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Cone Beam Computed Tomography as a Diagnostic Tool in Endodontics- A Review of the Literature

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Abstract

Cone-beam computed tomography is a three-dimensional imaging method that offers the possibility to view an individual tooth or teeth at any view and overcomes many of the limitations of conventional radiographs. A review of the literature has been conducted in order to summarize the main criteria for the use of cone-beam computed tomography in the field of endodontics. Three-dimensional imaging is proven to ensure more accurate diagnosis and therefore improved management of complex endodontic cases and so to rapidly influence the assessment of complex root canal anatomy, periapical periodontitis, root resorption, dental traumas and root fractures. Cone-beam computed tomography can be a powerful tool in endodontic treatment planning, assessing the outcome of the root canal treatment and follow-ups. That is the reason for the rapid increase of the use of cone beam computed tomography in the field of endodontics worldwide.

Keywords: Cone-Beam Computed Tomography; Radiography; Endodontic Treatment; Diagnostic Images; Endodontic Complications

Abbreviations: CBCT: Cone beam computed tomography; 3D: Three dimensional; 2D: Two dimensional

Introduction

Conventional radiology is the fundamental tool of endodontic practice and needed for the successful management of every endodontic case [1]. Radiography is essential to successful diagnosis of odontogenic and nonodontogenic pathoses, preoperative, intraoperative and postoperative assessment of endodontic cases [2]. Conventional radiographic techniques, regardless of whether they are film based or digital, have some limitations. These include the two-dimensional nature of the produced images [3]. The image produced is a 2D representation of a 3D object. Intraoral radiography requires an optimized geometric configuration of the X-ray generator, the tooth and the sensor to provide an accurate projection of the tooth. If any component of the imaging chain is compromised, the resulting image may demonstrate exposure of geometric errors [2]. Most of the limitations, associated with conventional radiography, are overcome with CBCT. CBCT is an extra-oral imaging system, designed for 3D imaging of the oral and maxillofacial structures [4]. The 3D nature of the produced images allows visualization of additional root canals, earlier detection of periapical lesions, resorptive deffects, and help identifying the anatomical relations of the root apices to important neighbouring structures. The aim of this literature review is to systemize the main criteria for the use of CBCT in the field of endodontics. Despite its numerous advantages CBCT has also some limitations that need to be taken into consideration. The ALARA principle for the ionizing radiation ("as low as reasonably achievable ") has to be considered in all cases, and the benefits of the CBCT scan must overweight the potential risks [3].

Results and Discussion

Assessment of the Tooth Morphology and Root Canal System Anatomy

The success of endodontic treatment depends on the possibility to identificate all of the root canals so that they can be later accessed, cleaned, shaped and obturated. Anatomical variations exist with each type of tooth. The two-dimensional nature of radiographs means that they do not always reveal the actual number of canals present in teeth [5,6]. This may potentially lead to the inabbility to identify all the root canals present and can therefore lead to a poorer outcome of the root canal treatment [7]. The prevalence of a second mesio-buccal root canal (MB2) in maxillary first molars has been reported to vary from 69% to 93% depending on the study method. This variability occurs in the bucco-lingual plane where superimposition of anatomic structures impedes detection of small structural density changes [8]. Conventional radiographic techniques can only detect up to 55% of these configurations [8]. Ramamurthy et al. [9] found that the evaluation of two-dimensional film modalities can rarely lead to a detection of more than 50% presence of MB2 canals. Matherne et al. [10] found that on average at least one root canal in 40% of the teeth included in their experiment was not found when evaluating intraoral radiographs. CBCT evaluation identified an average of 3,58 root canals per maxillary molar, 1,21 per mandibular premolar and 1,5 per mandibular incisor. Evaluation of different plates, used for 2D-radiographs, demonstrated an average number of 1-1,3 root canals per mandibular incisor, 1-1,1 per mandibular premolar and 3-3,1 per maxillary molar.

Baratto Filho et al. [11] investigated ex vivo the root canal system anatomy of extracted maxillary first molars by comparing detection rates obtained using an operating microscope and CBCT. They concluded that CBCT provided a good method for the initial evaluation of maxillary first molar's root canal system but that the use of operating microscope was optimal. CBCT imaging has also been reported to help identifying anomalies of the root canal system of mandibular premolars [12] and assist in the determination of root curvatures [13]. Estrela et al. [13] in their study used CBCT to determine the radius of curvature of root canals. The authors concluded that CBCT is reliable tool to assess the severity of the radius of curvature of root canals. This information is important to minimize the risk of instrument fracture and creating of perforations in the root canal wall. Prior knowledge of the number of root canals and their location not only results in predictable identification of all the root canal entrances but can also lead to minimizing the size of the access cavity [5, 14]. CBCT can help in identifying an additional distal root canal of mandibular molars and "C"-shaped configuration. It has been shown that CBCT reports 33% presence of a second distal root canal of mandibular molars, compared to conventional radiography - 21% [13,15].

Detection of Periapical Pathosis

Apical periodontitis is a disease, associated with infection of the root canal system. Currently, the accepted reference standard for the detection of periapical lesions is periapical radiography. But in the early stages of apical periodontitis, periapical bone destruction may be minimal or can be masked by adjacent anatomy. So, its presence in not always manifested on conventional radiographs [16-18]. CBCT allows periapical radiolucencies to be detected before they would be apparent on conventional radiographs [19,20]. Abella et al. [21] investigated the ability of periapical radiographs and CBCT to detect periapical lesions of 307 paired roots. Radiographs were positive about the presence of periapical lesions in 3% of the roots, while CBCT – in 14%. Cheng et al. [22] investigated in a similar study tooth with already obturated root canals and reported the higher percentage of detected periapical lesions to be on CBCT images. Lofhag-Hansen et al. [23] published the results of a study where 38% more periapical lesions were detected with CBCT than with conventional radiographs. Similar results are conducted by other studies, as well [24-26].

CBCT imaging is also a reliable method for exact measuring the volume of artificially created bone defects, giving a reference standard and providing a tool for monitoring the healing rate of apical periodontitis [27]. Stavropoulus and Wenzel [28] found CBCT to be twice as sensitive as radiography for detection of artificially created periapical lesions of different sizes in pig mandibles. CBCT may help revealing the presence of undiagnosed periapical lesion, especially in cases when patients have poorly localized symptoms and clinical and radiographic examination show no evidence of existing lesions [29]. Another indication of CBCT is to confirm the absence of an odontogenic lesion as an aetiology of pain [30]. Estrela et al. [31] proposed a new periapical index (CBCT-periapical index) for the identification of periapical lesion. CBCT was also proven useful in 1-year post treatment follow-ups by evaluating the existence of periapical radiolusency, which was undiagnosed by periapical radiography [32].

Detection of Root Fractures

Root fractures are often challenging to diagnose. Vertical root fractures manifest with nonspecific clinical features such as localized deep periodontal pocket, sinus tract or lateral radiolucency. All these unspecific symptoms can make the diagnosis very complicated when using only 2D radiographs [33]. The ability of CBCT to detect root fracture lines has been investigated by numerous studies and researches. In cases with simulated root fractures it has been suggested that the higher accuracy of CBCT could be due to the wide gaps between the two fragments and some of the fracture lines could also be detected with 2D radiographs [34]. Nevertheless, ex vivo studies do not take into consideration slight patient movements during the 10-20 sec CBCT scan that could have a negative outcome on the image producing [35]. Wang et al. [36] and Edlund et al. [37] in their clinical studies proved the higher sensitivity of CBCT scans in diagnosing vertical root fractures. These results should also be taken with caution, because the observer's initial diagnose is usually influenced by an alveolar bone loss in the investigated area. CBCT cannot be recommended for the diagnosis of vertical root fractures. But a 3D image may reveal signs of bone loss associated with an undetected vertical fracture line and so could rapidly influence the diagnosis and treatment options.

Assessment of Dentoalveolar Trauma

Dentoalveolar traumas are often challenging with regard to their diagnosis and treatment plan. Radiographic assessment is essential for diagnosis and establishing a differential diagnosis of dentoalveolar traumas [38]. The absence of radiographis sighns when the x-ray beam is not parallel to the plane of the root or alveolar bone fracture line or tooth displacement can limit the diagnostic potential of intra-oral radiographs [39]. Periapical radiography provides poor diagnostic value in the detection of minimal tooth displacement and alveolar fractures mostly because of the projection geometry, the superimposition of anatomic structures and processing errors. CBCT is considered the imaging system of choice for the evaluation of facial traumas, identification and direct localization of fractures and their complications and degree and direction of luxations [39,40]. CBCT has been suggested as an

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adjunct imaging tool when the true nature and position of dental traumas cannot be surely diagnosed from a clinical examination and conventional radiographic images [39,41]. A significant risk exists of a possible misdiagnosing of root fracture line's position in anterior teeth when using intra-oral radiography because of the possibility of oblique direction of the fracture line in the sagittal plane [41]. Barnstein et al. [25] highlighted on the significant difference in the nature of horizontal root fractures when assessed with conventional radiography and CBCT. The 3D images reveal a considerable amount of information about the nature of dento-alveolar traumas, which can influence the diagnosis, prognosis and treatment planning and therefore may improve the treatment outcome. When the diagnosis from clinical examination and radiographic images in unconvincing, CBCT should be considered as a potentially useful imaging device [38].

Assessment of Root Resorption and Perforations

Root resorption is a pathological condition, causing loss of dental hard tissue. The root resorption can be internal or external. Internal root resorption is usually asymptomatic and found on routine radiographic examination. Conventional 2D radiographic images are currently most often used for the detection of root resorption lesions. Clinical study be Estrela et al. [42] demonstrates that conventional radiographs underestimate the extent of root resorption when compared to CBCT. CBCT is reported to have superior diagnostic accuracy over periapical radiographs in the detection of simulated root resorptive lesions – internal and external by numerous in vitro studies [43-45]. CBCT allows assessing the real extent of the root defect and possible communication with the periodontal space [45]. The highest accuracy of CBCT among the others imaging modalities in detecting perforations is due to the possibility of 3D visualizations of the perforation or resorptive lesion without the superimposition of neighboring structures. Detection of the exact location and extent of the perforation and root dentin thickness around the resorptive defect can have a positive influence on the treatment decision and outcome.

Pre-surgical assessment

CBCT has been an extremely useful tool in the planning of surgical endodontic retreatment. CBCT allows clear identification of the anatomical relation of the root apices to important neighbouring anatomical structures [23]. The true size, location and extent of the periapical lesion can be appreciated, and also the actual root with which the lesion is associated [46]. This information will help the decision of non-surgical or surgical management [23]. Rigolone et al. [47] in their study investigated 43 upper first molars and concluded that CBCT provided enough information for a minimally invasive microsurgical technique. Low et al. [24] assessed 37 premolars and 37 molars referred for apical surgery. They reported that due to the CBCT scan it was possible to identify clearly the expansion of the lesion into the maxillary sinus, the sinus membrane thickening, the presence of apicomarginal communication, bony topography and pattern of root morphology. Root morphology and bony topography can be visualized in three dimensions, as well as the number of root canals and whether they converge or diverge from each other. Previously unidentified root canals may also be seen on the axial slices of the three-dimensional image [23]. In addition to revealing radiographic signs of periapical pathosis and root canal anatomy, CBCT scans accurately determine the relationship of adjacent anatomical structures in teeth with endodontic problems. This clinically relevant information may be useful for the treatment planning and the management of the tooth in question [38]. The information from the CBCT-scan and the prior knowledge of the exact relations between the anatomical structures allow performing of surgical endodontic procedures in the posterior region, which is considered to be more difficult due to anatomical conditions (maxillary sinus, mandibular canal, number of root canals, inaccessible posterior oral cavity, etc.) [48].

Assessment of the outcome of root canal treatment

Monitoring the healing of apical lesions is an important aspect of postoperative assessment. Earlier identification of periapical changes with CBCT may lead to earlier diagnosis and more effective management of periapical lesions. Literature data show that high percentage of clinical cases confirmed as healthy by radiographic examination revealed apical periodontitis on CBCT and CBCT confirmed enlargement of the chronic periapical lesion where reduced size of the existing radiolucency was diagnosed by radiographic examination [49]. Salceanu et al. [50] in their study investigated periapical healing of endodontically treated periapical lesions by CBCT follow-ups. The authors concluded that CBCT diagnostic is a reliable tool in following up the results of endodontic therapy of cases with chronic periapical periodontitis and must be considered for an extended use in the endodontic field. CBCT images represent the "true" status of periapical tissues both before and after treatment [51]. As adequacy of root canal obturation is an important determinant of endodontic success, it might be considered that CBCT is used in the initial and subsequent monitoring of the integrity of root canal filling [2].

Sogur et al. [52] investigated different analog film images and CBCT images for the evaluation of length and homogeneity of root fillings. The authors found that radiographic images were superior to the corresponding CBCT images, which may be due to the presence of streaking artefacts from the gutta-percha and sealer. Cheng et al. [53] compared periapical radiography and CBCT for the evaluation of endodontic obturation length and concluded that 30,3% of the radiographically acceptable root canal obturations were evaluated by CBCT as inadequate. Moller et al. [54] conducted an in vitro study comparing CBCT and radiographic images for detection of voids in root canal fillings. The authors concluded that intraoral receptors underestimate the presence of voids in root canals however CBCT overdiagnoses their presence, possibly due to artefacts from the gutta-percha root fillings. Therefore, CBCT should not be recommended for the assessment of quality of root fillings. One of the most important advantages of the cone beam

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computed tomography in endodontics is that it demonstrates anatomic features in 3D, in three orthogonal planes – axial, sagittal and coronal. In addition, because reconstruction of CBCT data is performed using a computer, data can be reoriented in their true spatial relationships. Cursor-driven measurement algorithms provide the clinician with real-time dimensional assessment. The measurements are free from distortion and magnification [2].

CBCT overcomes some of the limitations of 2D radiography such as image distortion and overlapping of neighboring anatomical structures. However, CBCT presents also with some limitations. Metal restorations, metal posts, and root fillings, and to some extent dental implants cause artefacts to the reconstructed image [55]. This possibility should be evaluated before even considering a CBCT-scan [56].

The spatial resolution of even the smallest voxel size may be too low to identify small objects such as fractured instruments or incomplete vertical root fractures [2,34]. The scan time of CBCT devices can be as long as 20 sec and is therefore significantly longer compared with that of intra-oral radiography. Even the slightest movement of the patient during the scan may render the resulting reconstructed images of minimal diagnostic use. This may be a problem with children, elderly patients and those with neurological disturbances [2]. The radiation dose and also the price of a CBCT scan are also higher compared to intraoral and panoramic radiographies. The potential benefits of a CBCT scan should always overweight the potential risks. The European Society of Endodontology published in 2014 a position statement about the use of CBCT in endodontics. According the criteria for the use of CBCT in endodontics a request for scan should only be considered if the additional information from the 3D images will potentially aid formulating a diagnosis and/or enhance the management of a tooth with endodontic problem [3].

Conclusion

CBCT overcomes many of the limitations of 2D radiography. The 3D nature of the reconstructed images should lead to more accurate diagnosis and therefore improved management of complex endodontic problems. Every clinical case should be judged individually and CBCT should be considered only in cases where the information from alternative imaging systems is not enough to allow appropriate management of the endodontic problem.

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