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REVIEW ARTICLE

Cone Beam Computed Tomography: A New Boon and a Ray of Hope to the Endodontist—A Series of Cases

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ABSTRACT

Aim: This article aims to provide comprehensive information related to the cone beam computed tomography (CBCT) as a diagnostic aid and its potential applications in dentistry.

Background: A study was done on 10 different patients with different findings, such as Radix entomolaris, calcifications, vertical root fracture, internal resorption, cystic lesion, perforation, radicular cyst, preparation for endo surgery. These all findings could not be diagnosed by two-dimensional (2D) imaging which were diagnosed with the help of CBCT.

Review results: Cone beam computed tomography is a revolutionary and innovative procedure that has changed the paradigms in the management of various endodontic conditions. Cone beam computed tomography offers speed and versatility to the practitioner and patient alike. Within few minutes of acquiring the scan, the dentist may fully explore the patient's three-dimensional (3D) image. The image can then be rotated, color-contrasted, and slices can be isolated and further analyzed. With its accurate and high-quality 3D representations, this technology offers tremendous improvements in diagnostic capabilities, eliminating surprises and minimizing the need for exploratory surgery.

Conclusion: Cone beam computed tomography is an invaluable endodontic tool for use before, during, and after treatment CBCT scanning drives diagnostic accuracy, which positively impacts clinical decisions, increases speed of treatment, and improves productivity and patient outcomes. In short, it has provided the greatest advancement in digital imaging over the past decade.

Clinical significance: When used for preoperative assessment, CBCT imaging provides highly detailed information on the entire tooth structure, including the location and number of canals, pulp chamber size and degree of calcification, curvature of root morphology, tooth and root fractures, inflammatory lesions and defects.

Keywords: Cone beam computed tomography, Endodontic diagnosis, Management of endodontic problems, Radiography.

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BACKGROUND

Cone beam computed tomography (CBCT) is a new medical imaging technique that generates three-dimensional (3D) images at a lower cost and absorbed dose compared with the conventional computed tomography (CT). It is also known as C-arm CT, cone beam volume CT, flat panel CT. First invented in European market in 1996 by QR SRL and into US market in 2001. Cone beam computed tomography or digital volume tomography (DVT) utilizes an extraoral imaging scanner which was developed in the late 1990's to produce 3D scans of the maxillofacial skeleton at a considerably lower radiation dose than conventional CT (Mozzo et al 1998, Arai et al 2001). The X-ray beam is cone-shaped (hence the name of the technique) and captures a cylindrical or spherical volume of data, described as the field of view. Cone beam computed tomography was introduced in the field of endodontics in 1990's.

Images were obtained using Kodak Carestream 9300C model CBCT machine in Government Dental College and Hospital, Aurangabad, Maharashtra.

The X-ray beam is pulsed, therefore, the actual exposure time is a fraction of this (2–5 s), resulting in up to 580 individual 'mini-exposures' or 'projection images' during the course of the scan. This contrasts with the continuous exposure of CT and conventional tomography, and affords the major advantage over CT scanners of substantially reduced radiation exposure. Further reduction comes from fast scanning times and the use of advanced image receptor sensors. The images to be displayed in the three orthogonal planes axial, sagittal and coronal simultaneously, allowing the clinician to gain a truly 3D viewing area of interest.

Selecting and moving the cursor on one image simultaneously alters the other reconstructed slices, thus allowing the area of interest to be dynamically traversed in 'real time'. Cone beam computed tomography is set to revolutionize diagnosis and management of endodontic problems. Cone beam CT scanners use simpler, less complicated, and (therefore, less expensive hardware (X-ray source and detector) than CT scanners and use powerful, but low cost computers (Baba et al 2004, Cotton et al 2007), which means that the cost of a CBCT scanner is significantly less than a CT scanner. This has resulted in an increase in its uptake in dental practices (Arnheiter et al).

Advantage of CBCT over CT is its significantly lower effective radiation dose.

The effective dose of CBCT scanners vary, but can be almost as low as a panoramic dental X-ray and considerably less than a medical CT scan.

The limited volume CBCT scanner is, therefore, best suited for endodontic imaging of only one tooth or two neighboring teeth. Indeed, the effective dose of one CBCT scanner (3D Accuimoto, J Morita, Kyoto, Japan) has been reported to be in the same order of magnitude as two to three standard periapical radiographic exposures (Arai et al 2001). Computed tomography and CBCT data are composed of a huge volume of data consisting of millions of 3D pixels called voxels.

Limitations of Conventional Radiograph

Compression of 3D anatomy: Conventional radiography compresses 3D structures on to a 2D image. The radiograph provides a visualization of the anatomy radiograph provides a visualization of the anatomy under examination in the mesiodistal plane, whilst affording very little appreciation of structures in the third (buccolingual) dimension.[1]

Furthermore, anatomical complexities and diseases affecting the dental hard tissues, such as resorption,[2] as well as operative procedural errors may not be appreciated if more accurate imaging are not used. Diagnostic performance is consequently impaired.[3]

Anatomical noise: Anatomy in, or projected over, the area of interest during conventional radiographic imaging may impair visualization of the object under investigation, and complicate interpretation of the radiograph. This anatomical interference can vary in radiodensity and is referred to as anatomical noise[4,5] which is avoided by the use of CBCT.

Geometric distortion: Geometric distortion by paralleling technique of intraoral periapical radiography is possible because of improper positioning of cone beam or film which is avoided in CBCT.

REVIEW RESULTS

Case 1

Extra Root

A 35 years old female presenting with spontaneous toothache and sensitivity to heat and cold which was clinically diagnosed as symptomatic irreversible pulpitis reported to the department. In conventional radiographs on orthopantomogram (OPG) and intraoral periapical (IOPA) radiography shows an presence of an extra root.

The presence of radix entomolaris (RE) in a mandibular first molar is a common occurrence in certain ethnic groups, but the presence of RE in a mandibular second molar is a rare occurrence. In the present case, RE was identified from preoperative radiographs and confirmed using CBCT. From the CBCT axial images, the RE was determined to have a type III curvature by the De Moor classification, type B separate RE by the Carlsen and Alexandersen classification, and radiographically, a type I image by the Wang classification. The presence of RE in the mandibular second molar makes it essential to anticipate and treat the distolingual root canal. The usefulness of CBCT for assessing RE in the mandibular second molar, which can help the clinician in making a confirmatory diagnosis and assessing the morphology of the root canal. Three-dimensional (Fig. 1) view extra root canals location, curvature and inclination was noted. Apical level axial view (Fig. 2) enlightened four canals in which the mesial roots were fused and distal roots were separated reducing the chances of postoperative complications.

Another case of extra root was reported. A 38 years old female presented to the department with throbbing night pain. Root canal treatment was started after conventional

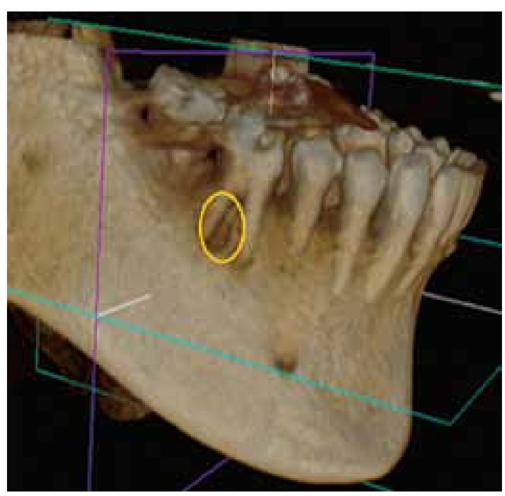


Fig. 1: Three-dimensional view

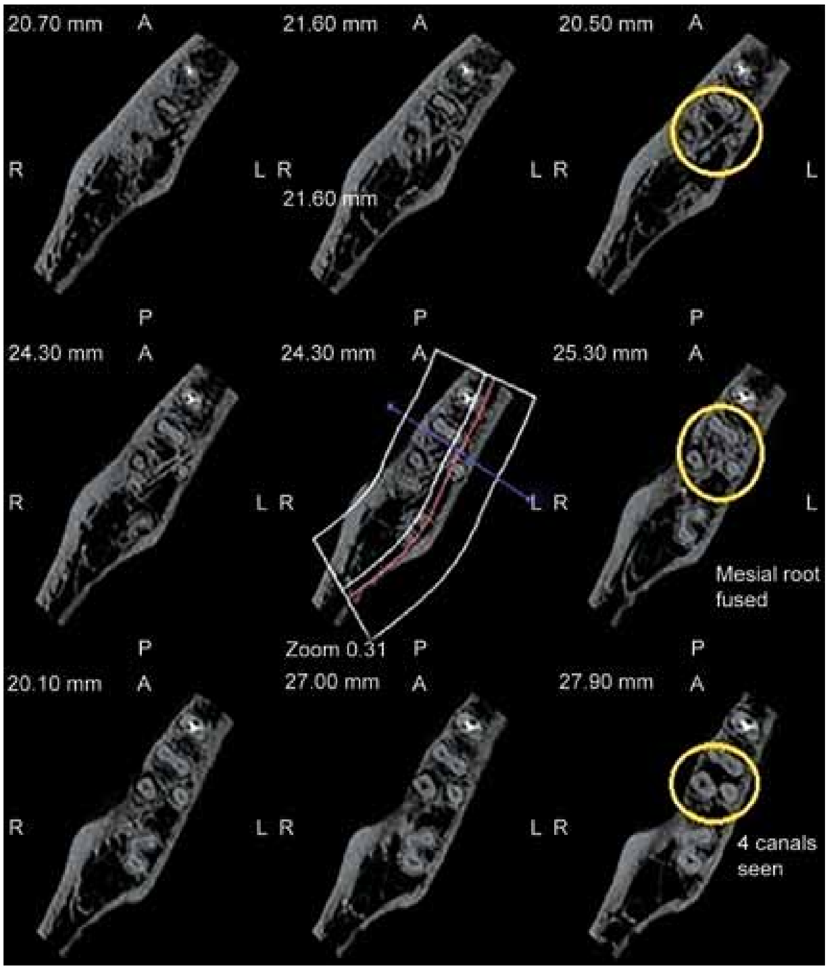


Fig. 2: Axial view-slice taken at apical level 4 canals are seen mesial roots are fused distal roots are separated

radiograph which revealed an extra root, but during the procedure the clinician was not sure whether the tooth had 4 or 5 canals because five orifices were seen. So, CBCT was advised.

Cone beam computed tomography when taken showed five canal orifices at pulp chamber level and four canals in middle and apical third (Fig. 3).

Case 2

Vertical Fracture

A 45 years old male presented with complaint of food lodgement with 37, gave history of root canal treatment 6 months back with the dislodged crown. On CBCT, a vertical fracture was seen in sagittal view (Fig. 4) which was not appreciated in the conventional radiographs (Fig. 5).

Identifying the presence of vertical root fractures (VRF) is often an endodontic challenge.[6] Clinical and radiographic evidence of the presence of root fractures does not always present itself until the fracture has been present for some time. However, even with longstanding VRF clinical signs of their existence maybe little more than a draining buccal sinus,[7] which is certainly not pathognomonic of the problem. While a deep, isolated, thin periodontal pocket is suggestive of VRF,[7] difficulty aligning the periodontal probe along the periodontal defect sometimes means this sign is missed. Radiographic features suggestive of VRF, such as J-shaped and halo-shaped radiolucencies[7] do not appear until significant bone destruction has occurred and similarly shaped radiolucencies may manifest themselves in cases of apical periodontitis not associated with VRF. *Ex vivo* studies have demonstrated that CBCT is more sensitive than conventional radiography in the detection of vertical fractures in roots.[8] However, care should be taken when assessing root filled teeth for VRF using CBCT as scatter produced by the root filling or other high-density intraradicular material may incorrectly suggest the presence of a fracture.[8]

Case 3

Thickening of Maxillary Sinus Lining

A 35 years old male was referred from the medical college for the complaint of fullness in upper left back region and was taking medicines since 3 months but was not relieved. After radiographic investigations it was found that 26 was

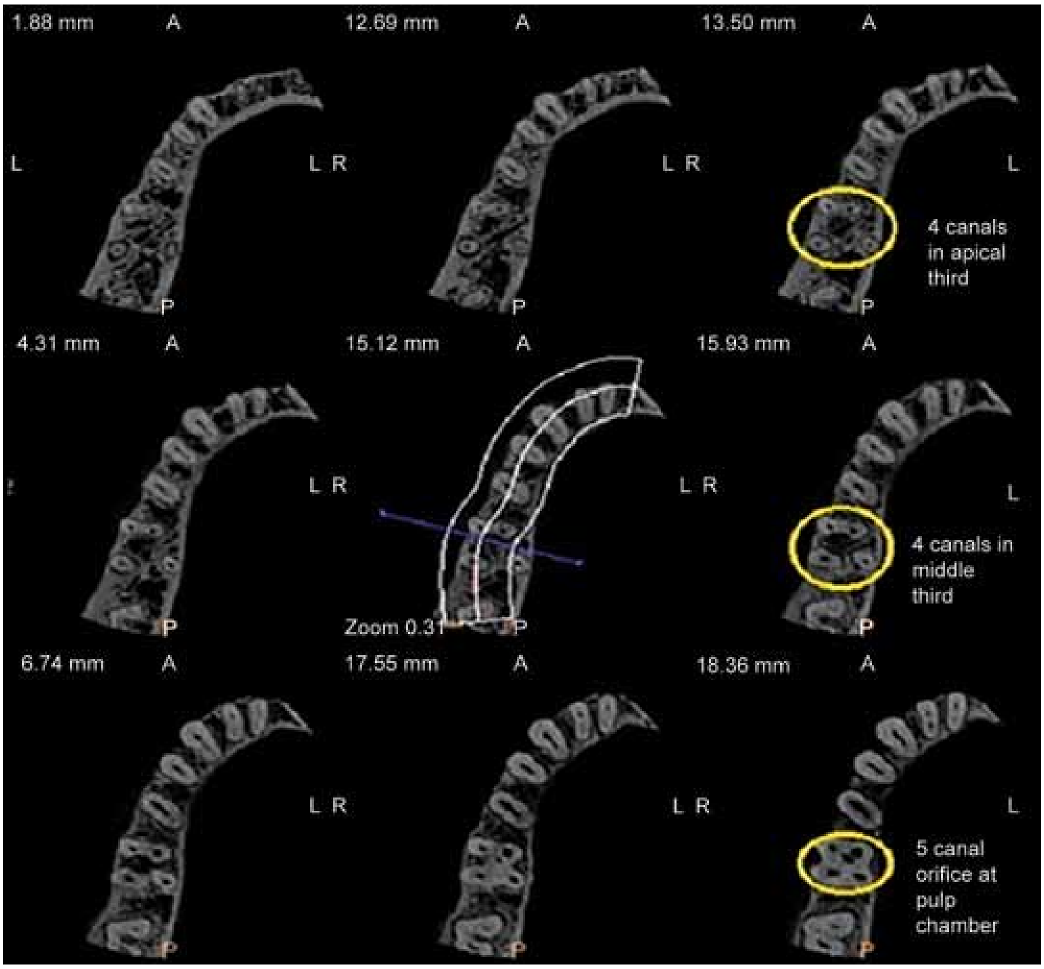


Fig. 3: Axial views at different levels 0.5 canal orifices at pulp chamber level and 4 canals in middle and apical third

carious. Cone beam computed tomography was advised. Thickening of lining was only diagnosed by CBCT (Fig. 6) which could not be possible by conventional radiographs. Cone beam computed tomography showing thickening of lining. The patient was then referred to ENT surgeon for management of sinusitis also.

Case 4

Radicular Cyst

A 21 years old male presented with pain, swelling, pus discharge with 11, 12 region since 1 year.

Conventional radiograph showed a large periapical radiolucency in 11,12,13. Cone beam computed tomography was advised to see the extent and further analysis of the lesion. On CBCT, 3D view (Figs 7A and B) suggested a large perforation extending from labial to palatal cortical plate. Root morphology and bony tomography was also visualized.

Relationship to the neighboring anatomical structure like-floor of maxillary sinus, floor of nose, etc. was seen. Linear and volumetric and measurements are taken (Fig. 8). This has an important role for planning periapical microsurgery.

Another case of an 18 years old female visited with discomfort in 12 tooth. Axial view show slices taken at apical third shows depth of the lesion and pattern of bone and these slices are 1 mm apart (Fig. 9). Another case was similar type was reported to the department. A 20 years old male reported to the department with pain and swelling in left side of the jaw since 2 and half year. Swelling is bony hard both extraorally and intraorally.

Teeth under question were tender on percussion conventional radiograph shows a large radiolucent lesion. Type of bone pattern, thickness of cortical bone, extent of the lesion, Inclination of the roots planned for surgery, exact periapical lesion (Fig. 10). Hence, CBCT is highly sensitive and specific for true nature and status of periapical lesion. Therefore, considering it as a gold standard. The exact nature and extent of the injuries to the teeth and the alveolar bone can be assessed accurately by eliminating anatomical noise and image compression, thereby allowing appropriate treatment to be confidently implemented. The degree and direction of displacement associated with luxation injuries can be evaluated easily using CBCT.[9] Furthermore, CBCT has been shown to be far more sensitive than multiple periapical radiographs in the detection of horizontal root fractures.[10] Failure to identify the presence of root fractures following dental

Fig. 4: Sagittal view of CBCT showing vertical root fracture

Fig. 5: Conventional radiograph taken

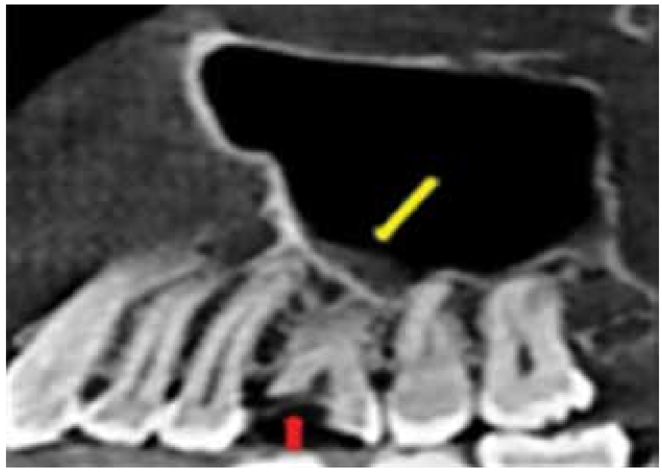
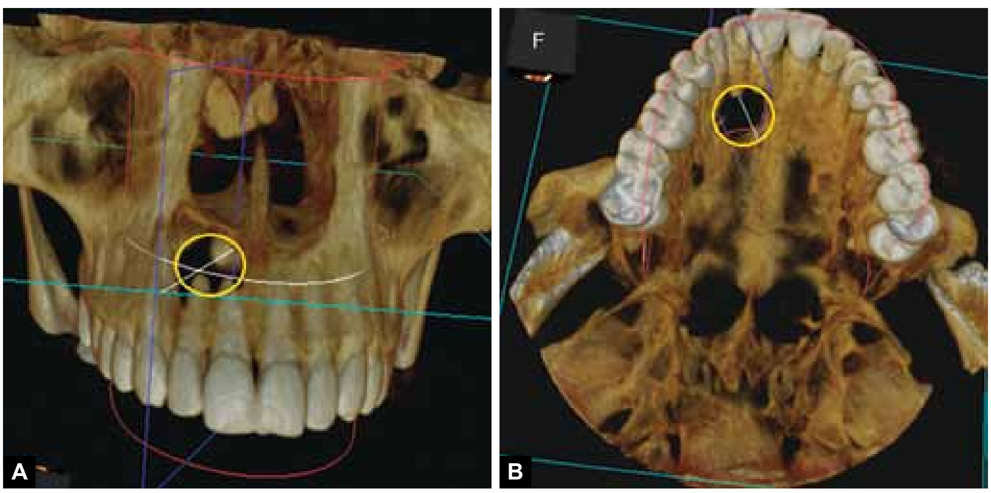


Fig. 6: Cone beam computed tomography showing thickening of lining



Figs 7A and B: Three-dimensional view suggested a large perforation extending from labial to palatal cortical plate

trauma may lead to inappropriate treatment and poorer prognoses for these teeth.

Case 5

Missed Canals MB2

A 28 years female came with complaint of pain with 16 tooth morphology of maxillary first permanent molars has been studied extensively for its complexity in canal configuration. It is well accepted that mesial root of maxillary first permanent molar contains more than one canal. Revealing the location of this second mesiobuccal (MB2) canal has proven to be the most formidable component of adequately treating these canals. Wolcott et al concluded that failure to find and treat the existing 2nd canal decreases the long-term prognosis.[11] Factors, such as ethnic background,[12] age[13,14] and gender may also play a role in imparting variations in canal morphology.

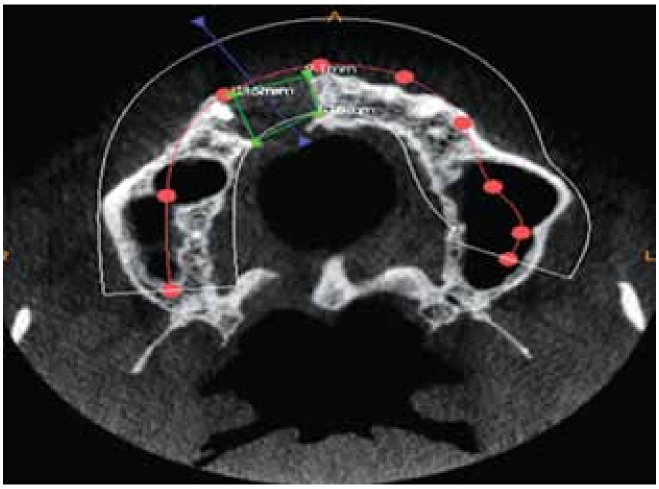


Fig. 8: Linear and volumetric measurements

- Various methods have been used to identify this 2nd canal. These include clearing technique combined with dye penetration,[15,16] cross-section analysis, conventional radiographic examination, macroscopic examination and magnification with operating microscope.

Root canal treatment was started but pain still persisted even after biomechanical preparation.

Various criteria have been proposed to consider the canal as a 2nd mesiobuccal canal. To be included and recorded as a 2nd mesiobuccal canal, the canal has to be traced till a depth of 4 to 5 mm from the cementoenamel junction (CEJ). Presence of additional canal beyond this depth was considered as an anatomic variation and not as a 2nd mesiobuccal canal.

Cone Beam Computed Tomography Views

Cone beam computed tomography showed MB2 canal which was missed by radiographs and clinically (Fig. 11). Success of an enododontic treatment depends on correct identification of the canal and knowledge of root morphology and anatomy of the tooth.

Case 6

Internal Resorption

A 20 years old female reported to the department with impacted 38 along with severe pain.

- Impacted 38 was surgically removed but pain still persisted.

Conventional radiograph revealed just an resorptive defect. But CBCT confirming an internal resorption extending below CEJ from middle to apical third indicating perforating type of resorption and from buccal to the labial surface revealing the true location and spread of resorption (Figs 12A and B).

The clinical diagnosis of root resorption relies on the radiographic demonstration of the process.[17] The sensitivity of conventional radiography is significantly poorer than CBCT in the detection of ERR in its early stages[18] and significant hard tissue damage may have potentially occurred to the affected tooth before the resorption becomes evident on conventional radiographs. Furthermore, when a diagnosis of root resorption is made based on conventional radiographic findings it must be remembered that external root resorption (ERR) superimposed on the root canal may mimic

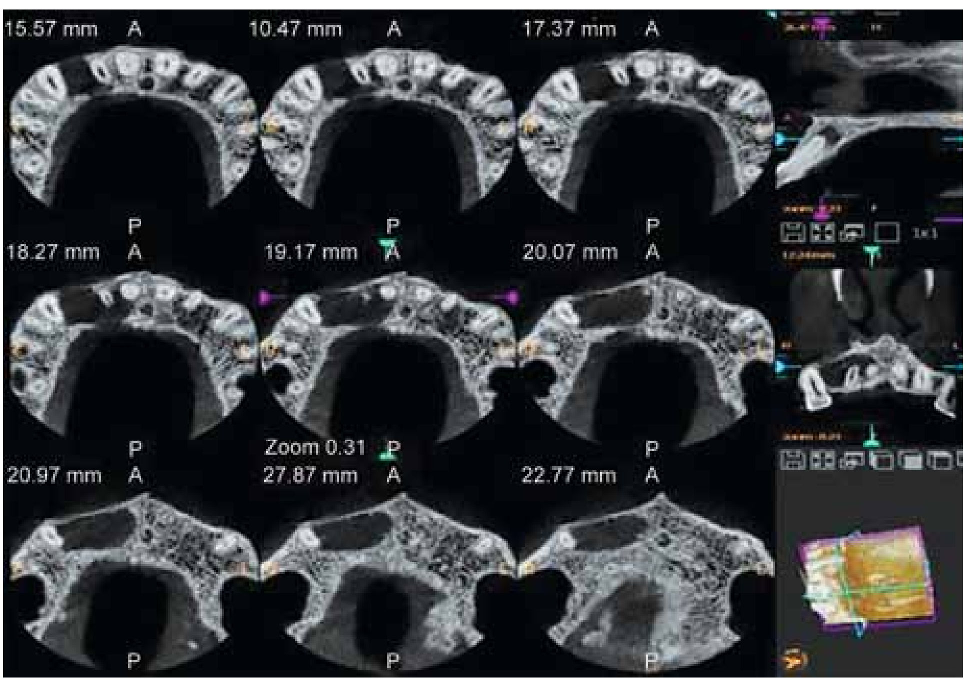


Fig. 9: Axial view-slices taken at apical third shows depth of the lesion and pattern of bone and these slices are 1 mm apart

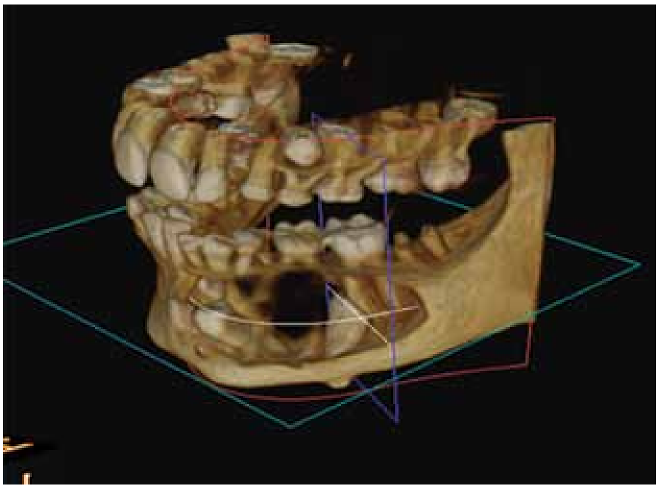
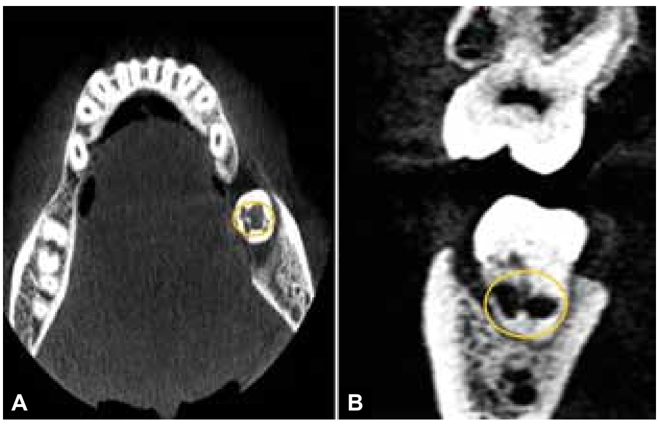


Fig. 10: Three-dimensional view of CBCT

Fig. 11: Second mesiobuccal canal on CBCT



Figs 12A and B: Cone beam computed tomography revealing the true location and spread of resorptive defect

internal resorption.[19] Differentiating between external cervical resorption (ECR) and internal resorption can be particularly difficult.[19] Clinical studies directly comparing the ability of intraoral radiographs and CBCT to detect and assess the nature of root resorption are limited. One clinical study did report that CBCT is superior to conventional radiography in diagnosing and determining the extension of nonspecific inflammatory resorption on root surfaces.[20] Patel et al,[21] in a further clinical study, compared the accuracy of conventional intraoral radiography and CBCT in the diagnosis and management of external cervical and internal resorption lesions. The authors reported CBCT to be 100% accurate in the diagnosis of the presence and type of the root resorption and the overall sensitivity of intraoral radiographs was lower than CBCT. These findings have been validated in *ex vivo* studies. Kamburoğlu et al[22] assessed examiner ability to identify and differentiate between simulated ECR and simulated internal root resorption (IRR) at the cervical region of the root canal, using CBCT and conventional, periapical radiography. Cone bean computed tomography performed statistically better than intraoral periapical radiography in the detection and localization of the simulated resorption cavities. It was concluded that CBCT is an effective and appropriate method for identifying and differentiating between incipient, simulated ECR and IRR cavities, whilst conventional radiography is not.

Case 7

C-Shaped Canals

A 28 years old female presented with pain in 42 tooth. But surprisingly on CBCT 4 teeth were having C-shaped canals and negotiation of such C-shaped canals is very challenging to diagnose on conventional radiographs (Fig. 13). Conventional radiographs frequently fail to disclose the number of canals in teeth undergoing nonsurgical root canal treatment.[23,24] Failure to identify and treat accessory canals can negatively influence treatment outcome.[25] Matherne et al[26] using an *ex vivo* human model demonstrated the superiority of CBCT over conventional radiography in detecting the presence of supplemental canals. Conventional radiographs failed to identify at least one root canal in 4 out of 10 of the

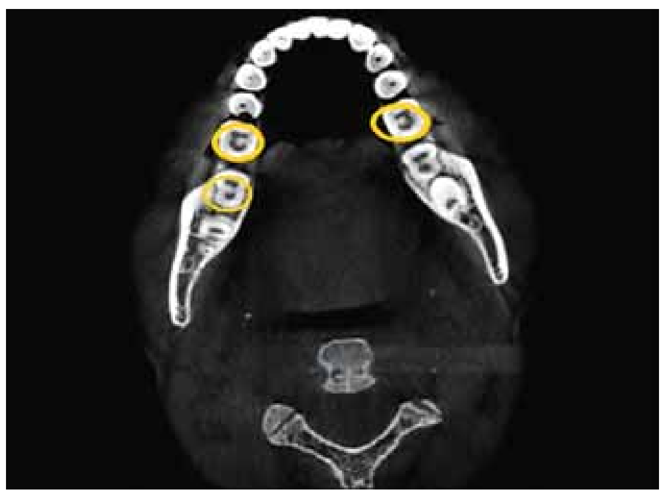


Fig. 13: Cone beam computed tomography showing C-shaped canals

examined teeth. Tu et al[23] reported a higher prevalence of distolingual roots in the mandibular first molar teeth of a Taiwanese population when they were assessed using CBCT (33%) as compared to when conventional radiographs were used (21%). Knowledge of the presence or absence of supplemental canals and roots prior to the commencement of treatment should lead to higher detection rates in the former and more conservative access cavity preparations in the latter.

DISCUSSION

Advantages of CBCT

Cone beam computed tomography is a revolutionary and innovative procedure that has changed the management of various endodontic conditions. As it is—major break-through in dental imaging, simple to use, take same space as panoramic machines, helps in diagnosing true cause, decreases in patients exposure by: decreasing the size of field of view, increasing the voxel size, decreases the number of projection images.

Limitations of CBCT

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 to 20 line pairs mm)[1] (Farman and Farman 2005). Cone beam computed tomography images only have a spatial resolution of 2 line pairs mm)[1] (Yamamoto et al 2003). However, as CBCT technology improves at a rapid rate, so may the resolution of the reconstructed scans.

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 (Mora et al 2007, Soğur et al 2007). When the CBCT X-ray beam encounters an object of very high density, such as enamel or metallic restorations, lower energy photons in the beam are absorbed by the structure, in preference to higher energy photons. The result is that the mean energy of the X-ray beam increases. This is called 'beam hardening' and the phenomenon produces two types of artifact: distortion of metallic structures, called 'cupping artifact', and the appearance of streaks and dark bands between two dense.

These artifacts can reduce the diagnostic yield of the images. Furthermore, patient movement during the scan can adversely affect the sharpness of the final image. Cone beam computed tomography imaging is sometimes affected by radiographic artifacts related to the X-ray beam.

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 (Lofthag-Hansen et al 2007, Estrela et al 2008). Finally, scan times are lengthy at 15 to 20 s and require the patient to stay absolutely still. Cone beam computed tomography makes it easy to analyze specific areas of interest and provides highly detailed anatomical information, which is very helpful and reliable in diagnosis.

CONCLUSION

Cone beam computed tomography is a valuable endodontic tool for use before, during, and after treatment. Cases outlined in this case series shows clinical situation that might benefit from further advance imaging to provide best clinical care. In short, it has the greatest advancement in digital imaging over the past decade.

CLINICAL SIGNIFICANCE

Cone beam computed tomography is a revolutionary and innovative procedure that has changed the paradigms in the management of various endodontic conditions. Cone beam computed tomography offers speed and versatility to the practitioner and patient alike. Within few minutes of acquiring the scan, the dentist may fully explore the patient's 3D image. Cone beam computed tomography imaging provides highly detailed information on the entire tooth structure, including the location and number of canals, pulp chamber size and degree of calcification, curvature of root morphology, tooth and root fractures, inflammatory lesions and defects.

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REFERENCES

1. Patel S, Dawood A, Whaites E, Pitt Ford T. New dimensions in endodontic imaging: part 1—conventional and alternative radiographic systems. Int Endod J 2009;42(6):447-462.
2. Durack C, Patel S, Davies J, Wilson R, Mannocci F. Diagnostic accuracy of small volume cone beam computed tomography and intraoral periapical radiography for the detection of simulated external inflammatory root resorption. Int Endod J 2011;44(2):136-147.
3. Webber RL, Messura JK. An in vivo comparison of digital information obtained from tuned-aperture computed tomography and conventional dental radiographic imaging modalities. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999;88(2):239-247.

4. Revesz G, Kundel HL, Graber MA. The influence of structured noise on the detection of radiologic abnormalities. Invest Radiol 1974;9(6):479-486.
5. Kundel HL, Revesz G. Lesion conspicuity, structured noise, and film reader error. Am J Roentgenol 1976;126(6):1233-1238.
6. Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. J Endod 1999;25(7):506-508.
7. Tamse A, Kaffe I, Lustig J, Ganor J, Fuss Z. Radiographic features of vertically fractured endodontically treated mesial roots of mandibular molars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;101(6):797-802.
8. Hassan B, Metska ME, Ozok AR, va der Stelt P, Wesselink PR. Detection of vertical root fractures in endodontically treated teeth by a cone beam computed tomography scan. J Endod 2009;35(5):719-722.
9. Patel S, Durack C. Section 7. Case 7.2. Lateral luxation. In: Pitt Ford's problem based learning in endodontology. Patel S, Duncan HF, editors. 1st ed. Chichester: Wiley Blackwell; 2007. p. 256-263.
10. Kamburoğlu K, Ilker Cebeci AR, Gröndahl HG. Effectiveness of limited cone-beam computed tomography in the detection of horizontal root fracture. Dent Traumatol 2009 Jun;25(3): 256-261.
11. Wolcott J, Ishley D, Kennedy W, Johnson S, Minnich S. Clinical investigation of second mesiobuccal canals in endodontically treated and retreated maxillary molars. J Endod 2002;28(6): 477-479.
12. Weine FS, Hayami S, Hata G, Toda T. Canal configuration of the mesiobuccal root of the maxillary first molar of a Japanese sub-population. Int Endod J 1999;32(2):79-87.
13. Fogel HM, Peikoff MD, Christie WH. Canal configuration in the mesiobuccal root of the maxillary first molar: a clinical study. J Endod 1994;20(3):135-137.
14. Neaverth EJ, Kotler LM, Kaltenbach RF. Clinical investigation (in vivo) of endodontically treated maxillary first molars. J Endod 1987;13(10):506-512.
15. Gulabivala K, Aung TH, Alavi A, Ng YL. Root and canal morphology of Burmese mandibular molars. Int Endod J 2001;34(5):359-370.
16. Omer OE, Al Shalabi RM, Jennings M, Glennon J, Claffey NM. A comparison between clearing and radiographic techniques in the study of the root-canal anatomy of maxillary first and second molars. Int Endod J 2004;37(5):291-296.
17. Andreasen JO. Experimental dental traumatology: development of a model for external root resorption. Endod Dent Traumatol 1987;3(6):269-287.
18. Durack C, Patel S, Davies J, Wilson R, Mannocci F. Diagnostic accuracy of small volume cone beam computed tomography and intraoral periapical radiography for the detection of simulated external inflammatory root resorption. Int Endod J 2011;44(2):136-147.
19. Patel S, Ricucci D, Durack C, Tay F. Internal root resorption: a review. J Endod 2010;36(7):1107-1121.
20. Estrela C, Reis Bueno M, Alencar AHG, Mattar R, Neto JV, Azevedo BC, et al. Method to evaluate inflammatory root resorption by using cone beam computed tomography. J Endod 2009;35(11):1491-1497.
21. Patel S, Dawood A, Wilson R, Horner K, Mannocci F. The detection and management of root resorption lesions using intraoral radiography and cone beam computed tomography: an in vivo investigation. Int Endod J 2009;42(9):831-838.
22. Kamburoğlu K, Kurşun S, Yüksel S, Oztaş B. Observer ability to detect ex vivo simulated internal or external cervical root resorption. J Endod 2011;37(2):168-175.
23. Tu MG, Tsai CC, Jou MJ, Chen WL, Chang YF, Chen SY, et al. Prevalence of three-rooted mandibular first molars among Taiwanese individuals. J Endod 2007;33(10):1163-1166.
24. Zheng Q, Xue-dong Z, Jiang Y, Sun T, Liu C, Xue H, et al. Radiographic investigation of frequency and degree of canal curvatures in Chinese mandibular permanent incisors. J Endod 2009;35(2):175-178.
25. Wolcott J, Ishley D, Kennedy W, Johnson S, Minnich S, Meyers J. A 5 years clinical investigation of second mesiobuccal canals in endodontically treated and retreated maxillary molars. J Endod 2005;31(4):262-264.
26. Matherne RP, Angelopoulos C, Kulilid JC, Tira D. Use of cone beam computed tomography to identify root canal systems in vitro. J Endod 2008;34(1):87-89.