Comparison of Charge-Coupled Devices and Photostimulable Phosphor Storage Plates for Detection of Vertical Root Fractures in Endodontically Treated Teeth: An *In Vitro* Study

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Abstract

Objective: Vertical root fracture (VRF) is among the most common causes of endodontic treatment failures. This study aims to compare charge-coupled devices (CCD) and photostimulable phosphor plates (PSP) for detection of vertical root fractures in endodontically treated teeth.

Methods: In this diagnostic *in vitro* study, 40 maxillary anterior teeth were selected and after preparation and root canal filling, their crowns were cut 2mm above the cementoenamel junction (CEJ). The teeth were embedded in a piece of dried bone and radiographed using CCD and PSP with equal geometry at zero and 15° horizontal angles. VRFs were then induced and the fractured fragments were reattached. The teeth were radiographed again. Three observers evaluated the radiographs for detection of fracture line. Data were analyzed using the Proportion test and Wilcoxon's Signed Ranks test.

Results: No significant difference was found between the two sensors in detection of VRFs [p-value (complete)= 0.592, p-value (absolute)= 1]. The sensitivity of the two sensors for detection of buccolingual and mesiodistal fractures was not significantly different [p-value BL (absolute)= 0.109, p-value BL (complete) 0.180] [p-value MD (complete)=0.593, p-value MD (absolute)= 0.102]. The sensitivity of both sensors for detection of buccolingual fracture was higher than for mesiodistal fractures ($p<0.001$).

Conclusion: CCD and PSP had equal efficacy for detection of VRFs in endodontically treated teeth.

Key words: Dental radiography, Diagnosis, Digital radiography, Endodontically treated tooth, Root canal, Tooth, Vertical root fracture.

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Introduction:

Vertical root fractures are among the most common causes of endodontic treatment failures (1). VRFs account for 0.5-7% of all traumas to the permanent teeth (2) and more frequently occur in the maxillary premolars and the mesial root of mandibular molars (3). Endodontic therapy is the most common treatment leading to VRFs (1, 4). If not diagnosed early, VRF can cause pain and lead to the spread of infection into the underlying tissues resulting in more severe complications. These complications may lead to invasive unnecessary treatments and subsequently poorer prognosis (5). Radiographic and clinical signs and symptoms of VRFs are not pathognomonic and definite diagnosis is made only by the observation of fracture line (6). Radiographic diagnosis of VRF immediately after the trauma (particularly if the fractured segments are not displaced) requires high precision and use of high-resolution receptors.

Different imaging techniques are used in the clinical setting. Digital systems have gained popularity due to easy accessibility, enabling image adjustment by the user and lower patient dose compared to conventional radiographic films. CCDs and PSPs are two common technologies in digital radiography. CCDs use a thin silicon wafer as a base for image acquisition. PSPs are comprised of a polyester base covered with a layer of fluorohalide and europium in a crystalline structure (7). One of the most important factors affecting the ability for detection of VRFs is the quality of radiographic images. In digital radiography, use of image enhancement software programs to improve the quality of images may significantly help in this respect (8). Some previous studies have evaluated the efficacy of conventional and digital radiography for detection of VRFs. It appears that conventional film radiography does not have the required efficacy for detection of VRFs and provides false negative results in VRF cases (9). One study reported similar efficacy of digital and conventional radiography for detection of VRFs (2). Another study reported significantly higher efficacy of digital images for detection of VRF in endodontically treated teeth compared to conventional film radiography (8). In general, based on the literature, conventional radiography is not an acceptable technique for detection of VRFs (10). Limited studies have compared the efficacy of digital sensors for detection of VRFs. Wenzel and Kirkevang (2005) demonstrated that high resolution CCDs compared to medium resolution PSPs had higher efficacy for detection of horizontal root fractures (11). The above-mentioned studies along with the growing use of digital sensors instead of conventional films justify the need for further evaluation of digital sensors. On the other hand, number of studies on VRFs in endodontically treated teeth is scarce. Thus, taking into account different characteristics of digital detectors, this study aimed to compare the efficacy of CCD and PSP for detection of VRFs in endodontically treated teeth.

Methods:

In this *in vitro* study, 40 maxillary anterior teeth with straight roots were selected and absence of root fracture, caries or resorption was confirmed via observation with a magnifier at 40X magnification. Crowns were cut 2mm above the CEJ by a disc. Root canals were prepared by files #15-60 (MAF=35) using the step-back technique and filled with #35 gutta percha master cone and #20 accessory cones along with ZOE sealer using the lateral condensation technique.

In the next step, the teeth were mounted in a piece of dried sheep bone. To simulate soft tissue, 3 layers of red wax were placed over the buccal and lingual tablets (11). Primary radiographs were obtained using CCD and then PSP at zero and 15° distal horizontal angulations.

The CCD used was Dr. Suni (Suni Medical Imaging, San Joe, USA) size 2 with 22µm pixel size and 23 Lp/mm resolution. The PSP scanner used was Digora®Optime (Soredex, Tulsa, Finland) size 2 with 40µm pixel size and 12.5 Lp/mm resolution. Radiographs were obtained by Minray intraoral radiographic device (Soredex, Tulsa, Finland) at 70kVp and 8mA. The exposure time based on a pilot study was 0.12s for CCD and 0.03s for PSP. A sensor holder was used to maintain a fixed distance from the tube to the alveolar bone. Images were saved in two separate files for CCD and PSP in a computer. Vertical fractures were then induced in all teeth. For this purpose, a copper ring was placed over the mid-third of the root, surgical chisel was placed into the canal orifice and vertical fracture was induced by gentle hammering (12). Fracture line in teeth was detected with a magnifier. Fractured fragments were reattached using super glue (Razi, Iran). Teeth with undesirable fractures were excluded. After obtaining 40 teeth with VRFs, the teeth were radiographed again using CCD and PSP with the same geometry and the mentioned horizontal angulations (Figure 1).

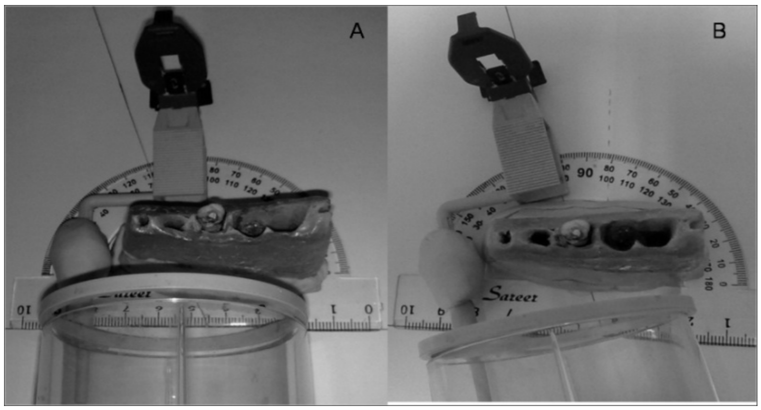

Figure 1- Radiographs were obtained from teeth in dried bone. A: Zero degree horizontal angulation (orthoradial). B: 15° distal angulation (distoradial)

All images were coded and radiographs of each tooth taken at the two angulations were placed next to each other. Radiographs of teeth with and without fractures (a total of 160 radiographs) were randomly viewed by three observers including a radiologist and two endodontists who were aware of the study design but blinded to the presence or absence of VRF, type of sensor and angulations. The images were viewed on a 17 inch LG monitor with a fixed resolution of 1280x960 under similar conditions of lighting and distance from the monitor in 4 folders of 40 double images each (Figure 2).

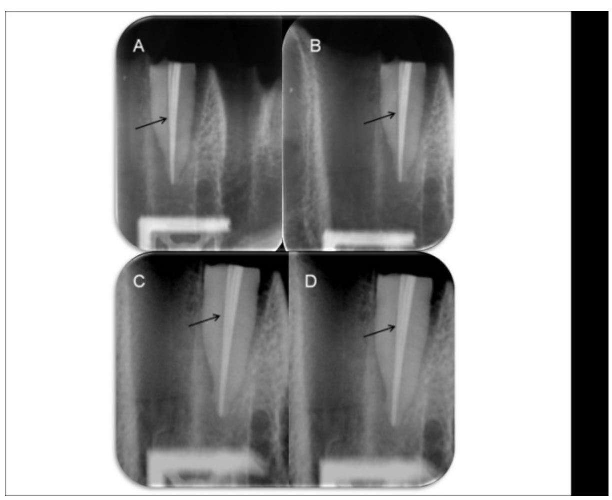

Figure 2- Images obtained by digital sensors: A, B: Orthoradial and distoradial images of PSP sensors, C, D: Orthoradial and distoradialimages of CCD sensors

Interobserver reproducibility was calculated using weighted kappa coefficient. This value was 0.72 (0.12) for CCD and 0.75 (0.14) for PSP. Intraobserver reliability was not calculated in this study.

The results of the comparison of the two sensors were recorded in specific forms. Observers could select one of the 5 choices of definitely a fracture, probably a fracture, definitely no fracture, probably no fracture and unspecific. For statistical analysis, definitely a fracture and definitely no fracture choices were considered as “absolute” and definitely a fracture+ probably a fracture and definitely no fracture+ probably no fracture choices were considered as “complete” responses. Data were analyzed using Proportion test and Wilcoxon Signed Ranks test.

Results:

In this study, 40 single-rooted maxillary anterior teeth were evaluated. All teeth had intracanal filling and radiographed before and after the fracture at the two horizontal angulations with the two sensors. A total of 160 images were evaluated. The mean results of the observers for the sensitivity and specificity of the CCD and PSP are demonstrated in Tables 1 and 2, respectively. Based on the Tables, no significant difference was found in the specificity of the two sensors for detection of VRFs in endodontically treated teeth [p-value (complete)= 0.592, p-value (absolute)= 1]. The sensitivity of the two sensors for detection of buccolingual and mesiodistal fractures was not significantly different [p-value BL (absolute) = 0.109, p-value BL (complete) = 0.180] [p-value MD (complete)= 0.593, p-value MD (absolute)= 0.102]. The sensitivity of both sensors for detection of buccolingual fracture was higher than for mesiodistal fractures ($p<0.001$).

Table 1- The mean sensitivity and specificity based on the type of sensor for absolute diagnosis of fracture

Diagnosis	Sensitivity		
Type of sensor	**Buccolingual**	**Mesiodistal**	**Specificity**
CCD	62.7	15.00	54.1
PSP	54.9	8.66	54.2

Table 2- The mean sensitivity and specificity based on the type of sensor for definite+ probable diagnoses of fractures (complete)

Diagnosis	Sensitivity		
Type of sensor	**Buccolingual**	**Mesiodistal**	**Specificity**
CCD	69.1	35.3	71.6
PSP	65.4	33.0	73.3

Discussion

Radiographic detection of VRF is somehow difficult requiring high precision. VRFs are not easily identified on conventional radiographs. In cases of VRFs, the two fragments are usually separated by a very thin radiolucent line; which is usually in the buccolingual direction. At an early phase, detection of VRF is not easy (1, 13). Previous studies recommend digital (compared to conventional) radiography for detection of VRFs despite their limitations in comparison with the 3D techniques (2, 5, 8, 10).

This study compared CCD and PSP for detection of VRFs in endodontically treated teeth and found no significant difference in this respect between the two systems.

In this study, fractures were induced in buccolingual and mesiodistal directions and statistical analyses showed that the two sensors had higher efficacy for detection of buccolingual fractures.

In clinical studies, superimposition of soft and hard tissues may mask the fracture line but under *in vitro* conditions, clinical setting is relatively simulated and by the control of confounding factors, the accuracy of systems is correctly assessed. On the other hand, number, size and direction of fracture lines may be variable under different conditions. In this study, the teeth were embedded into dried bone and in order to better simulate the clinical setting, layers of wax were used to simulate the soft tissue. Moreover, if the X ray beam does not pass through the fracture line, the fracture will not be identified radiographically and more radiographs need to be taken at different angulations (9).

Tsesis *et al*. (2008) compared the efficacy of digital and conventional radiography for detection of VRFs in endodontically treated teeth after extraction and found no difference. They radiographed the teeth in 3 different horizontal angulations increasing the odds of detecting the fracture line (8). In our study, radiographs were obtained at 2 different horizontal angulations and fracture was confirmed by observing the fracture line in any of the zero or 15° horizontal angulations. Kamburoglu, *et al*. (2010) used different image enhancements such as reverse-contrast and sharpness functions but could not significantly improve the efficacy of imaging systems for detection of fracture line (14). Thus, we only allowed magnification, contrast and brightness adjustments in our study.

Tsesis, *et al*. (2008) did not mention the direction of fracture lines (8). In a study by Hassan, *et al*. (2009) the efficacy of digital radiography for detection of mesiodistal root fractures was much lower than that for buccolingual fractures (12). This finding is in accord with our results. Also, they reported that the sensitivity and overall accuracy of intraoral digital radiography decreased by the effect of the opacity of intracanal materials. They compared fractured teeth in two groups of with and without root canal filling. Analyses revealed that although CBCT is a superior technique for detection of fractures, intracanal filling decreases the specificity of imaging technique due to causing artifacts that resemble the fracture lines; whereas, in digital radiography specificity is not influenced by these factors (12).

In a study by Varshosaz, *et al*. (2010) sensitivity and specificity of CBCT were higher than those of digital radiography with CCDs and since the teeth did not have intracanal filling, diagnosis was relatively easier and the sensitivity of techniques was reported to be higher than our values (15).

In a study by Valizadeh, *et al*. (2011) CBCT was found to be superior to conventional and digital radiography for detection of VRFs (10).

Gunduz, *et al*. (2013) also confirmed this finding (4). However, in all mentioned studies the teeth did not have intracanal filling, post or any foreign material (4, 10, 14, 15). Presence of fracture line is not the only sign for detection of VRFs. Clinical examinations also play a role in diagnosis that cannot be radiographically analyzed. It is not possible to radiographically analyze the indirect signs of bone defects; whereas, artifact due to intracanal foreign materials has a direct impact on the diagnostic value of CBCT and may affect the results. Although the superiority of CBCT for detection of fracture has been confirmed in some studies (4, 10, 12, 15-17), conventional digital radiography is more accessible and affordable than CBCT and is always the first choice in suspected patients. In a study by Kamburoglu, *et al*. (2010) CCD and CBCT (low resolution) had similar efficacy for detection of fracture (18). Also, Wenzel, *et al*. (2009) reported equal efficacy of PSP and CBCT (low resolution) for detection of fracture line (19).

Another study suggested CT scan for detection of VRFs in endodontically treated teeth; whereas, high dose of CT does not allow easy use of this technique for suspected cases (20). Although the radiation dose of CBCT is much lower, it is still several times the exposure dose of radiography limiting its application only to specific cases. To the best of our knowledge, there is no previous study solely focusing on the comparison of CCD and PSP for detection of VRFs in endodontically treated teeth. Based on the results, the diagnostic value of both digital sensors was almost the same and no significant difference was found between them. Also, the odds of detecting mesiodistal fracture lines in both systems were less than those for buccolingual fracture lines. Although digital radiography is capable of detecting the fracture line in many cases, 3D evaluation of suspected teeth with CBCT is recommended.

Conclusion:

CCD and PSP had similar efficacy for detection of VRFs in endodontically treated teeth. Moreover, both sensors had higher sensitivity for detection of buccolingual rather than mesiodistal fractures. Considering the variability of digital receptors and their different characteristics, further studies are required to better assess their capabilities in different fields.

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Conflict of Interest: "None Declared"

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