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Original Research Article

The Effect of Metal Artifacts Reduction Algorithm on Diagnostic Accuracy of Vertical Root Fracture by Cone Beam Computed Tomography, an *in Vitro* Study

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Abstract: Vertical root fracture is one of the most severe complications of root canal treatment. Cone beam computed tomography (CBCT) is the best diagnostic tool for this type of fracture. Presence of canal filling material especially metal material causes an artifact in CBCT images which can affect the diagnostic efficiency. This study was aimed to evaluate the effect of metal artifact reduction algorithm in the diagnosis of VRF in teeth with stainless steel metal post. Eighty anterior teeth were selected and sectioned 2 mm below the CEJ. After preparation of root canals, each root was mounted in acrylic resin. Vertical fracture was induced in forty teeth by Instron machine. A stainless steel post was inserted into each canal to simulate metal artifact. Two CBCT images with or without artifact reduction algorithm were taken for each tooth. Two observers which were blinded for the presence of fracture analyzed all CBCT images twice in a 2-week interval. Then, intra-examiner agreement with kappa value and diagnostic accuracy of CBCT after use of metal artifact reduction algorithm was determined. Sensitivity, specificity, and accuracy of CBCT images with artifact reduction algorithm was 57%, 69%, and 63% and without algorithm was 54%, 61%, 57%, respectively. Intra-examiner agreement with artifact reduction algorithm was 0.59-0.7 and without artifact reduction algorithm was 0.49-0.63. Application of metal artifact reduction algorithm improved sensitivity, specificity, and accuracy of VRF detection through CBCT images; however, the difference between sensitivity, specificity, and accuracy of CBCT with and without using the metal artifact reduction algorithms were not significant.
Keywords: cone beam computed tomography, diagnostic imaging, and algorithms

INTRODUCTION

Vertical root fracture (VRF) is one of the most severe root complications which can be found among root canal treated teeth with a rate of 3.7% to 30.8% [1, 2] and is uncommon among teeth without past root canal treatment [3]. This phenomenon could be a consequence of factors such as occlusion interferences, trauma, strong and eccentric force during endodontic treatment, repeated treatments of a tooth, inappropriate post, and inappropriate selection of tooth as a bridge abutment [4-6]. Regardless of etiologic factors, both single-rooted and multiple-rooted teeth are involved and the prognosis is poor in single-rooted teeth due to the need for more aggressive treatments such as extraction in 10-20% of cases [1]; however, in multiple-rooted teeth more conservative treatments including removal of the involved root, performing an alternative operation, and restoration with composite or hydroxy apatite are available [7]. Food debris and bacteria penetrate through access between oral cavity and fracture line into gingival sulcus, the canal space and therefore into the periradicular area [8] and cause an inflammation in periodontal tissues, alveolar bone resorption and formation of granulation tissue [9]. Consequently, due to progressive loss of bone and periodontal structures, prognosis of VRF worsens over time [10]. Therefore, a rapid and accurate diagnosis is essential to achieve the most appropriate therapeutic technique [11].

Usually, radiography is not helpful in diagnosis of early stages of VRF. Radiolucent fracture line and bone resorption are two diagnostic criteria for advanced stage of vertical fracture. Fracture line is visible radiographically provided that the difference between central beam and fracture line is only 4 degrees. Due to obliquity of fractures, in most cases several radiographies are necessary to obtain correct angle. The second VRF radiographic sign becomes evident if fracture progression causes inflammation, PDL widening and bone loss at a location other than apex which is usually towards alveolar crest coronally [12].

Superimposition of other structures, low sensitivity, and lack of three-dimensional view makes the radiographic diagnosis difficult. Cone beam computed tomography (CBCT) imaging technique provides faster and more accurate diagnosis of vertical fractures by creating three-dimensional images. X-ray energy spectrum is changed by passing through tissues and this change is more prominent when it passes through metal objects [13]. Metal artifact is one of the CT imaging artifacts that is generated as a result of various types of metal repairs, crown, bracket, implant and can affect the quality of images regenerated by CT via beam hardening, beam scattering, quantum, and photonic noise [14]. Hence, metal artifact can make diagnosis difficult and time-consuming by decreasing contrast and concealing structures [15]. Since quick and accurate diagnosis of VRF prevents unnecessary and inappropriate treatments and excessive expenses, we aimed this study to evaluate the effect of reduced metal artifact of post on the accuracy of VRF diagnosis by CBCT.

MATERIALS AND METHODS

This study has been reviewed by the medical research ethical committee of the Qazvin University of Medical Sciences and there is no conflict with ethical considerations (IR.QUMS.REC.1394.629). Eighty single-rooted anterior teeth with closed apex were selected. First of all, soft tissue remnants were washed away from teeth and crown of each tooth was sectioned 2mm below the level of cement enamel junction (CEJ). Tooth canal preparation was performed as follows: To ensure the patency of each canal, file no. 20 was passed into the canal until the apical foramen, then the coronal segment of the root was pre-flared using Gates Gilden no. 2 or 3. All of the teeth canals were prepared using file no. 15 to 50 and washed with saline solution. In the next step, roots were covered with 1 mm of wax and teeth were mounted in acrylic resin. Finally, fixed-length prefabricated titanium post was placed in each tooth canal. Titanium posts are of very high flexural strength under pressure exertion by Instron mechanical test machine.

Teeth were randomly divided into two groups (N=40). Fracture was induced in group one using an Instron machine (Zwick/Roell 7020; Zwick, GmbH & Co. KG, Germany) while the control group was kept intact. This machine records the force in Newtons and exerts an increasing force on tooth until it is fractured (Fig. 1). Tooth fracture was determined according to the crack sound and sudden force release recorded in the graph (Fig. 2). To assess the validity of fracture, teeth were removed from acrylic block and stained with 1% methylene blue. In case of complete separation, the tooth was excluded from study. Afterwards, wax was removed and teeth were mounted on four acrylic casts (20 teeth in each cast) formed similar to human mandible (Fig. 3).

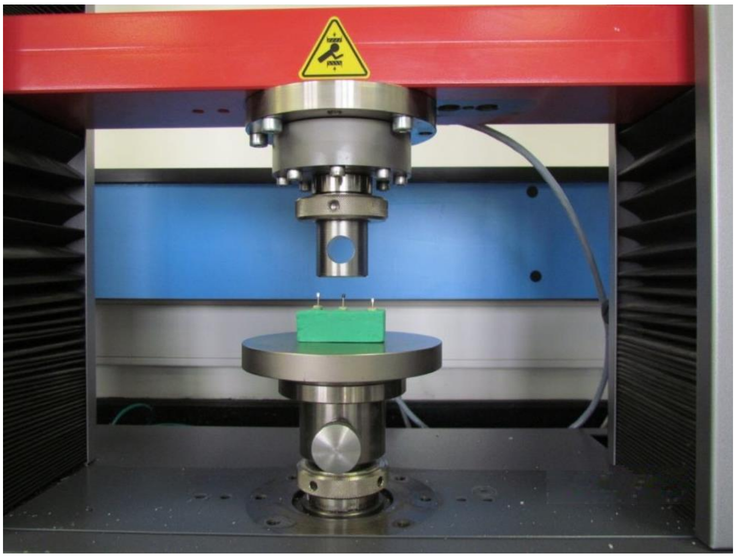

Fig 1: Instron machine for inducing tooth fracture.

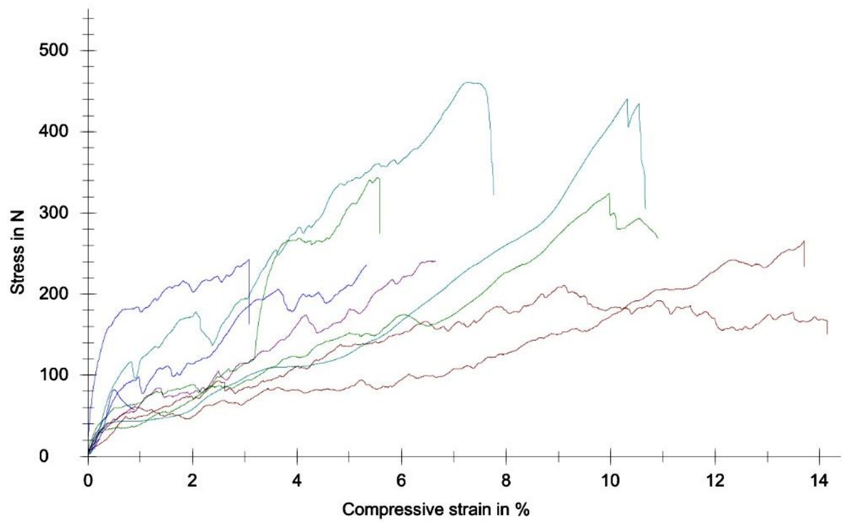

Fig 2: Diagram recorded by an Instron machine. The amount of force required for a root fracture is shown by a sudden drop of force in the diagram.

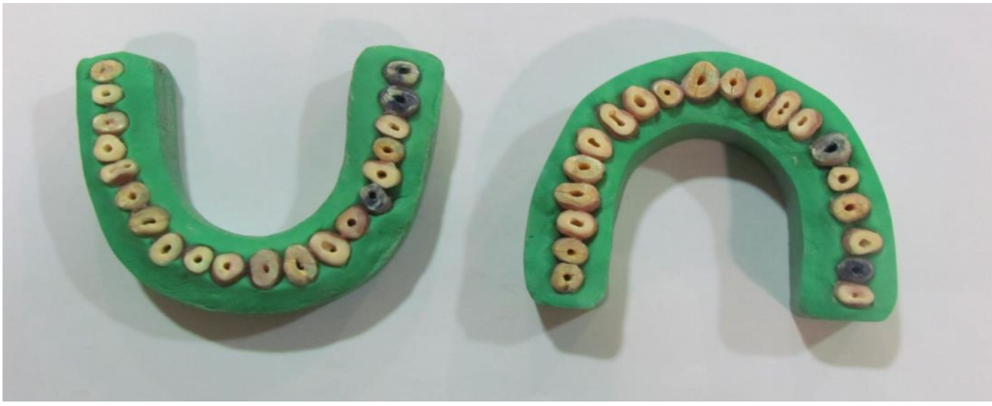

Fig 3: Teeth mounted on human mandible-shaped casts.

Stainless steel prefabricated posts sized M1 were inserted into teeth canals and fixed with wax. CBCT images were taken by Planmeca Promax 3D (Planmeca, Helsinki, Finland). Exposure settings were 66kVp, 8 mA and 12 sec. Field of view (FOV) of the device was 8×8 cm. Two scans for each cast were performed; one in the low artifact reduction mode and the other in the high artifact reduction mode. 3D files were numbered randomly from 1 to 8 and were analyzed by a radiologist and an endodontists blinded for the type of CBCTs. They submitted their results in tables according to fracture, no fracture, tooth no., and cast no. Observers could view images without any time limitation and were permitted to change the contrast, brightness, and image sections. Images were again analyzed after a one-month interval and data were gathered. Kappa coefficient was used to assess the degree of agreement between the observers. Level of significance was set at 0.05. Sensitivity, specificity, and accuracy were evaluated. Data were analyzed using SPSS software (SPSS version 21.0, SPSS, Chicago, IL, USA).

RESULTS

This study included 80 single-rooted anterior teeth; 40 had a VRF induced by an Instron machine and 40 without fracture to determine the effect of metal artifact reduction to diagnose accuracy of VRF by CBCT. Samples were assessed by two observers twice. Table 1 indicates a significant relationship between gold and observers ($p<0.05$, Fisher's exact test). After artifact reduction algorithm, observers accurately diagnosed 57% of teeth with fracture and 69% of teeth without fracture (sensitivity=57%, specificity=69%, and accuracy=63%). According to table 2, there was a significant relationship between gold and observers without artifact reduction algorithm ($p<0.05$, Fisher's exact test). Without artifact reduction algorithm, observers accurately diagnosed 54% of fractured teeth and 61% of teeth without fracture (sensitivity=54%, specificity=61%, and accuracy=57%). In agreement test, kappa value is of great importance. Kappa value was 0.595 for observer 1 with artifact reduction algorithm, which indicates an intermediate agreement level (Table 3). According to table 3, kappa value with or without artifact reduction algorithm was higher in observer 2 compared to observer 1.

Table 1: Accuracy, sensitivity, and specificity of CBCT for diagnosis of vertical root fracture after artifact reduction algorithm.

Gold / Observers	Without fracture		With fracture	
	N	%	n	%
Without fracture	108	69.2	70	42.7
With fracture	48	30.8	94	57.3
	P=0.00			

Table 2: Accuracy, sensitivity, and specificity of CBCT for diagnosis of vertical root fracture without artifact reduction algorithm.

Gold / Observers	Without fracture		With fracture	
	N	%	n	%
Without fracture	95	60.9	76	46.3
With fracture	61	39.1	88	53.7
	P=0.01			

Table 3: Comparison of intra-examiner agreement in vertical root fracture diagnosis using CBCT with or without artifact removal

Observer	Kappa
Observer 1 with artifact removal	0.595
Observer 2 with artifact removal	0.7
Observer 1 without artifact removal	0.487
Observer 2 without artifact removal	0.629

DISCUSSION

Root canal treated teeth are more prone to VRF [16]; therefore, this study was done *in vitro* on teeth with metal posts inserted after root preparation. Several studies support the advantage of CBCT over periapical radiography for diagnosis of VRF [17-19]. This study was designed to compare the accuracy of CBCT images in the diagnosis of VRF and the effect of metal artifact reduction algorithm on the accuracy of CBCT images in the diagnosis of VRF. Accuracy, sensitivity and specificity of CBCT were 0.63, 0.57, and 0.69 with artifact reduction algorithm and 0.57, 0.54, and 0.61 without artifact reduction algorithm, respectively. In 2014, Wenjian suggested that using this algorithm might improve the accuracy of CBCT for diagnosis of VRF [20].

According to our results, this algorithm had the potential to improve the diagnostic indices. Moreover, improvement of accuracy and specificity was higher than that of sensitivity using the algorithm. Studies by Jakobson SJ [21] and Ferreira RI [22] were also in concordance with this study regarding sensitivity reduction in the presence of metal artifact. Jackobson showed that sensitivity is decreased in the presence of metal posts [21] and in Ferreira's study, sensitivity for VRF diagnosis with fiber posts was higher than titanium posts. Regardless of type of images evaluated by CBCT, in both conditions specificity was higher than sensitivity [22]. In a study by Bassam, sensitivity and specificity of obturated canals was 87.5% and 77.8%, respectively [17]. Similar to our study, specificity was higher than sensitivity. However, both indices had higher values than present study. This could be due to two factors: First, difference in sample size which was 80 in our study and 40 in Bassam's study, and second, medium-sized metal post was used in our study, but Gutta Percha was used in Bassam's study.

In the current study, use of artifact reduction algorithm increased both specificity and sensitivity indices and this increase was higher for specificity. In this regard, presence of artifact had more influence on specificity. Surveys by Bassam [17] and P-Wang [18] indicated that use of canal filling materials had no effect on sensitivity but significantly decreased the specificity. Our study is consistent with the above-mentioned studies. In terms of sensitivity, inconsistency between our study and these studies could be due to the fact that in P-Wang and Bassam's studies, presence of filling material is compared to presence of no filling material.

Winjian [20] proposed that in order to differentiate between fracture lines and artifacts originated from radiopaque materials, images should also be evaluated in axial plan. Therefore, in case of fracture detection in coronal and lateral plan, teeth were also evaluated in axial plan in this study and if suspicious fracture line passed the tooth margin, the case was considered as normal. This could be the reason that in the current study specificity is higher in both methods. In 2011, Edlund performed an *in vivo* research to evaluate the sensitivity and specificity of CBCT for the diagnosis of VRF which were 88% and 75%, respectively [16]. In the current study, sensitivity and specificity with artifact reduction algorithm was 57% and 69% and without the algorithm was 54% and 61%, respectively. The difference between these two studies is due to that selected samples in Edlund's study had distal and mesial bone loss and thus fracture lines seemed to be old. This increases the chance of separation of fractured parts and increase of fracture line resolution.

In another *in vitro* study of evaluation of CBCT images with or without canal filling materials by Takeshita, there was no significant difference between two situations (p=0.959) which is in contrast to our study [19]. This could be due to low sample size including only 5 teeth in each group of Takeshita's study. In Ferriera RI's study, intra-examiner agreement value for detecting VRF using two types of CBCT was 0.42-0.8 and 0.31-0.71 for titanium posts and 0.5-0.7 and 0.35-0.76 for fiber posts [22]. It can be concluded that the average intra-examiner agreement is higher due to absence of metal artifact in fiber posts; this was in concordance with our study in which intra-examiner agreement was increased using artifact reduction algorithm (without algorithm: 0.49-0.63; with algorithm: 0.59-0.7).

CONCLUSION

Application of metal artifact reduction algorithm improved sensitivity, specificity, and accuracy of CBCT for detection of VRF; however, the sensitivity and specificity and accuracy of CBCT with or without using the metal artifact reduction algorithms were not statistically significant. Moreover, intra-examiner agreement was higher with artifact reduction algorithm compared to without algorithm. Since there is no limitation for using this algorithm, it is recommended to use this in the presence of metal structures.

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