IEJ
Iranian Endodontic Journal

Effect of Field of View and Resolution in Detection of Horizontal Root Fractures in CBCT images: An *In Vitro* Study

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ARTICLE INFO

Article Type:
Original Article

Received: 14 Apr 2018
Revised: 13 Aug 2018
Accepted: 28 Aug 2018
Doi: *10.22037/iej.v13i4.21537*

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ABSTRACT

Introduction: New cone-beam computed tomography (CBCT) devices are capable of imaging with different resolutions and field of views (FOVs), in which higher resolutions and FOVs impose a higher dose to the patient. This study was an attempt to investigate the detection accuracy from different FOVs and resolutions in detection of horizontal root fractures. **Methods and Materials:** Through this experimental study, in five different field of views (FOV) and resolutions (voxel size) of New Tom VGi CBCT (Italy) system was used to scan fifty teeth with horizontal root fractures in half of them. The images were evaluated by four observers (two maxillofacial radiologists and two general dentists) who recorded the presence or absence of horizontal root fractures. The data were analyzed by SPSS 22 software and MacNemar and kappa test were used to compare results with reality. **Results**: The highest sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy (A_Z) were attributed to 8×8 FOV and high resolutions (0.125 mm voxel size) but the difference between sensitivity, specificity, PPV and NPV was not significant. Kappa values for inter-observer agreement between radiologists and general dentists and also intra-observer agreement were in excellent ranges. The highest Kappa in both cases was attributed to 8×8 FOV and high resolutions. **Conclusion:** There was no significant difference to diagnose of horizontal root fracture between two observer groups and for all of the FOVs and voxel sizes.

Keywords: Cone-Beam Computed Tomography; Field of View; Horizontal Root Fracture

Introduction

Horizontal root fracture is a kind of uncommon fracture which is typically in line with perpendicular axis of teeth root and is often caused by acute trauma [1, 2]. The root fractures are most commonly observed in the middle third of the root and in roots with developed apexes [3, 4].

Diagnosis of horizontal root fracture is generally based on clinical and radiographic symptoms [5, 6]. To observe the fracture, the x-ray radiation should be in line with the fracture plane. Since the fracture line is usually slanted towards the bucco-lingual, so it is not clearly observed in a single conventional x-ray image. In this case, usually more than one periapical radiographs with two different horizontal angles are needed to detect radiolucent lines of fractures [7]. In addition, in intra-oral radiography, anatomic superimposition and geometric of radiation may suggest a root fracture [8].

In recent years the use of cone-beam computed tomography (CBCT) has expanded in different fields of dentistry. The three-dimensional nature of CBCT will lead to better observation of direct and indirect radiographic signs of root fracture [9, 10]. Despite having the advantage of providing three-dimensional images, it imposes higher doses to patients compared to the other conventional and digital radiographs [7, 11]. Radiation emitted during CBCT scans will be affected by the exposure parameters such as voxel size, field of views (FOV), the degree of rotation, the tube voltage and current [12].

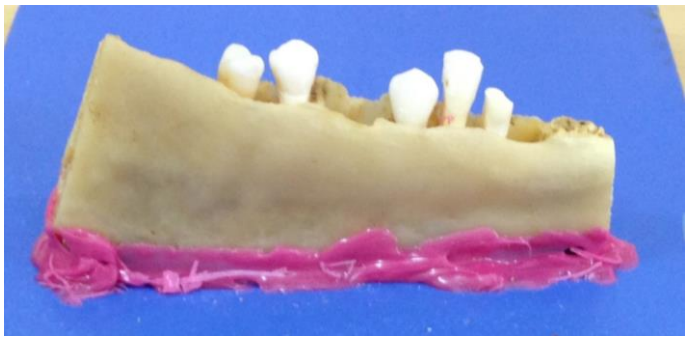

Figure1. View of the teeth in sheep jaw

One of these factors is the dimension of FOV [13]. The use of smaller FOV increases image resolution reduces fading and the partial volume artifact [14]. Also new CBCT systems are capable of imaging in different resolutions, which leads to more precise detection of image details, but images with higher resolutions imposes a higher dose to the patient [15].

From literatures, few studies have been carried out on the impact of different FOVs and resolutions [16, 17]. Since different FOVs and imaging with a variety of resolutions are available in different CBCT systems, the aim of this study is to investigate the impact of different FOVs and resolutions on diagnosis of the horizontal root fracture.

Materials and Methods

This *in vitro* experimental study is carried out in the Oral and Maxillofacial Radiology Department of Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.

Fifty single-rooted teeth (twenty five controls, twenty five cases) were investigated. The inclusion criteria included the teeth without distinctive decay, repair or fracture which were extracted due to periodontal or orthodontic problems. The twenty five teeth were first fixed by a clamp and then horizontally fractured by mechanical force applied on them by a hammer. The fractures were single linear ones and the teeth with crashing fractures were excluded from the study. Then the two broken pieces were attached together by using glue without displacement in standard conditions that could clearly stimulate *in vivo* fracture. The teeth were arranged in a straight line on the jaw. An acrylic plate with thickness of 1.5 cm was inserted between x-ray tube and the teeth for the purpose of reconstruction of periodontal ligament space in the jaw and also to create a visual contrast between the teeth and surrounding structure. Putty dough was used to fix the acrylic plate on the wooden blocks [15] (Figure 1).

Both broken and healthy teeth were scanned by CBCT system (New Tom VGi /Verona/ Italy) at 110 kVp, 0.65-3.29 mA and exposure time of 3.6 and 5.4 sec, which depends on the selected FOV. The focal spot size of the x-ray source was 0.3 mm. The samples were scanned at different FOV and resolutions available in the CBCT system, as follows: 1- high resolution 6×6 FOV with voxel size of 0.15 mm, 2- high resolution 8×8 FOV with Voxel size of 0.125 mm, 3- normal resolution 8×8 FOV with Voxel size of 0.25 mm, 4- high resolution 12×8 FOV with Voxel size of 0.15 mm, 5- normal resolution 12×8 FOV with Voxel size of 0.3 mm. The samples were placed on the chin rest and central line of the scanner was set on the center of the sample. After acquisition of the image, the data were saved in the form of DICOM (Etiam Corp, Cambridge, MA, USA) (Figure 2).

All images including the images of healthy and broken teeth were encoded and evaluated blind by two observer groups. The observer groups included two Oral and Maxillofacial radiologists with at least 2 years work experience and two general dentists with at least 10 years of experience. They were seen on a 14-inch LCD Monitor (VAIO SONY Corp., Japan) with a resolution of 1366×768 dpi.

Both observer groups, observed the images in a room with no windows and dim light [18, 19]. The observers were free to manipulate images in terms of contrast, brightness and zoom [16]. The images were randomly evaluated by observers and the observers independently recorded the presence or absence of horizontal root fractures on the questionnaire, in accordance with the following codes: (0: There is no fracture, 1: There is fracture). To assess intra-observer agreement, the first observer was asked to reevaluate all the images after two weeks again to make it possible to compare the results.

The results of this study were analyzed using SPSS software on windows version 22.0 (SPSS, Chicago, IL, USA). The validity criteria including PPV and NPV were measured. The McNemar test in the cross tables, and kappa test (kappa) in the above-mentioned software were used to investigate the significant relationship between the diagnoses made by the observer and the reality of the situation. Sensitivity, specificity, and overall accuracy were measured by the analyses of ROC curve (Receiver Operating Characteristic). The significance of all statistical tests was considered $P \leq 0.05$.

Results

According to Table 1 and Figure 3, in the evaluation of different FOVs, the greatest sensitivity, specificity, PPV and NPV was attributed to 8×8 FOV. And in The evaluation of different resolutions, the highest sensitivity, specificity, PPV and NPV were attributed to high resolution conditions (high resolution 8×8 FOV with voxel size of 0.125 mm and high resolution 12×8

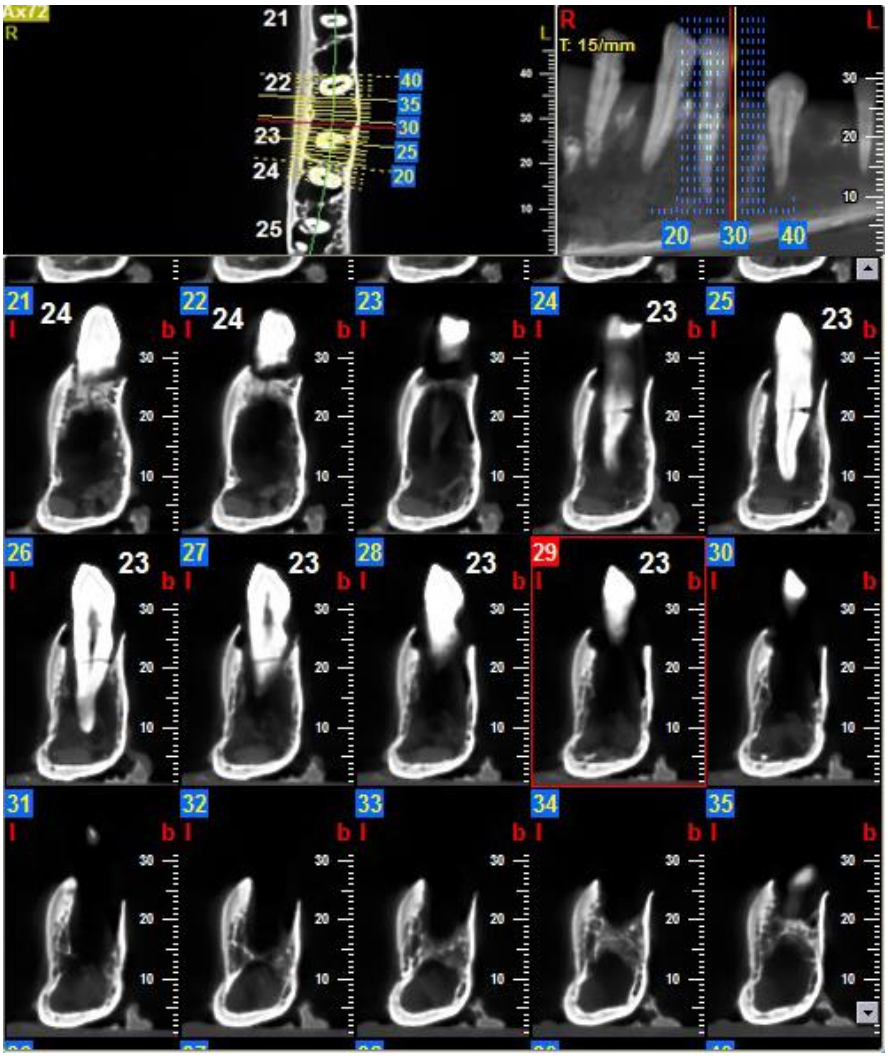

Figure2. CBCT images of broken teeth

FOV with voxel size of 0.15 mm) and among the above-mentioned conditions the 8×8 FOV showed greater values.

According to the McNemar test, there is no significant difference between different FOVs and resolutions used for detection of horizontal root fracture in radiologist and also general dentist groups. Furthermore, the FOV size and the type of resolution used did not affect the detection of horizontal root fracture (P>0.05).

According to the Kappa test, the agreement between the first and second observer in the radiologists group and between the third and fourth observers in dentists groups was almost perfect according to Landis and Kotch criteria [20]. The *Chi* square test results also showed that there was no significant difference between the two groups in horizontal root fracture detection at different resolutions and FOVs.

The Kappa values for inter-observer agreement and intra-observer agreement in different FOVs and resolutions were almost perfect. The greatest kappa value for both inter-observer and intra-observer agreement was attributed to high resolution 8×8 FOV (Table 2).

Discussion

Since the introduction of CBCT in the field of diagnostic radiology, different studies have been carried out on it, in order to make maximum use this system and remove its faults and weaknesses. The ability of visualizing three-dimensional facial structures in different planes can increase diagnostic ability of this system.

Based on the nature of imaging technology and characteristics image receptor systems in CBCT, reduction in voxel size leads to higher image resolutions. With the decrease in voxel size, the dose received by the patient will increase and this is a disadvantage in this context [15]. One purpose of this study was to examine whether increase in the voxel size will

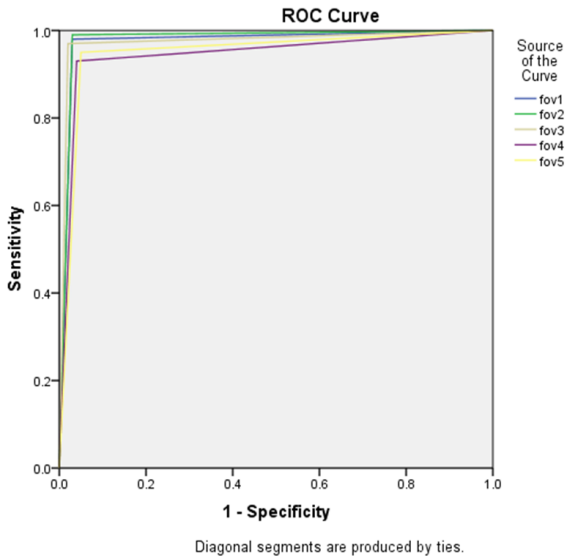

Figure3. Results of sensitivity, specificity, PPV, and NPV

affect the detection of horizontal root fractures, so that in case the answer is negative, we can detect horizontal root fracture by larger voxel sizes that lead to lower resolution and lower patient dose in CBCT examination, as much as possible.

According to the results of this study, there is no significant difference between the high resolution conditions and the normal resolution methods. From the perspective of sensitivity, specificity, PPV, NPV and accuracy, there are no significant differences between the two conditions. But increasing voxel size, leads to reduction of sensitivity, specificity, PPV, NPV and accuracy. Since there is no significant difference between five conditions in terms of sensitivity (detection of horizontal root fractures), it can be concluded that CBCT is considered an appropriate technique for detection of horizontal root fractures at all the above-mentioned FOV and resolutions. So in cases where the detection of horizontal root fracture is mentioned through low resolution CBCT scan with larger voxel size and the treatment plan moves towards the removal of tooth, we can trust to this diagnosis.

When specificity is low, the risk of misdiagnosis which leads to the removal of the tooth should be considered. According to the results which indicate that there is no significant specificity difference between high resolution an normal resolution conditions, we can argue that the health and lack of fracture in teeth can be trusted even in cases where low resolution or large voxel size are used.

In the present study the highest sensitivity, specificity, PPV, NPV and accuracy were attributed to high resolution modes and between them, high resolution 8×8 FOV was greater than the other mode. Since in this study, the 8×8 FOV had the smallest voxel size, this conclusion seems to be logical. Few studies have been done in this regard. These studies are reviewed briefly in the following part.

In a study carried out by Amintavakoli *et al.* [17], voxel sizes of 0.076, 0.1, 0.2 and 0.3 were investigated. The highest sensitivity, PPV and accuracy were attributed to 0.1 voxel size and the highest specificity and NPV were attributed to voxel size of 0.076 [17]. The results are similar to the results of the present study. In another study carried out by Ozer *et al.* [21], the voxel sizes of 0.125, 0.2, 0.3, 0.4 were investigated and it was concluded that the voxel sizes of 0.125 and 0.2 have higher sensitivity and specificity in detection of horizontal root fracture. Since these two voxel sizes were the smallest selected voxel sizes, the results are comparable to our study [21]. In another study carried out by Kamburoğlu *et al.* [22], different voxel sizes were selected to investigate the internal resorption, the results showed that the highest levels of accuracy were attributed to voxel size of 0.125, and the lowest accuracy was attributed to the voxel size of 0.3 but this difference was not significant, and therefore is consistent with the results of our study [22].

The effect of FOV size on detection of horizontal root fracture was also considered in this study. The highest levels of sensitivity, specificity, PPV, NPV and accuracy were attributed to the 8×8 FOV, but there was no significant difference between these FOVs. It may be due to the fact that in this system, the 8×8 FOV has the smallest voxel size and this could have a significant impact on the detection of details. In a study carried out by Costa *et al.* [23], it was reported that CBCT with small FOVs features a high degree of accuracy (73-84%) in detection of horizontal root fractures, in case of no metal posts [23]. Eskandarloo *et al.* [16] investigated the CBCT images provided by New Tom VGI CBCT in two FOV sizes of 6×6 and 15×15 to detect the maxillofacial fractures. The results showed that sensitivity, specificity, PPV, NPV and accuracy of 6×6 FOV is greater than those in 15×15 FOV [14]. In another study carried out by Safi *et al.* [24], CBCT images were taken in 2 different 6×6 cm and 12×8 cm FOVs both with the same voxel size of 0.2 mm to assess simulated external root resorption. Also the sensitivity and specificity of 6×6 FOV was greater than those in 12×8 FOV, but there was no significant difference.The results of these studies confirm our results.

According to all previous studies, the highest levels of sensitivity, specificity, PPV, NPV and accuracy were attributed to the smallest FOV. In the present study, the 8×8 FOV had the highest levels of sensitivity, specificity, PPV, NPV and was not the smallest one, which may be due to the specific settings of this CBCT system, in which 8×8 FOV has the smallest voxel size.

For better detection of horizontal root fractures by CBCT, the clinicians need to be familiar with displaying three-dimensional anatomies and how to use the CBCT images [21]. The results of our study showed no significant difference between the two groups (maxillofacial radiologists and general dentists) in horizontal root fracture detection at different FOVs and resolutions. The findings of this study confirm the results obtained by Eskandarloo *et al.* [16]. According to the results obtained by Amintavakoli [17], no significant difference was found in detection of horizontal root fractures between the two groups (radiologists and the residents of radiology) which in fact confirm the results of our study.

Inter-observer agreement was almost perfect at different FOVs and resolutions which confirms the results obtained by Eskandarloo *et al.* [16, 17], but is inconsistent with the results obtained by Amintavakoli [17] which the agreement between the groups was fair. This may be because of the fact that in the mentioned study both the horizontal and vertical root fractures were investigated. In addition, the group of observers were oral and maxillofacial radiology assistants who may have little experience in observation of the CBCT and therefore their results were more different with the results of oral and maxillofacial radiology specialists.

In the present study, the highest level of inter-observer agreement was attributed to the smaller voxel sizes which are also justifiable by the increased resolution of CBCT images with a voxel size reduction. In FOVs investigation, the 8×8 FOV had the highest agreement between observers. In addition, in the study carried out by Eskandarloo *et al.* and Kamburoğlu *et al.* [22], the highest inter-observer agreement was attributed to small voxel sizes, which confirm the results of the present study.

Intra-observer agreement in all FOVs and resolutions was almost perfect and this is consistent with results obtained by Eskandarloo *et al.* [16], but is inconsistent with the results obtained by Amintavakoli [17] which showed moderate to substantial levels of agreement between the observers. This again may be attributed to the lower experience of radiology residents in the field of CBCT [16, 17].

In investigation of voxel sizes, the highest Intra-observer agreement was attributed to smaller voxel sizes and in investigation of FOVs, the 8×8 FOV showed the highest intra-observer agreement. The results of this item greatly depend on the experience of observers who perform the second observation. In the studies carried out earlier, the highest intra-observer agreement and reproducibility was attributed to smaller voxel sizes and this confirms the results of the present study [16, 21].

The limitation of this study includes creation of the fractures at *in vitro* conditions. Therefore the results of this study may be different from the results of other studies with *in vivo* samples. So the confirmation of the present study results requires additional evidence on the basis of the *in vivo* studies.

Table 1. Effect of FOV and different resolutions on sensitivity, specificity, PPV, and NPV at general status

	Sensitivity	Specificity	Positive predictive value (PPV)	Negative predictive value (NPV)
6×6 FOV and high resolution	98%	97%	97.02%	97.97%
8×8 FOV and high resolution	99%	99%	99%	99%
8×12 FOV and high resolution	97%	96.7%	97%	97.02%
8×8 FOV and ordinary resolution	93%	96%	98.87%	93.2%
8×12 FOV and ordinary resolution	95%	95%	95%	95%
High resolution	98%	98%	98%	98%
Ordinary resolution	94%	95.5%	95.43%	94.08%

Table2. The Kappa values for inter-observer agreement and intra-observer agreement in different FOVs and resolutions

FOV	Intra-observer Kappa (*k*)	Inter-observer Kappa (*k*)
6×6 FOV and high resolution	Almost perfect 0.92	Almost perfect 0.90
8×8 FOV and high resolution	Almost perfect 0.88	Almost perfect 0.96
8×12 FOV and high resolution	Almost perfect 1.00	Almost perfect 0.96
8×8 FOV and ordinary resolution	Almost perfect 0.97	Almost perfect 0.98
8×12 FOV and ordinary resolution	Almost perfect 0.94	Almost perfect 0.96
High resolution	Almost perfect 0.96	Almost perfect 0.96
Ordinary resolution	Almost perfect 0.97	Almost perfect 0.97

Conclusion

Although CBCT images with small voxel size and FOVs are favorable for detection of details such as tooth fractures, due to their high spatial resolution, but according to the lack of significant differences between the results and also the presence of identical results between the two observer groups at almost all voxel sizes and FOVs, larger voxel sizes can be used to determine the horizontal root fracture in order to reduce the patient dose.

Acknowledgement

This study was supported by a grant from Ahvaz Jundishapur University of medical science

Conflict of Interest: 'None declared'.

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Please cite this paper as: Sharifi Shoshtari S, Shams N, Dabbaghi A, Rohani A, Dadolahi M, Khosravi N. Effect of Field of View and Resolution in Detection of Horizontal Root Fractures in CBCT images: An *In Vitro* Study. Iran Endod J. 2018;13(4):492-7. *Doi: 10.22037/iej.v13i4.21537.*