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Cone Beam Computed Tomography (CBCT) Attributes to Diagnosis of Dental Disease in Children: A Systematic Review

Suganya M[1], US Mahadeva Rao[2]*

[1.]1st Year Post Graduate Student, Department of Pediatric and Preventive Dentistry, People's College of Dental Sciences and Research Centre, Bhopal, Madhya Pradesh, India.
[2.] Professor, School of Basic Medical Sciences, Universiti Sultan Zainal Abidin (UniSZA), Kuala Terengganu, Malaysia.

Abstract

Cone Beam Computed Tomography (CBCT) was urbanized in the 1990s as encroachment in technology resulting from the demand for three-dimensional (3D) information obtained by conventional computed tomography (CT) scans and now it is more habitually used for clinical and research purposes in dentistry. There is a bundle of recompense allied with employ of CBCT and radiation protection which has made this dexterity very popular for imaging of the craniofacial region. The intend of this article was to conduct a systematic review for the justification of CBCT application in pediatric population and to make available evidence for diagnostic exercise of CBCT in a pre-orthodontic pediatric population. This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA).

Keywords: Cone Beam Computed Tomography; Radiation; Imaging; Craniofacial.

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Corresponding Author: Dr. US Mahadeva Rao Professor, School of Basic Medical Sciences, UniSZA, Kuala Terengganu, Malaysia.

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1 | INTRODUCTION

Cone Beam Computed Tomography (CBCT) was urbanized in the 1990s asencroachment in technology resulting from the demand for three-dimensional (3D) information obtained by conventional computed tomography (CT) scansand now it is more habitually used for clinical and research purposes in dentistry. CBCT endow withexact and twist free images of the maxillofacial region and a lower absorbed radiation dose compared with multi slice computed tomography. Theimprovement of CBCT technology reduces exposure by means of lowerradiation dose, compared with conventional CT. As the commandfor the technology increases, so has the market for norm built craniomaxillofacialCBCT devices. The toll of augment for CBCTs hasbeen escalating in number on the marketplace over the last decade and anarray of applications to the facial and dental environments have beenreputable [1].

CT technology was urbanized by Sir Godfrey Hounsfield in 1967 andthere has been a gradual progression to five generations of the system [2].First generation scanners consisted of a single radiation source and asingle detector and information was obtained slice by slice. The secondgeneration was introduced as a development and multipledetectors were built-in within the plane of the scan. The thirdgeneration was made promising by the expansion in detector anddata acquisition technology. These great detectors condensed the needfor the beam to translate around the object to be calculated and wereoften known as the “fan-beam” CTs. Ring artefacts were often seen on the images captured distorting the 3D image and obscuring certainanatomical landmarks. The fourth generation was urbanized to counterthis problem. A moving radiation source and a fixed detector ringwere introduced. This designed that modifications to the angle of theradiation source had to be engaged into account and more scattered radiationwas seen. Finally, the fifth (now and then known as the sixth) generationscanners were the foreword to reduced “motion” or“scatter” artefacts. As with the previous two generations, the detectoris motionless and the electron beam is electronically swept along acurved tungsten strip anode. Projections of the X-rays are sobrisk that even the heart beat may be captured. This has led someclinicians to summon it as a 4D motion capture device [3].

In 2007, theToshiba “dynamic volume” scanner based on 320 slices is screeningthe potential to significantly reduce radiation exposure by eliminatingthe requirement for a helical examination in both cardiac CT angiographyand whole brain perfusion studies for the valuation of stroke CBCTs for dental, oral, and maxillofacial surgery and orthodonticindications were premeditated to counter some of the limitations of theconventional CT scanning devices [4]. The radiation source consists of aconventional low-radiation X-ray tube and the resultant beam is projectedonto a flat panel detector (FPD) or a charge-coupled device(CCD) with an image intensifier. The FPD was shown to have a toweringspatial resolution. The cone beam produces a more focused beamand much less radiation scatter compared with the conventional fan shaped CT devices. This significantly increases the X-ray exploitationand reduces the X-ray tube capacity required for volumetricscanning. It has been reported that the total radiation is something like20% of conventional CTs and corresponding to a full mouth periapicalradiographic exposure. CBCT can for that reason be recommendedas a dose-sparing technique compared with unusual standard medicalCT scans for common oral and maxillofacial radiographic imagingtasks. The images are comparable to the conventional CTs and maybe displayed as a full head view, as a skull view, or as localized regionalviews [5].

1.1Advantages of Radiation protection

There is a bundle of recompenseallied with employ of CBCT and radiation protection which has made this dexterity very popular for imaging of the craniofacial region.

Some of these advantages are as follows:

1. Image exactness
2. Express scan time
3. Abridged image artefact
4. Compact radiation dosage
5. X-ray beam constraint

As child patients are more vulnerable to radiation dose therefore use of CBCT should be reasonable. As children are highly susceptible to ionizing radiations exposure should be kept as low as reasonably achievable [6].

1.2 Basic Principles of Radiation Protection

The three basic and fundamental principles of radiation protection should always be kept in mind by the pediatric dentist before exposing the pediatric patient to unnecessary radiations.

1. Justification principle-meaning that radiographs is only indicated if there is no means of obtaining the obligatory information. If the patient cannot cope with the course of action, then no radiographs ought to be taken.
2. Limitation principle- It states that the expert should always try to remain the radiation dose as low as reasonably achievable (ALARA) as supported by American Dental Association.
3. Optimization principle- It states that any expert should always try to acquire the best possible investigative image [7].

1.3 Objectives

The intend of this article was to conduct a systematic review for the justification of CBCT application in pediatric population and to make available evidence for diagnostic exercise of CBCT in a pre-orthodontic pediatric population. Therefore, population Intervention Comparator Outcomes (PICO) approach was formulated as follows: Population: pediatric patients; Intervention: CBCT; Control: conventional 2D radiography; Outcome: treatment changes due to 3D imaging.

2.| Materials and Methods

2.1 Protocol and registration

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement and was not registered. [8]

The subsequent Medical Subject Headings (MeSH) were functional during the literature hunt: cone-beam computed tomography; root resorption; tooth, impacted; tooth, unerupted; transplantation, autologous; cleft lip; hypodontia; cyst, jaw; Arthritis, Juvenile; Congenital Abnormalities; Tooth, Supernumerary; Fused Teeth; wounds and injuries; Tooth Injuries; Tooth Ankylosis; not adult; not animal.

2.2 Eligibility criteria

Study designs

In vivo pediatric studies of diagnostic efficacy as defined by Fryback and Thornbury [9].

Included:

• Systematic reviews of in vivo diagnostic efficacy studies.

• Primary studies of in vivo diagnostic efficacy (if not included in a systematic review).

• Narrative reviews, case series, case reports, surveys of clinical use of CBCT and other research study designs (observational studies; observer reliability studies) and parameter documents as secondary sources of information.

Excluded:

• Studies of technical efficacy

• Studies of any design for which the objectives were to evaluate treatments, in which the use of CBCT was simply as a diagnostic tool.

• Ex vivo/in vitro studies

• Animal studies.

• Research on orthodontic applications of CBCT, although flexibility was permitted if these had relevance to paediatric dentistry.

• Radiation dosimetry studies.

3. |General Indications

3.1 Dental caries

CBCT images display enhanced detection of proximal carious lesions ascompared to conventional digital intraoral techniques. However, CBCT has its own precincts as it is incapable to detect carious lesions in metalrestored crowns and tooth in the midst of radiopaque restorations.Among the various types of methods in the diagnosis of caries, probing, visual examination, intraoral film, and digital sensors are commonly used in routine clinical practice. Such diagnostic methods in the management of dental caries are used to determine the presence of caries and its extent, to monitor the course of caries progression, and to evaluate the effectiveness of treatment [10].

3.2 Supernumerary teeth

CBCT consideration of impacted supernumerary teeth is recommended to reduce the menace of damage to the neighbouring anatomical structures as they are in close association with cortical bone.Supernumerary teeth (hyperdontia) are excess teeth found in primary or permanent dentition. Although its etiology still remains unclear- hereditary influence, disease processes, dichotomy of the tooth germ, excessive growth of the dental lamina have been suggested as possible causative factors [11].

3.3 Endodontic applications

CBCT is an exceptional diagnostic tool for complex endodontic cases. It is not always viable to analyze the coverage of periapical pathologies, perforations, obturations, root fractures, location of fractured root canal instruments in root canals by means of traditional radiographic techniques. CBCT is a resourceful diagnostic tool to give an enhanced view of calcified canals and missed canals, and to appraise root length and angle of curvature [12].

3.4 Dental Trauma

It has been originated that CBCT can lead to very towering diagnostic accuraciesfor root fractures of non-endodontically treated teeth as comparedto conventional periapical radiographs.Traumatic injuries to teeth and their supporting structures comprise something like five percent of all traumatic injuries [13]. CBCT has lately been used expansively in all aspects of dentistry. Several studies showed that CBCT is valuable in diagnosis of dental horizontal root fractures and alveolar fractures. According to the American Association of Endodontics (AAE), CBCT should be the imaging modality of pick for diagnosis and management of restricted dento-alveolar trauma, root fractures, luxation, and/or displacement of teeth and localized alveolar fractures [14].

3.5 Temporomandibular Joint (TMJ) disorders

CBCT is a commercial and dose-effective substitute to CT for TMJexamination. It is more advanced in assessment of osseous TMJ abnormalitiesas compared to traditional imaging modalities like radiographyand MRI. The diagnostic prospective of CBCT *vs* conventional radiographic examinations was recommended in three cases of different state of affairs; intra-articular fractures, osteoarthritis (OA) and fibro-osseous ankylosis. 3 years later, an additional case report indicated its value in the consideration of early and late OA, as well as hypoplasia of the TMJ [15].

3.6 Patients undergoing Orthodontic treatments

Pediatric patients undergoing orthodontic treatment can benefitfrom CBCT as it can endow with valuable diagnostic in sequence regardingconsideration of ankylosed and submerged primary tooth, assessment ofimpacted canine and premolar, assessment of buccal and lingual corticalplates and appraisal of proposed sites of temporary anchorage devices.It is also a precious tool for planning of orthognathic surgeries [16].

In orthodontics, the same set of radiographs must not be characteristically made for all patients. Orthodontists find the panoramic and cephalometric radiography to be adequate for most initial, progress, and final records. However, CBCT may provide evidence to be profitable in several clinical encounters. The great advantage of CBCT is that it provides images of diverse dental, oral, and maxillofacial structures in multiple orthogonal images (i.e., coronal, sagittal, axial). CBCT can also endow with curved or flat slices of capricious thickness. In addition, CBCT provides multi-planar reformatted images, volume rendering, maximum intensity projection, and other 3D visual representations [17].

3.7 Forensic Odontology

Currently CBCT has been used commonly in forensic odontology forage estimation, forensic facial reconstruction, analysis of bite-marks,sex determination, and frontal sinus pattern. Through CBCT radiology, evolutionary forensic odontology has been developed extensively in many applications, such as the estimation of age through teeth, the role of dentists in trials or forensic witnesses, analysis of bite marks, investigation of trauma cases, and determination of sex and race [18].

4. |Future Perspectives

4.1 Optical scanners with CBCT

The majority of the digital imaging techniques have not yet satisfactorily been validated to be used for upshot measures in implant dentistry. In clinical research, CBCT is progressively more being used for 3D assessment of bone and soft tissue following augmentation procedures and implant placement [19]. At present, there are no valuable methods for the reduction of artefacts in the order of implants in CBCT. Optical scanning is being used for the 3D assessment of changes in the soft tissue contour.

The combination of optical scan with pre-operative CBCT allows the fortitude of the implant position and its spatial relation to anatomical structures. Spectrophotometry is the method most regularly used to neutrally assess the colour match of reconstructions and peri-implant mucosa to natural dentition and gingiva. New optical imaging techniques may be well thought-out possible approaches for monitoring peri-implant soft tissue health. MRI and ultrasonography appear hopeful in non-ionizing radiation imaging modalities for the judgment of soft tissue and bone defect morphologies. Optical scanners and OCT may characterize efficient clinical methods for accurate judgment of the misfit between the reconstructions and the implants. Optical scanners have been introduced which combined with CBCT leads to enhanced treatment planning. It helps a clinician in evidently visualizing the patient's anatomy and planning minimal invasive surgeries [20].

4.2 Phase Contrast Tomography

Differential phase-contrast (DPC) technique is capable as the next breakthrough in the field of X-ray CT imaging. Utilizing the long ignored X-ray phase information, DPC technique has the potential of providing us with projection images with higher contrast in a CT scan without increasing the X-ray dose. While traditional absorption-based X-ray imaging is not very resourceful at differentiating soft tissues, DPC is shows potential as a new method to boost the superiority of the CT reconstruction images in term of contrast noise ratio (CNR) in soft tissue imaging [21]. In order to corroborate and inspect the use of DPC technique in CBCT imaging scheme, a new bench-top micro-focus DPC-based cone-beam computed tomography DPC-CBCT system has been premeditated and constructed in our lab for soft tissue imaging. The DPC-CBCT system consists of a micro-focus X-ray tube (focal spot 8 μm), a high-resolution detector, a rotating phantom holder and two gratings, i.e. a phase grating and an analysis. The detector system has a phosphor screen, an optical fiber coupling unit and a CMOS chip with an effective pixel pitch of 22.5 microns. The optical elements are united to minimize astonishing moiré patterns, and system parameters, including tube voltage (or equivalently X-ray spectrum), distances between gratings, source-to-object distance and object-to-detector distance are chosen as practicable to be applied in a rotating system. The system is tested with two simple phantoms for performance evaluation. 3-D volumetric phase-coefficients are reconstructed. The performance of the system is compared with conventional absorption-based CT in term of contrast noise ratio (CNR) under the condition of equal X-ray dose level [22].

5. |Conclusion

Although CBCT is just 20 years old, it has revolutionized the practice of dentistry, so much that there is scarcely a dental specialty which has not been affected by this technology. Nevertheless, it presents the dentist with a number of key challenges. An initial steep learning curve must be addressed without superfluous exposure to the patient. This is particularly important when the patient is a child. CBCT can endow with precise and accurate information on normal and pathologic conditions such as odontomas, supernumerary teeth, developmental anomalies and traumatic injuries. The main advantages of CBCT are; multi-planar imaging of dental tissues, shorter acquisition time and less ionizing radiation dose compared to CT, and ease of data transfer. It is occasionally not possible to diagnose and make treatment planning by using routine radiographs.Therefore, multiplanar visualization may help practitioner to decide suitable treatment plan. In recent years CBCT has been comprehensively used to spot impacted and supernumerary teeth. The rationale of this study was to scrutinize the impacted supernumerary teeth using CBCT which were detected on panoramic radiographs.

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