Review Article

Application of Cone Beam Computed Tomography in Endodontics: A Review Article

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Abstract

Background and Aim: Cone beam computed tomography (CBCT) has attracted considerable attention as a new diagnostic imaging technique in dentistry. The aim of this study was to review its application in Endodontics.

Materials and Methods: Electronic databases (MedLine, EMBase, Cochrane, Iran Medex, Science citation index, Scopus and Google scholar) were searched by the authors for articles published from 1999 to 2012. "CBCT imaging", "Endodontics", "vertical root fracture or VRF" and "periapical or PA lesions" were the searched key words.

Results: The assessment of PA lesions, healing process, tooth morphology, accessory canals, root curvature, traumatic injuries, internal and external tooth surfaces, root resorption, fracture lines specially vertical root fracture, perforations, broken instruments, overextended filling materials, calcified canals, proximity and superimposition of roots and pre-surgical evaluation are the challenges that cannot be adequately addressed by conventional radiography.

Conclusion: Cone beam computed tomography is a valuable imaging modality with minimal radiation exposure to the patient that provides maximal information for the clinician. It is going to be the front-line dental imaging modality in near future.

Key Words: CBCT imaging, Endodontics, Vertical root fracture, Periapical lesion

Introduction

Radiographic assessment is an essential part of endodontic treatment for accurate endodontic diagnosis, treatment planning, control of the procedure and evaluation of results [1]. At present, radiographic assessment in endodontics is performed by intraoral conventional and panoramic radiography [2]. Intraoral radiography provides valuable information regarding the presence and location of periradicular lesions, root canal anatomy, and close vicinity to anatomical landmarks [3]. However, it has some limitations due to its two-dimensional (2D) nature, geometric distortion, anatomical superimposition or a combination of all these factors [4]. For instance, in periapical (PA) radiographs, characteristics of the teeth and the surrounding tissues are only seen in the mesiodistal (proximal) plane; while similar characteristics may exist in the buccolingual plane (third dimension) that arehidden from sight in 2D radiographs [5]. Anatomical structures that cause noise can be opaque (like the zygomatic bone) or lucent (like the maxillary sinus and the incisive foramen). Such complex anatomy and the surrounding structures can make interpretation of the gray shadows difficult. Regarding the geometric factors of the image, radiographic mag-

nification and changing the tube angulation change the location of an object on a radiograph [5].

Cone beam computed tomography enables 3D visualization of dentition, maxillofacial skeleton and the adjacent anatomical structures [6].

In CBCT, the X ray beam is cone-shaped and divergent. A detector turns around the patient (area of interest) and cylindrical data (field of view or FOV) are obtained [7]. A FOV has millions of voxels, which can be isotropic (of equal dimensions) or anisotropic (of different dimensions). In CBCT, voxels are of equal dimensions. Data are processed by a computer and images are reconstructed in sagittal, axial and coronal planes (7).

The clinician can select the desired slice thickness [8] and the three planes can be viewed simultaneously. Changing one plane simultaneously changes the images of the other two planes [8]. FOV dimensions depend on the size and shape of the detector, image geometry and collimation of beams [9]. The smaller the FOV, the higher the resolution of image and the less the number of beams required [10]. The height of voxels depends on the slice thickness that determines the accuracy of the reconstructed image [10].

In endodontics, the periodontal ligament (PDL) integrity is very important and the thickness of the PDL space is 200µm. Use of limited-FOV CBCT is preferred overlarge volume CBCT [11]; unless the lesion is extensive enough to involve several teeth apices, or there is a multifocal lesion with a systemic etiology or a non-endodontic cause compromising tooth vitality [11].

The most important limitation of CBCT is its artifacts that make interpretation of images difficult [12]. These artifacts are divided into three groups of physical artifacts (i.e. beam artifacts, partial volume artifacts, noise and hardening artifacts) [13], patient-related artifacts (like metallic streak artifacts and motion artifacts) and scanner-related artifacts [14].

Complex endodontic treatments require high precision at work, accurate instruments and highly precise radiographic technique. Cone beam computed tomography as a new imaging modality has attracted much attention in dentistry. This study aimed to collect information in this regard to easier achieve endodontic objectives.

Materials and Methods

This review study evaluated factors that improve the quality of endodontic treatment and enhance endodontic diagnosis, treatment planning, perioperative assessments and evaluation of results. Related articles published during 1999-2012 were searched in Cochrane, Medline, Scopus, Iran Medex, Science Citation Index and Google Scholar using the keywords "CBCT", "imaging", "endodontics", "VRF", and "periapical lesion". Considering the research background of authors, the chosen papers were reviewed and conclusions were drawn.

Results

In the initial search, 93 articles were found using the mentioned keywords. The articles were reviewed and those in line with our study objectives were selected. It has been reported that CBCT has some contraindications [15] and should not be used for endodontic diagnosis in a regular basis. Also, it should not be used for screening purposes in absence of clinical symptoms or for pregnant women or young individuals [16]. Moreover, CBCT is not suitable for the assessment of soft tissue lesions unless these lesions have caused changes in the hard tissue like the tooth or bone. CT scan is often more suitable for assessment of changes caused by a tumor because soft tissues can be observedon CT scans [17].

Overall, use of CBCT in endodontics is limited to the assessment and treatment of complex cases.

1.It can be used for the assessment of the presence of periapical lesions and their process of healing. Also, it has high accuracy for determining the extent of the lesion and its effect on adjacent structures [18]. In many cases, superimposition of roots or areas of the maxillofacial skeleton makes it difficult to detect the presence of a lesion or its extension [19]. The prevalence of apical periodontitis in evaluation with CBCT has reported to be much higher than that in PA or panoramic radiographic assessment [20].

2.It can be used for the assessment of tooth morphology and its complexities like root curvature, accessory canals, presence of an extra canal, which is hard to find [21], presence of calcified canals [22] and assessment of the internal and external root surfaces. For example, detection of a C-

shaped RCS with conventional radiography is very difficult, if not impossible [23]. CBCT can be used for the assessment of traumatic injuries causing root or alveolar bone fracture or tooth dislocation [24] because by using CBCT the location of tooth and bone fracture can be easily detected [25].

3.CBCT can be used for the assessment of problems encountered during endodontic treatment like over-extension or under-extension of root canal filling material, presence and location of a broken instrument and site and extension of root perforation [26].

4.CBCT is useful for pre-surgical assessment; for example, determining the exact location of root apex and the adjacent landmarks before apicoectomy [27]. For implant surgery, CBCT is used for the assessment of the quality and quantity of the edentulous ridge, bone density and location of important anatomical landmarks like the inferior alveolar nerve [28].

5.Detection of internal or external root resorption, cervical resorption, inflammatory resorption or ankylosis is also much easier with CBCT [29] and helps accurate treatment planning and improves patient prognosis [30].

CBCT can be used for detection of VRF; which is a vertical fracture line along the longitudinal axis of the tooth often caused by iatrogenic trauma during dental treatments [31]. In most cases, VRF reaches the PDL space. In such cases, soft tissue fills the fracture gap and further moves apart the two pieces of the fracture. Over time, resorption areas also appear at the site [31]. A VRF is often detected by clinical symptoms like pain, swelling, presence of a single, deep periodontal pocket, sinus tract or pockets resembling a sinus tract at two opposite sides of the root along with radiographic symptoms like lateral and PA lucency [32]. Exploratory surgery is often performed to see the fracture. This is often done by surgically elevating a flap and direct observation of the fracture line under adequate light, magnification and staining with methylene blue [33]. The results showed that the accuracy of CBCT for detection of VRF was much higher than that of PA radiography [32]. Also, one study compared the accuracy of CBCT scan with 4.0 mm, 3.0 mm, 2.0 mm and 125.0 mm voxels and demonstrated that 2.0 mm voxel with the lowest exposure dose provided the best diagnostic

quality for detection of VRF [33]. For detection of VRF, axial images are significantly more accurate than sagittal and coronal images [32]. It is expected that newer versions of CBCT systems can faster detect VRF in the future before the bone and tissue destruction occurs.

Discussion
Although CBCT enhances the detection of afore mentioned conditions, type of CBCT device used is also very important and affects the quality of images. In a study by Hassan et al, in 2010, five CBCT systems were compared for detection of VRF and it was found that I-CAT and then SCANORA® 3Dwere the most accurate systems, respectively [34]. They mentioned that the superiority of these two systems over others is due to their different detectors. I-CAT and SCANORA® 3D use image intensifier tube/charged coupled device (IIT/CCD); while the other systems evaluated in their study namely the NewTom, Accuitomo and Galileo have flat-panel detectors (FPD) that result in decreased dynamic range, low contrast and spatial resolution and increased artifact in images [34]. However, newer versions like the VG and the NewTom VG have flat panel detector and a smaller voxel size that increases the quality of images; thus the ability of thesesystems has greatly increased for detection of VRF.

Youssefzadeh et al. reported that metal artifacts due to the presence of metal objects like the metal posts decrease the quality of images and the diagnostic sensitivity for detection of VRF [35]. The most important drawback of CBCT is the high exposure dose and high cost [36]. Some solutions have been provided to reduce the exposure dose; like the use of a smaller FOV that decreases the radiation dose [10]. It has been demonstrated that Accuitomo 3D with a minimum voxel size (0.08 mm) requires the same dose of radiation [37]. Also, one study revealed that among different detectors, Kodak 9000 3D decreases the required patient dose by 0.4-2.7 times the dose in digital panoramic radiography [38].

Conclusion
Considering the high accuracy and sensitivity of CBCT, it may be used as the first line radiography

for complex cases given that its shortcomings mainly its high radiation dose are resolved.

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