X-rays on a digital receptor. It requires optimized geometric configuration of the X-ray generator, tooth and sensor to provide an accurate image of the tooth. The image projected is 2D representation of 3D object. If any component of the imaging chain process is undermined, the final image may display exposure or geometric errors, thus, being suboptimal. 3D traits like complex dental morphology and surrounding structures (both hard and soft) can make elucidation of 2D "shadows" cumbersome which can lead to non healing endodontic cases. Success in endodontics is dependent on healing of the periapical bone adjacent to obturated canals. Goldman *et al*. proved that in analyzing healing of the periapical lesions using 2D radiographs, there was only 47% agreement between six examiners. He also surveyed that when those same examiners evaluated the same films at two different times, they only had 19%–80% agreement between the two evaluations.

***Uses of Cbct In Endodontics***

CBCT can be used in diagnosis and treatment and post treatment follow-up of complex endodontic conditions such as:

- Identifying root canal system anomalies (dens invaginatus, fused teeth, taurodontism) and determination of root curvature.
- Diagnosis of periapical pathosis in patients who present nonspecific clinical signs and symptoms corresponding to an untreated or previously endodontically treated tooth where no evidence of pathosis is recognized by conventional radiography. It also marks wonders in cases where anatomic superimposition of roots or areas of the maxillofacial skeleton is required to perform task-specific procedures. High resolution focused field CBCT provides 100% accuracy and specificity in the detection of artificially created periapical lesions in dry human mandibles.
- Detection of apical periodontitis
- Diagnosis of pathosis of non endodontic origin in order to determine the extent of the lesion and its effect on surrounding structures.
- Intra- or postoperative assessment of endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, calcified canal identification and localization of perforations.
- Diagnosis and management of dentoalveolar trauma, especially root fractures, luxation and/or displacement of teeth (degree as well as direction) and alveolar fractures.
- Localization and differentiation of external from internal root resorption or invasive cervical resorption from other conditions (the "portal of entry" of a resorptive lesion), and the determination of appropriate treatment and prognosis.
- Presurgical case planning to determine the exact location of root apex/apices and to evaluate the proximity of adjacent anatomical structures.
- Pulp chamber size and degree of calcification.

***Types of Cbct***

***Based On Patient Positioning***

Depending on the system employed, CBCT can be performed in three possible positions: (1) sitting, (2) standing, and (3) supine. Equipment that demands the patient to be in supine position has a larger physical footprint and thus is not approachable for physically challenged. Standing equipments might not be able to modify to a height to oblige wheelchair bound patients. Seated units are the most agreeable; however they may not allow ready scanning of physically challenged or wheelchair bound patients. As scan times are often near to or greater than those used with panoramic imaging, perhaps more important than patient orientation is the head restraint mechanism used.

***Based on scan volume***

The dimensions of the FOV, or scan volume, rely on the detector size and shape, beam projection geometry, and the ability to collimate the beam. The shape of the FOV can be either a cylinder or spherical (e.g., NewTom 3G). Based on available or selected scan volume height, the use of units can be designed as follows:

1. localized region (also referred to as *focused, small field* or, *limited field*)—approximately 5 cm or less,
2. single arch—5 cm to 7 cm,
3. inter-arch—7 cm to 10 cm,
4. maxillofacial—10 cm to 15 cm,
5. Craniofacial—greater than 15 cm.

In general, smaller the scan volume, higher the spatial resolution of the image. CBCT imaging system used in endodontics does not exceed 200 $\mu$m—the average width of the periodontal ligament space.

Based on modality Hybrid multimodal systems combine digital panoramic radiography with a relatively small-to medium-FOV CBCT system. Examples of other hybrid units are the Veraviewepocs 3D (J. Morita, Corporation, Kyoto, Japan), the Picasso Trio (Vatech/E. Woo Corporation, Korea), and the Kodak Dental Imaging 9000 DS (Kodak Dental Imaging/Practiceworks Atlanta, GA, USA)


**Figure 1** Types of CBCT machine in A) supine B) sitting C) standing positions

***Limitations of Cbct***

In cone-beam technology based on an image intensifier the periphery of the image might be distorted. CBCT give a little hindrance in soft tissue detail. Even though newer algorithms have been advanced to upgrade this disadvantage, it is not able to counterpart the ability of conventional CT. Another drawback in diagnostic accuracy of CBCT is the scatter and beam hardening artifacts caused by high density adjacent structures, such as enamel, and hindrance by radiopaque materials such as metal posts, restorations and root filling materials.

**Table 1** Current commercially available CBCT equipment

| Unit | Model(s) | Manufacturer/Distributor |
|---|---|---|
| Accuitomo | 3D Accuitomo—XYZ Slice View Tomograph/Veraviewpacs 3D | J. Morita Mfg. Corp., Kyoto, Japan |
| Asahi Roentgen | PSR 9000N (Alphard 3030) | Asahi Roentgen, Kyoto, Japan/Distributed by Belmont, Somerset, NJ, USA |
| Galileos | Galileos | Sirona Dental Systems, Charlotte, NC, USA |
| GENDEX | CB 500 | Imaging Sciences International, Hatfield, PA, USA/Distributed by Gendex, Chicago, IL, USA |
| Hitachi | CB MercuRay/CB Throne | Hitachi Medical Corp., Chiba-ken, Japan |
| iCAT | Classic/Next Generation | Imaging Sciences International, Hatfield, PA, USA |
| ILUMA | Ultra Cone Beam CT Scanner | IMTEC Imaging Ardmore, OK, USA/Distributed by GE Healthcare, Piscataway, NJ, USA |
| KaVo | 3D eXam | Imaging Sciences International, Hatfield, PA, USA/Distributed by KaVo Dental Corp., Biberach, Germany |
| KODAK | 9000 3D/9500 3D | KODAK Dental Systems, Carestream Health Rochester NY, USA/Distributed exclusively in the USA by PracticeWorks, Atlanta, GA, USA |
| Newtom | 3G/NewTom VG | QR, Inc. Verona, Italy/Dent-X Visionary Imaging, Elmsford, NY, USA |
| ORION | RCB-888 | Ritter Imaging GmbH, Ulm, Germany |
| Picasso Series | Trio/Pro/Master | E-Woo Technology Co., Ltd/Vatech, Giheung-gu, Korea |
| PreXion | 3D | PreXion, Inc. San Mateo, CA, USA |
| Promax | 3D | Planmeca OY, Helsinki, Finland |
| Ritter | Orion RCB-888 | Ritter Imaging GmbH, Ulm, Germany |
| Scanora | Scanora 3D CBCT | SOREDEX, Tuusula, Finland |
| SkyView | 3D Panoramic imager | My-Ray Dental Imaging, Cefla Dental Group, Imola, Italy |
| Suni | 3D | Suni Corp., CA, USA |
| TeraRecon | Fine Cube | Yoshida Dental Mfg. Co. Ltd., Tokyo, Japan/Distributed by TeraRecon, Inc., San Mateo, CA, USA |

## DISCUSSION

On the above basis it can be summarized that every technology has its own pros and cons.

### *Advantages of Panoramic Radiograph*

- Cost-effective.
- High-resolution imaging.
- Requires low exposure.

### *Disadvantages of Panoramic Radiograph*

- Image quality (superimposition, magnification, distortion, overlap, GHOST image).
- 2D presentation.
- Does not give a clear view of TMJ when compared to CBCT.
- Images that lie only on focal trough are clear

### *Advantages of Cbct*

- Evaluation of all possible sites.
- No image distortion like magnification or superimposition.
- Estimates internal bone density and bone resorption.
- Stimulates placement with software.
- Rapid scan time.
- Interactive display modes.
- Multiplanar reformatting.
- 3D volume rendering.
- High quality image with good spatial resolution.
- Comfortable and safe.

### *Disadvantages of Cbct*

- Limited availability.
- High cost.
- High radiation exposure.
- Special training for interpretation.

| Maxillofacial region (large FOV) | | Dentoalveolar region (medium FOV) | | Localised region (small FOV) |
|---|---|---|---|---|
| CBCT units | Effective dose (μSv) | CBCT units | Effective dose (μSv) | CBCT units |
| NewTom 3G[a] | 68 | CB Mercuray panoramic FOV[a] | 560 | CB Mercuray I FOV maxilla[a] |
| CB Mercuray maximum quality[a] | 1073 | Classic i-CAT Standard scan[a] | 69 | Promax 3D small adult[a] |
| CB Mercuray standard quality[a] | 569 | Next Generation i-CAT landscape mode[a] | 87 | Promax 3D large adult[a] |
| Next Generation i-CAT portrait mode[a] | 74 | Galileos default exposure[a] | 70 | PreXion 3D standard exposure[a] |
| Illuma standard[a] | 98 | Galileos maximum exposure[a] | 128 | PreXion 3D high resolution[a] |
| Illuma ultra[a] | 498 | | | |
| Galileos Comfort[b] | 84 | 3D Accuitomo 170[b] | 54 | 3D Accuitomo 170 (lower jaw, molar region)[b] |
| i-GAT Next Generation[b] | 83 | i-GAT Next Generation[b] | 45 | Kodak 9000 3D (upper jaw, front region)[b] |
| Illuma Elite[b] | 368 | Veraviewepocs 3D[b] | 73 | Kodak 9000 3D (lower jaw, front region)[b] |
| Kodak 9500[b] | 136 | Kodak 9500[b] | 92 | Pax-Uni 3D (upper jaw, front region)[b] |
| NewTom VGi[b] | 194 | NewTom VGi[b] | 265 | |
| NewTom VG[b] | 83 | Picasso Trio (high dose)[b] | 123 | |
| Scanora 3D[b] | 68 | Picasso Trio (low dose)[b] | 81 | |
| SkyView[b] | 87 | ProMax 3D (high dose)[b] | 122 | |
| | | ProMax 3D (low dose)[b] | 28 | |
| | | Scanora 3D (upper jaw)[b] | 46 | |
| | | Scanora 3D (lower jaw)[b] | 47 | |
| | | Scanora 3D (both jaws)[b] | 45 | |

**Figure 2** Radiation effective dosage for different regions with respect to various commercially available machines.

## CONCLUSION

The functionality of the CBCT cannot be suspected. It is a valuable and beneficial task-specific imaging modality that provides maximum information to the clinician. It drives diagnostic perfection, which instantly gives a clear picture on clinician's mind that influences treatment planning favourably. This multiplies the swiftness of treatment and enhances efficiency and patient outcomes. The practice is empowered with instant access to detailed 3-D images of anatomical structures, critical to precise diagnoses, more effective treatment planning, increased case acceptance, and better care for the patient. CT is almost certainly going to revolutionize dental radiology and impact on almost all aspects of dental practice.

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