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Cone Beam Computed Tomography in Endodontics

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Abstract: *Radiographic imaging is essential in diagnosis, treatment planning and follow-up in endodontics. The applications of cone beam computed tomography (CBCT) in endodontics has been widely reported in the literature.It provides high-quality, accurate three- dimensional (3D) representations of the osseous elements of the maxillofacial skeleton. The purpose of this article is to discuss the features, advantages and limitations of using CBCT in endodontics.*
Keywords: *CBCT, cone beam computed tomography, diagnosis,periapical radiograph, root canal treatment.*

I. Introduction

Diagnostic imaging helps the clinician to visualize the dental anatomy in areas that cannot be seen clinically. Radiography is essential to successful diagnosis of odonto- genic and nonodontogenicpathoses, treatment of the pulp chamber and canals of the root of a compromised tooth. Imaging serves at all stages in endodontics like preoperative intraoperative and postoperative assessment [1].

For years, periapical radiographs have been used as an adjunct to help endodontists diagnose pathology and aid the clinician in developing a treatment strategy.

Recently a new imaging modality, cone-beam computed tomography (CBCT), has been introduced in the market and has been found to be useful in a number of applications.

II. Limitations of periapical radiograph

Despite their long history and widespread use, periapical radiography yields limited information for a number of reasons. They compress three-dimensional anatomy, create geometric distortion and anatomical noise, and are ultimately limited by the fact that information is rendered in only two dimensions. Interpreting radiographs is also difficult when roots of teeth overlap and anatomical structures are present. Dental materials such as crowns, posts, and filling materials may also add additional difficulty in interpreting the radiograph [2].

Goldman et al. (3) showed that in evaluating healing of periapical lesions using 2D periapical radiographs there was only 47% agreement between six examiners. Goldman et al. (4) also reported that when those same examiners evaluated the same films at two different times, they only had 19%–80% agreement between the two evaluations.

III. Cone-Beam computed tomography (CBCT)

CBCT is accomplished by using a rotating gantry to which an X- ray source and detector are fixed. A divergent pyramidal- or cone-shaped source of ionizing radiation is directed through the middle of the area of interest onto an area X-ray detector on the opposite side of the patient. The X-ray source and detector rotate around a fixed fulcrum within the region of interest (ROI). During the exposure sequence hundreds of planar projection images are acquired of the field of view (FOV) in an arc of at least 180◦. In this single rotation, CBCT provides precise, essentially immediate and accurate 3D radiographicimages.As CBCT exposure incorporates the entire FOV, only one rotational sequence of the gantry is necessary to acquire enough data for image reconstruction. CBCT is a complementary modality for specific applica- tions rather than a replacement for 2D imaging modalities (5-9).

CBCT's utilize a smaller, limited field of view along with a high spatial resolution in all planes (10,11,12). They can be classified into two categories based on the machines field of scan or field of view (FOV). A limited CBCT is more often utilized for endodontic purposes while a full CBCT is more suited for ortho or facial scans. The FOV of limited CBCT ranges from 40-100 mm, while the FOV of full CBCT ranges from 100-200mm (13).

IV. Patient Selection Criteria

CBCT must not be used routinely for endodontic diagnosis or for screening purposes in the absence of clinical signs and symptoms. The patient's history and clinical examina- tion must justify the use of CBCT by demonstrating that the benefits to the patient outweigh the potential risks.

V. Limitations of CBCT in Endodontics

Despite the provi- sion of the third dimension, the spatial resolution of CBCT images (0.4mm to 0.076mm or equivalent to 1.25 to 6.5 line pairs permm−1[lp.mm−1]) is inferior to conventional film-based (approx. 20lp.mm−1) or digital (ranging from 8–20lp.mm−1) intraoral radiography[14]. Maxillofacial CBCT images presently lack the ability to record subtle changes in attenuation across a wide range of tissue radiodensities. In endodontics, contrast resolution might well be of importance in distinguishing the nature of periapical or sinus soft tissue contents. Three factors, inherent in the CBCT acquisition process, presently limit contrast resolution: (1) scattered radiation contributing to the potential for increased noise, (2) CBCT systems pronounced “heel effect” due to the divergence of the X- ray beam over the area detector producing nonuniformity of the incident X-ray beam, and (3) detector imperfections affecting linearity in response to x-radiation. These factors, and a desire to restrict dose, contribute to restricting the application of current maxillofacial CBCT imaging to the assessment of osseous structures. Work continues to develop systems capable of a wide contrast range supporting both hard tissue and soft tissue applications while still limiting dose.

CBCT images, like those from other diagnostic modali- ties,aresusceptibletoartifactsthataffectimagefidelity.Arti- facts can be attributed to four sources [15]: (1) the patient; (2) the scanner; (3) artifacts specific to the CBCT system used including partial volume averaging, undersampling, andtheconebeameffect;and(4)X-raybeam artefacts arising from the inherent polychromatic nature of the projection X- ray beam that results in what is known as beam hardening.

Beam hardening results in two types of artifact: (1) distortion of metallic structures due to differential absorption, known as a cupping artifact; and (2) streaks and dark bands that can appear between two dense objects. The presence of dental restorations, including apically positioned retrograde restorations,in the FOV can lead to severe streaking artifacts. As the CBCT X-ray beam is heterochromatic and has lower mean kVp energy compared toconventional CT,suchartifact can be pronounced in CBCT images.

VI. CBCT Applications in Endodontics

1)Assessment of Tooth Morphology

The success of endodontic treat- ment depends on the identification of all root canals so that they can be accessed, cleaned, shaped, and obturated [16]. Unidentified and untreated root canals may be identified using axial slices, which may not be readily identifiable with periapical radiographs [13,17]. The ef- ficacy of CBCT as a modality to accurately identify the presence of second mesiobuccal canals in maxillary first and second molars has been evaluated[18]. The CBCT images accurately identified the presence or absence of the MB2 canal in 78.95% of samples. Statistical analysis showed that there was no significant difference in the ability of CBCT scan- ning to detect the MB2 canal when compared with the gold standard of clinical sectioning.

2)Diagnosis of Apical Periodontitis

CBCT enables the detection of radiolucent findings before they are visualized on con- ventional radiographs [19-24]. Lesions in the cortical bone can only be detected radiographically when there is perforation of the bone cortex, erosion from the inner surface of the bone cortex, or extensive erosion or defects on the outer surface. It is known that periapical lesions in cancellous bone cannot be detected radiographically[25]. CBCT, however, can reveal bone defects of the cancellous bone and cortical bone separately. The prevalence of apical periodontitis was found to be significantly higher when using CBCT, in com- parison with periapicalradiographs[20].

3)Diagnosis of root fracture

The prevalence of VRF has been reported to range from 10.9% [26] to 12.9% [27], with highest incidence occurring in an age group of 40–60 years [28]. CBCT has found particular application for the diagnosis of root fractures. Hassan et al.[29] compared the accuracy of 4 observers in detecting ex vivo vertical root fractures (VRFs) on CBCT and periapical images and assessed the influence of root canal filling on fracture visibility. They found an overall higher accuracy for CBCT (0.86) scans than periapical radiographs (0.66) for detecting VRF which was slightly reduced by the presence of opaque obturation material.

4)Diagnosis of root resorption

CBCT has been implicated as a reliable and valid method of detecting external inflammatory root resorption and performs significantly better than intraoral PA radiography [30]. Conventional radiographs don’t provide a true and full representation of the lesion, especially in the buccal-lingual direction. They are unable to identify the true extent, location or the portal of entry of a resorptive lesion [13]. Internal root resorption (IRR) within the root canal itself is rare, usually asymptomatic, slowly progressing, and presents as a serendipitous finding on intraoral radiographic examination. It is very common that internal and external inflammatory root resorption are confused and misdiagnosed. Still, accurate assessment is essential as these conditions represent totally different pathological processes, with different etiological factors and treatment protocols. Diagnosis using conventional radiogra- phy is difficult; however, unlike external resorption, which presents with irregular radiolucency and intact root canal, internal resorption has clearly defined borders with no canal radiographically visible in the defect [31]. CBCT has been used successfully to confirm thepresence of IRR and differentiate it from ERR [32].

5)Pre-surgical Assessment

CBCT play an important role in planning for periapical microsurgery on the palatal roots of maxillary first molars [33]. The distance between the cortical plate and the palatal root apex could be measured, and the presence or absence of the maxillary sinus between the roots could be assessed. By selecting relevant views and slices of data, the thickness of the cortical plate, the cancellous bone pattern, fenestrations, as well as the inclination of the roots of teeth planned for surgery, can be accurately determined preop- eratively[34].

VII. Conclusion

Conventional intraoral radiography provides clinicians with cost-effective, high-resolu- tion imaging that continues to be the front-line method for dental imaging. However, it is clear that there are many specific situations where the 3-D images produced by CBCT facilitates diagnosis and influences treatment. The usefulness of the CBCT cannot be disputed. It is a valuable task-specific imaging modality, producing minimal radiation exposure to the patient and providing maximal information to the clinician**.**

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