Cone beam computed tomography: a new era in diagnosis and treatment planning

Mohamed Fayad discusses the use of cone beam computed tomography in endodontic diagnosis and management of treatments

Clinical examination and diagnostic imaging are both essential components of endodontics preoperative diagnosis and treatment planning. Clinical examination must be carried out before considering any radiographic examination. Accurate diagnostic imaging supports the clinical diagnosis and allows the clinician to better visualise the area in question. Preoperative imaging is an essential part of endodontic practice, from diagnosis and treatment planning to outcome assessment.

Conventional two-dimensional radiographs continue to be the most popular method of imaging today. However, the diagnostic potential of periapical radiographs is limited. Information may be difficult to interpret, especially when the anatomy and background pattern is complex. Intraoral radiographs have inherent limitations due to the compressed three-dimensional structures in a two-dimensional image. Interpreting the film-based radiograph or digital image continues to be a somewhat subjective process. Goldman and colleagues showed that the agreement between six examiners was only 47% when evaluating healing of periapical lesions using two-dimensional periapical radiographs (1972). In a follow-up study, Goldman and colleagues also reported that when examiners evaluated the same films at two different times, they only had 19%-80% agreement with their previous interpretations (1974). In a recent study, interobserver and intraobserver reliability in detecting periradicular radiolucency by using a digital radiograph system was evaluated. Agreement among all six observers for all radiographs was less than 25%, and agreement for five of six observers was approximately 50% (Tewary, Luzzo and Hartwell, 2011).

New radiographic imaging systems have recently become available for use in dentistry. Among these new imaging technologies is the cone beam volumetric tomography (CBVT). In 2000, the US Food and Drug Administration approved the first CBCT unit for dental use in the USA. CBCT systems are available in different field of views (FOV): CBCT limited (dental) ranges in diameter from 40-100 mm or full (ortho or facial) CBCT ranges from 100-200 mm. The voxel size is generally smaller for the limited version (0.1-0.2 mm vs 0.3-0.4 mm), thus offering higher resolution and greater utility for endodontic applications. For endodontic application, the limited field of view is the most acceptable as it is capable of providing images at a low radiation dose and with sufficient spatial resolution for applications in endodontic diagnosis and treatment planning.

The advent of cone beam computed tomography (CBCT) can overcome these issues by visualising the dentition and the relationship of anatomic structures in three dimensions. CBCT units reconstruct the projection data to provide interrelational images in three orthogonal planes (axial, sagittal and coronal). For most endodontic applications, limited or focused FOV CBCT is preferred over large volume CBCT. This article will review the utilisation of CBCT in endodontic diagnosis and management of periradical pathology, diagnosis of pain, cracked teeth and vertical root fractures, internal and external resorptive defects.

Imaging application

While there are presently no definitive patient selection criteria for the use of CBVT in endodontics, the use of CBVT in endodontic diagnosis and treatment should not be ignored or avoided. In May 2015, an updated joint position statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology was published, with the intention to provide scientifically based guidance to clinicians regarding the use of cone beam computed tomography in endodontic treatment and reflect new developments since the 2010 statement. The updated statement addressed the potential applications of cone beam computed tomography in different phases of treatment.

Potential applications of cone beam computed tomography in endodontic practice are as follows.

Utilisation of cone beam computed tomography in endodontic diagnosis of pain and detection of periapical lesions

Endodontic diagnosis is dependent upon evaluation of patient’s chief complaint, medical and dental history, clinical and radiographic examination. Preoperative imaging is an essential part of endodontic practice, from diagnosis and treatment planning to outcome assessment.

CBCT imaging has the ability to detect periradicular pathology...
prior to being apparent on two-dimensional radiographs (De Paula-Silva et al, 2009). This was validated in clinical studies in which periapical periodontitis detected in intraoral radiographs and CBCT was 20% and 48% respectively (Patel et al, 2012). Ex vivo studies in which simulated periapical lesions were created showed similar findings (Sogur et al, 2012; Patel et al, 2009a).

Diagnosis of pain is a challenging process for the clinician prior to and after treatment. In challenging diagnostic pain cases, the clinical and radiographic evaluation of the patient is inconclusive. Inability to determine the etiology of the pain can be attributed to the limitations in both clinical vitality testing and intraoral radiographs to detect the etiology of the source of the pain.

Persistent pain following root canal therapy presents with a diagnostic challenge to the clinician. Atypical odontalgia (AO) is an example of persistent dentoalveolar pain (Nixdorf and Moana-Filho, 2011). The diagnostic yield of intraoral radiographs and CBCT was evaluated in the differentiation between patients presenting with apical periodontitis and suspected AO without the evidence of periapical bone destruction. CBCT imaging detected 17% more teeth with apical bone loss (apical periodontitis) than intraoral radiographs (Pigg et al, 2011). Figure 1 is an example of a case that presented with non-localised pain. CBCT imaging information was able to aid in the determination of the aetiology of the odontogenic pain.
Utilisation of cone beam computed tomography in preoperative anatomy assessment

The success of endodontic treatment depends on the identification of all root canal systems so that they can be treated. The efficacy of CBVT as a modality to accurately explore tooth anatomy and identify the prevalence of a second mesiobuccal canal (MB2) in maxillary molars when compared to the gold standard (clinical and histologic sectioning) has been well documented (Blattner et al, 2010; Michetti et al, 2010). CBCT showed higher mean values of specificity and sensitivity when compared to intraoral radiographic assessments in the detection of the MB2 canal (Vizzotto et al, 2013). Figure 2 is an example of using the three-dimensional rendering in determining the presence and location of canals in lower mandibular molar (UR8) prior to root canal therapy.

Utilisation of cone beam computed tomography in endodontic diagnosis and detection of cracked teeth and vertical root fracture

Two-dimensional radiographs are of limited value for the diagnosis of VRFs and usually only provide indirect evidence of the presence of a VRF. Several studies have demonstrated the validity of utilising CBVT to detect VRFs. In a comparative study evaluating the sensitivity and specificity of CBCT and periapical radiographs (PR) in detecting VRFs, sensitivity and specificity for VRF detection of CBCT were 79.4% and 92.5% and for PR were 37.1% and 95%, respectively. The same study reported that the specificity of CBCT was reduced in
the presence of root canal filling material (Hassan et al, 2009). Higher sensitivity and specificity were observed in a clinical study where the definitive diagnosis of vertical root fracture was confirmed at the time of surgery to validate CBCT findings, with sensitivity being 88% and specificity 75% (Edlund, Nair and Nair, 2011).

Several case series studies have concluded that CBCT is a useful tool for the diagnosis of vertical root fractures. In vivo and laboratory studies (Metska et al, 2012; Brady et al, 2014) evaluating CBCT in the detection of vertical root fractures agreed that sensitivity, specificity, and accuracy of CBCT were generally higher and reproducible. The detection of fractures was significantly higher for all CBCT systems when compared to intraoral radiographs. However, these results should be interpreted with caution because detection of vertical root fracture is dependent on the size of the fracture, presence of artifacts caused by obturation materials and posts, and the spatial resolution of the CBCT. In a recent study, the diagnostic
periapical and lateral root radiolucency ‘halo’ appearance is valuable information, indicating the possible presence of VRF. Several of the previously mentioned clinical and radiographic elements have to align to establish a presumptive diagnosis of VFR (Tsesis et al, 2010); however, dye examination, usually requiring surgical exposure, is still the gold standard for diagnosis of VRF.

In a case series, the following five findings on CBVT exam were consistent with confirmed VRF (Fayad, Ashkenaz and Johnson, 2012): 1) loss of bone in the mid-root area with intact bone coronal and apical to the defect; 2) absence of the entire buccal plate of bone in axial, coronal and/or three-dimensional reconstruction; 3) radiolucency around a root where a post terminates; 4) space existing between the buccal/lingual plate of bone and fractured root surface; 5) visualisation of the VRF on the CBVT spatial projection views. Figures 3, 4 and 5 are different examples of the sensitivity of CBCT imaging in the diagnosis of cracked teeth and VRF.

**Figure 8:** A is periapical radiograph of UR6 that was referred for periapical surgery. A non-surgical retreatment attempt was performed prior to periapical microsurgery. Mesiopalatal canal was blocked. The black line corresponds to the level of the axial view in E; B is sagittal view demonstrating the extent of the periapical defect; C is three-dimensional rendering of the periapical defect; D is clinical picture demonstrating the endodontic/periodontal communication; E is axial view of the mesial, distal and palatal roots. Note the fused distal and palatal roots; F and G are the coronal view of the mesial root and the fused distal-palatal roots respectively.

**Figure 9:** Continued: A is three-dimensional rendering demonstrating the periodontal defect at the marginal bone (black arrow); B is after flap reflection demonstrating the periodontal defect communicating with the periapical defect (blue arrow); C is root resection of the fused distal and palatal roots prior to ultrasonic preparation; D is MTA root end filling of the ultrasonically prepared distal and palatal preparation; E is periodontal and periapical defects grafted with Puros allograft (Zimmer Dental) material; F is grafted defect covered with Copios membrane (Zimmer Dental).
Utilisation of cone beam computed tomography in non-surgical and surgical treatment planning

Diagnostic information directly influences treatment planning and clinical decisions. Accurate data leads to better treatment decisions and potentially more predictable outcomes (Liang et al, 2011). Ee and colleagues evaluated compared endodontic treatment planning with CBCT and periapical radiography (2014). Thirty endodontic cases completed in a private endodontic practice were randomly selected to be included in this study. Each case was required to have a preoperative digital periapical radiograph and a CBCT scan. Three board certified endodontists reviewed the 30 preoperative periapical radiographs. Two weeks later, the CBVT volumes were reviewed in random order by the same evaluators. The evaluators were asked to select a preliminary diagnosis and treatment plan based solely on interpretation of the periapical and CBCT images. Diagnosis and treatment planning choices were then compared to determine if there was a change from the periapical radiograph to the CBVT scan.

Under the conditions of the previous study, CBCT was a more accurate imaging modality for diagnosis of endodontic pathology when compared to diagnosis using only periapical radiographs. An accurate diagnosis was
reached in 36.6% to 40% of the cases when using periapical radiographs compared to an accurate diagnosis in 76.6% to 83.3% of the cases when using CBCT. This high level of misdiagnosis is potentially clinically relevant, especially in cases of invasive cervical root resorption and vertical root fracture where a lack of early detection could lead to unsuccessful treatment and tooth loss. The previous study also demonstrated that the treatment plan may be directly influenced by information gained from a CBCT scan as the examiners altered their treatment plan after viewing the CBCT scan in 62.2% of the cases overall (range from 56.6% to 66.7%). This high number indicates that CBCT had a significant influence on the examiners' treatment plan (Figures 6 and 7).

The use of CBCT has been recommended for treatment planning of endodontic surgery (Venskutonis et al, 2015; Bornstein et al, 2011; Low et al, 2008). CBCT visualisation of the true extent of periapical lesions and their proximity to important vital structures and anatomical landmarks is superior to that of periapical radiographs.

The use of CBCT has enabled the clinician to evaluate the true extent of the periapical lesion and their spatial relationship to important anatomical landmarks and vital structures (Figures 8-10).
Utilisation of cone beam computed tomography in endodontic diagnosis and detection of inflammatory restorative defects

Diagnosis and detection of root resorption is often challenging due to the quiescent onset nature and varying clinical presentation. The definitive diagnosis and treatment planning is ultimately dependent on the radiographic representation of the disease. Two-dimensional imaging offers a limited diagnostic potential when compared to three-dimensional imaging (Estrela et al., 2009; Durack et al., 2011) (Figures 11-13).

Conclusion

Several studies evaluated the use of CBCT in endodontics (Patel et al., 2015; Cotton et al., 2007; Patel et al., 2009b; Patel, 2009; Scarfe, Farman and Sukovic, 2006; Nair and Nair, 2007). Cone beam computed tomography overcomes many of the limitations of periapical radiography. The increased diagnostic information provided by the CBCT study should result in more accurate diagnosis and improved decision-making for the management of complex endodontic problems. It is a desirable addition to the endodontist’s armamentarium.

The effective radiation dose to patients when using CBCT is higher than conventional two-dimensional radiography and the benefit to the patient must therefore outweigh any potential risks of the additional radiation exposure. Radiation dose should be kept as low as reasonably achievable (ALARA) (Farman and Farman, 2005a; Farman, 2005b). The value of CBCT for endodontic diagnosis and treatment planning should be determined on an individual basis to assure that the benefit-risk assessment supports the use of CBCT.

References