

# The Effect of Intra-Canal Posts on Diagnostic Accuracy of Cone Beam Computed Tomography and Digital Radiography in Detection of Vertical Root Fractures

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## Abstract

**Objective:** Diagnosis of vertical root fractures (VRFs) is critical in endodontics. Cone Beam Computed Tomography (CBCT) has significantly enhanced image quality compared to digital radiography (DR) and greatly aids the diagnosis of VRFs but, metal artifacts has remained as a problem in VRF detection. This study evaluated the effect of intra canal posts on the diagnostic accuracy of CBCT and DR for detection of VRFs.

**Methods:** In this experimental *in vitro* study eighty extracted human premolar teeth were cut at the cement-enamel junction. After root canal preparation, the casting posts were made. Samples were randomly divided into 2 groups of 40; group one with induced fracture and group 2 as the control group. Radiographs were taken for all specimens with and without posts with both imaging systems. Three observers assessed the presence or absence of VRF. Accuracy of the two imaging systems and the effect of post on VRF detection were assessed, using two-way ANOVA test and inter observer coefficient agreement was calculated.

**Results:** Absolute diagnostic sensitivity and specificity of CBCT and absolute sensitivity of DR in the group with intracanal posts were significantly lower than those in the group without posts ( $p=0.023$ ,  $p=0.034$  and  $p=0.034$  respectively). Absolute specificity of DR in the group with posts was significantly higher than that of the CBCT ( $p=0.014$ ). The absolute and complete specificity of CBCT in the group without posts was significantly higher than those of DR ( $p=0.024$ ,  $p=0.04$ ). No statistically significant difference was found in inter observer agreement coefficient in presence or absence of posts or between the two imaging systems ( $p=0.119$ ).

**Conclusion:** Intra canal posts decreased the diagnostic accuracy of CBCT and DR for detection of VRFs and this reduction was greater in CBCT. However, absolute specificity of DR in the group with posts was significantly higher than that of the CBCT, where as CBCT images of teeth without posts still had higher diagnostic accuracy than DR.

**Key words:** Artifact, Cone Beam Computed Tomography, Digital radiography, Intra canal post, Vertical root fracture.

**Please cite this article as:**

Valizadeh S, Abazarian N, Safi Y, Azizi Z. The Effect of Intra-Canal Posts on Diagnostic Accuracy of Cone Beam Computed Tomography and Digital Radiography in Detection of Vertical Root Fractures. *J Dent Sch* 2015; 33(4): 296-304.

Received: 14.04.2015

Final Revision: 15.08.2015

Accepted: 12.10.2015

## Introduction:

Diagnosis of root fractures especially vertical root fractures (VRFs) is a clinical dilemma because the patients do not have specific signs and symptoms and the existing ones often mimic

those of endodontic failures and periodontal disease (1). In the majority of these patients local pain and swelling, a deep periodontal pocket or a sinus tract associated with an endodontically treated tooth may be present and all these signs and symptoms are indicative of

the presence of root fracture. However, none of the mentioned signs and symptoms are pathognomonic for presence of vertical root fractures (2). Teeth with VRFs usually have a poor prognosis and tooth extraction is usually the treatment of choice in these cases. Thus, an accurate primary diagnosis is critical for these patients (3).

Conventional radiography is the most commonly used imaging technique for the diagnosis of root fractures. However, detection of root fracture in conventional radiographic images is associated with some difficulties (4). In these images, the fracture line is observed only when the X ray beam is parallel to the fracture plan (5).

Moreover, the superimposition of the adjacent structures and the 2-dimensional nature of conventional radiography make the diagnosis of VRFs more challenging (6).

In the recent years, digital radiography was introduced as a suitable alternative to conventional radiography due to some advantages (7, 8). However, digital radiographic images still have some of the limitations of conventional radiography and the obtained results have been controversial regarding the effects of digital enhancements of images on their diagnostic accuracy for detection of root fractures (9, 10). In 2-dimensional conventional and digital radiographs root fractures are usually detected by noticing indirect manifestations of destruction adjacent to the fracture line.

Use of CBCT imaging in dentistry was first suggested in 1999 (11). CBCT has significantly better diagnostic accuracy for detection of root fractures than conventional and digital radiography in absence of intra canal posts and gutta percha and has been proposed as an excellent imaging modality for diagnosis of VRFs (12-15). However, it should be noted that about 90% of teeth with VRFs have gutta percha root filling and approximately 61.7% of them have intra canal posts (16). These opaque materials cause streak-like artifacts in CBCT

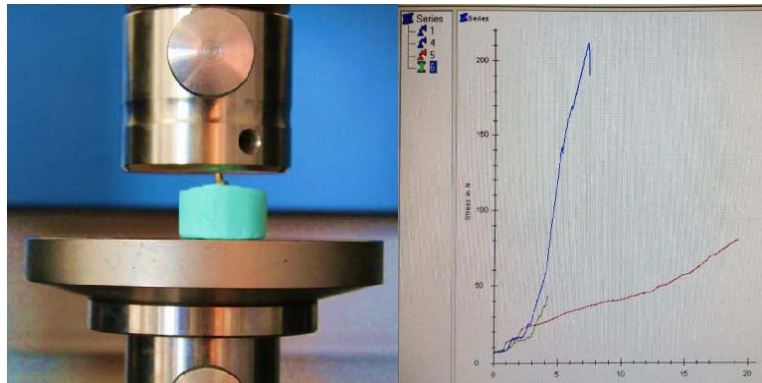
images and significantly decrease their diagnostic accuracy because the dark streaks may be mistaken for fracture and the light streaks may mask the actual fracture line (17). The magnitude of reduction in the diagnostic accuracy of imaging systems due to gutta percha and intra canal post artifacts has been variable in different studies. Many factors may affect the magnitude of artifacts and reduction in diagnostic accuracy of images (3, 17, 18). Thus, this study was performed to assess the effect of intra canal posts on the diagnostic accuracy of CBCT and DR for detection of VRFs.

## Methods:

This in-vitro study was conducted on 80 single-rooted human premolar teeth with no root fractures. Specimens were selected regardless of age and gender of patients or reason for tooth extraction. The extracted teeth were cleaned and the crowns were cut at the CEJ using a metal disc. The root canals were endodontically treated. The coronal section of the root was preflared with #2 or #3 Gates Glidden drills. Root canals were instrumented using K-files sizes 15 to 50 and filled with gutta percha and AH26 sealer. One week later, post space preparation was done with Peeso reamers leaving the apical one-third of the root canal filling. Post patterns were made for all teeth using Duralay acrylic resin.

Post patterns were cast using nickel-chrome (Ni-Cr) alloy. Posts were evaluated for fit but were not cemented for easy removal. Roots were covered with a layer of green wax and the teeth were mounted in acrylic blocks. Out of 80 specimens, 40 were randomly selected for artificial induction of vertical root fracture. The posts were removed and brass pins were inserted into the canals and vertical root fracture was induced by an Instron machine (Zwick/ Roell, GmbH & Co. KG, Germany). This system exerted an increasing force on the pin until the

root fractured. The force was immediately discontinued after the fracture was observed in



**Figure 1-A** block contains a sample in the Instron machine and force diagram to create fracture.

No fracture was induced in the remaining 40 specimens and they were considered as control samples.

All specimens were kept in a humid environment (distilled water) during the study period and only removed from this environment for fabrication of posts, inducing root fracture and obtaining images.

In order to obtain CBCT images, all the teeth (with and without induced fractures), with the posts in the canals were randomly divided into 8 groups of 10. Ten acrylic blocks were placed on the chin rest of CBCT New Tom VGi (Quantitative Radiology, Verona, Italy) in a curved fashion and radiographed before and after the insertion of intra canal posts. Thus, a total of 16 exposures were performed. Imaging was done with a field of view (FOV) of 12x8 cm and resolution of 0.2 mm (standard protocol) at 110 kVp and 1mm slice thickness; the mA was adjusted by the device for each specimen. Digital images of these 80 teeth with posts (with and without fractures) were also obtained of each sample using ARD 70 imaging system (Ardin Ind. Complex, Italy) at 70 kVp and 8 mA. The exposure time for all specimens was 0.12s; EVA digital X ray sensor (Dent-X, USA) was used. Digital radiographs were obtained at horizontal angles of 0° and 30° from the mesial and distal of the tooth. The reason for taking

the diagram on the monitor screen (Figure 1).

three radiographs for a tooth was due to this point that most non-displaced root fractures are usually difficult to reveal radiographically and often several views with different angles is necessary (14).

In the next step all the posts were removed and CBCT scans and digital radiographs of 80 specimens were obtained.

All specimens were removed from the acrylic blocks and stained with methylene blue as the gold standard. In teeth with VRFs, methylene blue penetrated into the fracture and thus the fracture line was visible as a dark blue line on the root surface. The teeth were observed by a magnifier and presence of fracture in the fracture group and absence of fracture in the control group were confirmed.

Three maxillofacial radiologists who were blinded to the group allocation of samples assessed the images in terms of presence of root fracture. Observers were allowed to adjust the contrast and brightness of images and no time limit was set for observation of images. All images were observed in LG Flatron W1752s monitor with 1440x90 pixel resolution. CBCT images were evaluated in axial, coronal and sagittal planes. Observers evaluated the three CBCT planes and graded their answers as follows:

0: Definitely no fracture

- 1: Probably no fracture
- 2: Not sure
3. Probable fracture
4. Definite fracture

The results were expressed as absolute and complete sensitivity and specificity values. Absolute sensitivity and specificity express the observers' definite opinions regarding the presence or absence of fracture but complete sensitivity and specificity values refer to the probable diagnosis of presence or absence of fracture. Obtained data were analyzed using SPSS software. For accuracy assessment, sensitivity, specificity, positive predictive value and negative predictive value were calculated and reported as absolute and complete values for

each imaging technique. The mentioned parameters were compared between the two groups using two-way ANOVA. Interobserver reproducibility was also calculated using agreement coefficient.

### Results:

The diagnostic accuracy indices including deterministic and probabilistic sensitivity, specificity, positive and negative predictive value for each system in presence and absence of intra canal post were estimated (Table 1) and two way ANOVA test was used to assess significant differences between them.

**Table 1- Summarizes the mean absolute and complete sensitivity, specificity, positive predictive value and negative predictive value of CBCT and DR images**

	CBCT no post	CBCT with post	DR no post	DR with post
Absolute sensitivity	40.6 (12.5)	12 (13.2)	17 (10)	9 (15.5)
Complete sensitivity	66.3 (9)	46 (16.7)	42 (5)	44 (20.8)
Absolute specificity	60 (18)	17 (10)	37.3 (6.4)	44 (5.2)
Complete specificity	81.6 (14.4)	61.3 (9)	51.6 (2.8)	61.3 (9)
Absolute positive predictive value	83 (19)	51.6 (12.7)	64.6 (19.2)	18.3 (31.7)
Complete positive predictive value	79 (14.7)	54 (6.2)	46 (3.4)	51 (9.8)
Absolute negative predictive value	76.6 (10)	51 (12.7)	44 (3)	54 (6.5)
Complete negative predictive value	71 (8.1)	55 (5.5)	46.6 (2.3)	51.3 (9.8)

Two- way ANOVA test showed that absolute sensitivity and specificity of CBCT images in the group with posts were significantly lower than those in the group without posts ( $p=0.034$ ,  $p=0.02$ ). However, the two groups (with and without posts), were not significantly different in terms of complete sensitivity and specificity ( $p=0.308$ ,  $p=0.107$ ). Absolute sensitivity of digital images in the group with posts was significantly lower than that in the group without posts ( $p=0.034$ ). However, complete sensitivity and absolute and complete specificity were not significantly different between the two groups of with and without posts ( $p=0.238$ ,  $p=0.308$ ,

$p=0.152$ ).

In the group with posts, absolute specificity of digital images was significantly higher than that of CBCT ( $p=0.014$ ) but no significant difference was found between the two imaging systems in terms of complete specificity and absolute and complete sensitivity in the group with posts ( $p=0.107$ ,  $p=0.146$ ,  $p=1.000$ ).

In the group without posts, absolute and complete specificity of CBCT images were significantly higher than those of digital images ( $p=0.04$ ,  $p=0.024$ ). But, no significant differences existed between the two imaging systems in absolute and complete sensitivity ( $p=0.107$ ,

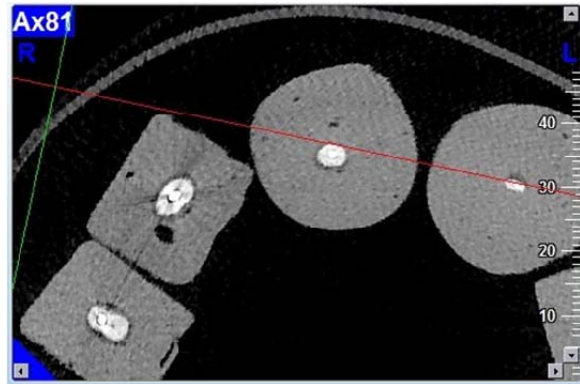
$p=0.146$ ).

The inter- observer reproducibility coefficient agreement for CBCT was 42.3 (10.3) in the group without posts and 30.9 (6.13) in the group with posts. This value for DR was 26.73 (9.97) in the group without posts and 24.77 (9.5) in the group with posts. No significant difference was found in the mentioned values among the 4 groups ( $p=0.119$ ).

**Discussion:**

Reviewing the articles in VRF studies shows that several in vitro researches have concluded that CBCT is more accurate than intraoral radiography at detecting the presence/absence of VRF detection (13, 19-22) and overall accuracy of CBCT for detecting simulated VRFs in root filled and non-root filled teeth was significantly higher than periapical radiographs. however Patel *et al.* (2015) resulted in his review article that cone beam computed tomography cannot be recommended for the diagnosis of VRF clinically and more clinical studies are required to quantify and assess the value of CBCT in diagnosing root fractures, especially in root filled teeth and with a proper control group (22). Based on the obtained results, presence of intracanal posts decreased the absolute sensitivity and specificity of the CBCT imaging system for detection of VRFs but by considering

the possibility of presence of fracture lines this correlation for complete specificity was not significant. This finding can be explained by the fact that in CBCT, due to the presence of radiopaque materials such as intracanal posts and gutta percha, some dark and light streaks still exist in the area (Figure2).



**Figure 2- Streak line artifacts related to the posts which is exerted out of the tooth showing with an arrow**

These streaks are responsible for false positive and false negative results when evaluating the presence of fracture lines in areas adjacent to intracanal posts because in some intact teeth, dark streaks are mistaken for fracture lines and in some teeth with VRFs, opaque lines mask the actual fracture line. Table 2 compares our obtained results with the findings of previous studies.

**Table 2- Diagnostic sensitivity and specificity of CBCT for detection of VRFs in various studies**

Studies/Root canal filling material	Voxel size	Gutta-percha	Gold post	Ni-Cr post	Sensitivity %	Specificity %
Our study	0.2	+	-	+	46	61.3
	0.2	+	-	-	66.3	81.6
Melo <i>et al.</i> (3)	0.3	+	+	-	51	71
	0.2	+	+	-	82	74
Da Silveria <i>et al.</i> (2)	0.2		-	+	83	80
	0.2		-	-	97	100
Costa <i>et al.</i> (16)	0.2	+	-	+	61.6	59.1
	0.2	+	-	-	77.5	80
Hassan <i>et al.</i> (12)	0.25	+	-	-	77.5	91.3
Hassan <i>et al.</i> (18)	0.25	+	-	-	79.4	92.5
Wenzel <i>et al.</i> (4)	0.25	-	-	-	72	100
	0.125	-	-	-	87	98

Bassam Hassan *et al.* (2010) studied 5 different CBCT imaging systems to assess the amount of artifacts and their effect on the diagnostic accuracy of the imaging system for detection of VRFs and concluded that systems with flat-panel detectors had less metal artifacts, less noise, less contrast and higher resolution than systems with image intensifier tubes/CCD detectors (23). We also used flat-panel detectors in our study.

Metska *et al.* (2012) compared the validity of different CBCT scanners for diagnosis of root fractures and mentioned that the diagnostic accuracy for detection of VRFs in presence of intracanal posts depends on the type of imaging system(24). They revealed that the sensitivity, specificity and diagnostic accuracy of 3D AccuTomo for detection of root fracture were greater than those of NewTom 3G.

According to studies by Melo *et al.* (2010)(3), Ozer *et al.*(2011)(18) and Silveria *et al.* (2013)(2) on appropriate voxel size for detection of VRFs, 0.2 mm voxel size with the consideration of low exposure rate and adequate diagnostic accuracy was introduced as the most suitable protocol. Thus, we used the same voxel size in our study.

Concerning the FOV, Costa *et al.* (2011 and 2012) showed that in large FOVs, the diagnostic accuracy for detection of fractures was low regardless of the presence or absence of posts and the interobserver agreement was very low as well (16, 17). Small FOVs are accurate for detection of fractures in absence of posts but the presence of posts decreases this accuracy.

Estrela *et al.* (2011) evaluated the effect of type of intracanal posts on the amount of artifacts and reported that the highest amount of artifacts belonged to gold and silver alloys while the lowest rate of artifacts belonged to carbon fiber posts (25). In our study, we used Ni-Cr posts and detected significant amount of artifacts around them. Estrela *et al.*(2011) demonstrated that changing the slice thickness (0.2 mm, 0.6 mm,

1mm, 3mm, 5mm) did not have a significant impact on the rate of artifacts and related changes in posts(25). Considering this finding, we also chose 1 mm slice thickness in our study.

In DR, absolute diagnostic sensitivity significantly decreased in group with posts compared to the group without posts. Due to the 2-dimensional nature of DR, intracanal posts can be superimposed on the fracture site and increase the false negative results. This issue explains the reduction of diagnostic sensitivity in presence of intra canal posts.

Based on studies by Kamburoglu *et al.* (9) in 2010 and Hassan *et al.* (13) in 2009, the direction of fracture line (bucco-lingually or mesio-distally) may affect the diagnostic sensitivity and specificity of digital radiographies. Mesio-distal fractures often decrease the diagnostic sensitivity to a greater extent because the X ray beam must be at approximately a 4° angle in relation to the plane of fracture in order for the fracture to be detectable; whereas, in CBCT imaging due to its 3D nature, the fracture plane has no effect on detection accuracy. In our study the fracture was artificially induced by the Instron machine and we had no control over the direction of fracture line (being bucco-lingually or mesio-distally).

The two imaging systems of DR and CBCT in presence of post were not significantly different in terms of complete and absolute diagnostic sensitivity and complete specificity. DR had high diagnostic specificity comparable to that of CBCT which is attributed to the fact that in DR, fewer reasons are available for interpretation of false positive results in teeth with VRFs and absence of root fracture is more accurately detected; whereas, in the CBCT system high false positive results due to the presence of hair lines mimicking the fracture line decrease the diagnostic specificity of the system. An interesting finding in our study was that the absolute diagnostic specificity of the DR in

presence of post was significantly higher than that of CBCT; which means that DR was more suitable than CBCT for definite diagnosis of intact teeth; whereas false positive results due to the presence of artifacts decreased the absolute specificity of CBCT. Patel *et al.* (2013) reported the exact same result regarding the diagnostic specificity of the mentioned two imaging systems in presence of gutta percha (26).

In absence of posts, no significant difference existed in absolute and complete diagnostic sensitivity between the two imaging systems but the absolute and complete diagnostic specificity of the CBCT system was greater than those of Valizadeh *et al.* (2011) in their study evaluated the diagnostic accuracy of three imaging techniques namely CBCT, conventional and digital radiography for detection of VRFs (14). They reported that the highest sensitivity (94.6%) and specificity (98.2%) belonged to CBCT whereas these rates were 66.7% and 76.9% for conventional and 74.1% and 76.3% for digital radiography, respectively. In another study Hassan *et al.* (2009) compared the diagnostic accuracy of CBCT and digital

imaging systems for diagnosis of VRFs in non-filled roots and reported the sensitivity and specificity of CBCT to be 80% and 97.5%, respectively (13). While these values were 47.5% and 96.2% for DR, respectively. These findings were near to the result of Ardakani *et al.* (2015) which the sensitivity and specificity of the CBCT technique was reported higher than film base periapical radiography in overall (97.5% and 95% versus 67.5% and 92.5%)(21)

### Conclusion:

Considering the decreased sensitivity and specificity of CBCT images and diagnostic sensitivity of DR in presence of intracanal posts, we conclude that presence of intracanal posts decreases the accuracy of images specially in CBCT for detection of VRFs. Nevertheless absolute specificity of DR in the group with posts was significantly higher than that of the CBCT, CBCT images still had higher accuracy than DR, in the situation of the absence of intracanal posts.

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