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ORIGINAL ARTICLE

Comparison of Digital Diagnostic Value and Cone Beam Computed Tomography (CBCT) in Determining Vertical Root Fracture in Single-Root Teeth

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Abstract

Objective: To compare the accuracy of digital radiography and CBCT for the diagnosis of vertical root fractures in single root teeth. **Material and Methods:** For this descriptive-analytic study, 50 non-fractured, single-root teeth were selected. The teeth were randomly divided into a control and an experimental group (25 teeth in each group). The teeth in the control group did not have vertical root fractures. In the test group, after preparing the access cavity, the root canal was cleared and loosened up to No. 80 file, then a vertical root fracture was created by one of the K-Reamers Nos. 90-130.The images were prepared by CBCT radiography in axial and cross-sectional slices and in digital radiography with PSP sensors at mesial, distal, and parallel angles. The Chi-square test was used to express the correlation of variables. **Results:** In the diagnosis of vertical root fractures, the sensitivity of CBCT in the axial section was 32% and in the cross-sectional slice it was 20%, whereas the specificity in both the sections was 100%. The sensitivity of the digital radiography in detecting vertical root fractures for parallel, mesial, and distal angles was 38%, 16%, and 24%, respectively. **Conclusion:** According to this study, the sensitivity, specificity, and accuracy of digital radiography and CBCT were not significantly different.

Keywords: Cone-Beam Computed Tomography; Diagnostic Imaging; Tooth Fractures.

Introduction

The vertical root fracture is a fracture that extends from the root apex to the crown of the topline longitudinally [1] and the fracture line can either be complete or incomplete [2,3]. The vertical fracture of the root provides a pathway for bacteria between the oral cavity, the root canal, and the periodontium, which results in rapid degeneration of the periodontium [4] and can cause an inflammation resulting in bone loss and the formation of granular tissue [5].

In the root of an untreated tooth, the vertical root fracture is may be due to the apical extension of the crown crack to the root [6]. The etiological factors of root fractures can include heavy rodent forces, parafunctional habits, and previous restorative procedures [7]. The clinical features of vertical root fractures include direct observation of the fracture line, the presence of one or more sinuses, and the presence of periodontal deep narrow probing in one or more fracture sites and tooth luxation [8,9].

Radiographic diagnosis of vertical root fractures is based on two principles: 1) the radiolucent fracture line is detected in the dentin and bone, located either in the root or crown area of the tooth [10] and 2) the radiographic features of a vertical root fracture, include the presence of a radiolucent shadow or a J-shape radiolucency around the root with the complete detachment of the fractured root [10,11]. However, the clinical and radiographic symptoms of vertical root fractures are variable and non-specific and can be similar to periodontal lesions, which can result in the failure of root treatments [12-15]. Therefore, a precise diagnosis of root fractures is necessary to prevent inappropriate and unsuccessful treatments [9].

Digital radiography shows a two-dimensional (2D) image of anatomical structures that cause a superimposition of structures. For this reason, if the x-ray does not penetrate the fracture line, the fracture may not be detectable. In other words, the fracture line will be visible in the radiograph only if the x-ray path is parallel to the fracture plan. Due to the same challenge, intra-oral radiography may hinder the accurate diagnosis of the vertical root fracture [16-21].

Cone-Beam Computed Tomography (CBCT) radiography scans give us 3D information, which is why morphology illustrates the dental root more accurately than the intra-oral radiographs [4]. The choice of the reconstruction plan (axial, coronal, and sagittal) used for the diagnosis [20] and a number of other variables including the scan unit, field of view, test time, tube voltage, as well as the current and the spatial resolution defined by the size of the voxel can affect the ability of CBCT imaging to detect the vertical root fractures [22,23].

The accuracy of the CBCT radiography in diagnosis of the vertical root fractures was reported to be higher than digital radiography, however, only the parallel and mesial angles were used for preparing the digital images [15]. CBCT radiography was found to be better than periapical radiography for the detection of incomplete fractures, however, the accuracy of both the devices was low. In this study, digital radiography with PSP sensor and CBCT radiography by 3D Accuitomo device were used in the premolar and mandibular molar teeth [24].

CBCT radiography has a higher accuracy than conventional radiography in the diagnosis of vertical root fractures [25]. However, the limitations included the use of angles of 20-30 degrees only on the number of patients that are similar to those found in previous study [12]. Because digital radiography scans are only for reviewing, the quality of these scans is less than the original films.

Only a few studies have been conducted on the comparison of digital radiography and CBCT in the diagnosis of vertical root fractures [12,15,20]. Secondly, there was no relevant study for the northwest population of Iran, and considering that race characteristics influence the type and structure of the teeth, the amount and type of fracture is expected to be different too. Given all these reasons, in this study, by using a dissimilar CBCT device to those in previous studies and by changing the imaging angle, we compared the sensitivity and specificity of this device with digital radiography.

Material and Methods

Study Design

To conduct this analytical-descriptive study, based on a similar study [4], 50 single-root teeth were divided in two groups, i.e. control and experimental (25 teeth in each group). The sample size was determined using the G-Power 3.1 Software (Heinrich Heine University Düsseldorf, Düsseldorf, Northrhine-Westphalia, Germany).

Sampling

The samples were selected from among extracted single-root, healthy teeth. The inclusion criteria were teeth that were single-root, vertical root non-fractured, root-untreated, without external root analysis, non-perforated at the external surface of the root, without hypromentesis, and non-anomalous (gemination, fusion, etc.). The exclusion criteria were teeth that were root-treated, multi-root, naturally fracturing, with external root analysis, with calcified canals, perforated at the external surface of the root, with hypromentesis, and/or anomalous (gemination, fusion, etc.).

After removal of debris from the root surface, the teeth were autoclaved. The roots were inspected visually and using a stereomicroscope to ensure that there was no fracture. In the test group, after preparing the access cavity, the root canal was cleared and loosened up to No. 80 file and then, by one of the K-Reamers Nos. 90-130, a vertical root fracture was created. To simulate the PDL (periodontal ligament) space, a thin layer of wax was placed around the teeth and then mounted on gypsum blocks. To simulate soft tissue, the samples were mounted in self-cure acrylic resin.

The images were prepared by digital radiography with angles of 15° mesial, 15° distal, and parallel for both the groups (Figure 1). For digital radiography, a photo-stimulable phosphor storage plate (PSP) and Optime Digora (Soredex, Helsinki, Finland) was used. The exposure conditions were as follows: tube voltage, 65 kV; tube current, 7.5 mA; exposure time, 0.25 seconds; and focus to imaging plate distance, 30 cm, with the tube perpendicular to the film. The digital radiographs were stored in the Scanora v. 4.3.1 Software (Soredex, Helsinki, Finland) after being prepared. They were calibrated and displayed on a 19-inch Samsung monitor to provide good contrast.

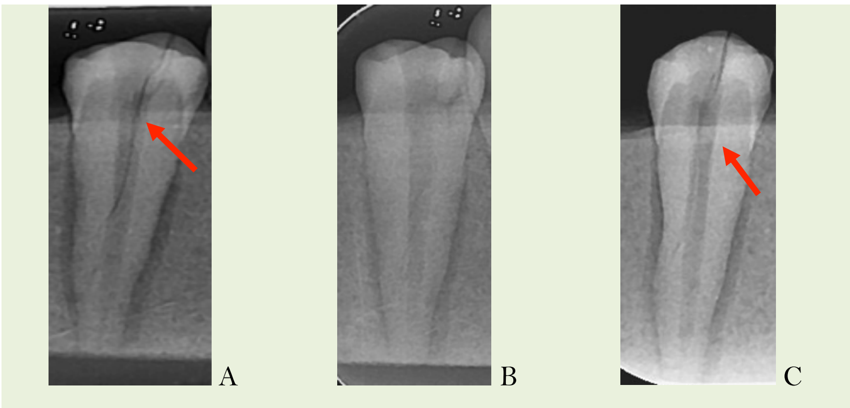

Figure 1. Digital radiography with: A) Parallel, B) Mesial and C) Distal angles.

The CBCT images were prepared with axial and cross-sectional slices, with a sectional thickness of 0.3 mm for both the groups (Figure 2).

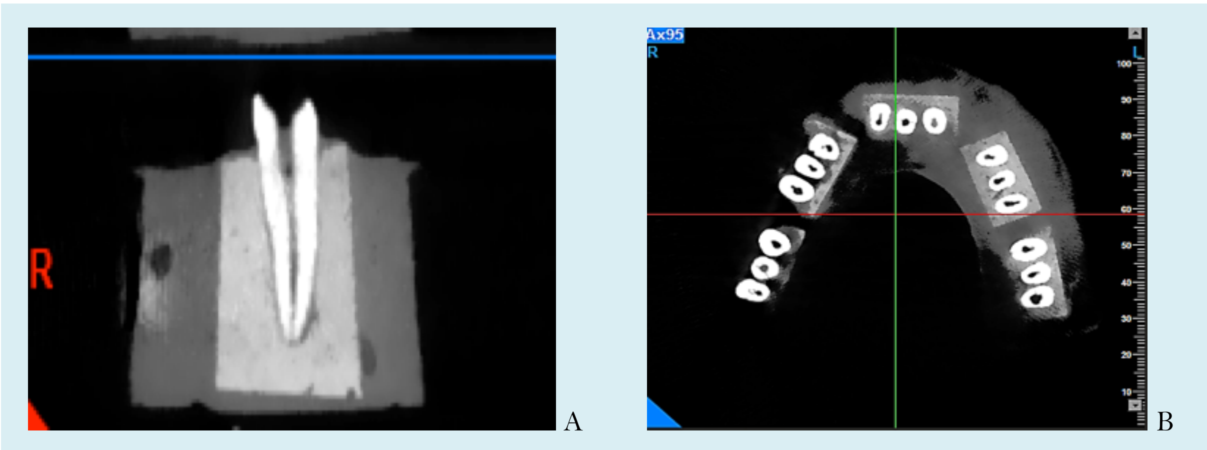

Figure 2. A) Cross-sectional section of CBCT and B) Axial section of CBCT.

The images were provided using the NewTom VGi cone beam (NewTom, Verona, Italy), conducted at the Department of Radiology, Faculty of Dentistry, Tabriz University of Medical Sciences. The primary and final restorations were performed using the NNT Viewer v.2.17 Software (QR srl, Verona, Italy). The radiation conditions (scan S18 and maximum 110 kVp) were automatically adjusted. The data obtained from the CBCT was entered into the NNT Viewer program and the images received were examined by an observer, on a 17-inch cathode-ray tube (CRT) desktop monitor, Hansol EP Iran, 32720 bits, 256 colors and resolution 1024 x 768. The images were displayed in a semi-dark room. The radiographic images for both the groups, prepared by the radiography devices, were scrutinized by two oral and maxillofacial radiologists. The observers were blind to the conditions and were unaware of the group types. The results of this assessment were recorded in a checklist, the Kappa coefficients were 0.86 (inter-examiners) and 0.89 (intra-examiners).

Data Analysis

To determine the diagnostic value of a test, it should be compared with a golden standard method. In this research, fractures were created and then, the diagnostic power of the two digital radiography devices and CBCT was measured for detection of the fracture. The golden standard has been created by the researcher. The golden standard divided the sample size into two groups, fracture and non-fracture, and the digital radiography and CBCT tests were also used in the separation of a positive (fracture) group and negative (non-fracture) group.

The Chi-square test was used to express the relationship between variables and the SPSS 17 software (IBM SPSS, Inc., Chicago, IL, USA) was used to calculate the sensitivity and specificity of the data, reported as positive and negative predictive values.

Ethical Aspects

The survey was approved by the Dean of the Faculty of Dentistry, Tabriz University of Medical Sciences.

Results

In this study, there was an agreement between both the observers ($p<0.001$), and the most agreement was related to the cross-sectional angle measurement.

The sensitivity test indicates that the result of digital radiography or CBCT will detect a major percent of actual fractures positive. In fact, sensitivity is the ratio of teeth with actual fractures to those identified as positive, accurately. Table 1 shows the highest sensitivity of 38% associated with the parallel angle approach. This means that out of 100 teeth that actually have fractures, based on the gold standard, 38 were correctly diagnosed by the parallel radiography angle. Furthermore, the lowest sensitivity is related to the mesial angle in radiography with the value of 16%.

Table 1. Sensitivity, specificity and sccuracy of digital radiography (DR) and CBCT in terms of measurement angles.

Method		Sensitivity	Specificity	Accuracy	Positive Predictive Value	Negative Predictive Value
CBCT	Axial	32.0%	100.0%	66.0%	100.0%	59.0%
	Cross sectional	20.0%	100.0%	60.0%	100.0%	55.0%
DR	Parallel	38.0%	92.0%	60.0%	77.0%	56.0%
	Mesial	16.0%	88.0%	52.0%	57.0%	51.0%
	Distal	24.0%	100.0%	62.0%	100.0%	56.0%

The specificity of this test is defined as the ratio of non-fracture teeth that can be accurately diagnosed with either the digital radiography or CBCT. The highest specificity was associated with the axial and cross-section angles in CBCT and distal angle in digital radiography with a value of 100%. This means that out of every 100 teeth that are healthy based on the gold standard, all of them tested negative for these angles. Moreover, the minimum specificity is related to the mesial angle with the value of 88%.

The limitation of sensitivity and specificity values lies in that they are unable to report and respond to the probability of the presence or absence of a fracture, as should be indicated by the positive or negative result of the test; therefore, the positive and negative predictive value indicators should be calculated.

The accuracy of a test is, in fact, the ratio of the correct responses of each diagnostic test. The accuracy of the test is defined as the percentage of cases detected accurately in comparison with the golden standard result. In this study, the highest accuracy is related to the axial angle in CBCT imaging with a value of 66%, and the lowest accuracy is associated with the mesial angle in digital radiography with a value of 52%.

The positive predictive value determines the probability of a fracture based on the diagnostic test result being positive. The highest positive predictive value is related to the axial and cross-sectional angles in CBCT and the distal angle in digital radiography with a value of 100%. This means that of 100 teeth with a positive test result, all of them had a fracture. Or, in other words, if the test is positive in the dent, it is 100% likely to have a fracture by these angles. Additionally, the lowest positive predictive value is related to the mesial angle in radiography with the value of 57%.

Negative predictive value determines the probability of not having a tooth fracture provided that the diagnostic test result is negative. This indicates the percentage of teeth showing a negative test result that are truly without fracture, or, in other words, if the test for a dent is negative, how likely it is to be healthy. The results show that the highest negative predictive value is related to the axial angle with a value of 59%. This means that if the test for examining dental fracture by the axial angle proves negative, there is 59% probability that the tooth is healthy. Furthermore, the minimum negative predictive value is related to the mesial angle with the value of 51%.

After determining the diagnostic value of both types of radiography at different angles, it was decided to examine the diagnostic accuracy of each test in general, in such a way that the fracture diagnosis was certain in CBCT imaging and digital radiography when this diagnosis is identical at all three angles in digital radiography and at two angles in CBCT in comparison to the golden standard. If even at one of the angles, the diagnosis of non-fracture was reported and was not the same as the golden standard, the final diagnosis reported an absence of a fracture.

According to the results of Table 2, the sensitivity, specificity, diagnostic accuracy, and predictive value in CBCT are greater than in digital radiography. Based on the chi-square test, the difference between these values is not significant for comparison of sensitivity ($p = 0.97$), ($p = 0.91$) and accuracy ($p = 0.94$).

Table 2. Sensitivity, specificity and accuracy of digital radiography (DR) and CBCT.

Method	Sensitivity	Specificity	Accuracy	Positive Predictive Value	Negative Predictive Value
CBCT	40.0%	100.0%	70.0%	100.0%	62.0%
DR	36.0%	80.0%	58.0%	64.0%	55.0%

Discussion

Radiographic observation is a helpful tool that can show abnormalities in the teeth and with the help of clinical examinations and medical history leads to the diagnosis and presentation of a treatment plan [26,27]. Root fractures can occur in the vital teeth with normal pulp and in root-untreated teeth [10,28,29] and these fracture lines may be limited to the apex of the tooth root or the entire length of the root [30]. A real root fracture in root-untreated teeth only limited to the root surface was identified in Chinese patients [28,29]. These root fractures may be related to the pattern of a particular diet or chewing habits of the Chinese people [31] or may be a result of intense and continuous stresses of heavy chewing [32]. Basically, any detection method for vertical root fracture should have the correct diagnostic capability.

The digital radiography has certain limitations such as the two-dimensional nature of images that cause superimposition of anatomical structures. For this reason, a vertical root fracture may not be detected due to the inability of the x-rays to pass through the fracture line. In other words, the fracture line will be visible in the radiograph when the x-ray path is parallel to the fracture plan. For this reason, intraoral radiography may cause problems in the accurate diagnosis of root fractures [16-21].

In the present study, the results showed that the sensitivity and specificity of CBCT and digital radiography did not differ significantly, indicating that the type of detector used in digital radiography, the diagnostic accuracy of the observer in examining the samples, and the similarity of the study groups were effective in obtaining the results of the study.

The results of a previous study have shown that in the absence of gutta-percha, the sensitivity of CBCT in detecting vertical root fractures is significantly higher than of multidetector computed tomography (MDCT) and digital radiography [15]. The results indicate that CBCT is superior to digital radiography in vertical root fracture diagnosis [12,33]. Furthermore, the accuracy of CBCT radiography was higher than digital radiography for the diagnosis of vertical root fracture [15]. In a previous research [15], parallel and mesial angles were used in the preparation of digital images, however in the present study, three angles, parallel, mesial and distal, were investigated in digital radiography. The type of digital detector was CMOS [15], while in the present study it is a PSP type detector. The results of both studies were not in agreement and the reason for this difference is the use of a CMOS detector and only two parallel and mesial angles to detect vertical fractures.

In a previous study, an universal testing machine (Instron machine) was used to induce a vertical root fracture [24]. The force applied to create the fracture by this device was gradually increased allowing the possibility of a controlled fracture. The extent of induced fractures was also variable from 30 μm to 110 μm [24]. In this research, the sensitivity of CBCT in the diagnosis of vertical root fracture was lower than the results of previous study [12], and a possible explanation for these results could be that the extent of fractures is not similar to the extent of fractures created in previous study [24]. The number of imaging angles used in this study was the same as in a previous study [24], but their sample size was 30 vis-à-vis 50 in the present study. Moreover, all the specimens used in our study were of the same type, while some authors used premolar and molar teeth specimens [24]. These reasons could explain the inconsistency of the results between both studies.

Regarding the type of tooth, dental premolar and molar specimens were used by some authors [12], mandibular premolar and molar teeth [24] and one study was on single-root teeth [15]. The results presented by some authors [12] are not consistent with our results, which is due to two-angle imaging, the type of radiography which is periapical and not digital, and not for identical specimens (premolar and molar teeth). In a recent study, all the teeth were single-root premolars and the Enhanced Visual Assessment (EVA) sensor was used for digital radiography; sensitivity by CBCT was found to be higher than digital radiography [34]. These results are also not consistent with with the findings in the present study.

It should be noted that this study is unlike other studies in that the determination of sensitivity and specificity for each angle is conducted individually and then for each of the radiographies, in general.

In most studies, the extent of fractures has not been reported. However, some authors found fractures of 0.2 mm and 0.4 mm, which is approximately 4 to 8 times the size of fractures [35]. As a result, fractures with such an area are readily recognizable clinically and do not require examination by the CBCT. The periapical radiograph dose is estimated to be about 0.9-3.45 microsievert [36] and the CBCT dose is estimated to be about 11-47 microsievert [37-39], depending on the field of view. Due to the fact that the effective dose of CBCT is higher than that of periapical radiography basically do not support the use of CBCT for vertical root fracture detection (considering the potential risk of the high radiation dose to the patient), the question remains whether the prescription of this radiography is in the best interest of the patient.

For future studies, it is suggested to investigate the value of digital radiography and cone beam computed tomography (CBCT) in determining other root fractures in single-root and multi-root teeth in the presence and absence of gutta-percha. It is also recommended to conduct a study with the consideration of interventional factors in other statistical societies in other countries, other cities in Iran, and on different populations.

Conclusion

Considering that the sensitivity, specificity, and accuracy, the two types of digital radiography and CBCT are not significantly different in the diagnosis of vertical root fractures in single-root teeth, digital radiography can be used instead of CBCT.

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