

Diagnostic Accuracy of Different Resolutions of Cone Beam Computed Tomography Imaging System for Detection of Vertical Root Fractures In Presence of Casting Posts

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Abstract

Objective: The diagnosis of vertical root fracture (VRF) in endodontically treated teeth is a clinical challenge due to lack of specific clinical and radiographic signs. Although radiographic evaluation such as CBCT is helpful, intracanal posts can produce artifacts and may impair the quality of CBCT scans. This study aimed to compare the diagnostic accuracy of different resolutions of CBCT in detection of VRF in roots with casting post.

Methods: Eighty extracted human premolars were under went routine endodontic procedure and cast posts were subsequently prepared. The teeth were randomly divided into two groups. The fracture lines were induced by an Instron machine in test group, while the teeth in control group had no fracture. The teeth were scanned by CBCT with two voxel resolution protocols (0.15mm and 0.2mm). Three observers assessed the scans for presence of VRF on a 5-point scale. Diagnostic accuracy indices were estimated and the difference were analyzed with the Mann-Whitney test ($p < 0.05$).

Results: Probabilistic sensitivity for 0.15mm and 0.2mm resolution was 59.16 (5.2) and 46.66 (16.64), respectively. Furthermore, probabilistic specificity for 0.15mm resolution was 56.16 (15.21) and for 0.2mm was 61.66 (8.77). There were no statistical differences between different resolutions in all diagnostic values including sensitivity, specificity, positive and negative predictive values ($p > 0.05$).

Conclusion: Diagnostic ability of CBCT in presence of casting posts was not influenced by system resolution. According to ALARA principle, 0.2mm voxel resolution protocol is recommended in these cases.

Key words: Cone Beam Computed Tomography, Post, Tooth fracture.

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Introduction:

Vertical root fracture (VRF) extends from root canal toward the periodontium and occurs primarily in the faciolingual plane (1, 2). VRF can be vertical or oblique and involve the root only or both the root and the crown (3). Depending on the nature of the stress factors, VRFs usually originate from the apical end of the root and spread coronally or can originate

from the cervical portion of the root with extension in an apical direction(4). Endodontically treated teeth and those with extensive restorations are more susceptible to VR F(5). The etiology of the VRF is often iatrogenic and can be secondary to the post or pin placement (6). VRF is reported in 3.7 - 30.8% of cases (7). Since there is no distinct clinical means for VRF detection, such as transillumination or bite test, its diagnosis is

more problematic compared with fractures in other parts of the tooth (8). Thus, a thorough clinical and radiographic inspection with special attention to long pain history, swelling and localized chronic infection, tooth mobility, isolated deep periodontal pocket, marginal sinus tract, abscess, tenderness to percussion, deep bony defects and periapical or lateral radiolucencies, can lead to a better diagnosis (5, 9-11).

The clinical and radiographic signs and symptoms of VRF can be misdiagnosed by similar situations like aggressive periodontal disease or failures in endodontic therapy such as untreated accessory canal or root perforations (3, 12). Definite diagnosis can be reached only by direct observation with or without surgical intervention (7). In general, radiographic examinations are the most practical for VRF detection (8). Conventional and digital intraoral radiography have been the most helpful till now (13), but the fracture line is detectable only when the beam is exactly parallel to it (8, 11). Since most of the time the beam traverses obliquely through the fracture line, different radiographies with dissimilar angles are needed which lead to increased patient radiation dose; thus the intraoral radiographs are not always efficient for VRF detection (14). Furthermore, VRF is not distinct in radiographs when there is no displacement between the root fragments and subsequent soft tissue growth (13, 15). Both conventional and digital intraoral radiography show low sensitivity for VRF detection which is due to the factors such as the anatomical superimpositions, unparallel beam angulation and 2D image of the 3D structures (8, 16). Recently, CBCT introduced as a new method, has reached acceptability in most of the dentistry fields (17); especially for the capability of supplying 3D images in every plane and overcoming superimpositions (11). CBCT is better for VRF detection than conventional radiography despite its increased radiation dose

(18). The amount of radiation depends on the voxel resolution and exposure time. The lower the voxel resolution size, the higher the radiation dose due to more image sections (11). CBCT has been approved in some studies for VRF detection in endodontically treated teeth (11, 19, 20). Higher contrast resolution and visualization of images in 3D mode provide more precise information about VRF. Many factors including FOV (field of view), voxel size, number of basic projections and image artifacts can affect the image quality of CBCT (21). Presence of metallic or dense materials in an endodontically treated tooth may lead to radiolucent or radiopaque streaks which can mask the VRF or lead to misdiagnosis by imitating a VRF (20, 22). The voxel size has a relationship with image quality (contrast and spatial resolution) and patient radiation dose; lower voxel sizes result in higher patient dose). Regarding to the possibility of choosing variable voxel sizes (different resolutions) in the acceptable diagnostic quality range beside the ALARA, we studied the diagnostic accuracy of different voxel sizes and resolutions for VRF detection in endodontically treated teeth with cast posts.

Methods:

In this cross sectional in vitro study 80 extracted premolar teeth without root fracture, irrespective of age, gender or the cause of extraction, were selected. The extracted teeth were debrided and sectioned through the cemento-enamel junction to decrease the effect of enamel cracks. The remaining roots were prepared with piezo number 2 and 3 and irrigated with normal saline. They were cleaned, shaped by No.15-50 files and obturated in order to be ready for the posts. A week later, the canals were prepared. Nickel-chrome posts were made and fit to the canals but were not cemented in order to inhibit the penetration of the cement into the fracture line. Periapical radiographic images were taken to

evaluate the process of fabrication and fitness of casting posts. All the roots were covered with 1mm-thick green wax and embedded in self-cure acrylic blocks for convenient handling and avoiding root separation during load application. Forty teeth were randomly selected and a prefabricated brass post was placed in the root canal and a fracture was induced with Instron machine (Zwick.roell, GmbH & Co.KG, Germany). This machine exerts an increasing load on the posts until a crack sound is heard, then the force is immediately aborted according to the diagram on the system monitor. Specimens that underwent complete fracture and separation of fragments were excluded and replaced with new samples. The remaining 40 teeth had no fracture and comprised the control group. The cast posts were placed in root canals. All samples were stored in water during the study except when tested.

Image Scanning

The blocks were divided randomly into 8 groups of 10 samples. Each group was placed in an arch line on the chinrest of the CBCT system (NewTom VGi, Quantative Radiology, Verona, Italy) and scanned by two different voxel sizes: 0.2 as the standard protocol and 0.15 as the high resolution; 16 scans were prepared. The FOV (field of view) 12*8, kVp 110 and 1mm slice thickness were set for all scans.

Observation

The scans were observed blindly by three oral and maxillofacial radiologists on the same monitor (FLATRON W1752s LG) with 1440*90 resolution. The observers were allowed to change the contrast and brightness. All the axial, coronal and sagittal images were accessible for viewers.

The results of evaluation were expressed on a 5-point scale as below:

- 0- Definitely with no fracture
- 1- Probably with no fracture
- 2- No idea whether there is a fracture or not

3- Probably with fracture

4- Definitely with fracture

The samples were extracted from the blocks, dyed using methylene blue and washed as the gold standard to ensure the presence or absence of root fracture.

Analysis:

The data were analysis with SPSS (Statistical Package for Social Sciences) version 18. Complete and absolute sensitivity, specificity, positive predictive value and negative predictive value for every observer were derived and with Mann-Whitney test, the diagnostic accuracy of each voxel size was evaluated. Inter observer reproducibility was also calculated using agreement coefficient.

Results:

The diagnostic accuracy indices including deterministic and probabilistic sensitivity, specificity, positive and negative predictive value were estimated and Mann –Whitney test was used to assess significant differences between them. The deterministic and probabilistic diagnostic sensitivity, specificity, positive and negative predictive values were found for 0.2mm and 0.15mm voxel sizes as shown in table 1.

Mann Whitney test was applied for the comparison of different voxel sizes and found no significant difference in deterministic and probabilistic sensitivity, specificity, positive and negative predictive values between the two different voxel sizes of 0.15 and 0.2mm ($p>0.05$).

Reproducibility: The inter-observer reproducibility was calculated using the coefficient agreement. The reproducibility coefficient was found to be 23.9%, 33.8% and 35.1% for 0.2mm voxel size and 26.3%, 32.6% and 15.1% for 0.15mm voxel size.

Table 1- The diagnostic indices values in two different voxel sizes

Voxel size (mm)/Diagnostic index	0.15	0.2
Deterministic sensitivity	21.66 (15.27) (<i>p</i> =0.07)	12.5 (13.22) (<i>p</i> =0.07)
Probabilistic sensitivity	59.16 (5.2) (<i>p</i> =0.04)	46.66 (16.66) (<i>p</i> =0.04)
Deterministic specificity	16.66 (13.76) (<i>p</i> =1)	17.5 (10) (<i>p</i> =1)
Probabilistic specificity	56.16 (15.21) (<i>p</i> =0.07)	61.66 (8.77) (<i>p</i> =0.07)
Deterministic positive predictive value	78.9 (18.34) (<i>p</i> =0.02)	51.26 (23.16) (<i>p</i> =0.02)
Probabilistic positive predictive value	61.46 (10.47) (<i>p</i> =0.7)	54.4 (5.96) (<i>p</i> =0.7)
Deterministic negative predictive value	84 (27.71) (<i>p</i> =0.4)	52.06 (12.29) (<i>p</i> =0.4)
Probabilistic negative predictive value	60.86 (5.94) (<i>p</i> =0.4)	55.06 (5.9) (<i>p</i> =0.4)

Discussion:

In this in vitro study, two voxel sizes were evaluated in increasing VRF detection accuracy. According to the results, no significant difference was found between 0.15 and 0.2 mm voxel sizes in VRF detection in endodontically treated root canals with casting post.

As the signs and symptoms of vertical root fracture are similar to other root canal failures or periodontal disease, detection is challenging for dentists (11, 23). Misdiagnosis can cause complications such as unknown pain, resorption or malfunction (18) and lead to unnecessary surgical procedures or tooth extraction; thus, early detection is essential for both the dentist and patient (5, 19).

Conventional radiography showed low sensitivity for VRF detection in different studies (25-47%) and digital radiography using software filters was unable to enhance it (5).

Thus priority of CBCT over other imaging modalities for detection of VRFs has been remarkable (14, 23-27). However, most previous studies ignored the effect of root canal filling or posts on detection of VRF while 61.7% of cases have reported to have interradicular posts (14, 23, 25-28).

Although artifacts are less in CBCT compared to CT, the streak artifacts around the high density materials like posts can lead to false positive or negative results (29). Many factors affect the amount of artifacts in CBCT images including voxel size, exposure settings, size of FOV, slice thickness, presence or absence of root filling material, type of CBCT system and the receptor (30). Selecting the lower resolution can lead to lower exposure time and subsequently lower patient dose (29). Considering the limited studies on the effect of different resolutions on the diagnostic accuracy for VRF detection in presence of root canal posts, we assessed the diagnostic accuracy of two different voxel sizes of 0.2 and 0.15 mm of CBCT imaging system (NewTom VGi) for detection of vertical root fractures in presence of cast posts.

Probabilistic sensitivity and specificity for 0.2 and 0.15 mm resolutions were 46.66 (16.64) and 59.16 (5.2), and 61.66 (8.77) and 56.16 (15.21), respectively. These values were lower than the rates reported in previous studies regarding post placement in the root canal and associated artifacts such as beam hardening and scattering. Ozer (2011) suggested 0.2 mm resolution to achieve acceptable diagnostic accuracy for detection of VRFs and less patient radiation

dose(18). The higher values of sensitivity and specificity in this study were because of the absence of the post in the canal. Many articles confirmed this difference for values with and without root canal filling and posts (11, 20, 22). de Silveira *et al.* (2013) also used 0.2 mm and 0.3 mm resolutions for VRF detection in situations with presence and absence of root canal fillings and post respectively (11). Different root canal filling materials or posts (gold or nickel- chrome) as well as different CBCT units and various FOV can be also the cause of this difference in the values (29). In the absence of filling materials or posts and subsequent absence of disarranging artifacts, choosing smaller voxel sizes, as an effective factor for image quality, can significantly improve the diagnostic accuracy (23).

As Metska *et al.* (2012) mentioned, another impressive factor in the accuracy of VRF detection in CBCT images is the system units. Different CBCT scanners had notably different potency (19). In support of this, Hassan (2010) expressed that systems with flat panel detectors (Next generation-CAT and Scanora 3D) have fewer artifacts, less noise and contrast resolution but higher spatial resolution than systems with image intensifier tubes/CCD detectors (Galileos 3D, NewTom 3G and 3DAccuiTomo)[21]. High resolution compared to low resolution CBCTs showed higher accuracy for this purpose as well (23).

FOV (field of view) is directly related to voxel size and affects the contrast and spatial resolutions. Extended FOV shave lower contrast and spatial resolutions and thus influence the diagnosis on CBCT images (21). In Costa's studies (2011, 2012), the diagnostic accuracy of large FOV for VRF detection, either in presence or absence of posts, was low (20, 22). In small FOV it was accurate in the absence of posts but imprecise in samples with post.

As an effective factor, Estrela *et al.* (2011) revealed that the highest amount of artifacts was

seen in images of teeth with gold and silver cast posts and the lowest was around the fiber – carbon posts (31). He also proposed that changing the slice thickness was not very influential on altering the artifact rates in CBCT images.

Ozer (2011) noted in his article that the gap size between the root fragments plays a role in the diagnostic accuracy for VRF detection in CBCT images; when this gap is more than 0.4 mm, VRF detection has the highest level of precision (27). Thus, the nature of non-displaced and hairline VRFs can affect the interpretations. Slight fractures with no displacement are undetectable in intraoral radiographies (22) or even in CBCT scans (32). The superimpositions or artifacts can resemble the fracture line (22). Regarding to the higher patient radiation dose in CBCT, it is reasonable to have the conventional radiographies as the first choice for VRF detection (13). When clinical examinations are highly suggestive of VRF, conventional radiography with different horizontal angles should at first be applied and if no indicative findings are seen, CBCT is indicated (11).

Despite several studies on VRFs, the limitations of in-vitro ones may affect the results. As Mora (2007) has stated factors such as the method of inducing a fracture line or the specimens' storage media can change the results (33). Furthermore, clinical parameters like the probing depth, alteration in PDL width, bone loss, positive percussion test and radiolucencies around the root are ignored and only the radiographic modality is assessed. The presence of the crown and the restorations can also affect the interpretation around the CEJ in axial sections (13, 22).

Conclusion:

Due to the lack of statistically significant differences between the resolutions of 0.15 and 0.2 mm voxel sizes in CBCT New Tom VGi

system and according to the principle of ALARA, 0.2 mm voxel size, is recommended for evaluation of vertical root fracture in teeth with metal posts regarding to the same

performance and less exposure dose.

Conflict of Interest: “None Declared”

References:

1. Khedmat S, Rouhi N, Drage N, Shokouhinejad N, Nekoofar MH. Evaluation of three imaging techniques for the detection of vertical root fractures in the absence and presence of gutta-percha root fillings. *Int Endod J* 2012; 45: 1004-1009.
2. Wang P, He W, Sun H, Lu Q, Ni L. Detection of vertical root fractures in non-endodontically treated molars using cone-beam computed tomography: a report of four representative cases. *Dent Traumatol* 2012; 28: 329-333.
3. Llana-Puy MC, Forner-Navarro L, Barbero-Navarro I. Vertical root fracture in endodontically treated teeth: a review of 25 cases. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001; 92: 553-555.
4. Tamse A. Vertical root fractures in endodontically treated teeth: diagnostic signs and clinical management. *Endodontic Topics* 2006; 13: 84-94.
5. Edlund M, Nair MK, Nair UP. Detection of vertical root fractures by using cone-beam computed tomography: a clinical study. *J Endod* 2011; 37: 768-772.
6. Kahler W. The cracked tooth conundrum: terminology, classification, diagnosis, and management. *Am J Dent* 2008; 21: 275-282
7. Varshosaz M, Tavakoli MA, Mostafavi M, Baghban AA. Comparison of conventional radiography with cone beam computed tomography for detection of vertical root fractures: an in vitro study. *J Oral Sci* 2010; 52: 593-597.
8. Kambungton J, Janhom A, Prapayasadok S, Pongsiriwet S. Assessment of vertical root fractures using three imaging modalities: cone beam CT, intraoral digital radiography and film. *Dentomaxillofac Radiol* 2012; 41: 91-95.
9. Moule AJ, Kahler B. Diagnosis and management of teeth with vertical fractures. *Aust Dent J* 1999; 44:75-87.
10. 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; 40:290-298.
11. da Silveira PF, Vizzotto MB, Liedke GS, da Silveira HL, Montagner F, da Silveira HE. Detection of vertical root fractures by conventional radiographic examination and cone beam computed tomography - an in vitro analysis. *Dent Traumatol* 2013; 29: 41-46.
12. 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: a report of 3 cases. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011; 111:797-801.
13. Kamburoğlu K, Murat S, Yüksel SP, Cebeci AR, Horasan S. Detection of vertical root fracture using cone-beam computerized tomography: an in vitro assessment. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2010; 109: 74-81.
14. Valizadeh S, Khosravi M, Azizi Z. Diagnostic accuracy of conventional, digital and cone beam computed tomography in vertical root fracture detection. *IEJ* 2011; 6: 15-20.
15. Youssefzadeh S, Gahleitner A, Dorffner R, Bernhart T, Kainberger FM. Dental vertical root

- fractures: value of CT in detection. *Radiology* 1999; 210: 545-549.
16. Kamburoğlu K, Ilker Cebeci AR, Gröndahl HG. Effectiveness of limited cone-beam computed tomography in the detection of horizontal root fracture. *Dent Traumatol* 2009; 25: 256-261.
 17. Pauwels R, Beinsberger J, Collaert B, Theodorakou C, Rogers J, Walker A, *et al.* Effective dose range for dental cone beam computed tomography scanners. *Eur J Radiol* 2012; 81: 267-271
 18. Özer SY. Detection of vertical root fractures by using cone beam computed tomography with variable voxel sizes in an in vitro model. *J Endod* 2011; 37: 75-79.
 19. Metska ME, Aartman IH, Wesselink PR, Özok AR. Detection of vertical root fractures in vivo in endodontically treated teeth by cone-beam computed tomography scans. *J Endod* 2012; 38: 1344-1347.
 20. Costa FF, Gaia BF, Umetsubo OS, Pinheiro LR, Tortamano IP, Cavalcanti MG. Use of large-volume cone-beam computed tomography in identification and localization of horizontal root fracture in the presence and absence of intracanal metallic post. *J Endod* 2012; 38: 856-859.
 21. 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: 126-129.
 22. Costa FF, Gaia BF, Umetsubo OS, Cavalcanti MG. Detection of horizontal root fracture with small-volume cone-beam computed tomography in the presence and absence of intracanal metallic post. *J Endod* 2011; 37: 1456-1459.
 23. Wenzel A, Haiter-Neto F, Frydenberg M, Kirkevang LL. Variable-resolution cone-beam computerized tomography with enhancement filtration compared with intraoral photostimulable phosphor radiography in detection of transverse root fractures in an in vitro model. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009; 108: 939-945.
 24. 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: 719-722.
 25. Bornstein MM, Wölner-Hanssen AB, Sendi P, von Arx T. Comparison of intraoral radiography and limited cone beam computed tomography for the assessment of root-fractured permanent teeth. *Dent Traumatol* 2009; 25: 571-577.
 26. Iikubo M, Kobayashi K, Mishima A, Shimoda S, Daimaruya T, Igarashi C, *et al.* Accuracy of intraoral radiography, multidetector helical CT, and limited cone-beam CT for the detection of horizontal tooth root fracture. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009; 108: 70-74.
 27. Ozer SY. Detection of vertical root fractures of different thicknesses in endodontically enlarged teeth by cone beam computed tomography versus digital radiography. *J Endod* 2010; 36: 1245-1249.
 28. Fuss Z, Lustig J, Katz A, Tamse A. An evaluation of endodontically treated vertical root fractured teeth: Impact of operative procedures. *J Endod* 2001; 27: 46-48.
 29. Melo SL, Bortoluzzi EA, Abreu M Jr, Corrêa LR, Corrêa M. Diagnostic ability of a cone-beam computed tomography scan to assess longitudinal root fractures in prosthetically treated teeth. *J Endod* 2010; 36: 1879-1882.
 30. Katsumata A, Hirukawa A, Okumura S, Naitoh M, Fujishita M, Arijji E, *et al.* Effects of image artifacts on gray-value density in limited-volume cone-beam computerized tomography. *Oral*

Surg Oral Med Oral Pathol Oral Radiol Endod 2007; 104: 829-836.

31. Estrela C, Bueno MR, Silva JA, Porto OCL, Leles CR, Azevedo BC. Effect of intracanal posts on dimensions of cone beam computed tomography images of endodontically treated teeth. *Dental Press Endod* 2011; 1: 28-36.
32. Ferreira RI, Bahrami G, Isidor F, Wenzel A, Haiter-Neto F, Groppo FC. Detection of vertical root fractures by cone-beam computerized tomography in endodontically treated teeth with fiber-resin and titanium posts: an in vitro study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2013; 115: 49-57
33. Mora AM, Mol A, Tyndall AD, Rivera EM, Hill C. In vitro assessment of local computed tomography for detection of longitudinal tooth fractures. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; 103: 825-829.