

## REVIEW ARTICLE

# APPLICATION OF CONE BEAM COMPUTED TOMOGRAPHY IN DENTISTRY: A REVIEW

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### ABSTRACT:

Two-dimensional imaging modalities have been used in dentistry since the first intra-oral radiograph was taken in 1896. Significant progress in dental imaging techniques has since been made, including panoramic imaging and tomography, which enable reduced radiation and faster processing times. However, the imaging geometry has not changed with these commonly used intraoral and panoramic technologies. Cone Beam Computed Tomography (CBCT) is an extra-oral imaging system specifically designed for three dimensional imaging of the oral and maxillofacial structures at a lower cost and absorbed dose compared with conventional computed tomography (CT).

Key words:- Maxillofacial, Tomography, Panoramic.

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## INTRODUCTION

Dental cone beam CT is a type of computed tomography that uses a cone shaped x-ray beam for image exposure. Figure 1 shows a typical CBCT machine with a schematic of the shape of the cone shaped x-ray beam<sup>1</sup>. The use of a cone shaped primary x-ray beam to expose the patient results in raw images. Also, in CBCT imaging, the x-ray source and receptor rotate an arc between 180° and 360° around the patient. Signal to noise ratio (SNR) for CBCT is approximately 15 to 20%. The result is that CBCT provides excellent images of dense objects such as teeth and bone<sup>2</sup>. At first glance, this lack of soft tissue detail may seem to be a disadvantage for CBCT; however, in dentistry most of our diagnostic tasks are focused on teeth and bone planning for implants, localizing impacted maxillary canines and mandibular third molars etc.; and as mentioned, CBCT imaging is an excellent choice for imaging these high density anatomic features. In addition, CBCT provides images with soft tissue

outlines from which we can determine orthodontic and airway landmarks providing assistance with 3D diagnosis and planning. In actuality, most diagnostic problems do not require the additional information of soft tissue details that MDCT can offer.<sup>3</sup>



Figure 1: CBCT machine

CBCT viewing software generally provides us with two types of images — multiplanar reconstructed images (MPR) or 3D volumetric reconstructions. Once the volumetric image is obtained, the computer processes this volume into axial, coronal and sagittal slices which the user can then scroll through, slice by slice. Many volumes are approximately 512 x 512 x 512 slices; the actual number of slices is dependent on the scanning and reconstruction resolutions. Different types of 3D volumes are obtained depending on the diagnostic task.<sup>4</sup>

CBCT systems can be categorized according to the available Field Of View (FOV) or selected scan volume height as follows<sup>4</sup>:

**Localized region:** approximately 5 cm or less (eg, dentoalveolar, temporomandibular joint)

**Single arch:** 5 cm to 7 cm (eg, maxilla or mandible)

**Interarch:** 7 cm to 10 cm (eg, mandible and superiorly to include the inferior concha)

**Maxillofacial:** 10 cm to 15 cm (eg, mandible and extending to Nasion)

**Craniofacial:** greater than 15 cm (eg, from the lower border of the mandible to the vertex of the head)

#### DIFFERENT IMAGING TECHNIQUES AND REQUIRED RADIATION EXPOSURE<sup>5</sup>

Imaging	Effective dose $\mu$ Sv
Intra oral radiograph	<8.3
Panoramic	9-26
Cephalometric radiograph	3-6
Cone beam CT( focused field of view) (dento-alveolar)	5-38.3
Full mouth series radiograph	35-388
Cone beam CT-Craniofacial	68-599
Medical fan beam CT-maxilla and mandible	2000

#### BASIC PRINCIPLES

The SEDENTEXCT project aimed to acquire key information necessary for sound and scientifically based clinical use of dental Cone Beam Computed Tomography (CBCT). As part of this aim, the project set an objective of developing evidence-based guidelines for dental and maxillofacial use of CBCT. European Academy of DentoMaxilloFacial Radiology (EADMFR) and SEDENTEXCT, a

decision was taken to collaborate in the development of a set of “Basic Principles” for the use of dental CBCT, based upon existing standards. These standards include fundamental international principles, EU Directives (Council of European Union, 1996, 1997) and previous Guidelines (European Commission 2004)<sup>6</sup>. A set of 20 “Basic Principles” on the use of dental CBCT were thus established. These act as core standards for EADMFR and are central to this Guideline publication.<sup>6</sup>

#### The “Basic Principles”

1. CBCT examinations must not be carried out unless a history and clinical examination have been performed.
2. CBCT examinations must be justified for each patient to demonstrate that the benefits outweigh the risks.
3. CBCT examinations should potentially add new information to aid the patient’s Management.
4. CBCT should not be repeated ‘routinely’ on a patient without a new risk/benefit assessment having been performed.
5. When accepting referrals from other dentists for CBCT examinations, the referring dentist must supply sufficient clinical information (results of a history and examination) to allow the CBCT Practitioner to perform the Justification process.
6. CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) radiography.
7. CBCT images must undergo a thorough clinical evaluation (‘radiological report’) of the entire image dataset.
8. Where it is likely that evaluation of soft tissues will be required as part of the patient’s radiological assessment, the appropriate imaging should be conventional medical CT or MR, rather than CBCT
9. CBCT equipment should offer a choice of volume sizes and examinations must use the smallest that is compatible with the clinical situation if this provides less radiation dose to the patient.
10. Where CBCT equipment offers a choice of resolution, the resolution compatible with adequate diagnosis and the lowest achievable dose should be used.

11. A quality assurance programme must be established and implemented for each CBCT facility, including equipment, techniques and quality control procedures.
12. Aids to accurate positioning (light beam markers) must always be used.
13. All new installations of CBCT equipment should undergo a critical examination and detailed acceptance tests before use to ensure that radiation protection for staff, members of the public and patient are optimal.
14. CBCT equipment should undergo regular routine tests to ensure that radiation protection, for both practice/facility users and patients, has not significantly deteriorated.
15. For staff protection from CBCT equipment, the guidelines detailed in Section 6 of the European Commission document 'Radiation Protection 136. European Guidelines on Radiation Protection in Dental Radiology' should be followed.
16. All those involved with CBCT must have received adequate theoretical and practical training for the purpose of radiological practices and relevant competence in radiation protection.
17. Continuing education and training after qualification are required, particularly when new CBCT equipment or techniques are adopted.
18. Dentists responsible for CBCT facilities who have not previously received 'adequate theoretical and practical training' should undergo a period of additional theoretical and practical training that has been validated by an academic institution (University or equivalent). Where national specialist qualifications in DMFR exist, the design and delivery of CBCT training programmes should involve a DMF Radiologist.
19. For dento-alveolar CBCT images of the teeth, their supporting structures, the mandible and the maxilla up to the floor of the nose (e.g. 8cm x 8cm or smaller fields of view), clinical evaluation ('radiological report') should be made by a specially trained DMF Radiologist or, where this is impracticable, an adequately trained general dental practitioner.
20. For non-dento-alveolar small fields of view (e.g. temporal bone) and all craniofacial CBCT images (fields of view extending beyond the teeth, their supporting structures, the mandible, including the TMJ, and the maxilla up to the floor of the nose),

clinical evaluation ('radiological report') should be made by a specially trained DMF Radiologist or by a Clinical Radiologist (Medical Radiologist).

## **APPLICATION OF CBCT**

### **ENDODONTICS**

CBCT is very useful in Endodontics. Various applications are:-

#### **DIAGNOSIS OF APICAL LESIONS**

##### **Detection of Apical Periodontitis**

Apical Periodontitis can be detected at an early stage using CBCT when compared to conventional radiographs. It appears that conventional radiography results in an under-estimation of the incidence of apical periodontitis<sup>7</sup>. Lesion confined within the cancellous bone cannot be detected by conventional radiographs, whereas they are easily detected in CBCT which captures images in slices thereby avoiding anatomic superimposition.

CBCT is a very useful tool in diagnosing apical lesions. It can be helpful in differential diagnosis of apical lesions by measuring the density from the contrasted images of these lesions, in whether the lesion is an apical granuloma or an apical cyst. CBCT acts as a tool to assess whether the lesion is of endodontic or non-endodontic origin.<sup>8</sup>

##### **Assessment of root and canal anatomy**

CBCT has been proved beneficial in assessing the exact anatomy and morphology of root canals. Increased number of MB2 canal can be identified with CBCT when compared to conventional radiographs<sup>9</sup>. CBCT imaging has also been reported to characterize the high prevalence of the distolingual canal, highlight anomalies in the root canal system of mandibular premolars, and assist in the determination of root curvature. In a study that evaluated 608 permanent mandibular second molars using CBCT a higher prevalence of "C" shaped canals was noticed CBCT is an effective tool for the detection of additional distolingual roots and C-shaped canals.<sup>10</sup>

##### **In assessing fractures**

CBCT also demonstrated superiority to 2-D radiographs in detecting fractured roots. Vertical and horizontal root fracture detection is described in several clinical cases. It is also agreed that CBCT is

superior to peri-apical radiographs in detecting these fractures, whether they are bucco lingual or mesiodistal.<sup>11</sup>

CBCT can also be used to determine root morphology, the number of roots, canals and accessory canals, as well as to establishing the working length and angulations of roots and canals. It also is accurate in assessing root-canal fillings. Owing to its accuracy, it is very helpful in detecting the pulpal extensions in talon cusps and the position of fractured instruments. It is also a reliable tool for presurgical assessment of the proximity of the tooth to adjacent vital structures, size and extent of lesions, as well as the anatomy and morphology of roots with very accurate measurements.<sup>12</sup>

### **ORTHODONTICS**

CBCT is a reliable tool in the assessment of the proximity to vital structures that may interfere with orthodontic treatment. Orthodontists can use CBCT images in orthodontic assessment and cephalometric analysis. Today, CBCT is already the tool of choice in the assessment of facial growth, age, airway function and disturbances in tooth eruption. In cases in which mini-screw implants are placed to serve as a temporary anchorage, CBCT is useful for ensuring a safe insertion and to assess the bone density before, during and after treatment.<sup>13</sup>

### **IMPLANTOLOGY**

With increased demand for replacing missing teeth with dental implants, accurate measurements are needed to avoid damage to vital structures. This was achievable with conventional CT. However, with CBCT giving more accurate measurements at lower dosages, it is the preferred option in implant dentistry today. With new software that constructs surgical guides, damage is also reduced further<sup>14</sup>. CBCT enables the assessment of bone quality and bone quantity. This leads to reduced implant failure, as case selection can be based on much more reliable information. This advantage is also used for post-treatment evaluation and to assess the success of bone grafts.<sup>15</sup>

### **PERIODONTICS**

CBCT provides accurate measurement of intrabony defects and allows clinicians to assess dehiscence, fenestration defects, and periodontal cysts. 3D imaging such as CBCT can visualize buccal and lingual defects. CBCT has been used to obtain

detailed morphologic descriptions of bone as accurately as direct measurement with a periodontal probe. CBCT can also be used to assess furcation involvement of periodontal defects and allow clinicians to evaluate postsurgical results of regenerative periodontal therapy<sup>16</sup>.

The first reported applications of CBCT in periodontology were for diagnostic and treatment outcome evaluations of periodontitis. Ex vivo studies later characterized the ability of CBCT to accurately reconstruct periodontal intrabony and fenestration defects, dehiscences, and root furcation. CBCT 3D geometric accuracy has been suggested to be equal to radiography and MDCT but with better observer-rated image quality than MDCT as well as superior periodontal-defect detection than radiography.<sup>17</sup>

### **ORAL AND MAXILLOFACIAL SURGERY**

#### **JAW PATHOLOGIES**

CBCT have been used to investigate the exact location and extent of jaw pathologies and assess impacted or supernumerary teeth and the relationship of these teeth to vital structures. CBCT images are used for pre- and postsurgical assessment of bone graft recipient sites and to evaluate osteonecrosis changes of the jaws and paranasal sinus pathology and/ or defect. CBCT technology has also been used for thorough pretreatment evaluations of patients with obstructive sleep apnea, to determine an appropriate surgical approach.<sup>18</sup>

#### **FRACTURES**

CBCT the technique of choice for investigating and managing midfacial and orbital fractures, postfracture assessment, interoperative visualization of the maxillofacial bones, and intraoperative navigation during procedures involving gunshot wounds. CBCT is used widely for planning orthognathic and facial orthomorphic surgeries, where detailed visualization of the interocclusal relationship and representation of the dental surfaces to augment the 3D virtual skull model is vital. Utilizing advanced software, CBCT allows for minimum visualization of soft tissue, allowing dentists to control post treatment esthetics and evaluate the outline of the lip and bony regions of the palate in cases of cleft palate.<sup>19</sup>

### **IMPLANT DENTISTRY**

CBCT is the preferred option for implant dentistry, providing greater accuracy in measuring compared to 2D imaging, while utilizing lower doses of radiation. New software has reduced the possibility of malpositioned fixtures and damaged anatomical structures. CBCT has reduced implant failures by providing information about bone density, the shape of the alveolus, and the height and width of the proposed implant site for each patient. CBCT is commonly utilized in postsurgical evaluations to assess bone grafts and the implant's position in the alveolus.<sup>20</sup>

### **TEMPOROMANDIBULAR JOINT DISORDER**

CBCT helps in defining the true position of the condyle in the fossa, which often reveals possible dislocation of the disk in the joint, and the extent of translation of the condyle in the fossa. With its accuracy, measurements of the roof of the glenoid fossa can be done easily. Soft tissues around the TMJ can also be visualize. Thus, CBCT is the imaging device of choice in cases of trauma, pain, dysfunction, fibro-osseous ankylosis and in detecting condylar cortical erosion and cysts. Because of the use of the 3-D features, the image guided puncture technique, which is a treatment modality for TMJ disk adhesion, can safely be performed.<sup>21</sup>

### **FORENSIC DENTISTRY**

Many dental age estimation methods, which are a key element in forensic science, are described in the literature. CBCT was established as a non-invasive method to estimate the age of a person based on the pulp-tooth ratio.<sup>22</sup>

### **CONCLUSION**

Cone beam Computer tomography is the greatest technological advancement that dental radiology has witnessed. The dental profession now has the ability to generate full 3D images of our patients' dental and maxillofacial complex. These images are reliably accurate with no magnification and unfettered by superimposition from other anatomic structures. CBCT is an excellent diagnosis tool, offering significant advantages regarding to the quality and quantity of anatomic information. When 3D image is necessary, CBCT should be the method of choice always justified by an accurate indication. This will provide an adequate cost/benefit ratio both

for the treatment and patient. CBCT is most frequently applied in oral and maxillofacial surgery, endodontics, implant dentistry and orthodontics. CBCT examination must not be carried out unless its medical necessity is proven and the benefits outweigh the risks. Furthermore, CBCT images must undergo a thorough clinical evaluation (radiological report) of the entire image dataset in order to maximise the benefits. Future research should focus on accurate data with regard to the radiation dose of these units.

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