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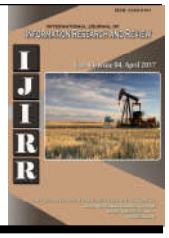

Research Article

CBCT A NOVEL IMAGING TECHNIQUE IN DENTISTRY – A RECENT UPDATE

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ABSTRACT

Cone beam computed tomography (CBCT) has gained its importance in the last few years and has been widely employed in dentomaxillofacial imaging. This technique provides relatively high isotropic spatial resolution of osseous structures with a reduced radiation dose compared with conventional CT scans. CBCT offers numerous advantages compared to traditional 2D radiography not just in terms of avoiding superimposition but also with its application in multiplanar reformation and face scan marking horizons in real time imaging. This article explores the possible applications of this novel CBCT technology and the ongoing research in the areas, with the goal of applying CBCT data in an evidence-based manner.

INTRODUCTION

Computed tomography (CT) gained its importance in surgical and medical practice since its introduction in 1973 by providing imaging in 3 dimensions. Practitioners at that time certainly marveled this new technology, however in dental practice; practitioners depended alm Miracle ost entirely on 2-dimensional plain films (Miracle, 2009). The establishment of Conebeam CT (CBCT) an advancement in CT imaging provided 3D images with potentially low-dose of radiation for visualizing bony structures in the head and neck. Cone beam CT (CBCT) was first developed focusing their interest primarily on applications in angiography. In 1998 Mozzo et al reported the first CBCT unit developed specifically for dental use, the NewTom 9000 (Quantitative Radiology, Verona, Italy) [2]. The soft-tissue resolution could be sacrificed in CBCT in favor of high temporal and spatial-resolution. The first CBCT system became commercially available for dentomaxillofacial imaging in 2001 (NewTom QR DVT 9000; Quantitative Radiology, Verona, Italy) (Miracle *et al.,* 2009; Hadi Mohammed Alamri, 2012). In 2003 Hashimoto et al reported that the 3DX CBCT produced better image quality with a much lower radiation dose than the newest multidetector row helical CT unit (1.19 mSv vs 458 mSv per examination) (Miracle, 2009).

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CBCT and Conventional CT offer similar advantages (in addition CT providing information about soft tissue); however image acquisition requires much higher levels of ionizing radiation and a longer scanning time. In addition, the larger size of conventional CT units makes them poor alternatives for dental office (Miracle, 2009; William, 2006). CBCT defers from "medical" CT scanners in a way that it uses low-energy fixed anode tube, similar to that used in dental panoramic x-ray machines, Secondly CBCT machines provides high isotropic spatial resolution acquired with a single gantry revolution. All of the CBCT scanners currently on the market use the same technology, with only slight differences. Then major difference is in the detector used, either an amorphous silicon flat-panel detector or a combination of an image intensifier and a charge-coupled device (CCD). CBCT offers numerous advantages compared to traditional 2D radiography, including a lack of superimposition, 1:1 measurements, the absence of geometric distortions and 3D display. It offers 3D representation of hard tissues with minimal soft tissue information with relatively low ionizing radiation (William, 2006). Limited contrast resolution, is a major drawback of this technology, several factors contribute to this limited contrast resolution, important factor being increased x-ray scatter in conebeam acquisition. Improvements in scatter subtraction methods continue to be the subject of research aimed at improving image quality in CBCT systems (Hadi Mohammed Alamri, 2012). Cone Beam Computed tomography (CBCT) for the maxillofacial region provides opportunities for dental practitioners to request

multiplanar imaging. CBCT allows the creation in "real time" of images not only in the axial plane but also 2-dimensional (2D) images in the coronal, sagittal and even oblique or curved image planes a process referred to as multiplanar reformation (MPR). In addition, CBCT data are amenable to reformation in a volume (Hadi Mohammed Alamri, 2012; Faisal and Quereshy). This article explores the possible applications of this advanced CBCT technology and the ongoing research in these areas, with the goal of applying CBCT data in an evidence-based manner. The article also highlights the versatile nature of the imaging modality by reviewing its application in various fields of dentistry.

Implantology

Assessment of sufficient crestal bone to the mandibular nerve and maxillary sinus, bucco-lingual dimensions, unanticipated undercuts further surgical planning is considered vital or otherwise is mandated during implant placement. Although clinical examination and traditional radiographs may be adequate for patients, these methods do not allow for precise measurements. For these concerns it is necessary to view the recipient site in a plane perpendicular to a curved plane through the arch of the maxilla or mandible in the region of the proposed implants, CBCT scan is thus recommended. Its use is considered ideal because of its ability to reconstruct a fully three dimensional model of the maxilla and mandible, which will help identify critical anatomic structures accurately for precise placement of dental implants avoiding complications (Faisal and Quereshy; Vandana Kumar, 2013). Practitioners have begun using office-based CBCT scanners in preoperative imaging for implant procedures, capitalizing on availability and low dosing requirements. Preliminary evidence addresses the ability of CBCT images to characterize mandibular and alveolar bone morphology, as well as to visualize the maxillary sinuses, incisive canal, mandibular canal and mental foramen all structures particularly important in surgical planning for dental implantation (Michael , 2014; Diniz *et al.,* 2008 and Frei *et al.,* 2004) have compared the success of implant planning comparing CBCT with spiral and conventional CT; they reported the superiority of CBCT over CT in terms of implant planning.

Craniofacial Fractures

CBCT through its ability to detect osseous structures clearly demarcates the fracture lines and fragments when compared with conventional images, thus it has been widely employed to evaluate craniofacial fractures, most importantly dento-alveolar and mid facial fractures (Gabriel, 2013). These fractures are frequently missed on a conventional CT, this can be attributed to a number of reasons most important being the slice thickness. CBCT on the other hand poses challenge to conventional CT in this aspect, as it picks up even a thin fracture line. It depicts precisely the position and orientation of displaced fragments reasonably. CBCT however cannot be considered in orbital floor fractures, although it can demonstrate orbital content herniation, it lacks the contrast resolution to differentiate the tissue composition of the herniated materials (Gabriel, 2013; Werner, 2009). John Wiley *et al.,* 2009 compared the imaging findings of CT and CBCT in airgun injuries, and these authors' preferred CBCT images as a result of less metallic artifacts providing superior information and diagnosis. CBCT has also been widely employed to evaluate fracture healing post surgery as the modality holds better image reconstruction with minimal dose and cost (Werner, 2009).

Orthodontics

CBCT has been well utilized in the field of orthodontics and its role in this field ranges from Assessment of growth, skeletal and dental structures, impacted teeth, pharyngeal airway and pathologies. Applications of CBCT includes Orthognathic surgical planning, planning for placement of temporary anchorage devices, accurate estimation of the space requirement for unerupted/impacted teeth, fabrication of custom orthodontic appliances (Genevive, 2015). Vizzotto *et al,* 2012, stated that axial cuts of 3D CBCT scans through projection of shaded areas, provide soft tissue points compared with conventional radiographs, thereby enhancing airway assessment. Further CBCT use has also been mandated in assessing treatment progress and outcome in dentofacial orthopedics, assessment of orthodontics-induced root resorption and periodontal tissues (Vizzotto *et al.,* 2012). Orthodontic surgical superimposition is a new advancement adding a boon to this technology. It facilitates the operator to superimpose a custom surface mesh of the first CBCT image onto a second CBCT image. Thus enabling comparison pre and post operatively. The application of CBCT for pharyngeal airway analysis and obstructive sleep aponea has showed significant statistical values in its trial. Ogawa et al 2007, concluded in his study that the Three-dimensional CBCT-assisted airway analysis facilitates the diagnosis and treatment planning of complex anomalies including enlarged adenoids and obstructive sleep apnea (Genevive, 2015; Vizzotto *et al.,* 2012).

Temporomandibular Joint

In a relatively short period of time, CBCT has emerged as a cost- and dose-effective alternative to CT for examination of the TMJ. The imaging modality is superior to conventional radiographic methods, as well as MRI, in the assessment of osseous TMJ abnormalities. CBCT has the ability to define the true position of the condyle within the fossa. However, it should be emphasized that the diagnostic information obtained is limited to the morphology of the osseous joint components, cortical bone integrity and subcortical osseous abnormalities. Pathologic processes such as degenerative changes and ankylosis, joint remodeling after diskectomy, malocclusion, congenital and developmental malformations can be diagnosed and evaluated by the modality precisely (Larheim, 2015). Several cadaveric series have explored the use of TMJ - CBCT to assess periarticular bony defects, flattenings, osteophytes, and sclerotic changes. Although early results are promising, more research is needed, to mandate CBCT as an imaging modality to assess the TMJ. ML dos Anjos Pontual *et al.,* 2012, SaraswathiGopal *et al.,* 2016, evaluated bone changes and range of motion of the temporomandibular joint using CBCT. They have concluded their research highlighting the efficacy of CBCT in picking up even minor bony changes, further the application of TMJ viewer enabled better assessment of the joint (Dos Anjos Pontual, 2012; SaraswathiGopal, 2016). Thus the images offered by current CBCT machines have been shown to provide a complete radiographic evaluation of the

bony components of the TMJ. The resulting images are of high diagnostic quality. Given the significantly reduced radiation dose and cost compared with conventional CT.

Maxillofacial surgery

The relationship of impacted third molars to the mandibular canal, adjacent teeth, sinus walls, and cortical borders are important diagnostic information that can directly impact the outcome of surgery. Using CBCT to locate and evaluate impacted cuspids and supernumerary teeth, seems to make the surgical procedure more efficient and less invasive (Danforth, 2003). CBCT for patients with cleft lip and palate is useful for both preoperative and therapeutic evaluations. The real-time creation of images in several planes and parasagittal sections through the imaging volume has broad applications in the assessment of cleft palate cases. Three-dimensional reconstructions of images in association with 3D navigation systems allow preoperative evaluations of the cleft palate regarding the volume of the bone defect, the location of the bone defect, the presence of supernumerary teeth, and an appraisal of permanent teeth and alveolar bone morphology. In a study by Albuquerque *et al.,* (2011), CBCT was found to be equivalent to multi-slice CT in both the volumetric assessment of bone defects in alveolar and palatal regions and in establishing donor area and the volume of the bone graft to be used in the rehabilitation of cleft patients (Walker *et al.,* 2005). Owing to the higher resolution, lower radiation dose, and lower cost in imaging the maxillofacial region, it stands to reason that CBCT can easily replace conventional CT in this regard. Three dimensional imaging of cysts and tumors of the maxillofacial region provides the surgeon vital information which is necessary for planning surgeries; with volumetric analysis this can help anticipate the need for volume of a potential graft for reconstruction. CBCT data also can be useful in creating a stereolithic model of the area of interest (Danforth *et al.,* 2013; Walker *et al.,* 2005).

Forensic odontology

The radiographs of cranium, long bones and teeth have been mostly used for forensic identification. Among them, skull radiographs are better considered particularly because of the presence of diverse geometrical contours which allow a precise superimposition into an identity (Moazzam Jawaid, 2014). With the advent of cone beam computed tomography - the number of image requests by forensic professionals has increased, making possible the use of this technique to support human identification by comparing images of significant anatomical structures of the cranium. The identification of age in anthropology and forensic medicine is sometimes difficult, but nonetheless important. The most widely used methods include assessement of tooth linear, angular, volume measurement and cervical vertebra morphology. Cone beam Computed tomography (CBCT) is the ideal and most accurate method for this purpose (Moazzam Jawaid, 2014; Yang *et al.,* 2006). For the purpose of sex determination six measurements are commonly used which include ramus length and breath, gonion-gnathion length, gonial angle, bigonial breadth and bicondylar breadth. SaraswathiGopal *et al.,* 2016, Tejashree et al 2016, have determined the sexual dimorphism using these landmarks in the ramus of the mandible and have reported significant values (SaraswathiGopal, 2016; Tejashree Bhagwatkar, 2016). CBCT imaging can provide the much-needed 3-D perspective in certain cases that require more information than can be obtained from traditional methods. CBCT in future will prove to be a great tool for forensic dentistry (Yang *et al.,* 2006).

Endodontics

CBCT has been employed in the field of endodontics for the purpose of evaluating periradicular, periapical pathology and dentoalveolar trauma. High-resolution imaging modality that continues to be of value in endodontic therapy demonstrating valuable 3D images for better understanding of spatial relationships that facilitates diagnosis and influences treatment (William , 2009; Donald *et al.,* 2008). With the advent and application of CBCT in this field, 3D images of even a single tooth has been made possible, the application offers diverse advantages in this aspect ranging from cost effectiveness to increased contrast resolution. The success of an endodontic therapy highly depends on identifying and obturating all the root canals accurately. With CBCT the delineation of the root canals along with its morphology has been possible. Thus increasing the success rate highly in this aspect. The diagnostic properties of CBCT at the root apices and periradicular region have been reported in several studies. CBCT has been suggested as superior to periapical radiographs in the characterization of periapical lucent lesions, reliably demonstrating lesion proximity to the maxillary sinus, sinus membrane involvement, and lesion location relative to the mandibular canal (Donald *et al.,* 2008). The usefulness of CBCT imaging can no longer be disputed CBCT is a useful task specific imaging modality and an important technology in comprehensive endodontic evaluation.

Paranasal sinuses

CBCT of the paranasal sinuses enables assessment of opacification and osseous details, it produces images that are adequate for screening purposes. Though eye lens dose in CBCT machine is lower than that encountered with our current multi detector CT machine clinical protocol, soft tissue assessment remains suboptimal with CBCT imaging, particularly when compared with Multi Detector CT and therefore leads to diagnostic uncertainty (Pl Kei, 2013). Saraswathi et al 2016, studied in detail the occurrence of abnormalities and anatomical variations in maxillary sinus using CBCT, assessing a sample of 100 patients they have concluded on the efficient role of CBCT in detecting these anatomical variations (SaraswathiGopal, 2016). Further a similar study conducted on frontal sinus and nasal septum patterns were attributed to forensic importance in personnel identification (SaraswathiGopal, 2016).

Limitations

In almost all aspects of CBCT imaging, from utilization to application, inherent limitations and pitfalls exist. Limited contrast resolution is considered one major disadvantage of CBCT, this mainly can be attributed to high scatter radiation during image acquisition and inherent flat panel detector related artifacts. Gutierez *et al.,* 2005, formulated a strategy to qualify the performance of radiographic monitors, they have argued with evidence that the usual desktop computer display

is not adequate for accurate diagnostic radiology (Gutierez *et al.,* 2005). CBCT is often being referred for an in office setup, with the above mentioned literature the ability of CBCT at an in office bases has to be justified. CBCT is not sufficient for soft tissue evaluation however if the objective is to only examine the hard tissues, CBCT would be ideal. Manufactures have limited the streaking and motion artifacts in current CBCT units; however, they are not completely avoided and can be achieved with more efforts to develop filters to resolve this problem. On the other hand application of these filters is still unclear whether the reconstruction of images will reduce the image quality or quantity (Know Shawn Adibi, 2012). More studies are needed in this area to provide a definitive answer.

Conclusion

CBCT an advanced form of CT technology has emerged to outstand its pioneer; the 3D imaging modality has potential applications in the head and neck as well as dentomaxillofacial regions, imaging high-contrast structures with superiority in detecting osseous changes. Multiple researchers have substantiated with evidence its ability to capture high-spatial-resolution images with comparatively low patient dose. The future researches in CBCT have aimed to produce hallmark in field of paranasal sinuses, middle and inner ear implant, and dentomaxillofacial imaging. Thus the article portraits not just the positive aspects of CBCT but also mentions the limitations of the imaging modality thus encouraging future research on the same.

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