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Use of cone beam computed tomography in dentistry

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Abstract
Cone Beam Computed Tomography (CBCT) have identified the importance of providing outcomes related to the appropriate use of this innovative technology in dentistry. The purpose of this article is to review the practical applications of CBCT in different dental disciplines, in order to update the general dental practitioners on the current status of this new imaging technology, and aid in their clinical decision-making process related to this imaging modality.

Keywords: Oral radiology; Dental radiology; Cone Beam Computed Tomography (CBCT);

Introduction

- Clinical reports revealed that CBCT is superior to multidetector CT (MDCT) in reducing the level of metal artifact, especially in secondary reconstructions to view maxillary and mandibular dentitions. Many CBCT units have options for selection of different field of view, which minimize tissue irradiation by exposing only the specific area of interest.
- Scan time for CBCT is approximately a minute or less. This allows for a quick collection of data from the patient thus reduces the possibility of motion artifacts. The compact size and affordability have allowed CBCT to be suitable for the dental office setting. Moreover, CBCT images can be reconstructed into many formats that an oral care provider is familiar with.

Disadvantages of CBCT

- The dynamic range of CBCT for contrast resolution can only reach 14-bit maximally. To accurately read a soft tissue phenomenon, a 24-bit contrast resolution is needed. 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 air way constrictions and obstructions for patient suffering from sleep apnea, and other soft tissue evaluation for orthodontic treatment [10].
- 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. 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 [7].

According to a study conducted by Ludlow *et al*. [11], the risk of fatal cancers per million exams of full month series with F speed film and round collimation is 9, for panoramic radiograph with CCD detector is 0-1.3, and for large field CBCT is 4-59. Some CBCT systems have a similar fatal cancer risk as MDCT. Potential benefits of using CBCT in dentistry to assess and diagnose pathologies and to develop treatment planning are undisputed. However, due to the additional radiation exposure necessary to achieve the desired results, justification of increased benefit in diagnostic value should be provided. In a study of the effective radiation dose of the ProMax 3D CBCT scanner (Planmeca Oy, Helsinki, Finland) using different dental protocols, Xing-min Qu *et al*. [12, 13], have concluded that choice of patient size, field of view, region of interest, and resolution may affect patient dose by an order of magnitude.

Oral and Maxillofacial Pathology and Surgery

Examination of fractured teeth and bone seem to be a logical application of CBCT. Evaluation of post-surgical complications such as losing screws or broken mandibular fracture fixation can be achieved with CBCT due to the low level metal artifact[1].

CBCT is recommended when there is a need for diagnosis of a cyst, tumor or infections in alveolar process and jaw bone [14]. Many unusual and rare calcifying lesions such as Calcifying Cystic Odontogenic Tumor (CCOT) can be examined in CBCT images for their particular variations. CBCT is very useful for evaluation of intra-osseous lesions that are in close proximity to vital organs and vasculature in the head and neck region. Although the reliability of CBCT to detect the invasion or erosion of oral malignancy such as Oral Squamous Cell Carcinoma (OSCC) is still under investigation, study has suggested that combination of Dynamic Contrast Enhanced (DCE)-Magnetic Resonance Image (MRI) and CBCT may be a useful tool to delineate tumor boundary and develop appropriate surgical intervention [15]. It would be safe to say that the application of CBCT for craniofacial pathology and surgery is in its infancy stage. Much more evidenced-based studies are needed to validate the role of CBCT in oral and maxillofacial pathology and surgery.

Temporomandibular Joint

Huntjens *et al*. [16]. demonstrates that condylar shape and volume can be measured accurately using CBCT-based method, knowing that there are distortions and errors in conventional radiograph. Balasundaram and colleagues demonstrate that CBCT is able to diagnose maxillofacial anomalies such as synovial chondromatosis of the TMJ at a reasonably low dosage. The advancement of CBCT technology has inspired many researches in TMJ imaging. CBCT is not ideal for evaluation of cartilage and soft tissue of TMJ, because it has limited contract resolution and cannot distinguish soft tissue densities, where MRI may be the method of choice. However, when examining the hard tissues of the TMJ, such as articular eminence and condylar head, CBCT can provide invaluable information for diagnosis and treatment planning of TMJ diseases.

Orthodontics

Using CBCT 3D hard and soft tissue segmentation along with photographic superimposition, orthodontists and other related specialists are able to simulate virtual patient and interact directly with the disease model, which improves the therapeutic outcomes in many clinical sceneries [17]. The applications of CBCT in orthodontics include assessment of palatal bone thickness, skeletal growth pattern, severity of tooth impaction, and upper airway evaluation for possible obstructions [18]. CBCT is helpful in treatment planning of orthodontic cases which need buccal tooth movement and arch expansion. Although CBCT has become more popular in orthodontics, further studies are needed to determine if it should be routinely ordered for orthodontic cases, especially because majority of the patients are young and the radiation dose associated with CBCT is much higher than the traditional plain film radiograph.

Periodontics

CBCT has been used in the evaluation of intrabony defects and furcation involvements. It helps to select absorbable membrane with the optimal shape to fit into interproximal bony defects, and shorten the time required for the guided tissue regeneration [19].

Endodontics

CBCT has been suggested as superior to periapical radiographs when the radiolucent lesion is in close proximity to the maxillary sinus and/or the sinus membrane is involved, or when the lesion is in close proximity to the mandibular canal. For more complicated cases, the input from CBCT images is very essential and valuable, such as periapical pathology due to failed root canal therapy, dentoalveolar trauma, and pre-surgical planning. CBCT is a precise imaging modality to measure the length and width of root canal [20, 21]. prevent iatrogenic exposure of the apex, and improves prognosis of root canal therapy. CBCT also plays an important role in early diagnosis of perforated defects due to internal root desorption which need nonsurgical endodontic management and long term follow up.

Implantology

Traditional 2D radiograph will provide adequate information about purposed implant sites in many clinical circumstances Dental imaging is an important tool for accurate treatment planning of a dental implant. However, limited size, image distortion, uneven magnification, and a 2D view restrict their use in many other cases. The ability of CBCT to produce cross-sectional images at reasonably low radiation exposure and cost makes it invaluable in coordination with a multidisciplinary implant treatment team [22]. Information important for implant planning, such as morphology and volume of alveolar bone, location and size of maxillary sinuses, incisive canal, mandibular canal, and mental foramina, can be easily assessed on CBCT images, which contributes to precise treatment planning and relatively low risks for surgical complications. In a study published by Georgescu *et al*. in 2010, CBCT was evaluated as a method of quantitative and qualitative analysis of the alveolar crest in the anterior mandible. It was concluded that CBCT provides the clinicians all the necessary information when planning dental implants. Therefore, this anatomical feature can be a contributory factor to an inadvertent perforation of the lingual cortical plate or injuries to the terminal branch of the sublingual artery during implant fixture placement, if a cross-sectional image is not obtained pre-surgically. In another study on immediate implant placement in the posterior mandible, it suggests that a CBCT scan [23] should be taken prior to tooth extraction, in order to evaluate all treatment options available, and try to avoid potential complications while fully informing the patient of the risks of each option. When various imaging modalities for implant site assessment were compared, CBCT exceeded all others, with only the category of bone quality was inferior to MDCT. It was concluded that CBCT provides the anatomical information that help generate a collaborative treatment plan and achieve an optimal outcome for radiologist, surgeon, restorative dentist, and patient [24].

Ethical and legal

CBCT allows the clinician to have an accurate 3D image of the teeth and areas of interest that aids their diagnosis and treatment planning. However, although CBCT is a useful tool in the clinician's armamentarium, it is essential that they are used when conventional means of radiograph is unlikely

to provide the needed information [25].

Ethical and legal considerations on CBCT instruments do not differ from other technological trends such as laser and robotic surgery. Additionally, oral health professionals must embark on extensive training to meet the challenge of the emerging imaging technology in dentistry. Clinicians have legal responsibility to read the entire volume of images, and if they do not have adequate training and experience, they should refer to a qualified oral & maxillofacial radiologist.

Conclusion

CBCT appears to have a promising future, and its utility in dentistry will depend on the results of studies that are currently underway. 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. Review of recent publications reveals that CBCT is here to stay and play an integral role in diagnosis and treatment planning for many dental disciplines. Additionally, at this point, we conclude that if used judicially, its benefits would outweigh the inherent risks. Finally, we should advocate more professional education and training on this emerging technology. Meanwhile, nothing should keep clinicians from continuing sound practices with appropriate aid of this extraordinary imaging technology.

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