Applications of Cone-Beam Computed Tomography in Dentistry

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ABSTRACT

Cone-beam computed tomography (CBCT) or cone-beam volumetric tomography (CBVT) is a diagnostic imaging technology that is changing the way dental practitioners view the oral and maxillofacial complex as well as teeth and the surrounding tissues. CBCT 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 CBCT application in dentistry.

Keywords: Cone-beam computed tomography, Cone-beam volumetric tomography.

INTRODUCTION

Radiographic examination is essential in diagnosis and treatment planning in dentistry. 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-dimensional anatomy of the area being radiographed is compressed into a 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 dentistry. These problems may be overcome using small volume cone-beam computed tomography (CBCT) 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 CBCT or CBVT specifically for dental use. CBVT differs from medical CT imaging in that the whole three-dimensional volume of data is acquired in the course of a single sweep of the scanner, using a simple, direct relationship between sensor and source (Fig. 1). 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. Essentially, a voxel is a 3D 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 directions.4

CBVT Units for Dental Uses

Currently available CBVT units are3,5-7 3D Accuitomo FPD XYZ Slice View Tomograph (J Morita USA, Irvine, Calif), 3D X-ray CT Scanner Alphard Series (Asahi, Kyoto, Japan) Quolis Alphard 3030 cone-beam (Belmont Equipment, Somerset NJ), CB MercuRay (Hitachi Medical Systems America, Twinsburg, Ohio), Galileos 3D (Sirona Dental Systems, Charlotte, NC), i-CAT (Imaging Sciences International, Hatfield, PA), Iluma ultra cone-beam CT scanner (Carestream, Rochester, NY),

Fig. 1: 3D skull image
NewTom 3G and VG (AFP Imaging, Elmsford, NY), Picasso (E-woo Technology, Houston), PreXion 3D (TeraRecon, San Mateo, Calif.), ProMax 3D (Planmeca USA, Roselle, Ill), Scanora 3D (Soredex, Tuusula, Finland), NewTom QR 9000 and NewTom Plus (Aperio, Inc. Sarasota, Fla).

**Indications/Applications in Dentistry**

Grondahl (2007) reported that in Sweden in 2007 the relative frequency in the use of CBCT between different oral specialties was:

- Implantology: 40%
- Oral surgery: 19%
- Orthodontics: 19%
- Endodontics: 17%
- Temporomandibular joint (TMJ): 1%
- Otorhinolaryngology: (ENT) 2%
- Other investigations 2% (periodontology, forensic dentistry, research).

**Implantology**

- To assess the quantity and quality of bone in edentulous ridges
- To assess the relation of planned implants to neighboring structures
- To assess the success of implant osseointegration
- To provide information on correct placement of implants (Fig. 2)
- Before ridge augmentation in anodontia
- Before bone reconstruction and sinus lifting
- During planning and in designing a surgical guidance template.

**Dentoalveolar and Maxillofacial Surgery**

To assess:
- The presence or absence of tumors
- Lower molars and relationship with mandible canal
- Impacted teeth, residual roots (Fig. 3)
- Superior teeth and position of the roots in respect to the maxillary sinus
- Perioral abscesses, facial pain, trismus, differential diagnostic (presence or absence, source and precise localization in maxillofacial area)
- Foreign bodies
- Cystic lesions and their delimitation (Fig. 4)
- Osteomyelitis.

In trauma cases, CBCT is able to show a larger number of fracture lines and fractures when compared with conventional images, depicting precisely the position and orientation of displaced fragments in a reasonably short time interval. Such cases include as follows:

**Dentoalveolar Fractures (Figs 5 and 6)**

- Tooth fractures (a fracture line is easier to visualize in an intact tooth rather than in a tooth that has been restored, due to artifacts)
- Avulsion
- Dislocation
- Luxation.

**Orbital Fractures**

MRI is more sensitive but CBCT can assess high-contrast structures, such as lateral and median walls or search for foreign bodies.

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![Fig. 2: Use of CBCT in sinus lifting and planning](image1)
![Fig. 3: Retained teeth, their relationship with neighboring structures and resorption of other teeth](image2)
![Fig. 4: Follicular cyst and impacted lower wisdom tooth, extension, relationship to the mandible nerve canal](image3)
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Condylar Fractures

Mid-face fractures: Larger-volume CBCT scanners acquire the entire maxillofacial region within a FOV up to 20 cm in diameter.

Orthodontics\textsuperscript{11-14}

- In cases of anodontia
- When planning orthognathic surgery
- In obstructive sleep apnea, evaluation of air space
- Clefts of the palate: Uni- or bilateral, positions of teeth (Fig. 7), planning operations and orthodontic treatment, localization of eventual bone, control of intervention. Supernumerary teeth in palate cleft—position, angulations.
- Cephalometric analysis (special programs).

Endodontics\textsuperscript{15-17}

To assess:

- Upper molars where, because three or more root canals are present, they are frequently superimposed on two-dimensional images when using conventional radiographic techniques
- Cysts, granulomas, periapical lesions (Fig. 8)
- Endodontic surgery, evaluation of fractured instruments in canal
- Unobturated, lateral or supernumerary root canals
- Maxillary sinus involvement after apical infection.

Temporomandibular Joint\textsuperscript{18}

- Investigating bony structures of TMJ; the disk is best visualized by MRI.
- Osteoarthritis (bone destruction) and ankylosis
- Condylar fractures (localization of fracture lines and dislocated fragments)
• Articular osteophytes
• The relationship of the condylar head to the glenoid fossa
• Bone erosions, malformations and condylar modifications (Fig. 9).

Periodontology19

• Very accurate analysis of bone loss as well as bone healing after periodontal treatment or regenerative therapy. CBCT is a sensitive method for imaging mineralized tissues (Fig. 10).
• Periodontal complications arising from root fractures, which can be visualized with CBCT when a two-dimensional image fails to give any information.

Other Investigations10

• Imaging of the ear
• Experimental use
• Osteoporosis and bone healing after antiosteoporotic medication.

Limitations of CBCT20

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 CBCT allows complete visualization of the oral and maxillofacial complex. CBCT technology aids in the diagnosis of endodontic pathosis and canal morphology, assessing root and alveolar fractures, analysis of resorptive lesions, identification of pathosis of nonendodontic origin and presurgical assessment before root end surgery. CBCT has increased accuracy, higher resolution, reduced scan time, a reduction in radiation dose and reduced cost for the patient. CBCT eliminates superimposition of surrounding structures, providing additional clinically relevant information.

REFERENCES


