

## Original Article

# *In vitro* diagnostic accuracy of cone-beam computed tomography with variable gamma values for detection of vertical root fractures in teeth with prefabricated metal posts

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## ABSTRACT

**Background:** Cone-beam computed tomography (CBCT) has the highest sensitivity and specificity for the detection of vertical root fractures (VRFs). This study aimed to compare the diagnostic accuracy of CBCT with different gamma values for the detection of VRFs.

**Materials and Methods:** In this *in vitro*, experimental study, multiplanar CBCT scans were obtained from 61 extracted premolars with prefabricated titanium posts using NewTom CBCT scanner. Next, VRFs were artificially induced in all teeth with a mallet, and the teeth underwent CBCT with three different gamma values. The images were evaluated by two observers twice with a 2-week interval for the presence/absence of VRFs. Data were analyzed using the kappa coefficient, McNemar test, and Chi-square test. The sensitivity, specificity, and overall accuracy of CBCT with different gamma values for the detection of VRFs were assessed by receiver operating characteristic curve. The level of significance was lesser than 0.05 ( $P < 0.05$ ).

**Results:** Changing the gamma value did not change the sensitivity, specificity, or accuracy of CBCT for the detection of VRFs. No significant difference was noted between the two observers in the detection of VRFs on CBCT scans taken with different gamma grades. The inter- and intra-observer agreement were excellent for all gamma grades.

**Conclusion:** Any gamma value preferred by the observer can be used for the detection of VRFs on CBCT scans.

**Key Words:** Artifact, cone-beam computed tomography, tooth fracture

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## INTRODUCTION

Radiography is a commonly used diagnostic modality for the detection of vertical root fractures (VRFs).<sup>[1]</sup> The conventional and digital intraoral radiographic modalities can be used for the detection of VRFs, given that the X-ray beam is radiated parallel to the fracture line.<sup>[1-3]</sup> At present, three-dimensional

imaging modalities such as cone-beam computed tomography (CBCT) have the highest sensitivity and accuracy for the detection of VRFs.<sup>[4]</sup> The 3D nature of CBCT enables better detection of direct and indirect radiographic evidence of VRFs.<sup>[5]</sup> However, the patient radiation dose of CBCT is higher than

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that of two-dimensional conventional and digital radiography.<sup>[6]</sup> Moreover, in case of the presence of metals such as dental implants or intracanal metal posts, metal artifacts would compromise the image quality and complicate the detection of VRFs. This is especially important in the detection of VRFs in teeth with intracanal metal posts.<sup>[6]</sup>

Restoration of endodontically treated teeth is a common challenge for many dental clinicians due to severe damage and loss of great portion of tooth structure due to caries, fractures, previous restorations, or access cavity preparation in such teeth.<sup>[3]</sup> Intracanal posts are commonly used for the restoration of nonvital endodontically treated teeth that have lost a great portion of their structure. Prefabricated posts are commonly used to retain a core for the final restoration or a substructure for crown placement.<sup>[3]</sup>

The use of different image enhancement software programs and the ability to change the contrast and brightness of images are among the main advantages of digital radiography and CBCT. By changing the gamma value of the images, the contrast of the gray and white parts of the image is reversed.<sup>[7]</sup>

This study aimed to compare the diagnostic accuracy of CBCT with different gamma values (high, medium, and low) for the detection of VRFs in endodontically treated teeth with prefabricated metal posts and VRFs.

## MATERIALS AND METHODS

This *in vitro*, experimental study evaluated 61 single-rooted and single-canal premolars with no caries, restoration, or root fracture. The teeth had been extracted as part of orthodontic treatment or due to poor periodontal prognosis. The study protocol was approved by the ethics committee of Ahvaz Jundishapur University (IR.AJUMS.REC.1397.282).

Sample size was calculated to be 61 according to a previous study.<sup>[8]</sup>

After access cavity preparation, the root canals were prepared by the step-back technique to #35 and were then obturated with gutta-percha and zinc oxide eugenol sealer with cold lateral compaction technique; 72 h was allowed for the sealer to set. Next, post space was prepared in all teeth. For this purpose, the gutta-percha was removed from the coronal two-thirds of the canal with a peeso reamer such that 5 mm of gutta-percha remained at the apical third. Next, a prefabricated titanium post (Dentsply,

Sirona, Switzerland) was placed in the canal without cementation (because the cement could penetrate into the fracture line). All teeth then underwent multiplanar CBCT. VRFs were then artificially induced by a mallet, and the teeth underwent CBCT with the same exposure settings. To obtain the CBCT scans, the teeth were aligned in a straight line in a sheep jaw. The teeth were then scanned before and after induction of VRFs in a CBCT VGi NewTom scanner (Verona, Italy) with 8 × 8 field of view in high-resolution mode with the exposure settings of 110 kVp, 0.3–65.29 mA, and 3.6–5.4 s time by the selection of denture settings of the scanner (to reconstruct the soft tissue). The images were saved in three different gamma values (+10, 0, and –10) of the scanner. Multiplanar images were reconstructed with 1 mm slice thickness and 1 mm slice interval. After image acquisition, all data were stored and the images of sound teeth and those with VRFs were coded. The images were then randomly evaluated by two oral and maxillofacial radiologists, with a minimum of 5 years of clinical experience in interpretation of CBCT images twice with a 2-week interval on a 14-inch LED monitor (Vaio; Sony, Japan) with 1366-pixel × 768-pixel resolution. The observers were blinded to the presence/absence of VRFs in teeth and the gamma value used. Both observers viewed the images on the same monitor in a dimly lit room under similar conditions. They had 50–70 cm distance from the monitor and were not allowed to change the contrast, brightness, or magnification of multiplanar images.<sup>[9]</sup> The observers independently recorded the presence/absence of VRFs on predesigned forms: 0 indicated the absence of VRF and 1 indicated the presence of VRF.

To assess the intra-observer agreement, the observers were requested to re-evaluate all multiplanar images after a 2-week period with the same conditions, and their opinion regarding presence/absence of VRFs was compared with their initial opinion.

Data were analyzed using SPSS version 22 (SPSS Inc., IL, USA) via the McNemar test, kappa coefficient, and Chi-square test. The kappa values were classified according to the classification by Edlund and Nair<sup>[10]</sup> such that the values <0.00 indicated poor, 0.00–0.20 indicated mild, 0.21–0.40 indicated relatively good, 0.41–0.60 indicated fair, 0.61–0.80 indicated good, and 0.81–1.00 indicated excellent agreement.

The sensitivity, specificity, and overall accuracy of CBCT with different gamma values for detection of

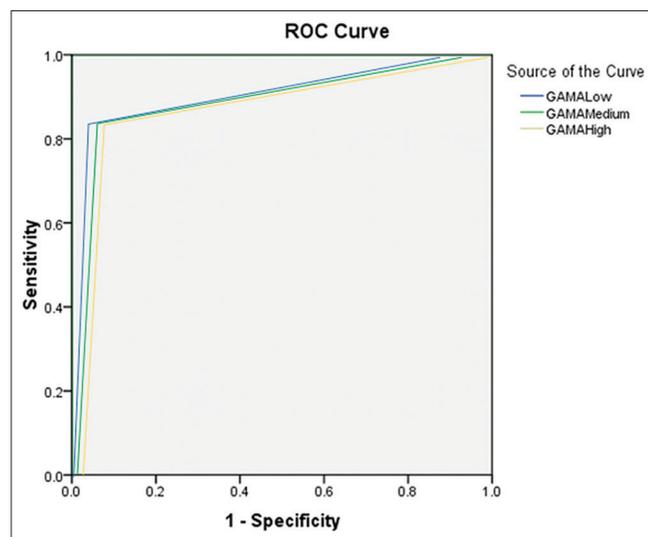
VRFs were determined using the receiver operating characteristic (ROC) curve at  $P < 0.05$  level of significance.

## RESULTS

The kappa value for the interobserver agreement was calculated to be 1.00, indicating excellent agreement. The Chi-square test showed no significant difference between the two observers in the detection of VRFs on CBCT scans with different gamma values (all  $P_s = 1.00$ ). The intra-observer agreement was also 1.00 for all three gamma values, which indicated excellent agreement with no significant difference.

Table 1 presents the sensitivity, specificity, and overall accuracy of CBCT with different gamma values for the detection of VRFs by the two observers. As shown, both observers correctly detected all sound teeth (true negative). Thus, CBCT with all gamma values had 100% specificity. In the detection of teeth with VRFs, both observers correctly detected 53 teeth (true positive). Thus, the sensitivity, specificity, and accuracy of both observers for 0, +10, and -10 gamma values were 86%, 100%, and 93%, respectively. No significant difference was noted in sensitivity, specificity, and accuracy of CBCT in the detection of VRFs by the two observers ( $P > 0.05$ ).

Figure 1 shows the ROC curve for all three gamma values. As shown, all three gamma values yielded similar accuracy for detection of VRFs. The area under the ROC curve for all three gamma values was 0.890.



**Figure 1:** Receiver operating characteristic curve for all three gamma values.

The McNemar test [Table 2] was used to compare different gamma values for the detection of VRFs by the two observers. The results showed no significant difference among the three gamma values in this respect, and different gamma values had no significant effect on the detection of VRFs ( $P = 1.00$ ) [Figures 2-4].

## DISCUSSION

This study compared the diagnostic accuracy of CBCT with different gamma values (high, medium, and low) for the detection of VRFs in endodontically treated teeth with prefabricated metal posts and VRFs. The results showed that CBCT with all three gamma values had acceptable sensitivity, specificity, and overall accuracy for the detection of VRFs, with no significant difference in any parameter between the three gamma values. Thus, CBCT with all gamma values is suitable for the detection of VRFs. In addition, the intra- and inter-observer agreements were excellent for all gamma values.

Search of the literature by the authors yielded no study comparing the diagnostic accuracy of CBCT with different gamma values for the detection of VRFs. Thus, we compared our results with those of studies on the effects of contrast of different imaging modalities on the detection of root fractures. Mehrizadeh *et al.*<sup>[11]</sup> evaluated the accuracy of reverse contrast enhancement filter of indirect digital radiography for the detection of VRFs and found

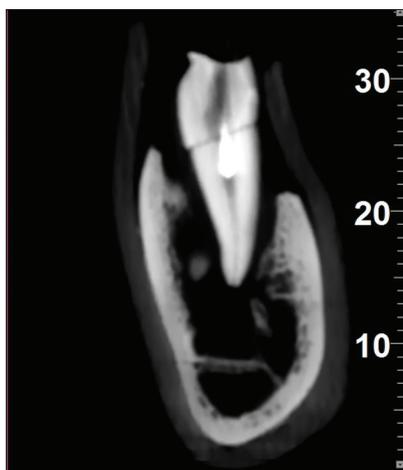
**Table 1: Sensitivity, specificity, and overall accuracy of cone-beam computed tomography with different gamma values for detection of vertical root fractures by the two observers**

Observer	Gamma value	Sensitivity (%)	Specificity (%)	Overall accuracy (%)
First	0000	86	100	93
	+10	86	100	93
	-10	86	100	93
Second	0	86	100	93
	+10	86	100	93
	-10	86	100	93

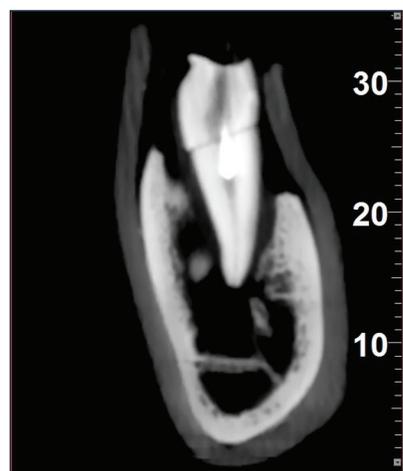
**Table 2: Comparison of different gamma values for detection of vertical root fractures**

Basic gamma value	Degree of difference	$P$
L 00	L+10+	1 (NS)
	L-10	1 (NS)

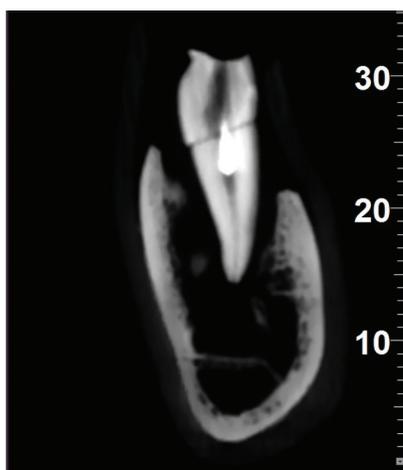
95% CI. NS: Not significant; CI: Confidence interval



**Figure 2:** Cone-beam computed tomography image performed with gamma 0.



**Figure 3:** Cone-beam computed tomography image performed with gamma -10.



**Figure 4:** Cone-beam computed tomography image performed with gamma +10.

that it did not enhance the detection of VRFs. Their results were in agreement with ours probably because

reverse contrast filter is highly similar to gamma format. Tofangchiha *et al.*<sup>[12]</sup> evaluated the detection of VRFs on digital radiographs with reverse contrast and colorization filters. They reported that original images were significantly superior to enhanced images for this purpose. Their results cannot be compared with ours since we used CBCT for the detection of VRFs. Sakhdari *et al.*<sup>[13]</sup> evaluated the efficacy of reverse contrast filter of direct digital radiography for detection of horizontal root fractures and found no significant difference between the original and enhanced images. Their results were in line with ours despite the use of a different imaging modality. Lee *et al.*<sup>[14]</sup> reported that the use of reverse contrast filter slightly, but not significantly, enhanced the detection of horizontal root fractures. Neves *et al.*<sup>[15]</sup> evaluated the effect of exposure settings and presence of gutta-percha, metal posts, and fiber posts in the root canal system on diagnostic accuracy of 3D Accuitomo 170 CBCT scanner for the detection of VRFs. The results showed that gutta-percha and metal posts negatively affected the diagnostic accuracy of CBCT while exposure settings had no significant effect in this respect. Their results regarding no significant effect of imaging settings on diagnostic accuracy of CBCT were in agreement with our findings. Ferreira *et al.*<sup>[16]</sup> evaluated the effect of CBCT enhancement filters on diagnostic accuracy for detection of VRFs. They showed that the use of enhancement filters had no advantage for detection of VRFs, which confirms our results. de Rezende Barbosa *et al.*<sup>[17]</sup> assessed the effect of metal artifact reduction algorithm and presence of gutta-percha and fiber post on the detection of VRFs by Picasso Trio CBCT and demonstrated no significant difference between the original and enhanced images in this respect. Their results were in agreement with ours despite the use of a different scanner and enhancement filter.

In general, it should be noted that radiographic interpretation is a highly sensitive task, and a number of factors such as the type of imaging modality, monitor characteristics, image manipulation, observation conditions, and experience and skills of the observers can all affect the results.<sup>[11,18]</sup> Furthermore, the efficacy of enhancement filters depends on the experience and attitude of the observers.<sup>[11,12,18]</sup>

It should be noted that this study had an *in vitro* design. Presence of hard and soft tissue structures in the oral environment can significantly alter the results.<sup>[12]</sup>

Furthermore, this study only evaluated premolar teeth. Future studies on other teeth with VRFs and different types of intracanal posts are recommended using other gamma values. Furthermore, *in vivo* studies are required to confirm the *in vitro* results.

## CONCLUSION

According to the result of this study, there is not any significant difference between varies gamma values for detecting VRFs in CBCT images. Agreement percent between observers in all gamma values was very high. Thus, any gamma value preferred by the observer can be used for the detection of VRFs on CBCT scans.

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### Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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