Comparison of Diagnostic Accuracy of Cone Beam Computed Tomography and Digital Radiography for Detection of Vertical Root Fractures with and without Gutta Percha

[1]Solmaz Valizadeh [2]Fatemeh Azimi [3]Hosein Babazadeh [*4]Zeynab Azizi

[1]Assistant Professor, Dept. of Oral & Maxillofacial Radiology, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[2]Assistant Professor, Dept. of Oral & Maxillofacial Radiology, School of Dentistry, Gilan University of Medical Sciences, Gilan, Iran.
[3]General Practitioner.
[*4]Assistant Professor, Dept. of Oral & Maxillofacial Radiology, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran. E-mail: dr_azizi_mp@yahoo.com.

Abstract

Objective: Diagnosis of vertical root fractures (VRFs) is critical in endodontics; which most of the times occurs in endodontically treated teeth with root canal fillings such as gutta percha. Despite Cone Beam Computed Tomography (CBCT) has significantly enhanced image quality compared to digital radiography (DR) which aid the diagnosis, artifacts has remained as a problem in VRF detection. The aim of this study was to compare accuracy of CBCT and digital radiography system in vertical root fracture with presence and absence of gutta-percha.

Methods: In this experimental *in vitro* study, 60 premolar teeth were cut at the cementoenamel junction .The teeth were randomly divided into two groups; for one group root canal therapy was done and the roots filled with gutta-percha. The other group was the control one .At the first stage CBCT scan and digital radiography was done and subsequently, vertical root fractures were induced for all samples. Then all the teeth were scanned by CBCT and digital radiography system and three observer assessed CBCT images and digital radiographies for presence of vertical root fracture. ANOVA and weighted Kappa tests estimated the diagnostic accuracy values and inter-observer agreement.

Results: All values for CBCT were higher than Digital radiography except for absolute specificity and negative predictive value (p=0.409, p=0.053). In both imaging systems, there was no statistical difference between presence and absence of gutta-percha. (p=0.599, p=1.000, p=0.673, p=0.373).

Conclusion: Diagnostic accuracy of vertical root fracture was not influenced by presence or absence of gutta-percha. Additionally, CBCT imaging system had higher diagnostic accuracy in comparison of digital radiography.

Key words: Cone Beam CT, Digital radiography, Gutta Percha, Vertical Root Fracture.

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Introduction:

Vertical root fracture is a longitudinal fracture line that originates from the apex and extends coronally (1). In a transverse section, this fracture initiates from the root canal wall and extends towards the root surface and may be incomplete involving one side or complete involving both sides of the root. In a sagittal section, it may also be complete or incomplete extending to part or the entire cervicoapical length (2).

Inflammatory reactions in the periodontal tissue, alveolar bone loss and formation of granulation tissue due to vertical root fracture necessitate an immediate decision regarding extraction of the affected tooth or root to prevent bone loss. The prognosis of vertical root fracture (VRF) is poor.

Considering the poor prognosis of VRF and its financial and clinical burden for the patient, finding a reliable method for detection of root fracture seems critical in order to avoid the unnecessary costs and ineffective treatments (3).
Clinical and radiographic signs of VRF are non-specific and the majority of patients have local pain and swelling, a deep periodontal pocket and a sinus tract in relation to the endodontically treated tooth (4, 5).
Although conventional radiography is the most commonly used imaging technique for detection of post-endodontic root fractures, detection of root fractures on these images is always challenging (6). The fracture line is visible on a radiograph only if the X ray beam is parallel to the fracture borders (7).Otherwise, the fracture will not be visible on 2D radiographs especially at the initial phases when fracture line is in the form of a fine crack without segment separation. For detection of such fractures, several PA radiographs taken at different angles are required so that in one of them the X ray beam will be parallel to the fracture line and display the radiolucent line.
In digital imaging technique, this issue has not been resolved and controversial results have been reported regarding the effect of different software enhancement systems on the accuracy of this system for detection of VRF (8, 9). Conventional CT has higher accuracy for detection of VRFs than digital radiography (3). However, its disadvantages namely limited access, high absorbed radiation and high cost have limited its application in dentistry (10, 11).
Cone beam computed tomography (CBCT) provides an image with adequate resolution with lower absorbed radiation and lower cost and is a suitable alternative to CT for dental purposes (12, 13).
During the recent years, the accuracy of this 3D technique for detection of root fractures has been extensively evaluated and it has been reported that CBCT is more accurate than conventional and digital PA radiography for diagnosis of root fractures (14-16).
One limitation of CBCT is formation of artifacts at high density areas. VRF commonly occurs in endodontically treated teeth that have been filled with radio opaque high density materials like gutta percha.
Considering the limitations and controversies in the relevant literature, this study sought to assess the effect of presence of gutta percha root canal filling material on the diagnostic accuracy of CBCT and digital radiography for VRF.

Methods:

This experimental *in vitro* study was conducted on 60randomly- selected extracted single-rooted human premolar teeth with no root fracture and any restoration regardless of the age or gender of patients. The extracted teeth were cleaned and the crowns were cut at the level of cementoenamel junction (CEJ) using a metal disc. Half the specimens were randomly selected and received endodontic treatment. Cleaning and shaping of the canals were done using #15 and #20 hand k-files and canals were filled with gutta percha (Ariadent, Iran) and AH26 sealer. Before the induction of fracture, the test and control (without root canal filling) group teeth were stained with methylene blue to ensure they had no pre-existing fracture.
A series of CBCT images and digital radiography was performed as the first series of images. In order to obtain CBCT images, all the teeth (with and without gutta percha) were randomly divided into 7 groups of 8 and one group of 4. Specimens of each group were placed on the chinrest of CBCT NewTom VGi (Quantitative Radiology, Verona, Italy). Imaging was done with 0.2mm resolution, 8x12 cm field of view (FOV) and 110 kVp; mA was adjusted for the device for each specimen. Digital radiographs were obtained using ARD70 (Ardin Ind. Complex) and EVA sensor at 8mA, 70 kvP

and 0.12s exposure setting at 3 different angles namely 90°, 30° mesially and 30° distally.

For inducing VRF in test samples, a brass pins were placed into the canals and VRF was caused by an Instron machine (Zwick/ Roell, GmbH & Co, KG, Germany). This system created an increasing force in the pin until the sound of fracture was heard. Immediately after fracture, the force was discontinued as shown on the system monitor. After induction of fracture by Instron machine in all specimens, only the teeth with an induced vertical fracture (confirmed with methylene blue staining) were included in the study. One layer of green wax was applied around the roots and the teeth were mounted in acrylic blocks.

Then the second series of CBCT images and digital radiography were obtained as the first series was taken. Three maxillofacial radiologists who were blinded to the coding of specimens randomly evaluated the pre- and post-fracture CBCT and digital PA radiographs in terms of root fracture. Observers evaluated the CBCT images in axial, coronal and sagittal sections on an LG Flatron W1752s monitor with no time limitation and were also allowed to adjust the contrast and brightness. The observers recorded their diagnosis by selecting one of the following choices:

0: Definite fracture
1: Probable fracture
2: Not sure about the presence of fracture
3. Probably no fracture
4. Definitely no fracture

For determination of the gold standard, after imaging all specimens were removed from the acrylic block and stained again with methylene blue. In cases with fracture, methylene blue penetrates into the fracture line and makes it visible as a dark blue line on the tooth surface. The teeth were observed by a magnifier and presence of fracture in all teeth was confirmed.

Accuracy assessment indices namely sensitivity, specificity, positive predictive value and negative predictive value for each method were calculated as absolute and complete values and compared using two-way ANOVA. Inter-observer reproducibility was also calculated using weighted kappa.

Results:

Considering the 5 answer choices available for observers, the results were expressed as absolute sensitivity and specificity, complete sensitivity and specificity, absolute positive and negative predictive value and complete positive and negative predictive value. In absolute sensitivity, specificity, positive and negative predictive value, observers expressed their definite opinion about the presence or absence of VRF. But, for complete sensitivity, specificity, positive and negative predictive value, probable diagnoses for presence or absence of VRF were also taken into account.

Sensitivity

For comparison of absolute diagnostic sensitivity using two-way ANOVA, no relationship was found between the two independent variables (p=0.920). Absolute diagnostic sensitivity in both groups of with and without gutta percha was higher in CBCT than on digital PA radiography (p=0.31). No significant difference was found between the two groups of with and without gutta percha in either the CBCT or the digital PA radiography groups (p=0.373).

Comparison of complete diagnostic sensitivity using two-way ANOVA revealed no significant differences between the two independent variables (p=0.231). Complete diagnostic sensitivity value in both groups of with and without gutta percha in the CBCT group was significantly higher than in digital PA radiography (p=0.004). However, no significant difference existed between the two groups of with and without gutta percha in either the

CBCT or the digital radiography group (p=0.673).

Specificity

Comparison of absolute specificity using two-way ANOVA found no differences between the two independent variables (p=0.867). Absolute specificity was not significantly different between the CBCT and digital PA radiography (p=0.409).

This difference between the two groups of with and without gutta percha was not statistically significant either (p=1.000). Comparison of complete specificity using two-way ANOVA revealed no relationship between the two independent variables (p=0.194). Complete specificity in both groups of with and without gutta percha in the CBCT group was significantly greater than in digital PA radiography (p=0.01). No significant difference existed in this respect between the two groups of with and without gutta percha in either the CBCT or the digital radiography group (p=0.599).

Positive predictive value

Comparison of absolute positive predictive value using two-way ANOVA found no relation between the two independent variables (p=0.935). Absolute positive predictive value in both groups of with and without gutta percha in the CBCT group was significantly higher than digital radiography (p=0.031).No significant difference existed in this respect between the two groups of with and without gutta percha in either the CBCT or the digital radiography group (p=0.373).

Comparison of complete positive predictive value using two-way ANOVA revealed no relation between the two independent variables (p=0.115). Complete positive predictive value in both groups of with and without gutta percha in the CBCT group was significantly greater than in digital PA radiography (p=0.003). No significant difference existed in this respect between the two groups of with and without gutta percha in either the CBCT or the digital radiography group (p=0.756).

Negative predictive value

Comparison of absolute negative predictive value using two-way ANOVA found no relation between the two independent variables (p=0.181).Absolute negative predictive value was not significantly different between the CBCT and digital PA radiography (p=0.053). No significant difference existed in this respect between the two groups of with and without gutta percha in either the CBCT or the digital radiography group (p=0.558).

Table 1- The mean absolute and complete sensitivity, specificity, positive and negative predictive values for diagnosis of VRF in CBCT and digital PA radiography

	CBCT in samples without gutta	CBCT in samples with gutta	Digital radiography in samples without gutta	Digital radiography in samples with gutta
Absolute specificity	52.2 (5.1)	51.1 (15)	45.6 (10.2)	46.7 (11.5)
Complete specificity	80.0 (6.1)	75.6 (5.0)	55.6 (13.4)	65.6 (10.2)
Absolute sensitivity	55.6 (17.1)	50.0 (3.3)	41.1 (1.9)	36.6 (5.8)
Complete sensitivity	70.0 (12.0)	63.3 (5.8)	50.0 (4.8)	53.3 (5.6)
Absolute negative predictive values	82.3 (4.0)	70.2 (7.3)	60.3 (11.9)	65.4 (14.4)
Absolute positive predictive values	92.9 (12.4)	91.1 (10.2)	74.3 (5.0)	73.4 (5.8)
Complete negative predictive values	73.3 (7.7)	67.4 (4.2)	53.2 (6.1)	60.6 (4.6)
Complete positive predictive values	77.5 (3.2)	72.2 (4.8)	56.3 (7.9)	63.8 (7.7)

Comparison of complete positive predictive value using two-way ANOVA revealed no relation between the two independent variables (p=0.085). Complete negative predictive value in both groups of with and without gutta percha in the CBCT group was significantly greater than in digital PA radiography (p=0.004). No significant difference existed in this respect between the two groups of with and without gutta percha in either the CBCT or the digital radiography group (p=0.829).

The mean absolute and complete sensitivity, specificity, positive and negative predictive values for diagnosis of VRF in CBCT and digital PA radiography are summarized in Table 1.

Discussion:

In this study in both imaging systems, CBCT and digital radiography, the presence or absence of gutta percha did not cause any significant difference in absolute sensitivity and specificity, complete sensitivity and specificity, absolute positive predictive value, complete positive predictive value, absolute negative predictive value or complete negative predictive value. Although the amount of artifacts in CBCT decreased in comparison with CT imaging system, but streak lines was still present manifesting as light and dark lines in the area. This issue is responsible for false positive and false negative results in detection of fracture lines adjacent to gutta percha. As the result, in some intact teeth, dark lines are mistaken for fracture and in some fractured teeth, opaque lines mask the actual fracture line. Table 2 shows the comparison of our results with the results of previous studies.

As observed in our study and previous ones on teeth with gutta percha fillings, its presence decreases the diagnostic sensitivity and specificity. This reduction has been significant in some studies (17, 18) and insignificant in some others including ours. However, the reported sensitivity and specificity values and amount of artifacts in these studies may be affected by voxel size, exposure settings, different FOVs used, thickness of slices and the type of imaging system and the related detector (16). It seems that these factors affect the results in our study and lead to insignificancy between the presence and absence of gutta percha for VRF detection.

Table 2- Comparison of current results in diagnosis of VRF with the results of previous studies.

	Voxel size	Gutta percha	Sensitivity	Specificity
Current study	0.2	+	63.3	75.6
	0.2	-	70.0	80.0
Wenzle (7)	0.25	-	72.0	100
	0.125	-	87.0	98.0
Hassan (16)	0.25	+	77.5	91.3
Hassan (21)	0.25	+	79.4	92.5
Melo (23)	0.3	+	51.0	71.0
	0.2	+	82.0	74.0

Hassan *et al*. in their study in 2010 on 5 CBCT imaging systems evaluated the amount of artifacts and its effects on the diagnostic accuracy of these systems for detection of VRFs and reported less metal artifacts, less noise, less contrast and higher resolution in systems with flat panel detectors compared to intensifier tubes/CCD image detectors (19). Flat panel

detectors are used in next generation I-CAT and Scan or a 3D systems; whereas, IIT/CCD based detectors are used in NewTom 3G, Galieos 3D and 3D AccuiTomo systems. Ozer in a study in 2010 evaluated the diagnostic accuracy of CBCT and digital radiography for detection of VRFs and concluded that CBCT was more accurate than the digital system for diagnosis of all fracture thicknesses and 0.4 mm slices/intervals had the highest diagnostic value (20).

According to studies by Melo *et al*. in 2010 (21) and Ozer in 2011 (22) on the proper size voxel for detection of VRFs, 0.2 mm voxel size was introduced as the best considering the low exposure dose and optimal diagnostic accuracy. Thus, 0.2 mm voxel size was used in our study.

Hassan *et al*. in 2009 evaluated the diagnostic value of CBCT for detection of VRFs in endodontically treated teeth and reported that the overall accuracy of CBCT images did not decrease in presence of gutta percha (15). However, its diagnostic sensitivity decreased in presence of gutta percha. Moreover, presence of gutta percha significantly decreased the overall accuracy and diagnostic sensitivity of digital PA radiographs as well. Moudi in 2014 in a study on VRF assessment with CBCT, also reported that gutta percha in comparison with prefabricated posts, has no significant effect on decreasing accuracy in CBCT images (23).Sensitivity and negative predictive value in teeth with gutta percha and prefabricated post showed a reduction due to the artifact lines resulting from post. According to their study absence of dark streaks in teeth with gutta percha compare with teeth with gutta percha and prefabricated post caused the difference between these two conditions. Patel *et al*. in 2013 noted to the overestimation of VRF detection in CBCT in a study on root filled teeth because of artefacts related to the presence of gutta percha (18).

Based on studies by Kamburoglu *et al*. in 2010 (24) and Hassan *et al*. also in 2010 (19), the direction of fracture lines (buccolingually or mesiodistally) can affect the diagnostic sensitivity and specificity of digital radiography. If the fractures are mesiodistally, the diagnostic sensitivity further decreases because the X-ray beam should be directed at approximately a 4° angle relative to the fracture plane in order for the fracture line to be detectable; whereas, the direction of fracture line has no effect on the diagnostic accuracy of CBCT because of its 3D nature. In our study, fractures were induced using the Instron machine and we did not have any control over the direction of the fracture line. Mesiodistal fracture lines are almost impossible to detect on 2D images (because the fracture line is masked by the root) and this issue may be the reason for decreased diagnostic sensitivity of digital periapical radiography.

Also, in our study, the overall accuracy and diagnostic sensitivity of CBCT images were found to be greater than digital PA images. This higher diagnostic sensitivity is attributed to the 3D nature of CBCT allowing image acquisition from different angles, preparing very thin cross-sections and higher contrast of CBCT versus the 2D nature and low contrast of digital PA radiographs. In our study, specificity of digital PA radiography was high and comparable to that of CBCT. The high specificity of digital PA radiography was due to the dominance of negative responses of observers to VRF because the majority of fractures were undetectable.

In a study by Melo *et al*. (2010) the diagnostic sensitivity and specificity in presence of root canal filling materials decreased (21). However, the overall accuracy was not significantly different in presence and absence of root canal filling materials. It should be noted that in Melo's study, the root canal filled group was divided into two subgroups of gutta percha and gold cast posts; whereas, in our study, canals were filled with gutta percha. A gold cast post has higher density and radiopacity than gutta percha and can cause more severe artifacts on CBCT images.

In our study, absolute specificity was not significantly different between the two groups of with and without gutta percha. However, complete specificity and absolute and complete sensitivity of CBCT images were significantly greater than those in digital PA radiographs. Considering the 2D nature of digital radiography and the possibility of superimposition of gutta percha over the fracture line (and increase in false negative results), reduction of diagnostic sensitivity in presence of gutta percha is completely verified.

As mentioned earlier, high diagnostic specificity of digital radiography (comparable to that of CBCT) is verified by the fact that in digital radiography, gutta percha filled teeth with root fractures are less likely to be diagnosed as false positive and cases without root fracture are more accurately detected; whereas, false positive results in CBCT due to the presence of hairlines mimicking the fracture line decrease the diagnostic specificity of this system.

Higher diagnostic accuracy of CBCT compared to PA radiography has also been confirmed by Valizadeh *et al*. in 2011(25). They compared CBCT, conventional and digital radiography for detection of VRFs and reported that CBCT had the highest sensitivity (94.6%) and specificity (98.2%); whereas, these values were 76.9% and 66.7% for conventional and 76.3% and 74.1% for digital radiography; respectively. In another study, Hassan *et al.* evaluated the diagnostic accuracy of CBCT and digital systems for detection of VRF and reported the sensitivity and specificity of CBCT to be 97% and 80%, respectively(15). These rates were 96% and 47.5% for digital radiography, respectively. Also, the overall accuracy of CBCT was higher than digital radiography (86% versus 62%).

Conclusion:

Considering the lack of any significant difference in sensitivity and specificity of CBCT and digital radiography neither in presence nor in absence of gutta percha, we concluded that presence of gutta percha had no effect on the diagnostic accuracy of these two imaging systems for detection of VRFs. Moreover, considering the higher complete and absolute sensitivity and complete specificity of CBCT than digital PA radiography, we may state that CBCT has higher diagnostic accuracy than digital PA radiography for detection of VRFs.

Conflict of Interest: "none Declared"

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