Review Article

# Cone beam computed tomography: An innovative tool in pediatric dentistry

**Jatinder Kaur Dhillon**[1*], **Gauri Kalra**[1]
[1]Division of Pedodontics & Preventive Dentistry, Centre for Dental Education and Research, All India Institute of Medical Sciences, New Delhi, India

## ABSTRACT

Since decades, two dimensional (2D) imaging modalities such as cephalometrics, panoramic, periapical radiography have been a standard of care for diagnosing and treatment planning in dentistry. However, this 2D representation has left some questions unanswered in oral diagnosis and treatment planning. Thus, evolution towards three dimensional technology was desired. The introduction of cone beam computed tomography (CBCT), specifically dedicated to imaging the maxillofacial region heralds a true paradigm shift. This innovative diagnostic tool has been used popularly in all fields of dentistry, but its application in children has remained unexplored. With this article, we attempt to discuss the applications of CBCT among pediatric patients.

**Key words:** Applications, Cone Beam Computed Tomography, Pediatric

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## INTRODUCTION

As a clinician it often becomes difficult to make a diagnosis based on the clinical examination alone. Various diagnostic aids such as imaging play an essential role in diagnosis in the dental practice. Among the various imaging techniques, periapical radiography has been a benchmark resource in dental imaging.[1] However, this scenario changed with the introduction of panoramic radiography in the 1960s.[2] It has provided the clinicians with a single comprehensive image of jaws and maxillofacial structures. This also provides broad anatomical coverage with lesser radiation dose as compared to full mouth periapical radiographs.[3] There is however an inherent drawback in both these techniques, namely two dimensional (2D) projection of three dimensional (3D) structures, which can lead to magnification of images, distortion of anatomical structures, superimposition and misrepresentation of structures. This led to the quest for a technology based on 3D projections.

Various imaging modalities such as densitometry methods,[4] magnetic resonance imaging,[5] computed imaging,[6] ultrasound[7] and nuclear techniques[8] have been used for dental imaging. These modalities provide detailed high resolution images of oral structures and permitting early detection of dental abnormalities. Among these, computed tomography (CT) has been widely available since a long time, but its application in dentistry has been limited because of cost, access and dose considerations.[9]

Recently, however cone-beam volumetric tomography or cone beam computed tomography (CBCT) has become a viable option for the dental office with the convergence of technology and affordability as compared with conventional CT. The term cone beam CT is derived from the cone shaped beam being used unlike the conventional CT, which utilizes a fan shaped beam.[2] The volume data of the human body can be acquired in a single rotation of the beam and sensor. Slice by slice axial, sagittal and coronal images are observed with both conventional CT and CBCT with the major difference being incorporation of reference lines in CBCT, which makes it easier to locate the slices.[3]

The advantages of CBCT which have led to a widespread use of this technique for imaging of the craniofacial area are:

***Address for correspondence**
Dr. Jatinder Kaur Dhillon, Department of Pedodontics & Preventive Dentistry, Centre for Dental Education and Research, All India Institute of Medical Sciences, New Delhi - 110 029, India. E-mail: dr.jatinderdhillon@gmail.com

## ADVANTAGES

- X-ray beam limitation and reduction in radiation dose: Reduces the size of the irradiated area by collimation of the primary X-ray beam to the area of interest thus, minimizing the radiation dose. Most CBCT units can be adjusted to scan small regions for specific diagnostic tasks. Using both the 1990 and recently approved 2007 International Commission on Radiological Protection recommended tissue weighting factors, effective doses range from 52 to 1025 μSv depending upon the equipment and imaging protocol and field of view (FOV) selected.[10,11] Moreover, patient positioning modifications (tilting the chin) and use of additional personal protection (thyroid collar) can substantially reduce the dose by up to 40%.[12]
- Image accuracy: In conventional CT, the voxels, which determine the image resolution is anisotropic, i.e., rectangular cubes where the longest dimension of the voxel is the axial slice thickness. Instead, CBCT units provide voxel resolutions that are isotropic, i.e., equal in all 3 dimensions. This produces sub-millimeter resolution ranging from 0.4 mm to as low as 0.125 mm.
- Rapid scan time: Scan time is rapid as CBCT acquires all basic images in a single rotation. This leads to less motion artifacts due to reduced subject movement.
- Display modes unique to maxillofacial imaging: Reconstruction of data is easier and less time consuming as compared with the conventional CT. In addition, analysis software is available to the clinician as well as the radiologist, either via direct purchase or innovative "per use" license from various vendors. This enables the dental professional to make real-time assessment chairside and perform task specific analysis.
- Reduced image artifact: With manufacturers' artefact suppression algorithms and an increasing number of projections, it has been observed that CBCT images can result in a low level of metal artifact, particularly in secondary reconstructions designed for viewing the teeth and jaws.

Keeping the above advantages of CBCT, it has been increasingly advocated in several fields of dentistry such as including orthodontics, orthognathic surgery, trauma and implantology. However, the application of this innovative technology in the field of pediatric dentistry has not yet been addressed.

An important aspect in considering the use of CBCT in children is the radiation exposure. This is due to two factors: Rapid tissue growth and chances of subsequent deoxyribonucleic acid damage and secondly, as the child is expected to live longer than a 50-year-old adult, the chances of damaging effects of radiation manifesting in a tumor are higher.[12] This means that the three basic principles of protection from radiation, i.e., "justification principle," "limitation principle" and "optimization principle" should be followed.[12]

The justification principle means that if relevant information cannot be obtained without radiographs, only then we must consider their use. This principle also states that also suggests that if the patient cannot cope with the procedure, no radiographs should be taken. The limitation principle states that the radiation dose should always be kept as low as reasonably achievable for all patients. Thirdly, there is the "optimization principle," which states that best diagnostic images should be obtained keeping in mind the aforesaid principles.[12]

The major advantages of CBCT in pediatric patients arise from lesser scan time and less complicated apparatus, which reduces anxiety in children. Images obtained with CBCT are highly magnified, with less distortion. A major advantage of CBCT as compared to conventional CT is the reduced dosage. Though, CBCT has higher dose as compared with intra-oral radiography, the range of dose reduction is between 96% and 51% compared with conventional head CT[13] [Table 1].

Further, total annual effective doses from natural radiation sources to the Indian population residing in normal background areas work out to be 2.299 mSv/year.[14]

Theodorakou *et al*. estimated the average organ and effective doses using two pediatric anthropomorphic phantoms for a range of CBCT units and imaging protocols and the preliminary results showed that the effective doses ranged from 5 to 99 μSv for the 10 year old phantom and from 4 to 63 μSv for the adolescent phantom. The effective doses for the 10 year old phantom were higher than those of the adolescent phantom for most of the CBCT units and imaging protocols.[15] However, doses of such range may not be considered higher for a single exposure. Further reduction in exposure dosage can be achieved with using proper protection against radiation hazards and collimated beam.[16]

It has been observed that the exposure from CBCT is within the same range as traditional dental imaging as seen in the Table 1.[2,3,13] Moreover, a complete series of

**Table 1: The effective doses of various radiographic procedures**

| Radiographic procedure | Effective dose (μSv) |
|---|---|
| Intra-oral periapical | 5 |
| Full mouth series | 35 |
| Panoramic | 9-26 |
| i-CAT (CBCT) | 14.4-29.6* |

*After collimation and reducing the FOV to particular jaw. CBCT: Cone beam computed tomography, FOV: Field of view, i-CAT traditional dental radiographs has a higher radiation dose than CBCT.[17]

An important aspect to keep in mind while calculating the effective radiation dose from CBCT is the FOV. The exposure is less if FOV is small; however, the effective dose significantly increases with a larger FOV.[12]

Smith *et al*.[18] reviewed the use of CBCT in postgraduate orthodontic programs in United States and Canada. They observed that most of the CBCT scans were being used for specific diagnostic applications. Moreover, they observed that orthodontic residents are being trained to interpret the entire CBCT volume and not just the specific anomaly. In our opinion, pediatric dentists should also be trained in a similar fashion so as to conform to the optimization principle.

Keeping these factors in mind, this review is an attempt to describe the role of CBCT amongst pediatric dental patients.

## CLINICAL APPLICATIONS

### Development of teeth

Conventional imaging techniques make it difficult to visualize the complex phenomenon of tooth development. CBCT can help evaluate eruption pattern of teeth along with any anomalies in number or shape.[19] This can help clinicians plan eruption guidance and serial extraction customized to individual patients.

### Caries diagnosis

CBCT imaging appears to be the best prospect for improving the detection and depth assessment of caries in approximal and occlusal lesions. Akdeniz *et al*. compared the accuracy of limited cone beam computed tomography, an image plate system and F-speed film in assessing the depth of proximal carious lesions and concluded CBCT method appears to be a promising tool for detection and monitoring of proximal carious lesions.[20] The only limitation of this newer diagnostic aid is its inability to detect carious lesions in metal restored crowns or radiopaque restorations.[21]

### Diagnosis of impacted/supernumerary teeth

CBCT imaging modality can be used broadly for diagnosing impacted teeth in pediatric patients. Maxillary canines are the most common teeth to get impacted. Other than canines, permanent second molars may also get impacted due to malpositioning of third molars inside the alveolar bone. It is also observed that impacted teeth may often seem to be present with supernumerary teeth such as mesiodens. Often, pediatric dentists may be the first one to diagnose the problem. Thus, CBCT is thought to be of great utility in such cases.

### Diagnosis of temporomandibular (TMJ) disorders

Conventional tomography has been used extensively for the evaluation of TMJ hard tissues; however, technique sensitivity and the length of the examinations have made it a less attractive diagnostic tool for the dental clinicians. The application of CBCT in imaging the TMJ has been most significant in the evaluation of hard tissue or bony changes of the joint. Pathologic changes, such as fractures, ankylosis, dislocation and growth abnormalities such as condylar hyperplasia, are optimally viewed on CT.[22]

### Diagnosis of root resorption and root fractures

CBCT allows determining the exact site of resorption and this is particularly useful in cases where resorption is occurring on the lingual or facial side of the tooth. In multirooted teeth, the root in which resorption is present can be easily visualized. A very commonly observed root resorption phenomena is present with lateral and central incisors in case of canine eruption. Thus, with CBCT, this problem could be diagnosed and the extraction of deciduous canine can be planned well in time. In case of oblique fractures, which are not viewed properly on a 2D radiograph, CBCT provides an enhanced view with finer details.

Another advantage of CBCT is that it can be acquired easily post-trauma also when periapical radiographs cannot be easily done due to swelling, bleeding and discomfort experienced by patients. The ability to view the cut of a single tooth of interest in the three planes of space makes determining if the involved tooth displays fracture much easier.

### Craniofacial morphology

Lateral cephalograms have been most commonly used for this purpose. However, these come with their own set of limitations such as superimposition of structures, distortion of images, magnification and head positioning. CBCT offers better image clarity as extraneous superimposing structures can be removed and it is also possible to reorient the head position after the initial scan if the head was not properly positioned at the time of scanning. In addition, the unilateral nature of posterior crossbites can be diagnosed more specifically. A determination of an asymmetric maxilla or mandible can be accomplished more easily by viewing and measuring the bones in 3D.

### Orthodontic temporary anchorage device (Mini implants) placement

Thorough knowledge of root positioning can greatly enhance the opportunity for proper placement and success of Temporary anchorage device or mini implants in children requiring orthodontic treatment. CBCT data can be used to construct placement guides for positioning mini-implants between the roots of adjacent teeth in anatomically difficult sites, which had been difficult with 2D radiography.[23] CBCT images have been shown to be an accurate way to assess the volume of bone present at the proposed location.

### Soft-tissue analysis

Using the soft-tissue data gathered in the CBCT scan, it is possible to rotate and tilt the head in an infinite number of positions to evaluate symmetry of the soft-tissue. CBCT allows for the creation of separate images of the left and right sides for assessment of asymmetries. Surface area and volume analysis have also been possible through 3D software such as *in vivo* which aid in evaluating facial symmetry.

### Cleft lip and palate

CBCT can provide the exact anatomic relationships of the osseous defect and bone thickness around the existing teeth in proximity to the cleft or clefts, which is not possible with 2D imaging modalities. This provides more accuracy and ease in graft placement and other surgical procedures.

### Airway analysis

Airway analysis had also been an area of interest among most of the orthodontist or even general practitioners. It is of great importance in understanding complex conditions such as obstructive sleep apnea and enlarged adenoids. Conventionally, lateral cephalograms were used to analyze the airway of a patient. All this evaluation, however, is limited by the fact that we are looking at a flat projection seen in a sagittal or coronal plane. CBCT is of paramount value in this regards as there is a clear distinction between the soft-tissue of the pharynx and the airway space. This allows for clear segmentation of the airway while doing volumetric analysis. Aboudara *et al*. compared airway information from 11 normal adolescent children between lateral cephalometric headfilms and 3D CBCTs. They concluded that intra-subject proportion of airway volume to area shows moderate variability and that CT airway volume shows more variability than corresponding headfilm airway area. They also indicated that there may be airway information that is not accurately depicted on the lateral headfilm.[24]

### Endodontic applications

It becomes difficult to analyze the extent of periapical pathologies, canal morphology, root fractures, exact location of broken instruments in root canal etc., with conventional 2D imaging modalities. CBCT provides an enhanced view in locating missed canals, calcified canals and curvature of roots. Measurements in relation to roots such as root length, type of canals present, angle of curvature etc., are simply available with CBCT, making it an effective diagnostic aid.[25]

*In vivo* and *in vitro* investigations demonstrate the superiority of CBCT to conventional imaging for almost all endodontic applications, except for assessing the quality of root canal fills. Patel *et al*.[26] have extensively researched the endodontic applications of CBCT and has found to play a major role in detection of periapical lesions more early than a 2D radiograph. It has also been proved to be an effective tool in planning periapical microsurgery even in difficult accessible areas such as palatal roots of maxillary first molars.[27]

### Diagnosis of hard tissue lesions of the oral cavity

It can provide valuable information regarding cystic lesions and their extent, various bony pathologies such as tumors, fracture lines in case of traumatic injuries, condensing osteitis and focal apical osteopetrosis. The latter is also useful in determining the limitation to tooth movement in case orthodontic treatment is required.

## FUTURE OF CBCT IN PEDIATRIC DENTISTRY

Till date the major application of CBCT in children has been in relation of orthodontics. However with development of newer software, it might become possible to diagnose caries, determine the outcome of treatment and provide real time imaging in surgical cases. It can also be used in a manner similar to adults for determining root morphology, diagnose complex clinical situations such as root fractures and facilitate retrieval of broken instrument from canal.

## CONCLUSION

There is strong evidence to suggest that CBCT imaging could replace conventional 2D imaging. When considering such a shift in imaging strategy, dose and costs must come into consideration especially in children. It should be balanced with the perspective that most CBCT studies are easier to perform in a dental office when compared with a full-mouth series of radiographs, or perhaps even a panoramic radiograph with bitewings and selected periapical images. However, use of CBCT in children should be justified depending upon the case such that its application outweighs the potential risks of radiation exposure and all the basic principles should be followed apparently.

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