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Review Article

CBCT: A Replacement for Conventional Imaging Techniques in Orthodontics or Not

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Abstract

The purpose of this article is to emphasize on the understanding of the clinical use of CBCT in orthodontics and knowledge about the protocols for the use of CBCT in specific cases. The CBCT should be done on a case-by-case basis following an assessment of benefits vs risks of scanning in these situations.

Keywords: *Orthodontics; CBCT; Diagnostic Imaging; Treatment Planning*

Introduction

The goal of diagnosis and treatment planning of individuals requiring orthodontic treatment is to plan a course of treatment based on the patient's chief complaint, the initial condition of the patient's problems, the achievable treatment goals and the patient's willingness to accept and co-operate with a specific treatment protocol. Diagnostic imaging should be accurate to know the correct diagnosis and plan the treatment accordingly, for monitoring and document the treatment progress and final outcome of the treatment [1].

Comprehensive visualization and records of the craniofacial complex have always been important goals in orthodontic imaging. For this purpose, plaster models, photographs and radiographs are taken routinely. Till now, imaging techniques in the dental office are essentially two-dimensional (2D) representations of three dimensional (3D) objects which show several limitations like magnification, distortion, superimposition and misrepresentation of structures. However, cone-beam computed tomography (CBCT) has achieved a considerable importance worldwide in recent years as a viable 3D imaging modality.

Since its introduction to the dental profession in the 1990s, specifically dedicated to imaging the maxillofacial region heralds a true paradigm shift. Now, the dental practitioners have entered a new era in radiographic imaging. The introduction of CBCT has created a revolution in maxillofacial imaging expanding the role of imaging from diagnosis to image guidance of operative and surgical procedures with the help of various software applications. It produces a three-dimensional (3-D) image more quickly and easily than the conventional medical CT, and provides more information than 2-D imaging. It provides accurate multi-planar 3-D imaging that specifically suits dental imaging needs across all specialties [2].

In CBCT, instead of pixels, the resolution is measured in voxels and often is sharper than a conventional CT. Cone-beam refers to the cone shape of the X-ray beam, whereas conventional CT uses a fan-shaped beam to create multiple thin slices. CBCT produces panorex and cephalometric views, which become 3D when the data is rearranged in a volume. With CBCT technology, it is possible to take all radiographs in 1 minute. While obtaining conventional images, complexities of the craniofacial complex, dentition and airway present challenges. The orthodontist now has the diagnostic quality of periapicals, panoramic, cephalograms, occlusal radiographs, and TMJ series at their disposal, along with views that cannot be produced by regular radiographic machines like axial views, and separate cephalograms for the right and left sides. But as every coin has two sides, so every technological advancement has some negative aspects associated along with it and so is with CBCT. The problems associated with CBCT have to be well kept in mind before referring the patient to get the scan done.

Cone beam and orthodontics

The patient selection criteria should stem from a comprehensive assessment of the benefits and burdens to each patient which should not be completely objective rather it should be based on current evidence. The already existing guidelines dealing with orthodontic diagnosis given by the SEDENTEXCT project of the European Union suggest that large volume CBCT should not be used routinely for orthodontic diagnosis.

A similar recommendation was given by the guidelines of The British Orthodontic Society suggesting that the routine use of CBCT even for most cases of impaction of teeth cannot yet be recommended [3].

In 2010, the American Association of Orthodontists concluded that while there may be clinical situations where a cone-beam computed tomography (CBCT) radiograph may be of value, the use of such technology is not routinely required for orthodontic radiography [4].

Radiation Burden

CBCT, a recently introduced three-dimensional imaging technique is being more frequently used in orthodontic assessment [5]. The effects of ionizing radiation are considered hazardous. This illustrates that the risk of the condition (eg, cancer) depends on the dose.

Using a low-dosage vs a high-dosage CBCT machine, the probability of an important stochastic effect (cancer and severe hereditary effect) is 7.3×10^{-2} Sv [6]. For patients aged 10 to 20 years, this doubles to approximately 0.15 Sv. Since a large field-of-view CBCT will provide a dose of 68 to 368 mSv [7] compared with approximately 30 mSv for the cephalometric and panoramic combination, this translates to a risk of about 1 in 170,000 to 1 in 20,000 above the current customary procedure [6].

The significant improvements offered by CBCT in patient outcomes, should not be confused with the benefits to the patient with the technical capabilities of CBCT technology. The CBCT images are 3-dimensional but this fact is not directly relevant. Use of CBCT images over conventional methods can only be considered when the treatment outcome will be significantly better to outweigh the above risks. Conventional images may deliver the lowest doses to patients from a radiation-protection point of view. CBCT is preferred over a CT image, when a 3-D imaging is required for orthodontic assessment as CBCT has lower radiation, but at the same time, lower resolution than spiral CT [8].

Many factors correlate to exposure from CBCT machines. Prime considerations before going for a CBCT scan should be the technology offered by the manufacturer and the type of sensor used to capture the data. Radiation exposure is not always dependent on field of view. These factors may result in greater CBCT radiation exposure using a small field rather than that of a standard full field of view. However, at a standard resolution, a standard full field of view can be as little as 36 μSv. The additional reduction in radiation exposure can be provided by the machines that collimate. Another important factor to be considered is the size of voxel; the smaller the voxel the greater the resolution (similar to pixel size in 2-D images) and the more exposure. The currently available CBCT units have a range of radiation exposure i.e. from 87 to 206 mSv for a full craniofacial scan [9,10]. Thus, when compared with the combined radiation exposure of conventional orthodontic images including a panoramic radiograph (14.2 - 24.3 mSv), a lateral cephalogram (10.4 mS) and a fullmouth series (13 - 100 mS), CBCT radiation exposure is equivalent to or slightly higher than traditional imaging [9].

Efficacy of procedures

To evaluate the efficacy of diagnostic imaging procedures [11], the following terms can be used: technical efficacy, diagnostic accuracy efficacy, diagnostic thinking efficacy, therapeutic efficacy, patient outcome efficacy, and societal efficacy.

Technical efficacy can be related to the quality of the image. The dimensional accuracy of CBCT images has been well established [12]. Voxel size is typically 0.3 to 0.4 mm, corresponding to a lower resolution than that of conventional intraoral radiographic imaging. Artefacts and noise are higher than those observed in multi-slice computed tomography, making it difficult, if not impossible, to obtain consistent density values and resulting in low contrast and poor depiction of soft tissues [12-14]. Segmentation is problematic, and even high-contrast objects, such as teeth, are measured with errors that can exceed 1 mm, limiting clinical usefulness [15].

Diagnostic accuracy efficacy measures the accuracy of diagnosis by using CBCT in comparison with a reference standard-either a cephalogram or panoramic radiograph. Alveolar bone thickness and height, and the presence of fenestrations and dehiscences, have been compared between CBCT images and direct measurements. Due to the relatively large voxel size, thin structures are difficult to detect, and alveolar bone covering the incisors might be underestimated, although the results are conflicting [16,17].

Errors in measuring bone thickness can exceed 1.4 mm for a 0.4-mm voxel size [17]. Fenestrations and dehiscences are overestimated to a large degree [15,16]. At present, no accurate studies are there for diagnosis, regarding the localization of impacted canines, this question has not been seriously debated till now [18,19]. Regarding resorption of adjacent teeth, CBCT images show improved sensitivity and specificity over panoramic radiography [20].

CBCT has been shown to have increased diagnostic accuracy over posteroanterior cephalograms in patients with skeletal asymmetry [21]. Regarding the periodontal assessment, although it has a definite 3-dimensional advantage, but one should keep in mind that CBCT only complements and it cannot replace intraoral radiography, mainly because of reduced resolution [22]. Studies on skull material have shown that CBCT images provide better diagnostic information [23], but there is no consensus regarding the accuracy of these measurements [22,24].

The SEDENTEXCT guidelines conclude that "CBCT is not indicated as a routine method of imaging periodontal bone support", although it might be indicated in selected patients, but preferably not with a large field of view [18].

The American Board of Orthodontics includes CBCT images as an option to document periodontal status but does not consider radiographic images, in general, as compulsory data and gives priority to clinical examination and conventional radiography [25].

Diagnostic thinking efficacy evaluates whether the imaging method changes the diagnosis from the pretest situation. Therapeutic efficacy assesses whether there are changes to the treatment plan as test produces. These efficacies have been evaluated for impacted third molars and impacted canines [26-28]. CBCT images are perceived to be more useful than traditional radiographs for such cases [27] and might change the recommended treatment plan in approximately 30% of them [26,28].

However, no patient outcome efficacy studies have been conducted, and CBCT is recommended only when "the information cannot be obtained adequately by lower dose conventional (traditional) radiography [18]. There are numerous cases when an impacted maxillary canine can be clearly localized based on conventional radiographs and clinical examination (eg, palpation, position, and inclination of adjacent teeth), and no further imaging is justified [3]. Regarding resorption of adjacent teeth, diagnostic thinking efficacy and therapeutic efficacy studies showed that resorption defects can be identified better with CBCT images, but these studies mostly used a medium or small field of view [26,27,29].

For the assessment of temporomandibular joint, asymptomatic patients surely do not need temporomandibular joint imaging. Position of the condyles in the fossa can definitely be seen on CBCT images, but the diagnosis and treatment plan should not be affected by this information [30]. There has always been a debate on the value of temporomandibular joint imaging even for patients with temporomandibular disorders, and till now, no evidence is there to show that CBCT images will provide better treatment [31]. It seems, therefore, that CBCT might benefit some patients with the conditions mentioned above, but there is no evidence whether the remaining majority of the patients will be benefitted or not.

The application of 3-dimensional cephalometrics, or increased measurement accuracy, could be an indication. However, at present, there are no established 3-dimensional cephalometric analyses and no 3-dimensional normative data. CBCT images are used to simulate old technology—ie, reconstruct 2-dimensional lateral cephalometric views. There is, till now, no evidence that increased accuracy from CBCT contributes to a change of treatment plan or better treatment. Even though such a notion might seem self-evident, one should consider that the treatment modalities are not so fine tuned to specific craniofacial patterns that a conventional cephalometric radiograph is inadequate to serve. Furthermore, introduction of significant errors while identifying landmarks on CBCT images might mitigate the advantage of increased accuracy [32]. Lastly, most of the diagnostic information is gained from clinical evaluations. The cephalogram serves as an adjunctive tool and has been shown to be superfluous in some circumstances, affecting treatment-planning decisions in some patients and to a limited degree [33,34].

Accuracy of CBCT-derived cephalograms and measurements vs gold standard

3D measurements from CBCTs can be made in several visualization modes, including multiplanar (MPR), volume rendered (VR) and shaded surface display (SSD) [32,33]. Of these, point-to-point measurements made in the MPR mode are highly accurate when compared with physical skull measurements, whereas the surface anatomy measured in VR and SSD modes have a measurement error of 2.3% as compared with direct physical measurements [33,34]. The surface contours are estimated in these modes, as a result there are errors in VR and SSD display modes. It is very much clear that the identification and targeting of landmarks should be done using the digital imaging and communications in medicine (DICOM) volume in an MPR display mode.

CBCT vs panoramic radiography

A subjective comparison of images from two CBCT units (NewTom 9000, QR s.r.l., Verona, Italy and Arcadis Orbic 3D, Siemens Medical Solutions, Erlangen, Germany) and routine panoramic radiography demonstrated that CBCT provides more information than the radiographs for localizing impacted and retained teeth, root resorption, cleft lip and palate (CLP), and third molar evaluations but not for changes in the TMJ [35].

CBCT and root spatial relationships

When using a typodont with ideally positioned teeth, CBCT has been shown to be better than orthopantomograms in determining root angulations, but still shows variations from the true anatomy [36]. CBCT is at least as good as periapical radiography for assessing root and tooth length [37]. It provides accurate assessment of alveolar bone height assessment, but because CBCT had a high number of false-positives in the determination of fenestrations, caution must be used regarding evaluating these defects on CBCT images [38,39].

Imaging goals and protocols

CBCT imaging protocols should take into consideration the relative advantages of this technology over routine radiography, including the quality of the information derived, its potential impact on diagnosis and treatment planning, the ease of use vs the risks (including radiation exposure) and financial costs. This subjective benefit-to risk assessment may be termed ''value proposition'' for taking CBCT scans for any given case.

Several factors should be considered before thinking about an imaging protocol for orthodontic purposes. The image should incorporate the desired field of view (FOV), which in turn is determined by the area of interest. It should be decided before taking the image that the image captured should accomplish for the patient. The FOV may be small (individual teeth or quadrant), medium (both arches including TMJ) or large (full head).

The smaller FOV is used for assessing individual teeth, for example impacted teeth, root morphology, supernumeraries, etc. or sites for placement of dental implants or TADs. Medium FOV includes the mandible, the maxilla or both, and would typically be used when additional information on occlusal relationships, facial asymmetries or bilateral TMJ evaluations is needed or when the condition/s of interest, such as potentially adverse boundary conditions, are present in both arches or jaws. The largest FOV includes the whole head and helps clinicians to visualize relationships between skeletal bases, between teeth and skeletal bases as well as significant anomalies in patients requiring orthognathic surgery or those with craniofacial anomalies.

For maximum quality and diagnostic value the images should give the maximum detail, minimal distortion and minimal superimposition. After imaging, the region of interest should be viewed from at least two planes at right angles to each other, which will offer a multidimensional perspective. The clinician should also view the volumetric rendering in a 3D format. Additionally, the clinician should scan through consecutive series of 2D views in any given plane over the entire region of interest.

Conclusion

The expanding use of CBCT technology is beneficial to both patients and practitioners and is especially important to orthodontists because its ability to capture the entire anatomy needed for orthodontic treatment planning. When used correctly and responsibly, the data derived from CBCT imaging provides insight into treatment planning that is unachievable with other imaging methods, and allows clinicians to provide more predictable patient care.

The decision to obtain a CBCT in any of the clinical presentations should be determined on a case-by-case basis depending on whether additional information may help modify diagnosis and the treatment plan.

Except for certain patients, conventional cephalometric and panoramic radiographs should not be replaced with a large field-of-view CBCT which potentially may lead to a public health problem. The clinician should carefully select the patients when CBCT imaging will provide a tangible benefit and resist the lure of technology for technology's sake.

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