Original Article

DIAGNOSTIC ACCURACY OF DIRECT DIGITAL RADIOGRAPHY & CONE BEAM COMPUTED TOMOGRAPHY IN DETECTING ROOT FRACTURES

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Abstract

Aim: - To evaluate diagnostic accuracy of direct digital radiography (DDR) and cone beam computed tomography (CBCT) in detection of root fractures (RFs).

Material and Method: - Twenty extracted human mandibular premolar teeth devoid of root fractures were divided into two groups of 10 teeth each according to the canals prepared with Hand Files (G1) and HyFlex rotary system (G2). The teeth were stabilized in copper rings filled with light body impression material, and a holder. A tapered chisel was inserted in the canal space and hydraulic machine was used to create fractures. The fractured teeth were inspected under the stereomicroscope to confirm the presence and number of root fractures (RFs). Human dry mandibles were coated with three layers of dental wax buccally and lingually to simulate soft tissue. The DDR images were made using paralleling technique. Then samples were scanned using CBCT in axial, sagittal & coronal planes. Number and orientation of fractures were evaluated in both DDR images and CBCT scans.

Results: - More number of fractures was observed using CBCT (102) as compared to DDR (26). CBCT (P value 0.210) was more effective in detecting fractures than DDR images (P value 0.833). More number of RFs were detected in G2 (HyFlex) than G1 (Hand Files). Axial sections of CBCT showed more number of RFs than sagittal and coronal. Mesiodistal fractures were detected only in CBCT scans.

Conclusion: - CBCT is superior in diagnosing most of the RFs as compared to DDR.

Keywords: - Root fractures, CBCT, DDR, HyFlex file

Introduction

The clinical and radiographic diagnosis of root fractures (RFs) is often complicated. A local deep pocket, dual sinus tracts, and a halo type of lateral radiolucency are among the symptoms. [1–8] Often these symptoms are not convincing to justify tooth extraction, which usually is the elected treatment because the prognosis of RFs is guarded. Therefore, the exact diagnosis of a RF is crucial to avoid erroneous extraction. However, because of the two-dimensional nature of periapical radiographs (PRs) and the inherent superimposition projection artifacts, visualizing a RF is difficult, especially when the fracture line is mesiodistally oriented. [9] The presence of a RF is only confirmed by direct visualization. [10] This may sometimes be accomplished by means of a surgical diagnostic flap, which is quite invasive. Conventional radiographs can be helpful for the diagnosis when the X-ray beam is parallel to the plane of the fracture, but this is scarcely possible.

Cone beam computed tomography (CBCT) scans were found superior to PRs in detecting RFs. [10] These scans use a cone-shaped x-ray beam to acquire a three-dimensional scan of the patient head in a single 360^0 rotation.[11-21] CBCT systems vary in their image quality and ability to visualize anatomic structures. [22–27] This variation is most prominent with small and delicate anatomic structures such as periodontal ligament and trabecular bone. Several scanning and reconstruction factors including scan field of view (FoV) selection and voxel size, the number of basis projections (acquisitions) used for reconstruction, and image artifacts have significant influence on image quality in CBCT.[28,29] Hassan B *et al* detected RFs in endodontically treated teeth prepared with ProTaper rotary system by a Cone Beam Computed Tomography. They concluded that CBCT are more accurate than PRs for detecting vertical root fractures. [30-35] Additionally, the selection of the reconstruction plane (axial, saggital, or coronal) used for the detection of different root fractures or the type of tooth have an influence on RF detection.

With technological advancements, canal preparation techniques have evolved rapidly in recent years. The introduction of rotary nickel-titanium instruments for canal preparation has changed canal shape, size and taper compared to hand instrumentation. The remaining dentin thickness has been lessened in teeth prepared with rotary instruments as compared to hand instruments and hence, these teeth are more prone to fracture.

In the past vertical root fractures have been studied mostly in relation to Protaper rotary files.[30] Recently HyFlex rotary files were introduced having improved flexibility, resistance to cyclic fatigue, good adaptation to the canal space anatomy. Remaining dentine thickness available with this system is more as compared to other rotary system (apical preparation 4%) so the number and pattern of fracture might change. As there are no studies on nature of fractures generated by these files, they were chosen and compared with K- flex hand files in this study to detect the number and orientation of root fractures by using CBCT and DDR. As CBCT and DDR both are digital techniques, periapical radiographs were taken by DDR. To evaluate the accuracy of two radiographic techniques to detect number of fractures, the teeth were evaluated under stereomicroscope before and after inducing fractures.

Methodology

Twenty freshly extracted human mandibular premolars were obtained from the department of Oral and Maxillofacial surgery. They were stored in sterile solution at room temperature until use. The teeth surfaces were cleaned by ultrasonic scaler and were inspected under stereomicroscope for the absence of root fractures. Access opening was made and working length was determined.

Teeth were divided into two groups: G1 and G2 of 10 teeth each. The G1 group was prepared with Hand K- flex file, using step-back technique from no.15 to 40 (0.02 taper). G2 group was prepared with HyFlex rotary files. Orifice opening was done with 25 number 8% file. Apical preparation was done by 4% 20 number upto the working length followed by 4% 25 number upto the working length. Middle portion of the canal were shaped with 6 % 20 number and again apical preparation was done with 4 % 30 number upto the working length followed by 4 % 40 number upto the working length.

The teeth of both the groups were stabilized in copper rings filled with light body impression material, and a holder was used to fix the samples in place. A tapered chisel was inserted in the canal space (Figure 1a) and hydraulic machine (Sirio dental Srl Italy, p400) (Figure 1b) was used to create fractures.

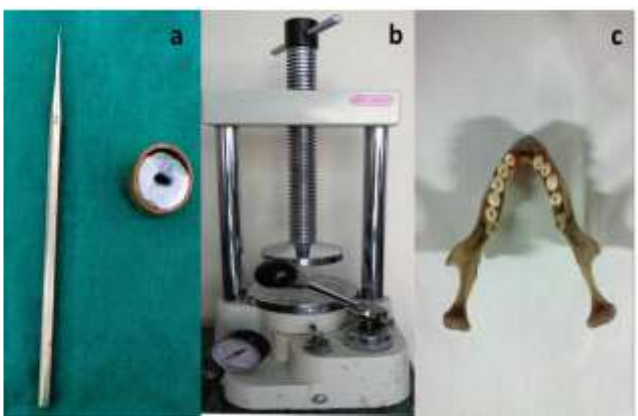

Figure 1: - (a) Chiesel with copper ring, (b) Hydraulic machine, (c) Teeth placed in dry human mandible

These fractured teeth were inspected again under the stereomicroscope to observe the number of root fractures. To simulate the effect of bone on the quality of image, dry human mandible was taken to stabilize the teeth (fig 1c). Mandible was coated with three layers of dental wax buccally and lingually to simulate soft tissue and to fix the teeth in the sockets. Direct digital images were captured with a dental X-ray Unit (70 Kv, 8 ma, KDS INDIA) and DDR (KODAK RVG 5100) with Sensor measuring 35mm x 15mm using paralleling cone technique. These images were adjusted for brightness and contrast by using software provided by the Kodak RVG. (Figure 3a)

These samples were again scanned using CBCT (CS9300 Carestream, 84Kv 5mA, 19.96s, 607 mGy cm^2, 90µm × 90µm × 90µm) (Figure 2a, 2b). The scanner had a radiation field of 30 mm height and 40 mm width at the centre of rotation. The imaging time was 17.5 sec at 80 kv 5mA. The size of the isotrophic voxel was 0.125 mm. The 3 DX images were optimized for the visualization of the effected teeth by re-slicing in different planes and adjusting histograms by using software supplied with machine.

The diagnosis of the fracture on the DDR (Figure 3a) and CBCT images (Figure 3b, 3c, 3d) was based on direct visualization of a radiolucent line which traversed the root separating it partially or completely into two segments. The axial, saggital & coronal images were created to study the number and orientation of fracture. (Figure 3b, 3c, 3d). The roots were considered fractured when a fracture line was detected on any of these slices. The results from both types of images were compared with the findings of stereomicroscopy. This helped to establish the diagnostic accuracy of CBCT and DDR in detection of root fractures. The observations were tabulated and the results were subjected to statistical analysis. Chi Square test and Fisher Exact test was used to assess differences between the groups.

Figure 2: - (a) Carestream CBCT With Mandible Placed. (b) 3D view

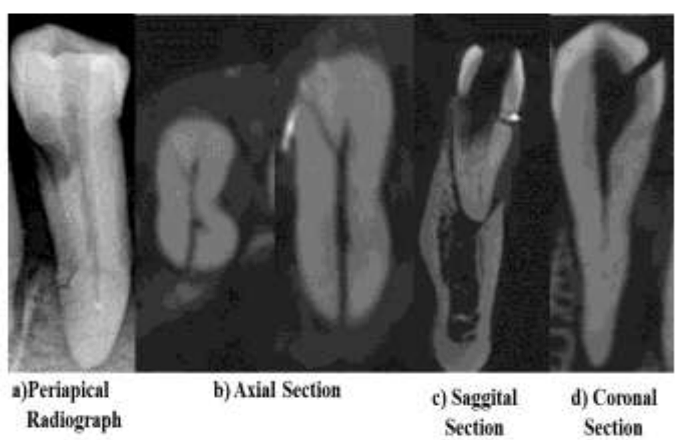

Figure 3: - Periapical radiograph and various slices of CBCT

Results

More number of fractures was observed by using CBCT (102) than DDR (26). (Table 1 and 2). CBCT (P value 0.210) was more effective in detecting fractures as compared to DDR (P value 0.833) (table 3). More number of RFs were detected in G2 (HyFlex) (64) than G1 (Hand Files) (54). Out of 54 fractures observed under stereomicroscope in Group I only 17 (31.5%) was seen under DDR and 49 (90.7%) were observed under CBCT. Out of 64 fractures observed under stereomicroscope in Group II 9 (14.1%) were observed under DDR and 53 (82.8%) were seen under CBCT. Axial sections of CBCT showed more number of VRFs than saggital and coronal. Mesiodistal fractures were detected only in CBCT SCANS. (Table no 4)

Table No. 1 GROUP I (HAND FILES)

	TOTAL NUMBER OF FRACTURES AS SEEN UNDER					
Sample Number	Stereo microscope	PRS	**CBCT**			
			Axial	**Saggital**	**Coronal**	**Total**
1	6	2	3	1	1	5
2	7	2	2	1	1	4
3	4	1	2	0	1	3
4	5	2	2	1	1	4
5	5	1	3	1	1	5
6	6	1	3	1	1	5
7	5	2	2	2	1	5
8	5	2	3	3	2	8
9	6	2	2	2	1	5
10	5	2	2	1	2	5
Total	**54**	**17**	**24**	**13**	**12**	**49**

Table No. 2 GROUP II (HyFlex FILES)

	TOTAL NUMBER OF FRACTURES AS SEEN UNDER					
Sample Number	Stereo microscope	PRS	CBCT			
			Axial	**Saggital**	**Coronal**	**Total**
1	7	0	3	2	2	7
2	6	0	3	1	1	5
3	6	1	3	1	1	5
4	5	1	2	1	1	4
5	4	2	2	1	1	4
6	7	0	3	1	1	5
7	7	1	3	1	1	5
8	7	1	2	2	2	6
9	8	2	3	2	1	6
10	7	1	3	1	2	6
Total	**64**	**9**	**27**	**13**	**13**	**53**

Table No. 3. Number of Fractures in Two Groups as Seen Under Stereomicroscope, DDR And CBCT.

S. NO.	**STEREO MICRO SCOPE**	**DDR**	**CBCT**	**P value**
Number of fractures in group I	54	17 (31.5%)	49 (90.7%)	<0.0001*
Number of fractures in group II	64	9 (14.1%)	53 (82.8%)	<0.0001*
P value		0.833	0.210	

**significant at 0.05 significance level Nominal scale variables were described using absolute frequencies and percentages, and the chi-square test was used to assess differences between the groups. Fisher exact test was used if sample size was small (expected frequencies <5). P<0.05 was considered statistically significant.*

Table no 4. Number of Fractures According To Orientation In Two Groups

Group No.	**Buccolingual fractures**	**Mesiodistal fractures**	**Vertical fractures**	**Horizontal fractures**	**Oblique fractures**
Group I	09	11	09	05	08
Group II	08	08	10	05	10

Discussion

This study investigated the value of CBCT in the diagnosis of number and orientation of root fracture as compared to periapical radiograph by direct digital radiography in teeth prepared with both hand and rotary files. As compared to the fractures detected under stereomicroscope, more number of fractures were detected by CBCT as compared to periapical radiograph. In the study conducted by Hassan *et al*[30] also the sensitivity of CBCT for artificial root fracture detection were 79.4%. In Bernardes *et al*[37] report of 20 patients with suspected root fractures CBCT clearly viewed root fractures in 18 cases whereas conventional radiographs could show root fracture in only two cases. This is due to the fact that conventional radiographs can be helpful for the diagnosis when the X-ray beam is parallel to the plane of fracture. But this is not possible for all types of orientation of fractures. Superimposition of neighboring structures further limits the ability to detect root fracture by using periapical radiograph. In contrast the three-dimensional nature of CBCT scans allows visualizing the fracture line from multiple angles and different orientations at very thin slices and at a very high contrast.

Axial slices were more accurate than coronal and saggital ones in detecting RFs. RFs extend by definition longitudinally onto the root surface. Therefore, it is logical that a horizontal cross-section perpendicular to the RF should provide the best detection. So, fracture line orientation had significant influence on the detection accuracy. This corroborates a previous finding that CBCT is insensitive to VRF line orientation because of its three-dimensional nature.[16]

More number of fractures was seen in CBCT as compared to DDR.[35] Since 3D techniques such as CBCT rely on many projections acquired from a circle around the object the chances of having the fracture visualize on some of these projections are much higher. Fractures in mesiodistal direction were also detected by CBCT in coronal and saggital section which were not visible in DDR. Although number of fractures detected under CBCT was more as compare to periapical radiograph but still all the fractures seen under the stereomicroscope were not visible. Visualizing fractures in transmission light is only dependent on the probability that is sufficient number of measured rays is tangent to the fracture line so more number of fractures could be detected under stereomicroscope. In CBCT the fracture confined to the root apex was sometimes not distinguishable from root resorption; and the theoretical spatial resolution of CBCT in this study was 0.25 mm. Owing to the Nyquist theorem, two voxel sizes are required to be able to detect the structure.[34] This also meant that the fracture lines with a width less than 0.25 mm could not be detected. Additionally, there are some limitations for CBCT imaging. The presence of beam hardening and streak artifacts often compromises the quality of images. There is a lot of training needed for interpreting 3D images and a radiologist report is required for every scan. Consequently, CBCT scans should be preserved for those cases where root fractures are suspected, not confirmed, by clinical signs and periapical radiographs.

Conclusion

CBCT is superior to conventional radiography in detection of root fractures. But still all root fractures were not detected by CBCT as observed under stereomicroscope. Axial CBCT scans were ideal for the diagnosis of fractures because the plane is perpendicular to the fracture line. Coronal and saggital section can detect fractures in mesiodistal direction also. Rotary files can cause more number of root fractures than hand files.

References

1. Tamse A, Fuss Z, Lustig J, Ganor Y, Kaffe I. Radiographic features of vertically fractured, endodontically treated maxillary premolars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1999;88(3):348–52.
2. Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. J Endod. 1999;25(7):506–8.
3. Tamse A, Kaffe I, Lustig J, Ganor Y, 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.
4. Tamse A. Vertical root fractures in endodontically treated teeth: diagnostic signs and clinical management. Endod Topics. 2006;13:84–94.
5. Krell KV, Rivera EM. A six year evaluation of cracked teeth diagnosed with reversible pulpitis: treatment and prognosis. J Endod. 2007;33(12):1405–7.
6. Opdam NJ, Roeters JJ, Loomans BA, Bronkhorst EM. Seven-year clinical evaluation of painful cracked teeth restored with a direct composite restoration. J Endod. 2008;34(7):808–11.
7. Shemesh H, van Soest G, Wu MK, Wesselink PR. Diagnosis of vertical root fractures with optical coherence tomography. J Endod. 2008;34(6):739–42;.
8. Pitts DL, Natkin E. Diagnosis and treatment of vertical root fractures. J Endod. 1983;9(8):338–46;.
9. Rud J, Omnell K. Root fractures due to corrosion. Diagnostic aspects. Scand J Dent Res. 1970;78(5):397–403.
10. Moule AJ, Kahler B. Diagnosis and management of teeth with vertical root fractures. Aust Dent J. 1999;44(2):75–87.
11. Youssefzadeh S, Gahleitner A, Dorffner R, Bernhart T, Kainberger FM. Dental root fractures: Value of CT in detection. Radiology 1999;210(2):545–9.
12. Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64- Slice CT for oral and maxillofacial radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106(1):106–14.
13. Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG. Endodontic applications of cone-beam volumetric tomography. J Endod. 2007;33(9):1121–32.
14. Loubele M, Bogaerts R, Van Dijck E, Pauwels R, Vanheusden S, Suetens P *et al*. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. Eur J Radiol. 2009;71(3):461–8.
15. Tsiklakis K, Donta C, Gavala S, Karayianni K, Kamenopoulou V, Hourdakis CJ. Dose reduction in maxillofacial imaging Using low dose cone beam CT. Eur J Radiol. 2005;56(3):413–7.
16. Patel S, Dawood A, Ford TP, Whaites E. The potential applications of cone beam Computed tomography in the management of endodontic problems. Int Endod J. 2007;40(10):818–30.

17. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol. 1998;8(9):1558–64.
18. Kobayashi K, Shimoda S, Nakagawa Y, Yamamoto A. Accuracy in measurement of distance using limited cone-beam computerized tomography. Int J Oral Maxillofac Implants. 2004;19(2):228–31.
19. Araki K, Maki K, Seki K, Sakamaki K, Harata Y, Sakaino R *et al*. Characteristics of a newly developed Dentomaxillofacial X-ray cone beam CT scanner (CB MercuRay): system configuration and physical properties. Dentomaxillofac Radiol. 2004;33(1):51–9;.
20. Sukovic P. Cone beam computed tomography in craniofacial imaging. Orthod Craniofac Res. 2003;6(suppl 1):31–6 discussion 179-82.
21. Arai Y, Tammisalo E, Iwai K, Hashimoto k, Shinoda K. Development of a compact computed Tomographic apparatus for dental use. Dentomaxillofac Radiol. 1999;28(4):245–8.
22. Loubele M, Guerrero ME, Jacobs R, Suetens P, van Steenberghe D. A comparison of jaw Dimensional and quality assessments of bone characteristics with cone-beam CT, Spiral tomography, and multi-slice spiral CT. Int J Oral Maxillofac Implants. 2007;22(3):446–54.
23. Loubele M, Maes F, Schutyser F, Marchal G, Jacobs R, Suetens P. Assessment of bone segmentation quality of cone-beam CT versus multislice spiral CT: A pilot study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;102(2):225–34.
24. Loubele M, Maes F, Jacobs R, van Steenberghe D, White SC, Suetens P. Comparative study of image quality for MSCT and CBCT scanners for dentomaxillofacial radiology applications. Radiat Prot Dosimetry 2008;129(1-3):222–6.
25. Mischkowski RA, Scherer P, Ritter L, Neugebauer J, KeeveE, Zoller JE. Diagnostic quality of multiplanar Reformations obtained with a newly developed cone beam device for maxillofacial imaging. Dentomaxillofac Radiol 2008;37(1):1–9.
26. Kwong JC, Palomo JM, Landers MA, Figueroa A, Hans MG. Image quality produced by different Conebeam computed tomography settings. Am J Orthod Dentofacial Orthop. 2008;133(2): 317–27.
27. Bryant JA, Drage NA, Richmond S. Study of the scan uniformity from an i-CAT Cone beam computed tomography dental imaging system. Dentomaxillofac Radiol 2008;37(7):365–74.
28. Liang X, Jacobs R, Hassan B, Limin Li, Pauwels R, Corpas L *et al.* A comparative evaluation of dentomaxillofacial CBCT and MSCT image data—Part I: on subjective image quality. Eur J Radiol 2010;75(2):265-269.
29. Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG. Endodontic applications of cone beam volumetric tomography. J Endod 2007;33(9):1121-32.
30. Hassan B, Metska Me, Ozok AR, van 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) 719-22.
31. Ilguy D, Ilguy M, Fisekcioglu E, Bayirli G. Detection of jaw and root fractures using cone beam computed Tomography. Dentomaxillofac Radiol. 2008;38(3):169–173.
32. Hassan B, Metska Me, Ozok AR, van der Stelt P, Wesselink PR. Comparison of Five Cone Beam Computed Tomography Systems for the Detection of Vertical Root Fractures. J Endod. 2010;36(1):126-9.
33. Zou X, Liu D, Yue L, Wu M. The ability of cone-beam computerized tomography to detect vertical root fractures in endodontically treated and non-endodontically treated teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111(6):797-801.
34. Wang P, Yan XB, Lui DG, Zhang WL, Zhang Y, Ma XC. Detection of dental root fractures by using cone-beam computed tomography, Dentomaxillofac Radiol 2011;40(5):290–298.
35. Kambungton J, Janhom A, Prapayasatok S, Pongsiriwet S. Assessment of vertical root fractures using three imaging modalities: cone beam CT, intraoral digital radiography and film. Dentomaxillofac Radiol 2012;41(2):91–95.
36. Kajan ZD, Taromsari M. Value of cone beam CT in detection of dental root fractures. Dentomaxillofac Radiol 2012;41(1):3–10.
37. Bernardes RA, de Moraes IG, Duarte MA, Azevedo BC, Azevedo JR, Bramante MB. Use of cone-beam volumetric tomography in the diagnosis of root fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:270-277.

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