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Applications of Cone Beam Computed Tomography in Endodontics: A Review

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Abstract

Aim: This review aims to provide comprehensive information related to the principles of Cone beam computed tomography and its potential applications in the management of various endodontic conditions.

Methodology: A thorough and extensive electronic literature search was conducted utilizing PubMed, for articles related to endodontic applications of CBCT published during the period between January 2005 and September 30, 2013. Search words such as 'principles of CBCT', 'endodontic applications of CBCT' were employed to obtain information. Only those articles dealing with the principles and various endodontic applications of CBCT are included in this review.

Results: The search revealed 258 articles, 70 of which were found to be relevant to the scope of this review and were used in this review CBCT is a revolutionary and innovative procedure that has changed the paradigms in the management of various endodontic conditions. The information provided by this tool–three dimensional view of anatomic and pathologic structures, ability to provide details of root and canal anatomy, assessment of dento-alveolar trauma, assessment of root resorptions, etc. has contributed substantially to its extensive utilization in a short period of time.

Clinical Significance: CBCT can be used in the management of a variety of conditions like dento-alveolar truma, root resorptions, early apical periodontitis, roots and canals with unusual anatomy, dental anomalies, etc. The effective dose of CBCT (focused field of view) varies from 5-38.3 μSv. The effective dose of intra-oral periapical radiographs and panoramic radiographs are <8.3 μSv and 9-26 μSv respectively. Thus CBCT has an effective dose in the similar range of magnitude as other dental radiographs, but, its three dimensional imaging capability and 100% sensitivity (1.0) and specificity (1.0) makes it an invaluable tool in the field of endodontics.

Keywords: Cone-beam computed tomography; Imaging; Three-dimensional; Root resorption; Tooth fractures; Periapical periodontitis; Anatomic variation

Introduction

Cone Beam Computed Tomography (CBCT) is an extra-oral imaging system specifically designed for three dimensional imaging of the oral and maxillofacial structures. Most of the limitations associated with conventional radiography like compression of a three dimensional object into a two dimensional image, image distortion, anatomic superimposition, are overcome with cone beam computed tomography (CBCT). CBCT produces clear images with higher resolution at a reduced radiation and lower cost when compared to medical CT [1]. It is a more compact, faster and safer version of the medical CT. The time needed for a full scan is typically under one minute and the radiation dosage is several times lesser than that of a CT scanner. The purpose of this article is to provide an overview of the associated principles, applications and advantages of CBCT in the management of various endodontic conditions. In order to provide a better understanding regarding the usefulness of this imaging system, CBCT images obtained for the management of various endodontic conditions are discussed.

Methodology

A thorough and extensive electronic literature search was conducted utilizing PubMed, for articles related to endodontic applications of CBCT published during the period between January 2005 and September 30, 2013. Search words such as 'principles of CBCT', 'endodontic applications of CBCT' were employed to obtain information. Only those articles dealing with the principles and various endodontic applications of CBCT are included in this review. In order to obtain information that is clinically relevant, only those articles on human investigation were selected, and animal investigations and studies like those performed on acrylic block, etc were not included in this review.

Result

The search revealed different kinds of paper dealing with various applications of CBCT in Endodontics. Among the 258 articles revealed, 70 were found to be relevant to the scope of this review and were used in this review. Among the 70 relevant articles, 31 were case report, 21 were *in vivo* studies, and 18 were *ex vivo* studies.

Analyzing these articles, it appears that CBCT being three dimensional is an effective tool in the diagnosis and management of conditions like early apical periodontitis tooth with complex anatomy, root fracture, root resorption, periradicular surgical planning, dental anomalies. Utilization of this imaging technology in appropriate conditions may result in accurate diagnosis and predictable management.

Discussion

Correct diagnosis is the key in the management of any pathologic

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condition. Imaging aids in visualizing internal structures that would be unseen otherwise. CBCT is a relatively new, three dimensional modality that can be useful in managing various endodontic conditions. In the following section basic principles of CBCT will be reviewed followed by a comprehensive review on condition wise application of CBCT in endodontics.

Principles of CBCT

Aria et al. from Japan [2] and Moshiri et al. from Italy [3] are credited with the development of CBCT scanners for use in oro-facial imaging. Unlike medical CT which employs a fan shaped beam of X-ray, CBCT projects a cone or pyramid shaped X-ray beam. Patient positioning during imaging varies, it can be supine, standing, or sitting based on the system manufacturer. CBCT units can be categorized into two types. One type of unit has Charge-Coupled Device (CCD) detector and the other utilizes Flat Panel Imager (FPI). Basically, the X-ray source and the scanner makes a full (360°) or half rotation (180°) around the patient's head. While doing so a cylindrical volume of data known as field of view is captured. This data is then analyzed by sophisticated software to display images in various planes. Hard copies of the images can be obtained through a printer connected to the computer. These images can be transferred to a compact disc (CD) or other portable memory devices and can also be mailed electronically to other clinicians for consultation and discussion purposes.

CBCT systems can be categorized according to the available Field Of View (FOV) or selected scan volume height as follows [1]:

Localized region: approximately 5 cm or less (eg, dentoalveolar, temporomandibular joint)

Single arch: 5 cm to 7 cm (eg, maxilla or mandible)

Interarch: 7 cm to 10 cm (eg, mandible and superiorly to include the inferior concha)

Maxillofacial: 10 cm to 15 cm (eg, mandible and extending to Nasion)

Craniofacial: greater than 15 cm (eg, from the lower border of the mandible to the vertex of the head)

Radiation Dosage

Much like conventional radiography, CBCT utilizes ionizing radiation. There is a misconception among the general population and probably even among the dental professionals that CBCT exposes individuals to very high amount of radiation. Even though CBCT produces more radiation than conventional radiography, the difference is at best marginal. On the other hand, radiation emitted in CBCT imaging is several times lower than medical fan beam CT imaging. Not all CBCT units produce the same dose of radiation. The same CBCT unit may produce different amount of radiation depending on the field of view (focused or large), power settings, rotation around head (180°or 360°), etc. The effective dose of one CBCT unit (3D Accuimoto, J Morita, Kyoto, Japan) has been reported to be equivalent to two or three standard periapical radiographic exposures [2].

Note that the effective dose of CBCT is almost similar to that of panoramic radiograph and equivalent to a few periapical radiographs, whereas it is several times lower than medical fan beam CT (Table 1).

Imaging	Effective dose μSv
Intra oral radiograph	<8.3
Panoramic	9-26
Cephalometric radiograph	3-6
Cone beam CT(focused field of view) (dento-alveolar)	5-38.3
Full mouth series radiograph	35-388
Cone beam CT-Craniofacial	68-599
Medical fan beam CT–maxilla and mandible	2000

Table 1: Comparison of effective radiation dosage among Cone beam CT, conventional radiography and Medical fan beam CT [3,4].

Accuracy of CBCT

Scientific literature suggests that CBCT is more accurate than radiography in imaging anatomic as well as pathologic dento-facial structures. Studies have shown the CBCT to be accurate and reliable in detecting apical periodontitis, vertical root fracture, resorptive defects. CBCT also provides a better view of root and pulp canal anatomy when compared to radiography. For example, presence of buccolingual curvature in a root is most often missed by radiographs, but it can be easily detected in CBCT image. Most often radiographs provide little or no information about the presence of additional canals, their shape and curvature. However CBCT imaging will reveal the same findings with high accuracy. In the following sections, accuracy of CBCT in detecting various endodontic conditions will be discussed along with representative cone beam computed tomographic images.

Detection of Apical Periodontitis

Apical Periodontitis can be detected at an early stage using CBCT when compared to conventional radiographs. It appears that conventional radiography results in an under-estimation of the incidence of apical periodontitis [3-5]. Lesion confined within the cancellous bone cannot be detected by conventional radiographs, whereas they are easily detected in CBCT which captures images in slices thereby avoiding anatomic superimposition. Lofthag-Hansen et al. [6] compared the periapical status of 46 posterior mandibular and maxillary teeth using CBCT scans and two angled periapical radiographs. Thirty-two teeth were diagnosed with periapical lesions using conventional radiographs and a further 10 (24%) with CBCT. When the periapical status of the individual roots of these teeth was assessed, CBCT allowed 38% more periapical lesions to be detected than with conventional radiographs. CBCT was found to have increased sensitivity for detecting apical periodontitis compared with periapical and panoramic radiography. The sensitivity of periapical and panoramic radiography was found to be 0.55 and 0.28 respectively. CBCT has 100% specificity (1.0) and sensitivity (1.0) in detecting artificially created periapical lesion in dried human mandibles [7]. Recently a periapical index based on cone beam-computed tomography (CBCTPAI) for identification of apical periodontitis has been proposed. The CBCT PAI is a 6-point (0–5) scoring system calculated from determining the largest lesional measurement in either the buccopalatal, mesio-distal, or axial dimension or taking into account expansion and destruction of cortical bone [8-14] (Table 2).

Assessment of Root and Canal Anatomy

Knowledge of root canal anatomy and variations between ethnic groups is essential for clinicians to facilitate effective root canal treatment (RCT). Successful endodontic therapy is dependent on identification of all root canals followed by proper cleaning, shaping and obturation of all canals. Most often radiographs may not show the presence of all canals within the root, especially in the buccolingual plane. Such missed canals may be responsible for persistent infection and post treatment disease. The prevalence of a second mesiobuccal

Author	Year	Sample	Study	Findings and conclusion
Estrela et al. [5]	2008	Endodontically infected 1508 teeth	Comparison of diagnostic accuracy of panoramic and periapical radiographs with CBCT for the detection of apical periodontitis	Increased sensitivity of CBCT for detecting apical periodontitis compared with periapical and panoramic radiography.
Lofthag-Hansen et al. [6]	2007	46 posterior teeth(in vivo	Compared the periapical status using CBCT and radiographs	CBCT allowed 38% more periapical lesions to be detected than with conventional radiographs
Patel et al. [7]	2009	6 molar teeth	Comparison of the diagnostic accuracy of intraoral digital periapical radiography with that of cone beam computed tomography (CBCT) for the detection of artificial periapical bone defects	CBCT improved the detection of the presence and absence of artificial periapical lesions
Low et al. [9]	2008	37 premolars, 37 molars, total 157 roots	Comparison between periapical (PA) radiography and cone-beam tomography (CBT) for preoperative diagnosis.	Detecting lesions with PA radiography alone was .difficult. Additional findings were seen significantly more frequently in CBCT
Bornstein et al. [10]	2011	38 molars with 75 roots	The type of PA lesion as diagnosed on PA radiographs was compared with the type of lesion seen on sagittal and coronal CBCT sections.	(25.9%) lesions diagnosed with sagittal CBCT slices were missed with PA radiography.
Paes da Silva. [11]	2012	300 patients	Determinationof the prevalence of apical periodontitis (AP) detected in cone beam CT (CBCT) images from a database.	Apical Periodontitis can be frequently found in CBCT examinations CBCT databases are useful for cross-sectional studies about Apical periodontitis prevalence in a population.
Estrela C et al. [12]	2009	1020 teeth	Assessment of the influence of intracanal post on apical periodontitis identified by cone-beam computed tomography.	AP was detected more frequently when CBCT method was used.
Moura MS et al. [13]	2009	503 root canals	Assessment of the influence of length of root canal obturation on apical periodontitis detected by periapical radiography and cone beam computed tomography.	Detection of apical periodontitis increased when CBCT was used.
Abella F [14]	2012	138 teeth	Evaluating the Periapical Status of Teeth with Irreversible Pulpitis by Using Cone-beam Computed Tomography Scanning and Periapical Radiographs.	The study highlighted the advantages of using CBCT for detecting AP lesions, especially in teeth with symptomatic irreversible pulpitis.

Table 2: Role of CBCT in the detection of apical periodontitis.

Author	Year	Sample	Study	Findings and conclusion
Jojo Kottoor et al. [16]	2010	Case report	Maxillary First Molar with Seven Root Canals Diagnosed with Cone-Beam Computed Tomography Scanning	Unusual morphology was confirmed with the help of cone beam computerized tomography (CBCT) scans
Zheng et al. [17]	2011	608 teeth	Evaluation of the anatomical features of C-shaped canal systems in Chinese mandibular second molars by cone-beam computed tomography (CBCT).	CBCT is a clinically useful tool in the assessment of additional distolingual root and “C” shaped canals
Zhang et al. [18]	2011	389 teeth	Use of cone beam computed tomography to evaluate root and canal morphology of mandibular molars in Chinese individuals	CBCT is an effective tool for the detection of additional distolingual root and C-shaped root/canals, and it is a valuable aid for dentists providing root canal treatment.
Mathrene et al. [19]	2008	72 extracted teeth	Comparison of CBCT and radiography in identifying the canal anatomy	CBCT identified more canals which were missed by radiographs
Tomoatsu Kaneko [20]	2011	Case report	Non-surgical endodontic treatment of dens invaginatus with the aid of (CBCT).	CBCT greatly helped the decision of avoiding further intervention that could have been difficult to negotiate.
Abella et al. [21]	2011	Case report	Managing severe curvature of radix entomolaris: three-dimensional analysis with cone beam computed tomography	CBCT provided more accurate information in terms of RE inclination and root canal curvature before commencing root canal treatment.
Je´ro^me Michetti et al. [22]	2010	90 teeth	Validation of Cone Beam Computed Tomography as a Tool to Explore Root Canal Anatomy	Strong to very strong correlation was found between the data acquired by using CBCT and histology
Patel S [23]	2010	Case report	The use of cone beam computed tomography in the conservative management of dens invaginatus	The true nature of dens invaginatus cannot always be estimated from conventional radiographs. Cone beam computed tomography is a useful diagnostic tool in the management of dens invaginatus.
Kottoor J et al. [24]	2011	Case report	Four-rooted maxillary first molar having C-shaped palatal root canal morphology evaluated using cone-beam computerized tomography	The evaluation of CBCT images can result in better understanding of root canal anatomy, which enables the clinician to investigate the root canal system and to clean, shape, and obturate it more effectively.
Kottoor J [25]	2010	Case report	Endodontic management of a maxillary first molar with eight root canals evaluated using cone-beam computed tomography scanning	The use of CBCT imaging in endodontically challenging cases can facilitate a better understanding of the complex root canal anatomy, which ultimately enables the clinician to explore the root canal system and clean, shape, and obturate it more efficiently.
Vier-Pelisser FV et al. [26]	2012	Case report	Use of cone beam computed tomography in the diagnosis, planning and follow up of a type III dens invaginatus case.	CBCT may aid the diagnosis as well as the management plan and follow-up of teeth with this developmental anomaly.
La SH et al. [27]	2010	Case report	Identification of independent middle mesial canal in mandibular first molar using cone-beam computed tomography imaging.	This case report highlights the usefulness of CBCT imaging for accurate diagnosis and management of the unusual canal morphology.

Bernardes RA et al. [28]	2012	34 teeth	Comparative study of cone beam computed tomography and intraoral periapical radiographs in diagnosis of lingual-simulated external root resorptions.	Cone beam computed tomography showed better diagnostic ability compared with intraoral radiography, regardless of the tooth or the dimensions of the resorption evaluated.
Reis AG [29]	2013	100 patients, 343 teeth	Correlating second canal in mesiobuccal root of maxillary molars with root third and patient age	The prevalence of MB2 canals was found to decrease as the root canal approaches the apical third and as age increases. CBCT scanning proved effective in mapping MB2 canals present in different thirds of the root.
Guerrero ME [30]	2013	256 Patients	Comparison of panoramic radiography and CBCT to predict postoperative outcome after wisdom tooth removal	This study concluded that, CBCT was not better than panoramic radiography in predicting postoperative complications for moderate-risk cases of impacted third mandibular molars. Nonetheless, a CBCT buccolingual view can accurately confirm the number of roots and root morphology of the third molar better than PA
Vizzotto MB [31]	2013	89 maxillary molar teeth	CBCT for the assessment of second mesiobuccal (MB2) canals in maxillary molar teeth: effect of voxel size and presence of root filling.	CBCT was associated with higher mean values of specificity and sensibility than radiographic examination for the detection of MB2 canals. When endodontic retreatment is necessary removal of the root filling prior to the CBCT examination eliminates artifacts.

Table 3: Role of CBCT in studying the internal anatomy of tooth.

canal (MB2) in maxillary first molars has been reported to vary from 69% to 93% depending on the study method employed. Increased number of MB2 canal can be identified with CBCT when compared to conventional radiographs. Recently it was reported diagnosis and management of a maxillary first molar with seven root canals using CBCT. CBCT imaging has also been reported to characterize the high prevalence of the distolingual canal, highlight anomalies in the root canal system of mandibular premolars, and assist in the determination of root curvature. In a study that evaluated 608 permanent mandibular second molars using CBCT a higher prevalence of "C" shaped canals was noticed [15-17]. CBCT is an effective tool for the detection of additional distolingual roots and C-shaped canals [18] (Table 3).

Assessment of Dentoalveolar Trauma

The exact extent and severity of dentoalveolar traumatic injuries can be assessed with just one scan from which multiple views can be selected and analyzed. Various studies have shown CBCT to be effective in the diagnosis of vertical root fracture when compared with radiograph [32-34]. The diagnostic ability of CBCT in detecting vertical root fracture was not influenced by the presence of posts or gutta-percha [35]. Limited cone beam CT, outperformed the two-dimensional intraoral, conventional as well as digital, radiographic methods in detecting simulated horizontal root fracture [32]. CBCT can be an ideal alternative in the diagnosis of root fracture in the field of endodontics. CBCT is also more effective in detecting the alveolar fracture compared to radiographs. As CBCT is an extra-oral technique it is also more comfortable for trauma patients when compared to several intra-oral radiographs. CBCT also increases diagnostic quality and help decrease the potential failure of treatment and/or the prescription of unwarranted dental procedures. It has also been demonstrated that presence of root canal fillings and metallic post may cause streaking artifact which may lower the diagnostic value of CBCT (Table 4).

Author	Year	Sample	Study	Findings and conclusion
Kamburog˘ lu et al. [32]	2009	18 teeth	Effectiveness of limited cone-beam computed tomography in the detection of horizontal root fracture	Limited cone beam CT, outperformed the two-dimensional intraoral, conventional as well as digital, radiographic methods in detecting simulated horizontal root fracture.
Lu-Tang et al. [33]	2011	Case report	Detection of vertical root fracture using cone beam computed tomography	CBCT imaging is useful in rapid diagnosis of VRFs and designing of further treatment
Ping Wang et al. [34]	2011	Report of four cases	Detection of vertical root fractures in non-endodontically treated molars using cone-beam computed tomography	CBCT provides more information on the presence of VRFs.
Melo SL et al. [35]	2010	180 teeth	Evaluation of the diagnostic ability of a cone-beam computed tomography scan to assess longitudinal root fractures in prosthetically treated teeth	Limited cone-beam CT is more useful than the other 3 radiographic modalities for diagnostic imaging of horizontal tooth root fracture.
Dalili et al. [36]	2012	10 teeth	To evaluate the value of cone beam CT in detection of dental root fractures	CBCT shows good potential for use in the detection of root fracture as it ensures a high level of diagnostic score accuracy.
Masoud et al. [37]	2010	100 teeth	Comparison of CBCT and radiography in detecting vertical root fractures	CBCT achieves a more accurate diagnosis of vertical root fracture when compared to radiographs
P. Wang et al. [38]	2011	128 patients, 138 teeth	Detection of dental root fractures by using cone-beam computed Tomography and radiography	CBCT appears to be more accurate than conventional dental radiography in the detection of root fractures.
Zou X et al. [39]	2011	Report of 3 cases	Evaluation of the ability of cone-beam computerized tomography to detect vertical root fractures in endodontically treated and nonendodontically treated teeth	CBCT provided useful information in diagnosing VRFs in both endodontically treated and nonendodontically treated teeth, especially when VRFs could not be confirmed by clinical findings and PRs.
Hassan B et al. [40]	2009	80 teeth	Detection of vertical root fractures in endodontically treated teeth by a cone beam computed tomography scan.	Results showed an overall higher accuracy for CBCT (0.86) scans than PRs (0.66) for detecting VRF.
Ozer SY [41]	2010	80 teeth	Detection of vertical root fractures of different thicknesses in endodontically enlarged teeth by cone beam computed tomography versus digital radiography	CBCT scans are effective for detecting VRFs of different thicknesses.

Edlund M et al. [42]	2011	29 patients	Detection of vertical root fractures by using cone-beam computed tomography	This study revealed the superior diagnostic accuracy of CBCT for detection of VRF
Wang P et al. [43]	2011	Report of 3 cases	Evaluation of horizontal/oblique root fractures in the palatal roots of maxillary first molars using cone-beam computed tomography	CBCT might be a useful complementary diagnostic method to conventional radiography in cases of suspected horizontal/ oblique root fractures.
Varshosaz M et al. [44]	2010	100 teeth	Comparison of conventional radiography with cone beam computed tomography for detection of vertical root fractures	CBCT was shown to be significantly better than conventional periapical radiography for diagnosis of vertical root fractures in vitro
Bernardes RA et al. [45]	2009	20 patients	A report of cases that describes the use of cone-beam volumetric tomography in the diagnosis of root fractures	Cone-beam volumetric tomography was better than conventional radiography in the diagnosis of root fractures, thereby constituting an excellent alternative for diagnosis in general practice.
Dölekoğlu S et al. [46]	2010	Case report	Diagnosis of jaw and dentoalveolar fractures in a traumatized patient with cone beam computed tomography	According to 2D cephalometric analysis, no fracture existed. In the diagnosis of dentoalveolar fractures, CBCT has made it possible for the practitioner to get more detailed information
Mora MA et al. [47]	2007	60 teeth	In vitro assessment of local computed tomography for the detection of longitudinal tooth fractures	Local CT significantly improves the detection of longitudinal fractures in vitro compared with conventional periapical radiography.
Özer SY et al. [48]	2011	Report of three cases	Diagnosis and treatment of endodontically treated teeth with vertical root fracture: three case reports with two-year follow-up.	Cone beam computed tomography-assisted VRF diagnosis is helpful in detecting fractures; however, higher-resolution tomography units providing better image quality would be a better choice for improved visualization of these fractures.
da Silveira PF [49]	2013	60 single rooted teeth	Detection of vertical root fractures by conventional radiographic examination and cone beam computed tomography	If conventional imaging is not capable to provide adequate information, CBCT can be indicated if a root fracture is strongly suspected.
Avsever H [50]	2013	82 maxillary incisors	Comparison of intraoral radiography and cone-beam computed tomography for the detection of horizontal root fractures.	CBCT imaging offers the clear advantage over conventional imaging that traumatized teeth can be visualized in all three dimensions-especially the oro-facial dimension.

Table 4: Role of CBCT in the management of dento-alveolar trauma.

Author	Year	Sample	Study	Findings and conclusion
R Christiansen et al. [51]	2009	50 patients , 58 teeth	Periapical radiography and cone beam computed tomography forassessment of the periapical bone defect 1 week and 12 months after root-end resection	More remaining defects were detected 1 year after periapical surgery on CBCT images than on periapical radiographs
Christos Angelopoulos et al. [52]	2008	68 mandibular canals	Comparison Between Digital PanoramicRadiography and Cone-Beam ComputedTomography for the Identification of theMandibular Canal	The CBCT reformatted panoramic images outperformed the digital panoramic images in the identification of the mandibular canal
Kim TS et al. [53]	2010	12 Human mandibles	Comparison of cone-beam computed tomography and direct measurement in the examination of the mandibular canal and adjacent structures	Can be used to measure distances from the apices of the posterior teeth to the mandibular canal as accurately as direct anatomic dissection
Shekhar V [54]	2013	Case report	Cone beam computed tomography evaluation of the diagnosis, treatment planning, and long-term followup of large periapical lesions treated by endodontic surgery	It was concluded that CBCT was a useful modality in making the diagnosis and treatment plan and assessing the outcome of endodontic surgery for large periapical lesions.

Table 5: Role of CBCT in endodontic surgical planning.

Role of CBCT in Endodontic Surgical Planning

CBCT may play an important role in periapical surgery. The distance between the cortical plate and the root apex could be measured, and the presence or absence of the maxillary sinus between the roots could be assessed. Location of the lesion, position of the roots with in the bone, and the proximity of vital structures including the inferior alveolar nerve, mental foramen, maxillary sinus, and nasal cavity can be assessed. The true size, location and extent of the periapical lesion can also be appreciated. The cancellous bone pattern, fenestrations, as well as the inclination of the roots of teeth planned for surgery can be accurately determined preoperatively. Root morphology and bony topography can be visualized in three-dimensions, as can the number of root canals and whether they converge or diverge from each other (Table 5).

Assessment of Root Resorption

Treatment of resorption can be complex and unpredictable. Imaging is critical for accurate diagnosis and appropriate treatment .Conventional radiography does not provide the true and full representation of the lesion. CBCT has been shown to help and determine the treatment complexity as well as aid the clinician in offering an accurate prognosis on the basis of the extent of the resorptive lesion. As a result, both treatment and treatment outcomes are likely to become more predictable (Table 6).

Dental Anomalies

Anatomic variations should be carefully observed and considered during the diagnosis and treatment planning of teeth with anomalies in order to enhance the chances of success. The use of cone beam computed tomography (CBCT) is very helpful in endodontic diagnosis of complex anatomic variations. Root canal treatment of teeth with complex root canal anatomy such as dens invaginatus, fused root, talon's cusp, etc, can be problematic because infected pulpal tissues may be in inaccessible areas of the canal system. Cleaning and debridement of such root canal systems are therefore challenging. Conventional radiographs have limited role in the assessment of complex root canal morphologies. These modalities, however, do not provide detailed information of the complexity as a result of their inherent limitations. This calls for the use of more advanced imaging modalities such

Author	Year	Sample	Study	Findings and conclusion
S. Patel [55]	2009	15 teeth	Comparison of accuracy of intraoral periapical radiography with cone beam computed tomography (CBCT) for the detection and management of resorption lesions.	CBCT was effective and reliable in detecting the presence of resorption lesions
K. Kamburog˘ lu et al. [56]	2010	60 teeth	Comparison of the diagnostic accuracy of CBCT images of different voxel resolutions used to detect simulated small internal resorption cavities	Ultra-and high-resolution CBCT images performed similarly and better than low-resolution images in the detection of simulated internal resorption ex vivo.
V. S. H. Yu et al. [57]	2010	Case report	Case report on multiple idiopathic cervical resorption	CBCT demonstrated that the lesions were more extensive and more widely distributed than was seen using conventional radiography.
Roberto Estevez et al. [58]	2010	Case reprt	Invasive Cervical Resorption Class III managed using the aid of CBCT	CBCT is a very useful tool to achieve proper diagnosis and management of cervical resorption.
Kıvanc¸ Kamburo_glu, et al. [59]	2011	50 teeth	Observer Ability to Detect Ex Vivo Simulated Internal or External Cervical Root Resorption	High-resolution CBCT images performed better than film in the ex vivo detection and localization of simulated internal and external cervical root resorption.
Estrela C et al. [60]	2009	40 patients	Method to evaluate inflammatory root resorption by using cone beam computed tomography	CBCT seems to be useful in the evaluation of internal root resorption, and its diagnostic performance was better than that of periapical radiography.
Bhuva B et al. [61]	2011	Case report	The use of limited cone beam computed tomography in the diagnosis and management of a case of perforating internal root resorption.	This case report describes the use of CBCT in the diagnosis and treatment planning of a case of perforating internal root resorption.
Shokri A [62]	2013	54 teeth	Diagnosis of simulated external root resorption using conventional intraoral film radiography, CCD, PSP, and CBCT	For locations of root resorption, significant differences were found between CBCT and other methods in the apical regions. CBCT was only useful for detection of cavities located in the apical one-third of the root, compared to other digital or conventional methods
Castro IO [63]	2013	1256 roots from 30 Patients	Evaluation of apical root resorption due to orthodontic treatment detected by cone beam computed tomography	The results of this investigation showed that CBCT was effective for detecting in vivo even minimal degrees of ARR due to orthodontic treatment and allowed three-dimensional evaluation of dental roots and visualization of palatine roots of maxillary molars.

Table 6: Role of CBCT in the management of root resorption.

Author	Year	Sample	Study	Findings and conclusion
Kfir A [64]	2013	Case report	Management of complex type 3 dens invaginatususing cone beam computed tomography (CBCT) and 3D plastic models.	CBCT is a diagnostic tool that may allow for the management of such teeth with complex anatomy. 3D printed models may be a valuable aid in the process of assessing and planning effective treatment modalities and practicing them ex vivo before actually performing the clinical procedure.
Pradeep k [65]	2012	Case report	Management of Type III dens in denteUsing Cone Beam Computed Tomography.	Periapical radiographs are limited in revealing the type, extension, and complex morphology of dens invaginatus, as well as the actual bone loss. The reconstructed images from the CBCT data are particularly useful in assessing the true nature of the invagination, in particular, the relationship of the invagination with the root canal.
Narayana P [66]	2012	Case report	Management of a dens invaginatuscase by using a unique treatment approach	Endodontic clinical management of a tooth with dens invaginatus may be benefited by the inclusion of cone-beam computed tomography (CBCT) to aid in the diagnosis and treatment-planning phase
Vier-Pelisser FV [26]	2012	Case report	Use of cone beam computed tomography in the diagnosis, planning and follow up of a type III dens invaginatus case.	In this case the CBCT scans revealed that the periapical radiolucency was significantly larger than seen radiographically as well as an increased thickness of the buccal cortical plate. The authors concluded that CBCT may aid the diagnosis as well as the management plan and follow-up of teeth with this (Dens invaginatus) developmental anomaly.
Kaneko T [20]	2011	Case report	Management of dens invaginatus in a maxillary lateral incisor with the aid of cone-beam computed tomography	CBCT scan demonstrated inaccessible and unfilled canal and invagination areas because of complex internal morphology characterized by (i) C- or ring-shaped cross-sectional canal configuration with constrictions at different points in different root levels and (ii) a prominent intraradicular cavity that was communicated with the enamel-lined invagination and opened into the apical periodontium. CBCT is useful in the assessment of the feasibility in the treatment of dens invaginatus.
Durack C [67]	2011	Case report	Use of cone beam computed tomography in the management of dens invaginatus affecting a strategic tooth in a patient affected by hypodontia	The CBCT images facilitated the appropriate positioning of these orifices and provided valuable information regarding safe cavity dimensions and angulations.The authors concluded that, in this case, it is unlikely that endodontic treatment could have been as accurately planned and delivered as safely and successfully as it was without the aid of the CBCT images.
Patel S [68]	2010	Case report	Use of cone beam computed tomography in the conservative management of dens invaginatus	The true nature of dens invaginatus cannot always be estimated from conventional radiographs. Cone beam computed tomography is a useful diagnostic tool in the management of dens invaginatus. The reconstructed images from the CBCT data were particularly useful in assessing the true nature of the invagination, in particular, the relationship of the invagination with the root canal.

Baratto-Filho F [23]	2012	Case report	Multidisciplinary treatment involving a permanent maxillary lateral incisor fused to a supernumerary tooth with pulp necrosis and periapical lesion	CBCT scan and an operative microscope may help the diagnosis and facilitate root canal localization in cases of complex and varied morphology. In the present case, CBCT was performed to have a more detailed view of the complex root canal system morphology since CBCT enables three dimensional image reconstruction
Jaya R [69]	2013	Case report	Dilated invaginated odontome with talon cusp in a permanent maxillary central incisor diagnosed by cone beam computed tomography.	CBCT was useful in the interpretation of this complex tooth anomaly in multiple slices along the three axes. The reconstructed 3D CBCT images of the involved tooth revealed a complex structure comprising a ring-like formation of the root. The CBCT axial images revealed the pulp space to be compressed and discontinuous within the ring. As the CBCT revealed a very complex root canal anatomy not amenable to successful cleaning and shaping, the choice of surgical or non-surgical endodontics was ruled out and the tooth was extracted.
Kobayashi TY [70]	2013	Case report	Usefulness of cone beam computed tomography for treatment of complex odontoma.	In this case report, CBCT analysis enabled an accurate diagnosis of the localisation, extension, internal structure of the lesion, and the additional diagnosis of an impacted supernumerary tooth.
Liang RZ [71]	2012	Case report	Endodontic therapy of maxillary fused second and third molars, using cone-beam computed tomography	CBCT images clearly demonstrated the presence of fusion of the maxillary molars and the numbers, positions and morphologies of all root canals associated with each tooth. Examination of the CBCT images showed three slightly curved and patent root canals present in the maxillary second molar and a similar single canal in the fused third molar that merged with the distobuccal canal of the second molar.
Song CK [72]	2010	Case report	Endodontic management of supernumerary tooth fused with maxillary first molar by using cone-beam computed tomography.	In this case report, an iatrogenic communication between the maxillary first molar and the supernumerary tooth was observed in the CBCT image and was repaired by using flowable resin. The authors concluded that proper diagnosis and treatment planning for endodontic management of fused teeth by using CBCT can ensure predictable and successful results.

Table 7: Role of CBCT in the management of dental anomalies.

as CBCT, which can help the clinician in making a more accurate diagnosis. CBCT may aid the diagnosis as well as the treatment plan and follow-up of teeth with developmental anomalies. CBCT is a useful adjunct to the clinician's armamentarium in the endodontic treatment of anomalous tooth (Table 7).

To summerize, CBCT appears to be promising in the assessment and treatment of complex endodontic conditions such as:

a) Detection of suspected additional canals and unusual root and canal anatomy based on radiographic examination.

b) To assess the location and severity of root resorption. External and internal resorptions can be easily differentiated with CBCT.

c) To study the root canal system anomalies and for determination of direction and angulation of root curvature

d) To assess the dimensions of lesion or defect and its spatial relationship with vital structures before performing surgical endodontics

e) CBCT also plays vital role in the detection and management of dento-alveolar traumatic injuries, assessment of endodontic treatment complications, such as overextended root canal fillings, separated instruments, presence of denticles and diffuses calcification, and detection of iatrogenic perforations.

Limitations of CBCT

While the CBCT has documented advantages over other techniques, there are a few limitations that are reported. At present the images produced with CBCT technology do not have the resolution of conventional radiographs. The spatial resolution of conventional direct-action packet film and digital sensors is in the order of 15-20 line pairs/mm) [72]. CBCT images only have a spatial resolution of 2 line pairs/mm) [73]. However, the ability of this technology to demonstrate geometrically accurate images in all three dimensions and the elimination of anatomic noise facilitates the assessment of a number of features important in endodontic diagnosis, treatment, and long-term management. One significant problem, which can affect the image quality and diagnostic accuracy of CBCT images is the scatter and beam hardening caused by high density neighboring structures, such as enamel, metal posts and restorations. If this scattering and beam hardening is associated close to or with the tooth being assessed, the resulting CBCT images may be of minimal diagnostic value. In clinical Endodontic practice, CBCT scanners with a limited field of view might provide clearer images as they can avoid scanning structures outside the region of interest susceptible to beam hardening (e.g., metallic restorations, dental implants). Endodontic sealers have also been reported to produce artifacts that mimic fracture line. Reduction of voxel size has been suggested to minimize such artifacts. Women of childbearing age must be screened for pregnancy. In case of pregnancy, the benefits of performing a CBCT scan must be weighed against the possible risk to the fetus. But it should be remembered that, since the horizontal trajectory of the CBCT beam through the patient's jaw suggests that the patient's fetus would not be subjected to any direct radiation, and that the only exposure the fetus would receive would be from scattered radiation which is negligible, pregnancy is not an absolute contraindication for performing CBCT scan. Till date there are no reported fetal consequences due to CBCT scanning during pregnancy. Even though the exposure from CBCT is significantly less than that of Medical CT, it still utilizes ionizing radiation, hence a CBCT scan should be performed only if there is possibility that the scan would reveal additional important information not gained with conventional radiographs. Finally, scan durations are lengthy at 15-20 s and require the patient to stay absolutely still during that period.

Conclusion

Conventional radiographs have been used in endodontic practice for varied purposes. Radiography has its limitations in the form of anatomic superimposition, compression of three dimensional anatomy, geometric distortion, etc. Most of these limitations are overcome with the advent of three dimensional CBCT.CBCT has established itself as a highly useful tool in visualizing the exact root and canal anatomy, pathologic alterations, assessment or dentoalveolar trauma,

surgical assessment, assessment of root resorptions. Knowledge about CBCT will help clinicians to make the full use of this excellent three dimensional imaging system, starting from diagnosis to treatment outcome evaluation.

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