Review Article

Applications of cone-beam computerized tomography in dental practice: A brief review

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ABSTRACT

Cone-beam computerized tomography (CBCT) was developed in the 1990s as an evolutionary process resulting from the demand for three-dimensional (3D) information obtained by conventional CT scans. CBCT was introduced to the dental field to replace the expensive and high-radiation producing medical CT scans. It is found that CBCT scans were more accurate than CT scans. CBCT has a lower dose of radiation, minimal metal artifacts, reduced costs, easier accessibility, and easier handling than multislice CT; however, the latter is still considered a better choice for the analysis of bone density using a Hounsfield unit scale. CBCT reduces the overall exposure to radiation. CBCT is a new technique for maxillofacial imaging. The examination time is shorter and the patient dose is lower than that with conventional CT.

KEY WORDS: Cone-beam computerized tomography, Dental applications, Endodontics, Implant, Oral surgery, Orthodontics, Periodontics

INTRODUCTION

Radiology is important in the diagnostic assessment of the dental patient. For most dental practitioners, the use of advanced imaging has been limited due to cost, availability, and radiation dose considerations. However, the introduction of cone-beam computed tomography (CBCT) for the maxillofacial region provides opportunities for dental practitioners to request multiplanar imaging.[1] The purpose of this article is to provide a brief overview of CBCT and its clinical applications in dental practice.

CBCT systems have been designed for imaging hard tissues of the maxillofacial region. This imaging technique is based on a cone-shaped X-ray beam centered on a 2D detector that performs one rotation around the object, producing a series of 2D images. The object to be evaluated is captured as the radiation source falls onto a two-dimensional (2D) detector.[2] These images are reconstructed in 3D using a modification of the original cone-beam algorithm developed by Feldkamp *et al.,* in 1984. The introduction of CBCT is specifically dedicated to imaging the maxillofacial region provides a true shift from a 2D to a 3D approach to data acquisition and image reconstruction. There are currently four main system providers in the world market; N NewTom 3G, i-CAT, N CB MercuRay, and N 3D Accuitomo. The available CBCT machines differ in size, possible settings, area of image capture, and clinical usage.

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CBCT versus CT

Numerous efforts have been made toward 3D radiographic imaging and although CT has been available, its application in dentistry has been limited due to its access, cost, and dose considerations.[3] CT devices image patients in a series of axial plane slices that are captured as individual stacked slices or from a continuous spiral motion over the axial plane.[4] CBCTs were designed to counter some of the limitations of the conventional CT scanning devices. CBCT has short scanning times (10–70 s) and radiation dosages reportedly up to 15 times lower than those of conventional CT scans. The cone beam also produces a more focused beam and considerably less scatter radiation compared to the conventional fan-shaped CT devices. This significantly increases the X-ray

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utilization and decreases the X-ray tube capacity which is required for volumetric scanning.[5] It has been reported that the total radiation is approximately 20% of conventional CTs and equivalent to a full-mouth periapical radiographic exposure.[6] These component innovations are significant and allow the CBCT to be less expensive and smaller. Furthermore, the exposure chamber is custom built and reduces the amount of radiation. The images are comparable to the conventional CTs and may be displayed as a full head view, as a skull view, or regional components.

CBCT USED IN ORAL SURGERY

In oral surgery, CBCT is superior in generating images to locate root position and proximity of impacted third molars to the inferior alveolar nerve, compared to 2D cephalographs. It also enables the analysis of jaw pathology, supernumerary teeth, and their relation to vital structures changes in the cortical and trabecular bone and osteonecrosis of the jaw and the assessment of bone grafts.[7] It is also helpful in analyzing and assessing paranasal sinuses and obstructive sleep apnea [Figures 1-5].

CBCT USED IN TEMPOROMANDIBULAR JOINT (TMJ) DISORDERS

CBCT has ability to define the true position of the condyle in the fossa, which often reveals possible dislocation of the disk in the joint. It also helps to check TMJ function, occlusion, muscle attachment, and bone biology with tooth movement.[8] It is used as a choice of imaging device in cases of trauma, pain, dysfunction, fibro-osseous ankylosis, and in detecting condylar cortical erosion and cysts.

CBCT USED IN PERIODONTICS

CBCT is used in assessing a detailed morphologic description of the bone. It also used to detect buccal and lingual defects, which was not possible with conventional 2D radiographs. Using CBCT, intrabony defects can accurately be measured and dehiscence, fenestration defects and periodontal cysts assessed. It has also proved its superiority in evaluating the outcome of regenerative periodontal therapy.[9]

CBCT USED IN FORENSIC ODONTOLOGY

Many dental age estimation methods, which are a key element in forensic science, are described in the literature. In forensic odontology, CBCT was established as a non-invasive method to estimate the age of a person based on the pulp-tooth ratio.

CBCT USED IN ORTHODONTICS

In CBCT technology, all possible radiographs can be taken in under 1 min. The orthodontist has the diagnostic quality of periapicals, panoramic, cephalograms, and occlusal radiographs, and TMJ series at their disposal, along with views that cannot be produced by regular radiographic machines such as cephalogram and axial views for the right and left sides.

In impacted tooth and oral abnormalities, this is used to see the incidence of maxillary ectopic cuspids. CBCT is used to locate the ectopic cuspids and to design treatment strategies that allowed for minimally invasive surgery to be performed and helped to design effective orthodontic strategies.

3D conventional CT scans have shown that the incidence of root resorption to the adjacent teeth has been larger. The use of CBCT technology could add value to the management of patients with such anomalies.[10]

Another use of CBCT is the location of incidental oral abnormalities in patients. Some centers in the USA have begun to adopt CBCT imaging into routine dental examination procedures. It provides a better improvement in the airway analysis such as 3D and volumetric analysis.

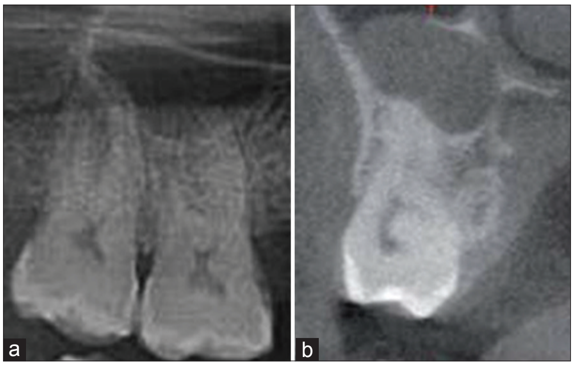

Figure 1: Apical cyst in orthopantomogram (a) and in cone-beam computerized tomography (b). Picture courtesy of Dr. Mohammed A. Alshehri

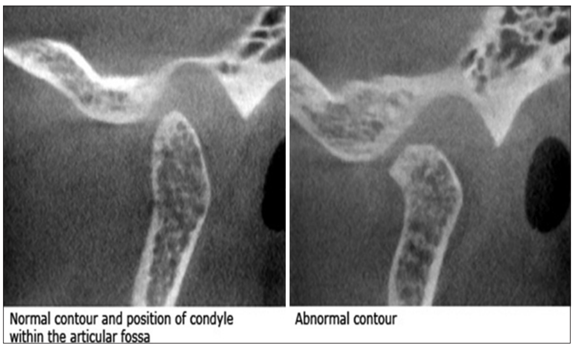

Figure 2: Cone-beam computerized tomography of normal and abnormal temporomandibular joint

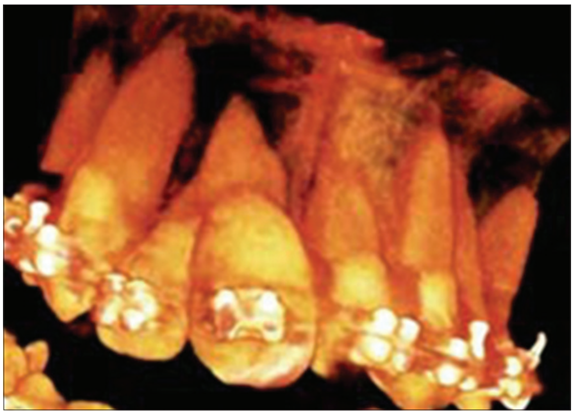

Figure 3: Cone-beam computerized tomography image to assess the bone density during treatment (Picture Courtesy of Dr. Mohammed A. Alshehri)

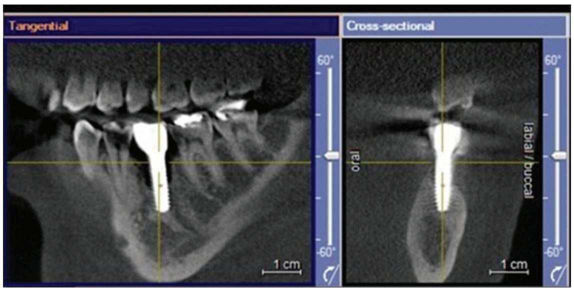

Figure 4: Cone-beam computerized tomography of implant placed in 36. (Courtesy: Omar Mohamed)

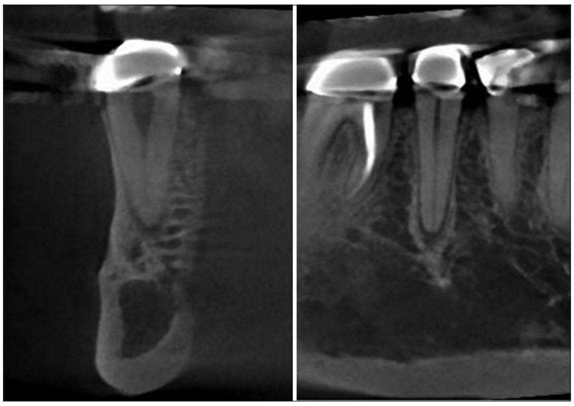

Figure 5: Periapical lesion shown as periapical radiograph (cone-beam computerized tomography)

Conventional CT scans are used routinely to assess bone dimensions, bone quality, and alveolar height. This has improved-more accurate and esthetic. They also used in clinical assessment of bone graft quality, alveolar surgery in patients with cleft lip and palate.[11] Condylar resorption occurs in 5–10% of patients who undergo orthognathic surgery. 3D CBCT is used to find how the condyle remodels and preliminary data of TMJ changes following distraction osteogenesis treatment and dentofacial orthopedics.[12] The quality of the images of TMJ with CBCT machines is comparable to conventional CTs, but the image taking is faster, less expensive, and provide less radiation exposure.

CBCT USED IN IMPLANTS

It is essential to check the angulations and positioning of the drills or implant fixtures through radiographs and clinical detection of a possible perforation in the osteotomy site. For pre-operative implants, CTs are preferred because cross-sectional views bring a clearer visualization of the anatomy of the surgical site. The major potential risks of encountering a lingual plate perforation are massive hemorrhage of submental and sublingual arteries.[5]

The mandibular canal and mental foramen involve the inferior alveolar artery and inferior alveolar nerve. The images of the accessory mental foramina and bony canal to the accessory mental foramen overlap in various trabecular bone patterns. It was reported that the presence of the bifid mandibular canal in the mandibular ramus region was observed more frequently with CBCT images, in 65% of patients compared with rotational panoramic radiographs, with a range from 0.08% to 0.95%.[13]

The nasopalatine canal is usually described as being located in the midline of the palate, posterior to the central maxillary incisors.[14] The funnel-shaped oral opening of the canal in the midline of the anterior palate is known as the incisive foramen and is usually located immediately below the incisive papilla. The canal divides into two canaliculi on its way to the nasal cavity and terminates at the nasal floor with an opening at either side of the septum.[15] The canal contains not only the nasopalatine nerve but also the terminal branch of the descending nasopalatine artery, as well as fibrous connective tissue, fat, and even small salivary glands. Contact of the implant with neural tissue may result in failure of osseointegration or lead to sensory dysfunction.[16]

CBCT USED IN ENDODONTICS

Radiographs are essential for the successful diagnosis of odontogenic and nonodontogenic pathoses, treatment of the pulp chamber and canals of the root of a compromised tooth through intracoronal access, biomechanical instrumentation, final canal obturation, and assessment of healing.[17] CBCT also demonstrated superiority to 2D radiographs in detecting fractured roots.

In cases with inflammatory root resorption, lesions are detected much easier in early stages with CBCT compared to conventional 2D X-ray. In other cases such as external root resorption, external cervical, and internal resorption not only the presence of resorption were detected but also the extent of it. Due to its accuracy, it is very helpful in detecting the pulpal extensions in talon cusps and the position of fractured instruments.

It is also a reliable tool for pre-surgical assessment of the proximity of the tooth to adjacent vital structures, size and extent of lesions, as well as the anatomy and morphology of roots with very accurate measurements.

In addition, in cases in which teeth are assessed after trauma and in emergency cases, its application can be a useful aid in reaching a proper diagnosis and treatment approach.[18]

ADVANTAGES OF CBCT

CBCT is well suited for imaging the craniofacial area. It provides clear images of highly contrasted structures and is extremely useful for evaluating bone.[9] Although limitations of CBCT currently exist in the use of this technology for soft-tissue imaging, many efforts are being directed towards the development of techniques and software algorithms which help to improve the signal-to-noise ratio and increase the contrast.

The use of CBCT technology in clinical practice provides a number of potential advantages for maxillofacial imaging compared with conventional CT.

X-ray Beam Limitation

It reduces the size of the irradiated area by collimation of the primary X-ray beam to the area of interest which minimizes the radiation dose.[19] Most CBCT units can be adjusted to scan small regions for specific diagnostic tasks. Others are capable of scanning the entire craniofacial complex when necessary.[10]

Image Accuracy

The data set comprises a 3D block of smaller cuboid structures which is known as voxels representing a specific degree of X-ray absorption. The size of these voxels determines the resolution of the image. In conventional CT, the voxels are anisotropic and rectangular cubes, whereas in CBCT, the voxels are isotropic.[20]

Rapid Scan Time

CBCT acquires all basis images in a single rotation, so the scan time is rapid and comparable with that of medical spiral MDCT systems. Although faster scanning time usually means fewer basis images from which to reconstruct the volumetric data set, motion artifacts due to subject movement are reduced.

Dose Reduction

Published reports indicate that the effective dose of radiation is significantly reduced by up to 98% compared with "conventional" fan-beam CT systems. This reduces the effective patient dose to approximately that of a film-based periapical survey of the dentition or 4–15 times that of a single panoramic radiograph. [21]

Display Modes which is Unique to Maxillofacial Imaging

Reconstruction of CBCT data is performed natively by a personal computer. The software can be made available to the user, not just the radiologist. This helps the clinician to use such as chairside image display, real-time analysis, and MPR modes that are task specific. Since the CBCT volumetric data set is isotropic, the entire volume can be reoriented so that the patient's anatomic features are realigned.[22]

Reduced Image Artifact

The level of image artifacts is much low with CBCT.

DISADVANTAGES OF CBCT

Poor Soft Tissue Contrast

The disadvantage is dynamic range of CBCT which is used for contrast resolution can reach only 14-bit maximally. To accurately read a soft tissue phenomenon, a 24-bit contrast resolution is needed.[23] Even though CBCT is not the best imaging modality to evaluate soft tissues, there are situations that CBCT can help, such as analysis of soft tissue airway constrictions and obstructions for patient suffering from sleep apnea and other soft tissue evaluation for orthodontic treatment. [24] In addition, unlike MDCT, the Hounsfield units of tissue density are not calibrated on CBCT, which makes it unreliable to compare tissue density based on CT numbers generated from different CBCT units.

Artifacts

Although great improvement has been made, streaking artifacts due to metal restorations and motion artifacts due to patient movement still exist on CBCT images. Manufacturers have developed their own specific filters to reduce these artifacts. However, there is not enough evidence to show if the post-processing algorithm affects the diagnostic value of the images. [25]

CONCLUSION

CBCT appears to have a promising future, and its utility in dentistry will depend on the results of studies that are currently underway.[26] The amount of existing literature from the past decade has been very encouraging for this imaging modality. Many questions have already been answered by virtue of these literatures documented.[6] If used judicially, its benefits would outweigh the inherent risks.[27] Finally, we should advocate more professional education and training on this emerging technology.

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