

## SUMMARIZING THE APPLICATIONS AND LIMITATIONS OF CONE BEAM COMPUTED TOMOGRAPHY – A REVIEW

**Running Title:** Cone Beam Computed Tomography-a review

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### **ABSTRACT**

Cone Beam Computed Tomography (CBCT) has progressed over 15-20 years from being a technique with great potential to one that has become primary diagnostic investigation. 3D imaging has made complex root canal anatomies more accessible and helps in accurate treatment planning for many endodontic problems. A modification of original cone beam algorithm was developed by Feldkamp et al in 1984<sup>[1]</sup>. Since then there were significant progress in imaging technique starting from linear to hypocycloidal tomographic movements wherein the centre of rotation remains the same and movement of the equipment becomes more complicated for better resolution. The goal of this article is to summarize the applications and limitations of CBCT in various clinical scenarios in day to day endodontic practice.

**Keywords :** Radiation, imaging modalities, periapical pathosis, vertical root fractures, regenerative endodontics.

### **Introduction:**

The science of endodontics has been continuously seeking to improve the performance of diagnostic aids. Intra oral periapical radiographs and orthopantomographs have been the mainstay of radiographic diagnosis in all specialties of dentistry. <sup>[1]</sup> Although both are indispensable the amount of useful information yielded by these are limited by accompanying its two dimensional presentation, geometric distortion and anatomic noise. Three dimensional CT scan imaging and MRI imaging has been considered only in limited number of patients till date because of unacceptably high radiation dose for routine dental care. CBCT is an alternative aid and is widely gaining popularity at a rapid rate all over the world. <sup>[2]</sup>

Cone beam CT has the ability to eliminate the superimposition of anatomic structures that normally overlap in two dimensional periapical radiographs. A limited-volume cone beam-computed tomography imaging technique can produce accurate 3 dimensional Images

of the teeth and surrounding dentoalveolar structures. It generates three-dimensional (3D) data at lower cost and absorbed doses comparing conventional CT found in the practice of medical radiology. Data collected from the craniofacial region are often higher resolution in the axial plane than those from conventional computed tomography systems. CBCT systems do not require a large amount of space and can easily accommodated into most dental clinics today. An accurate diagnosis leads to an accurate treatment plan which is crucial for successful endodontic treatment that relies on both clinical as well as radiographic data. Several studies have been conducted to evaluate cone beam CT's efficacy in identifying endodontic pathologies and to compare this technology with conventional periapical radiographs.<sup>[3]</sup>

#### **Basic principles of CBCT:**

Conventional CT equipment uses a fan shaped X-ray source that captures a series of axial plane slices or it forms a continuous spiral motion over the axial plane. A cone beam CT machine uses a cone-shaped beam and a reciprocating flat panel detector which rotates around the subject 180-360 degrees, covering the defined anatomical volume rather than sliced imaging found in conventional CT. This single scan captures standardized data that contrasts stacked axial slices found in computed tomography, further reducing the absorbed x-ray dose from 6 to 15 times in comparison to CT. The scanning time of CBCT equipment varies from nearly 5 to 40 seconds, depending on the manufacturers. The X-ray parameters of cone beam CT is comparable to that of orthopantomographs with a usual operating range of 1-15 mA at 90-120 kVp, while conventional CT is considerably higher at 120- 150 mA and 220 kVp. The captured 2D images are then conveyed to the digital analog, which reconstructs them, using modified Feldkamp algorithm (1984) into the anatomical volume for viewing at 1:1 ratio in orthogonal planes such as axial, coronal, and sagittal planes.<sup>[1,4]</sup>

Most of the CBCT equipment comes with more convenient viewing software containing basic 3 dimensional imaging tools. The software is accessible at a wide range of price, which provides extensive tools to examine and formulate treatment plans. Furthermore, the software is used to virtual study models, prepare surgical guides and laser generated resin models, easing the process of diagnosis, treatment plan and delivery of the treatment. The utmost benefit of cone beam CT in dental imaging is the facilitation to interact with the data and create images imitating those that are generally employed in clinical settings for example cephalometric or bilateral multiplanar projections of the TM joint, OPG. These reconstructed views, consecutively interpreted, examined and measured for diagnosis and treatment-planning. The CBCT provides following display modes such as oblique slicing, Curved slicing, cross-sectional view, ray sum and volume rendering apart from basic orthogonal views.<sup>[5]</sup>

#### **Applications of Cone Beam CT:**

##### **Periapical Pathosis:**

A sequence of pathologic changes in the pulpal tissue, the root canal system can harbour numerous irritants from infected root canals into the periapical & periradicular tissues can initiate the formation and perpetuation of periradicular pathosis. Pathologies are overcome with CBCT. This results in firstly, more roots being assessed, and secondly, more periapical pathologies.

A study conducted by Patel S et al to compare the prevalence of periapical lesions on separate roots of the same tooth viewed with intraoral periapical radiographs and cone-beam computed tomography (CBCT) of teeth treatment planned for endodontic treatment concluded that the limitations of intraoral periapical radiographs which may hinder the detection of periapical being detected with CBCT.<sup>[6]</sup>

##### **Vertical root fractures:**

A vertical root fracture is a longitudinally oriented fracture of the root that originates from the apex and extends to the coronal part. According to the literature, vertical root fracture is the third most common reason for extraction of a tooth that is endodontically treated.

A systematic review by Talwar S et al concludes that the better specificity and sensitivity of cone beam CT scans than periapical radiographs in the detection of vertical root fractures in unfilled teeth, especially when a voxel size of 0.2 mm was set. Low pooled sensitivity and specificity of CBCT imaging was noted in detecting vertical root fractures in teeth that are endodontically treated.<sup>[7]</sup>

### **Assessment of root morphology and its variations:**

A study conducted by Zand V et al to evaluate the accuracy of the results of CBCT evaluations, validate the presence or absence of the second mesiobuccal root canal in maxillary first molars and maxillary second molars, to get the measure of distance between the canal orifices, observe the root types based on Vertucci classification system, and make comparisons between CBCT and periapical techniques in relation to the identification of the root canal form and the second root canal of the MB root wherein they concluded that There was a significant difference between the results of intraoral periapical radiographs and CBCT radiographic techniques in relation to the second root canal in the MB roots of maxillary first and second molars, with better results being provided by the CBCT technique.<sup>[8]</sup>

Another study conducted by Lin et al to investigate the root canal morphology of mandibular incisors using cone-beam computed tomography and the following were observed (1) the number of canals; (2) the number of roots; (3) the position of canal bifurcations; (3) canal configuration according to Vertucci's classification. He concluded his study stating that the standard mode CBCT imaging was clinically useful for detection of two canals and determines the position of canal bifurcations in mandibular incisors.<sup>[9]</sup>

A case report documented by saatwika L et al discussed the morphologic variations of permanent mandibular central incisors and its management using clinical microscopes.<sup>[10]</sup> Another case report documented by Subbiya et al discussed a rare case scenario Radix Distolingualis in maxillary second molar which is reported to have 1.4% incidence rate. Its management included through clinical examination, surgical operating microscope, multi-angled periapical radiographs and an accurate assessment of this anatomy was made with the help of Cone Beam Computed Tomography (CBCT) imaging.<sup>[11]</sup>

### **Guided endodontics**

A case report of a 15-year-old male patient presented with pain of his upper right central incisor. The tooth showed signs of apical periodontitis by Krastl et al presents a new treatment approach for teeth with pulp canal calcification (PCC) which require root canal treatment for which a cone beam computed tomography (CBCT) and an intra-oral surface scan were carried out and matched using software for virtual implant planning since location of the root canal was suspected to be difficult and have a high risk of perforation. The case was reviewed after 15 months and was successful.<sup>[12]</sup>

### **Regenerative endodontics**

A study conducted by Meschi et al where Five patients who had undergone a REP based on the cell homing concept were recalled after 3, 6, 12, 24, and 36 months postoperatively to assess it in terms of periapical bone healing (PBH), pulp vitality and root development (RD). Qualitative and quantitative PR assessments were carried out on the teeth that underwent REPs. Quantitative CBCT analyses were carried out on the teeth that underwent REP and contralateral teeth. Finally they concluded that 36 months after the REPs, it resulted both radiographically and clinically in functional and asymptomatic teeth with

complete PBH and continued reparative RD. CBCT quantitative measurements and qualitative root development observations are more reliable and accurate than PR analysis.<sup>[13,14]</sup>

#### **Novel treatment approach using CBCT**

A case report by Kfir et al To study the use of 3D plastic models, printed from cone beam computed tomography data, for diagnosis and conservative treatment of a complex case of dens invaginatus. A novel method was adopted to allow for cleaning, shaping and obturation of the invagination, without compromising the vitality of the pulp in the complex root canal system. The CBCT data were used to produce accurate 3D plastic models of the tooth. These models simplified the treatment planning process and the trial of treatment approaches. This approach let the vitality of the pulp to be retained in the complex root canal space of the main root canal whilst enabling the healing of the periapical tissues.<sup>[15]</sup>

#### **Limitations of CBCT:**

A research article by kruse et al to assess the diagnostic validity of periapical radiographs and cone beam computed tomography for determining inflammation in SER cases that were re-operated due to failed healing, using histology as reference for inflammation. Of the re-operated teeth, 42% had no periapical inflammatory lesion, and hence no satisfactory results from SER-R. Not all lesions observed in CBCT represented periapical inflammatory lesions.<sup>[16]</sup>

Another study by Ramos Brito AC et al compared the detection of fractured instruments in root canals with and without obturation by intra oral periapical radiographs from 3 digital systems and cone-beam computed tomographic images with different resolutions. In the absence of obturation, accuracy values were high, and there were no statistical differences among the radiographic techniques, the different CBCT voxels sizes or different digital systems. In the presence of obturation, the accuracy of periapical radiographs was significantly higher than CBCT images. In the presence of obturation, the decision to perform CBCT should be taken into consideration because of its low accuracy.<sup>[17]</sup> Artefacts – artefacts in CBCT include factors such as noise, scatter, extinction artefacts, beam hardening artefacts, exponential edge gradient effect, aliasing artefacts, ring artefacts and motion artefacts-misalignment artefacts.<sup>[18]</sup>

#### **Conclusion**

The advantages of CBCT over OPGs are 3D analysis, no geometric distortion and anatomical noise, and the ability to create cross-sectional images. The disadvantages over panoramic imaging are increased radiation dosage, artifacts, and it is not economic.

Although CBCT is a great tool that provides 3 dimensional images, it does not replace standard dental radiographic modalities and should be utilized as aid for specific complicated cases, and not for routine diagnosis. CBCT studies with small focussed field of view and small voxel size will provide better spatial resolution, especially for endodontic practice.

#### **Reference:**

1. Feldkamp LA, Davis LC, Kress JW. Practical cone-beam algorithm. J. Opt. Soc. Am. A. 1984 Jun 1;1(6):612-9.
2. Vandenberghe B, Jacobs R, Bosmans H. Modern dental imaging: a review of the current technology and clinical applications in dental practice. Eur Radiol. 2010;20(11):2637-55.
3. Patel S, Dawood A, Pitt Ford T, Whaites E. The potential applications of cone beam computed tomography in the management of endodontic problems. Int Endod J 2007;40:818-30.

4. Danforth RA, Miles DA. Cone beam volume imaging (cbvi): 3d applications for dentistry. *Irish Dent.* 2007;10(9):14–8.
5. Howerton WB Jr, Mora MA. Advancements in digital imaging: what is new and on the horizon? *J Am Dent Assoc.* 2008. June;139 Suppl:20S–4S.
6. Patel S, Wilson R, Dawood A, Mannocci F. The detection of periapical pathosis using periapical radiography and cone beam computed tomography - part 1: pre-operative status. *IntEndod J.* 2012 Aug;45(8):702-10.
7. Talwar S, Utneja S, Nawal RR, Kaushik A, Srivastava D, Oberoy SS. Role of Cone-beam Computed Tomography in Diagnosis of Vertical Root Fractures: A Systematic Review and Meta-analysis. *J Endod.* 2016 Jan;42(1):12-24.
8. Zand V, Mokhtari H, Zonouzi HRM, Shojaei SN. Root Canal Morphologies of Mesiobuccal Roots of Maxillary Molars using Cone beam Computed Tomography and Periapical Radiographic Techniques in an Iranian Population. *J Contemp Dent Pract* 2017;18(9):745-9.
9. Lin Z, Hu Q, Wang T, Ge J, Liu S, Zhu M, Wen S. Use of CBCT to investigate the root canal morphology of mandibular incisors. *SurgRadiol Anat.* 2014 Nov;36(9):877-82.
10. Saatwika L, Prakash V, Anuradha B, Subbiya A. Permanent Mandibular Central Incisor with Two Root Canals: A Case Report. *Indian J Public Health Res Dev* 2019 Dec 15;10(12):947-9.
11. Subbiya A, Mitthra S, Banu S, Malarvizhi D. Radix Distolingualis: A Case Report, Review and Endodontic Treatment Guidelines. *J Clin Diagn Res.* 2017 Jun;11(6):ZD10-ZD13.
12. Krastl G, Zehnder MS, Connert T, Weiger R, Köhl S. Guided Endodontics: a novel treatment approach for teeth with pulp canal calcification and apical pathology. *Dent Traumatol.* 2016 Jun;32(3):240-6.
13. Kumar AP, Subbiya A. Regenerative endodontic therapy of non-vital immature maxillary incisors: Working protocol and a case report. *J. Interdiscip. Dent.* 2011 Jan 1;1(1):55-7.
14. Meschi N, EzEldeen M, Torres Garcia AE, Jacobs R, Lambrechts P. A Retrospective Case Series in Regenerative Endodontics: Trend Analysis Based on Clinical Evaluation and 2- and 3-dimensional Radiology. *J Endod.* 2018 Oct;44(10):1517-25.
15. Kfir A, Telishevsky-Strauss Y, Leitner A, Metzger Z. The diagnosis and conservative treatment of a complex type 3 dens invaginatus using cone beam computed tomography (CBCT) and 3D plastic models. *IntEndod J.* 2013 Mar;46(3):275-88.
16. Kruse C, Spin-Neto R, Reibel J, Wenzel A, Kirkevang L-L. Diagnostic validity of periapical radiography and CBCT for assessing periapical lesions that persist after endodontic surgery. *DentomaxillofacRadiol* 2017; **46**
17. Ramos Brito AC, Verner FS, Junqueira RB, Yamasaki MC, Queiroz PM, Freitas DQ, Oliveira-Santos C. Detection of Fractured Endodontic Instruments in Root Canals: Comparison between Different Digital Radiography Systems and Cone-beam Computed Tomography. *J Endod.* 2017 Apr;43(4):544-9.
18. Schulze R, Heil U, Gross D, Bruellmann DD, Dranischnikow E, Schwanecke U, Schoemer E. Artefacts in CBCT: a review. *DentomaxillofacRadiol.* 2011 Jul;40(5):265-73.