SEEING THE UNSEEN : CONEBEAM VOLUMETRIC TOMOGRAPHY AND ENDODONTICS: A REVIEW ARTICLE

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ABSTRACT:

Cone beam volumetric tomography (CBVT) or cone beam computed tomography (CBCT) is a diagnostic imaging technology that is changing the way dental practioners view the oral and maxillofacial complex as well as teeth and the surrounding tissues. CBVT has been specifically designed to produce undistorted three dimensional images similar to computed tomography (CT), but at a lower equipment cost, simpler image acquisition and lower patient radiation dose. This article highlights the CBVT application in endodontics and its treatment outcome.

KEYWORDS: conebeam computed tomography, conebeam volumetric tomography, CBCT, CBVT, endodontic applications

INTRODUCTION

Radiographic examination is essential in diagnosis and treatment planning in endodontics. The interpretation of an image can be altered by the anatomy of both the teeth and surrounding structures. The amount of information gained from conventional film and digitally captured periapical radiographs is limited by the fact that the three the dimensional anatomy of area beina radiographed is compressed into an two dimensional image. As a result of superimposition, periapical radiographs reveal limited aspects of the three dimensional anatomy.

The high radiation dose, cost, availability, poor resolution and difficulty in interpretation have resulted in limited use of CT imaging in endodontics. These problems may be overcome using small volume cone beam volumetric tomography (CBVT) imaging techniques.

Cone beam technology

In the late 1990s Japanese¹ and Italian² groups working independently of each other, developed a new tomographic scanner known as cone beam computed tomography (CBCT) or cone beam digital volume tomography (CBVT) specifically for dental

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acquired in the course of a single sweep of the scanner, using a simple, direct relationship between sensor and source. The x-ray beam is cone shaped (hence the name of the technique), and captures a cylindrical or spherical volume of data, described as the field of view(FOV).^{2,3} Just as a digital picture is subdivided into pixels, the volume acquired by a CBVT is composed of voxels.

use. CBVT differs from medical CT imaging, in that the whole three dimensional volume of data is

volume acquired by a CBVT is composed of voxels. Essentially, a voxel is a 3-D pixel. Because the data are captured in a volume as opposed to slices, all the voxels are isotropic, which enables objects within the volume to be accurately measured in different directions⁴.

CBVT units for dental uses

The majority of the machines scan the patients in a seated position, where as a few scan the patients in either an upright or supine position.

Currently available CBVT units include the following^{3,5,6,7}

- 3D Accuitomo FPD XYZ Slice View Tomograph (J. Morita USA, Irvine, Calif.)
- 3D X-ray CT Scanner Alphard Series (Asahi, Kyoto, Japan)

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- Quolis Alphard 3030 cone Beam (Belmont Equipment, Somerset, N.J.)
- CB MercuRay (Hitachi Medical Systems America, Twinsburg, Ohio)
- Galileos 3D (Sirona Dental Systems, Charlotte, N.C.)
- i-CAT (Imaging Sciences International, Hatfield, Pa.)
- Iluma Ultra Cone Beam CT Scanner (Care stream, Rochester, N.Y.)
- NewTom 3G and VG (AFP Imaging, Elmsford, N.Y.)
- Picasso (E-woo Technology, Houston)
- PreXion 3D (TeraRecon, San Mateo, Calif.)
- ProMax 3D (Planmeca USA, Roselle, III.)
- Scanora 3D (Soredex, Tuusula, Finland)
- NewTom QR 9000 and NewTom Plus (Aperio, Inc., Sarasota, Fla.)

All CBVT units provide 3D information, each manufacturer uses slightly different scanning parameters and viewing software. CBVT systems can be classified into 2 categories⁶

- 1. Limited (dental or regional) CBVT
- 2. Full (ortho or facial) CBVT

The field view of limited CBVT ranges in diameter from 40-100 mm, where as the focus of view of full CBVT ranges from 100-200mm. Another difference between the limited CBVT and full CBVT is that a voxel is generally smaller for the limited version (0.1-0.2mm Vs 0.3-0.4mm). Thus limited CBVT systems offer higher resolution and are better suited for endodontic applications.

As the source receptor rotate once around the patient , many exposures are made, ranging in duration between 8.9 and 40 seconds, although the actual exposure time is significantly less (2-5 seconds) as scans involve a number (upto 360) of separate, small , individual exposures rather than one continous exposure.

The software reconstructs the sum of the exposures via algorithms specified by the manufacturer into as many as 512 axial slice images. These images are in the Digital Imaging and Communications in Medicine Manufacturers (DICOM)(National Electrical Association, Rosslyn, Va) data format. DICOM is a standard for handling, storing, printing and transmitting information in medical imaging. One advantage of using a DICOM data format is that

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the dentist can make precise measurements in any plane within the viewing software⁷.

Endodontic applications of CBVT ^{6,8,9,10,11}

- 1. Evaluation of root canal morphology
- 2. Diagnosis of endodontic pathosis
- 3. Assessment of pathosis of non endodontic origin
- 4. Evaluation of root fractures
- 5. Analysis of external and internal root resorption
- 6. Diagnosis of invasive cervical resorption
- 7. Endodontic surgical planning
- 8. Identifying an untreated or missed canal
- 9. Visualizing extruded root canal materials which are affecting surrounding anatomical structures.

A major advantage of CBVT that has been reported is the three dimensional geometric accuracy compared with conventional radiographs. Sagittal, coronal and axial CBVT images eliminate the superimposition of anatomical structures.

Most endodontic applications only require a small FOV (40x40 mm). Limiting the FOV not only reduces the dosage, scan time and scatter artifacts, but also focuses the volume on structures familiar to dentists.

Evaluation of root canal morphology¹²

Root morphology can be visualized in three dimensions, as can the number of root canals and whether they converge or diverge from each other. Unidentified and untreated root canals in root filled teeth may be identified using axial slices which may not be readily identifiable with periapical radiographs even if taken at different angles.

Diagnosis of endodontic pathosis

CBVT enables periapical disease evidenced by radiolucent changes at the root apex to be detected earlier than on conventional radiographs. CBVT scans resulted in 62% more periapical radiolucent areas being detected on individual roots of posterior mandibular and maixillary teeth when compared with two angled periapical radiographs. Endodontic treatment is more successful in teeth treated early, before obvious radiographic signs of periapical disease. Thus, earlier detection of periradicular radiolucent changes with CBVT should result in earlier identification and management of endodontic disease.^{13,14,15,16}

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Simon¹⁵ et al compared the ability of CBVT and biopsy with histological examination to differentiate between periapical cysts and granulomas in teeth with large periapical lesions. It was stated that grey scale value measurements of periapical lesions onCBVT images were able to differentiate solid (granulomas) from cystic or cavity (cyst) type lesions. Of the total 17 lesions, 13 were correctly identified by CBVT.

Patel and co-workers⁸ reviewed the literature on CBVT applications to endodontics and found CBVT to be clinically superior to periapical radiography for the detection of periapical lesions.

Evaluation of root fractures^{17,18}

CBVT may also prove useful in the diagnosis of dento-alveloar trauma, because the exact nature and severity of alveolar and luxation injuries can be assessed from just one scan. It has been reported that CBVT has been used to detect a horizontal root fracture. The same fracture may have needed multiple periapical radiographs taken at several different angles to be detected and even than may not have been visualized.

Analysis of internal and external resorption of root $^{\rm 19}$

Treatment of resorption can be complex and unpredictable. Imaging is critical to accurate diagnosis and appropriate treatment. Conventional radiography does not provide the true and full representation of the lesion. Often unable to identify the true extent, location or the portal of entry of a resorptive lesion. CBVT has shown to help and determine the treatment complexity as well as aid the clinician in offering an accurate prognosis on the basis of the extent of the resorptive lesion. As a result, both treatment and treatment outcomes are likely to become more predictable. Invasive cervical resorption is often misdiagnosed as internal resorption, therefore, identification of the portal of entry is critical.

Endodontic surgical planning ^{20,21}

CBVT may play an important role in periapical microsurgery of palatal roots of maxillary first molars. The distance between the cortical pate and the palatal root apex could be measured, and the presence or absence of the maxillary sinus between the roots could be assessed. The use of CBVT technology in presurgical endodontic planning allows for assessment of the location of the lesion, position of the roots with in the bone, and the proximity of vital structures including the inferior alveolar nerve, mental foramen, maxillary sinus, and nasal cavity.

Limitations of CBVT ¹⁰

Crowns or any other metal elements in the mouth cause many artifacts during the acquisition of the three dimensional image due to the absorption of the x-ray beam. The nature of the metal leads to great variations in the quality of the image. In endodontics, it is common to examine teeth with posts and prosthetic restorations. Artifacts produced by metals limit the image reading. Sometimes interpretation even become impossible.

Currently, Planmeca is the first to adopt image processing software for their cone beam Promax, which minimizes the effect of metallic artifacts.

CONCLUSION

Two dimensional diagnostic imaging has served dentistry well and will continue to do so for the foreseeable future. However, the advent of CBVT allows complete visualization of the oral and maxillofacial complex. CBVT technology aids in the diagnosis of endodontic pathosis and canal morphology, assessing root and alveolar fractures, analysis of resorptive lesions, identification of pathosis of non endodontic origin, and presurgical assessment before root end surgery. CBVT has increased accuracy, higher resolution, reduced scan time, a reduction in radiation dose and reduced cost for the patient. CBVT eliminates superimposition of surrounding structures, providing additional clinically relevant information. Drawbacks of CBVT include limited availability, significant capital investment and extensive knowledge of radiologic interpretation.

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