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Role of Cone-Beam Computed Tomography in the Domain of Orthodontics

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Abstract

In order to reduce the radiation exposure of the patients and to overcome the restrictions of conventional CT scanning, the craniofacial cone-beam computed tomography (CBCT) scanning was introduced. For the oral and maxillofacial imaging, the New Tom (quantitative radiology, Verona, Italy) is prime profitable appropriated CBCT organization. New Tom VG is the fourth generation at present and it is approved by the Food and Drug Administration (FDA). When compared to the traditional cephalograms, the analytical omission is low in CBCT images. By utilizing the various aspects such as volume rendered, shaded surface display and multi-planar through CBCT, the 3D analysis can be carried out. There are various types of software which can be utilized in the 3D analysis for different target evaluation in the craniofacial region such as Dolphin 3D, Mimics, on demand 3D, *In vivo* Dental, OS and ITK-snap. There has been a remarkable experience in imaging technique for orthodontics and dentistry by using CBCT scanner, which provides 3D data sets, unlike the conventional 2D radiography. CBCT is used in the diagnosis and treatment planning of various cases in orthodontics, such as evaluation of cleft palate, assessment of impacted teeth, evaluation of dental and skeletal structures, temporomandibular joint complex evaluation and assessment of the space needed for the placement of temporary anchorage devices, etc. In this article, we tried to share our ideas and insights about the advantages and disadvantages of CBCT organization which has come after revising many literature reviews of the concerned topics and also from the discussion with coauthors and colleagues.

Introduction

The accurate diagnosis and treatment plan for an orthodontic patient requires the correct diagnostic images. To meticulously examine the treatment course and results, diagnostic imaging is a fundamental means [1]. In order to reduce the radiation exposure of the patients and to overcome the restrictions of conventional CT scanning, the craniofacial cone-beam computed tomography (CBCT) scanning was introduced [2]. The mechanics of CBCT are established by utilizing the X-ray beam which is cone shaped and aimed through the head of the patient on the flat 2D (two-dimensional) image detector, and the remainder beam is conquered [3]. Among the current modernistic imaging techniques of the orthodontic field, CBCT along with 3D facial photographs and digital dental models is being routinely used [4]. Since its introduction in 1938, it has granted progress in treatment planning of orthodontic-orthopedic cases; diagnosis of orthodontic cases and predicting the treatment results by producing the images with satisfactory sharpness and resolutions in multi-planar aspects [5]. The CBCT produces clinically precise and dependable images of craniofacial region and 3D linear measurements. The orientation of the skull during the scanning procedure does not cause any alteration in the precision of measurements [6]. The higher usage of CBCT in the field of dentistry stimulated the advancement of present software constructed mainly in the field of dentistry [7]. For numerous years, utilization of 3D imaging into a commonly used cephalometric system remained to contravene because of its higher doses of radiation exposure, more cost and technique sensitivity [8]. The objective of this review is to summarize the uses of the CBCT technique in the diagnosis and treatment planning of various aspects of orthodontics and also to assess its use as a routine diagnostic aid in the field of orthodontics.

CBCT imaging technique in craniofacial region

For the scanning of the integrated maxillofacial region, an individual record of radiation of CBCT scan is enough [9]. For the oral and maxillofacial imaging, the New Tom (quantitative radiology, Verona, Italy) is prime profitable appropriated CBCT organization. New Tom VG is the fourth generation at present and it is approved by the Food and Drug Administration (FDA). The CBCT organizations are largely classified into 3 groups: (1) large field of view (it is CBCT organization which requires only one exposure for imaging a larger portion of the cranial and maxillofacial complex); (2) smaller field of view CBCT organizations and (3) hybrid digital panoramic (CBCT organization having different components for 2 functions). There are reports on radiation exposure with CBCT, which states that in comparison to conventional CT, there is a reduction of 20% in the total dose of radiation exposure [10]. According to Schulze et al. [11], there is four times lesser radiation with 3D volumetric images acquired from CBCT when compared to conventional CT scanning. With the use of CBCT technology, for the patient radiation exposure dose ranges between 45 microsievert (μSv) to 650 microsievert (μSv) [12, 13].

CBCT in contrast to various imaging techniques

In comparison to conventional imaging like lateral cephalogram (10.4 μSv), full-mouth series (13-100 μSv), and a panoramic radiograph (14.2-24.3 μSv) and by combining all the radiation exposure, the radiation exposure of CBCT is equal or somewhat more than the traditional imaging system [14]. When compared with traditional cephalograms, the analytical omission is lesser in CBCT images [15]. By utilizing various aspects such as volume rendered (VR), shaded surface display (SSD) and multiplanar (MPR) through CBCT, the 3D analysis can be carried out [16, 17]. The CBCT innervate higher details in the cases of retained and impacted teeth, cleft lip and palate (CLP), root resorption and the third molar examination in comparison to conventional panoramic radiograph (Fig. 1) [18].

Various imaging software used in 3D analysis

There are various types of software which can be utilized in the 3D analysis for different target

evaluation in the craniofacial region. Some of the software programs are Dolphin 3D (Dolphin imaging and management solutions, Chatsworth, Clif), Mimics (Materialise, Leuven, Belgium), On-demand 3D (CyberMed, Seoul, Korea), In vivo Dental (Anatomage, San Jose, Calif**),** OS Irix (Pixmeo, Geneva, Switzerland) and ITK-snap (www.itksnap.org) [19]. The reproducibility is higher for all systems [20]. According to some studies, there was a diminutive systematic distortion in the dental measurement from CBCT, but by the conjugation of various measurements, it got remarkable statistically [21]. The 3D linear measurements of the craniofacial complex are clinically more precise and certain with CBCT. Further, with the CBCT scanning, the precision and certainty of the measurements are not affected by the orientation of skull [22].

Comparing 3D and 2D systems

The angular measurements carried out on 3D models customized through CBCT images when compared with the measurements carried out using conventional cephalometric radiographs [23]. There was a significant difference in the measurements of 3D models when compared to conventional cephalometric radiographs of the same human skull [24]. According to some studies, there has been a statistically significant and clinically pertinent difference between few measurements for 3D models of the same human skull constructed through two CBCT devices [25]. There has been a remarkable experience in imaging technique for orthodontics and dentistry by using CBCT scanner, which provides 3D data sets unlike the conventional 2D radiography [26]. One of the most important benefits of CBCT, when compared to 2D radiography, is that it can produce craniofacial regions 3D sectional, volumetric and surface information.

Uses of CBCT in orthodontic cases

Evaluation of cleft lip and cleft palate cases

3D images help in the preoperative examination of cleft palate concerning location and volume of bone defects, categorization of alveolar bone form and permanent teeth, and the inherence of supernumerary teeth [27]. The CBCT is believed to contribute enhanced orientation on the location, quality and number of teeth in the propinquity of the cleft point, the cause of impacted tooth on cleft site which is grafted and diagnosis of placement of implant [28]. The post-surgical success of bone fill can be determined by CBCT because the images obtained from it are used for the assessment of alveolar defect volume and in turn, the bone required for grafting cleft lip/palate patients can be assessed [29].

Assessment of impacted teeth and adjacent anatomic structures

In cases with the angle of inclination of canine greater than 30º, a noticeable resorption of the root of adjacent teeth and suspected canine root dilaceration, CBCT can be used instead of traditional panoramic X-rays [30]. The maxillary canines rank second, after the third molars to be commonly impacted [31] and are most commonly indicated for CBCT examination in orthodontic practice. CBCT improves the capability to confine impacted canines precisely, analyzes the juxtaposition of impacted teeth with surrounding structures and teeth, assesses the pressure of any pathology and size of follicles, evaluates the adjacent tooth resorption and helps in deciding the proper pathway for the eruption of impacted teeth in the oral cavity [32].

Dental and skeletal structure evaluation

To identify the anatomic landmarks bilaterally like gonion, orbitale and condylion, the multi-planar aspects of CBCT are gainful because these structures are usually superjacent with traditional radiography [33]. By utilizing CBCT scans, the evaluation of cervical vertebrae maturity can be done [34]. The cervical vertebrae maturation stages are possible to analyze with the use of CBCT images 3D reconstruction or sagittal sections and it can also provide a pubertal growth spurt (PGS) evaluation with the use of sagittal sections [35]. By reducing the superimposition artifacts and allowing the resolution of roots in 3D of impacted teeth associated with root resorption, CBCT provides better evaluation capability compared to 2D radiographs [36].

Temporomandibular joint (TMJ) complex evaluation

Although for diagnosing the disorders of the TMJ

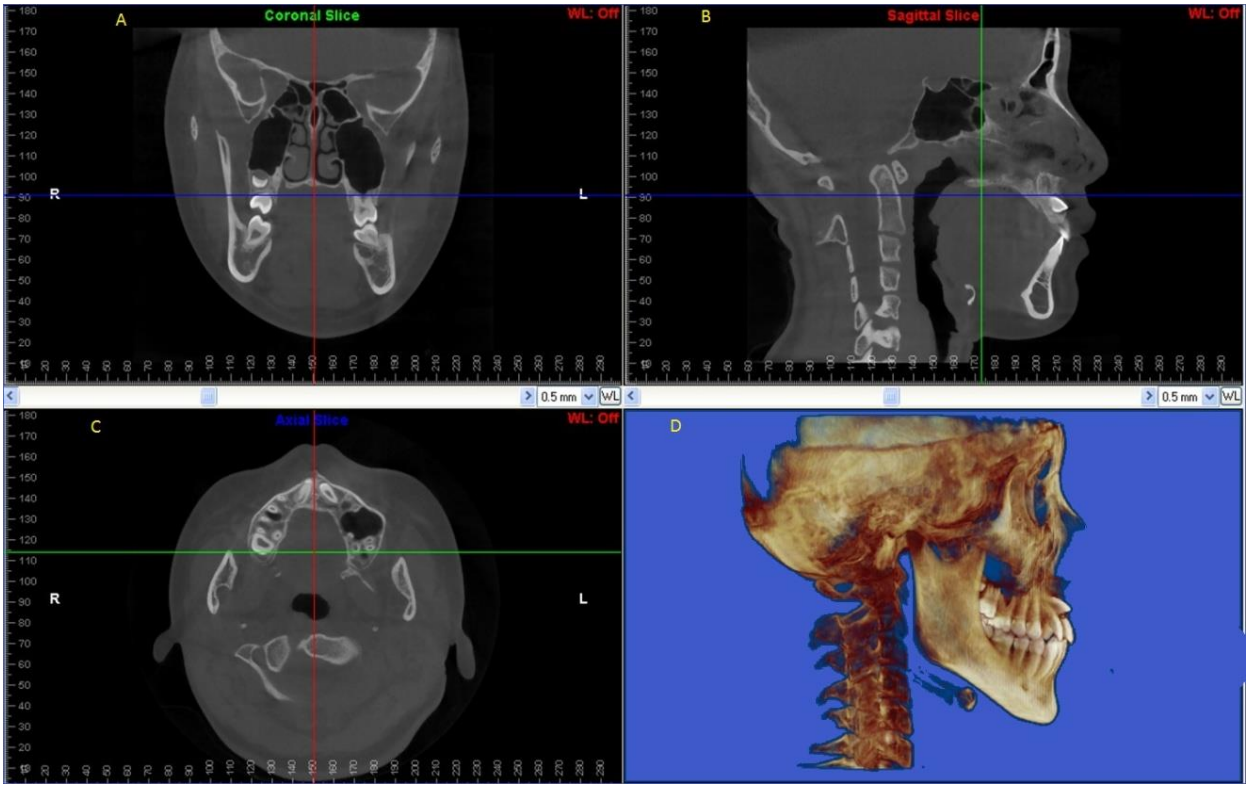

Fig 1 Pre-treatment CBCT scan image of impacted maxillary right lateral incisor in different plans such as coronal, sagittal and axial. (**A**) Coronal plane and frontal view of the occlusion of the maxillary and mandibular molars and hard tissues in the adjacent region; (B) sagittal plane and lateral view of the impacted maxillary right lateral incisor; (C) axial plane and occlusal view of impacted maxillary right lateral incisor and (D) depicts 3D lateral profile image of the dentition and maxilla-mandibular relationship of patient's right side.

like myofascial pain dysfunction and internal disc derangements, CBCT scanning is not the choice of technique, but it is more precise and more reliable for the diagnosis of condylar erosion and morphological disturbance [37]. The CBCT images enable the clinician to acquire more precise anatomical details of a temporomandibular joint complex than conventional 2D radiography. It also enhances recognition of minimal to frank changes in the hard tissues and facilitates the disclosure of pathological changes in the hard tissues [38, 39]

Assessment of pharyngeal airway

According to some studies, the morphology of the airway was disturbed in patients with obstructive sleep apnea (OSA), there was decreased airway area, distance and volume, hence, diagnosis with CBCT is important in such cases [40]. The soft tissue points in airway evaluation are much accurately seen in axial cuts of CBCT scans compared to conventional radiography [41].

Evaluation of the precise space needed for impacted/unerupted teeth

The impacted teeth, for example, impacted canines are evaluated precisely with the use of CBCT by enhancing the sensitivity to focalize resorption of neighboring teeth. In addition, assessment of the propinquity of the adjacent teeth and anatomic structures, assessment of the size of the follicle, and determining the pathologic presence using CTBT helps in the preparation of surgical approach and placing of the bond by guiding the accurate course for tooth extrusion within the oral cavity [42, 43].

Assessment of placing the temporary anchorage devices (TAD)

To ensure a reliable anchorage while applying orthodontic forces, TAD's are often used. The evaluation of micro and macro-anatomical structures, roots of teeth and nerve distribution, trabecular and cortical bone for the placements of TAD's can be done with CBCT [44, 45]. Hence, CBCT is useful in judging the placement of TAD'S at favorable sites

where the adjacent anatomical structures quality and quantity is not compromised [46].

Evaluation of dimensions needed for maxillary expansion

For widening the transverse dimension of maxilla patients indicated for rapid maxillary expansion (RME) by expanding the mid-palatal suture, CBCT can be utilized. It would assess the age effect and the effect of expansion forces on different maxillary regions relative to the intensity of skeletal expansion and dental tipping [47, 48].

Assessment of sensory perturbation relative to orthodontics background

Following the orthognathic surgeries, sensory perturbation of chin and lower lip areas is common, but the sensory disturbance is relatively rare in relation to the conventional orthodontic treatments. According to some studies, CBCT scanning plays a key role in acquiring the accurate diagnosis of transient mental nerve paresthesia induced by orthodontic treatment [49].

CBCT images superimposition of orthognathic surgeries

There is a new method called superimposition, in which the superimposition of 1st CBCT image onto 2nd CBCT image custom surface mesh of anterior cranial base is carried out [50]. After the mandibular advancement surgeries, virtual facial models are obtained from CBCT volume to analyze the changes after the surgery [51]. In some studies, the CBCT image color maps and analogous computer software analysis is compared [52].

Can CBCT be used in daily orthodontic practice: A contention?

When compared to conventional radiographic techniques which are routinely used in orthodontic practice, CBCT has a disadvantage of more radiation dose [53]. There may be genetic effects on irradiated organs and tissues and carcinogenesis hence can cause a conditional hazard to health because of effective radiation dose [54]. In comparison with the accustomed danger of carcinogenesis, the dental radiation risk and effective dose risk are favorably very less [55]. Point to counterpoint concourse on the study was published in 2012 because the routine use of CBCT in the field of orthodontics embossed a high debate [56]. From the University of Minnesota, orthodontic division's director Dr. Brent Larson supported the routine CBCT use during extensive orthodontic treatment [57]. Every orthodontist should consider five rules before advising CBCT scanning for diagnostic procedures.

(1) For every patient, CBCT scan should be clarified. It should provide a different orientation, which will not be provided by conventional radiography [58].
(2) The higher the field of view (FOV), the higher is the radiation dose. Therefore, the FOV of CBCT should be minimized. The ALARA principle (as low as reasonably achievable) should be followed to lower the radiation dose and only the regions of concern should be included in the examination [4].
(3) Utilization of CBCT as a routine procedure for orthodontic cases is recognized as an obnoxious method [4].
(4) The dimensions of voxel affect the resolution of CBCT image. The favored sizes of the voxel are 0.3mm to 0.4mm when there is no need of higher specification for the particular orthodontic patient [53].
(5) An orthodontist should not indicate for CBCT examination unless the clinical and history examination of the patient is completed [53].
(6) Therefore, if the probabilistic hazard of higher radiation dose is outweighed by the probable advantage for treatment planning and diagnosis of an orthodontic case then CBCT scan should be advised [58].

Conclusions

The CBCT scanning has gained noticeable importance since it was introduced in the field of dentistry in 1998. It has many advantages over the conventional radiography such as radiation exposure, accuracy, volumetric images and precision of the images. It can also be used in the diagnosis and treatment planning of various orthodontic cases and has also gained popularity in its contemporary use and recommendation in the field of orthodontics. The

orthodontists should wisely prescribe the diagnostic radiographs to the patients who also include CBCT scanning to acquire most relevant data for diagnosis and treatment planning, and also there should be the least radiation exposure to the patients.

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Conflict of interest

The authors declare that they have no conflict of interest.

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