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ORIGINAL ARTICLE

In Vitro Comparison of Three Dimensional Cone Beamed Dental Tomography with Intraoral Radiography in Detection of Dental Root Fractures

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ABSTRACT

The precise diagnosis of dental root fractures in clinical practice is quite difficult. **Objective:** Accurate diagnosis of dental root fractures in clinical practice is quite challenging. Here, we aimed to compare results of three-dimensional cone beam computed tomography (CBCT) and conventional intraoral radiography images for diagnosing dental root fractures. **Methods:** Fifty maxillary central teeth with healthy roots were included in this experiment. Ten teeth were subjected to a single blow in a laboratory to produce cracks, whereas horizontal root fractures with varying degrees of gaps between the fractured segments were created in 40 teeth. The teeth were divided into five equal groups: teeth with crack; teeth with root fractures without gaps; and teeth with root fractures with 0.2-, 0.4-, and 0.6-mm gaps between the fractured segments. CBCT and conventional intraoral radiography images were evaluated by 30 dentists. The mean diagnostic accuracy for detection of root fracture and the positive predictive value were calculated for both diagnostic modalities. **Results:** The mean diagnostic accuracy with the use of CBCT images was significantly better than that with the use of traditional intraoral radiography images. **Conclusion:** CBCT allows for more detailed characterization of root fractures and cracks than traditional intraoral radiography.

Key words: dental radiography, dental tomography, root fracture

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INTRODUCTION

Dental trauma is a frequent occurrence in children and adolescents.¹ Dental trauma may result in dental root fracture.² Root fractures account for 5–7% of all dental injuries pertaining to permanent dentition and 2–4% of all fractures pertaining to primary dentition.^{3,4,6} The most frequent age group sustaining root fractures in permanent dentition is 11–20 years; the upper maxillary central teeth account for 75% of these cases.^{4,5} The diagnosis of dental root fractures is typically challenging. Lack of timely diagnosis may necessitate surgery or endodontic treatment.² The structure of the root fracture and its location and size are key criteria for determining the appropriate treatment strategy. Thus, accurate diagnosis of root fracture or its exclusion is a key imperative to facilitate appropriate treatment decision-making. Inadequate imaging characterization

of the dental root fracture may result in erroneous diagnosis and improper treatment.⁶

While the ability to decide on the restoration strategy via visual approaches (examination via vital dyeing, magnification, and transillumination) and determine the fracture elongation between the gingival connections and apical are limited, it has been indicated that exact diagnosis can be made using surgical intervention and radiological imaging.⁷ Ionized radiation-based imaging methods, such as traditional two-dimensional (2D) radiography, are commonly used for the diagnosis of root fracture; however, these methods may help unravel the fracture only when there is a distinct displacement of the fractured segment and when the X-ray beam is oriented parallel to the fracture.⁸ To overcome these difficulties, three-dimensional (3D) imaging methods, such as cone beam computed tomography (CBCT),

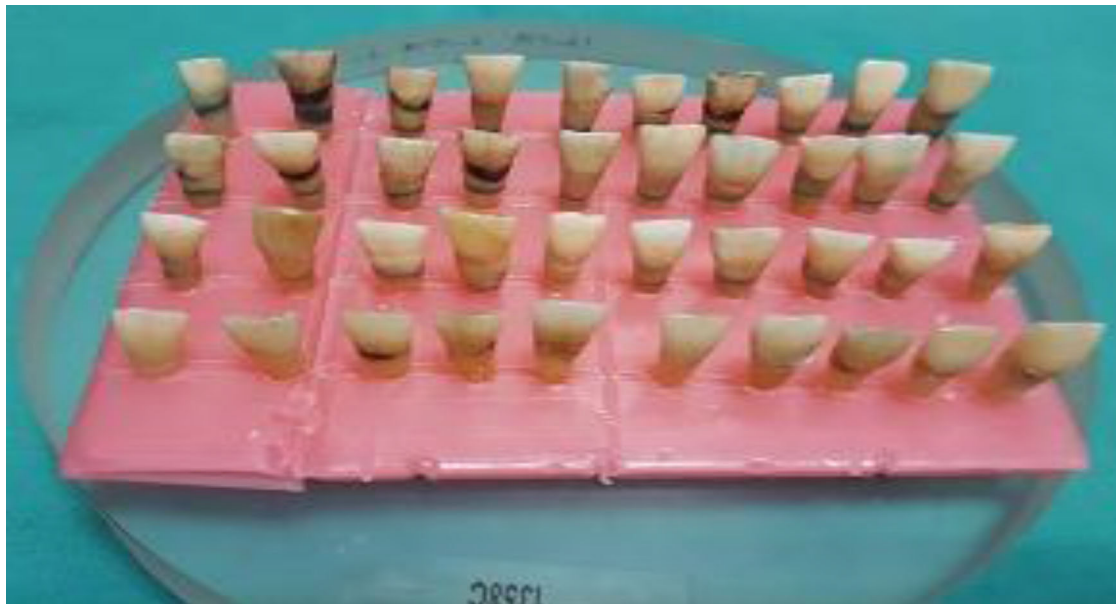


Figure 1. Photo for the CBCT imaging of four groups with root fracture

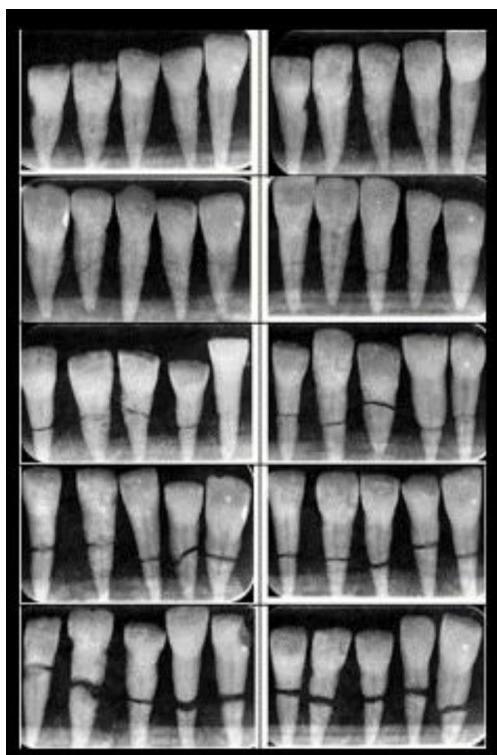


Figure 2. Periapical image for the five groups with crack and root fracture

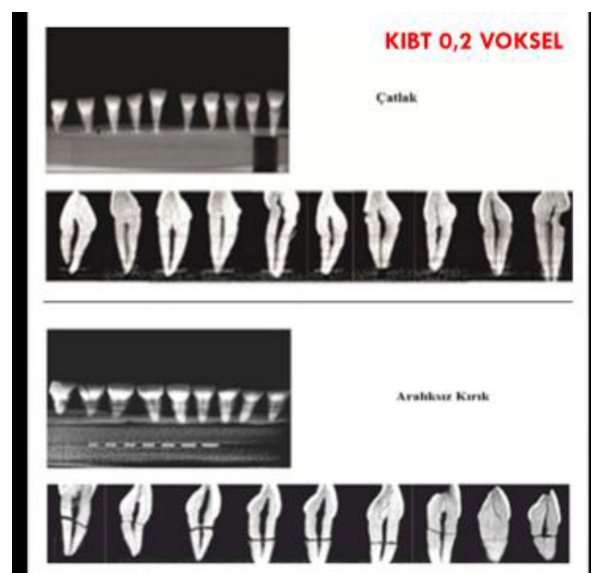


Figure 3. 0.2 voxel CBCT image for the group with crack and the group stuck without gap

have recently been developed to facilitate the diagnosis of root fractures.⁹

The aim of this study was to evaluate the usability of CBCT in dentistry for overcoming the difficulties in the diagnosis and localization of root fractures. In particular, we performed a comparative analysis

between the images acquired by traditional intraoral radiography and CBCT for diagnosis of root fracture.

METHODS

In this study, digital periapical radiography and CBCT images were acquired at the Dicle University Faculty

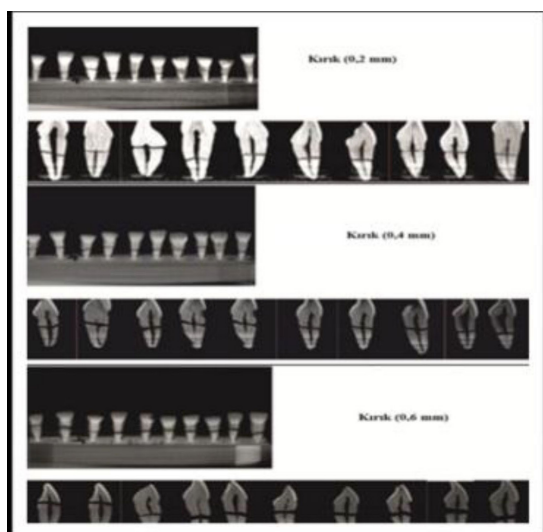


Figure 4. 0.2 voxel CBCT image for the groups stuck with 0.2 mm, 0.4mm, 0.6mm gaps

of Dentistry. The study protocol was approved by the Dicle University ethical council (decision no. 5/1; dated 27/06/2018). A total of 50 upper central teeth with no fracture, caries, or fracture line and which had not undergone endodontic treatment or extraction were used in this study. These were divided into five equal groups (n=10 for each group).

Ten teeth were subjected to a single blow of mechanical force in an *in-vitro* environment to induce a fracture, while horizontal root fracture was generated in 40 teeth with varying degrees of separation between the fractured fragments using casting wax: without gaps, with a 0.2-mm gap, with a 0.4-mm gap, and with a 0.6-mm gap (Figure 1). First, periapical images of all teeth were acquired using the XMind unity DC X-ray device and the Acteon Sopro Pspix phosphorous plaque scanner (Acteon Satalec, Germany) (Figure 2). Subsequently, CBCT images were obtained at 0.2 voxel (14.7 s) (Figures 3–4), at 0.3 voxels (8.9 s) and 0.4 voxels (4.8 s). CBCT images were obtained using i-CAT (Imaging Sciences International, Hatfield, Pa USA).

The images were transferred to the I-CAT VISION software and examined in the implant screen interface. A total of 200 images including periapical and CBCT images were examined by 30 dental researchers for determining cracks and root fractures. Binary responses pertaining to identification of fracture (Yes or No) were recorded in an evaluation form and subjected to statistical analysis.

The mean diagnostic accuracy refers to the average number of accurate diagnoses made by 30 dentists regarding the teeth root images in five groups with 10 images for each of the four different imaging methods used. Positive predictive value (PPV) of a clinical

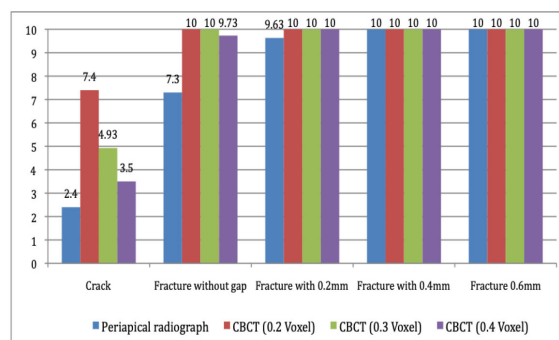


Figure 5. Complete image for the accurate diagnosis values for all groups

method of diagnosis indicates the probability of a positive diagnosis in a patient.¹⁰ The PPV value was calculated separately for each imaging modality based on the evaluation of 30 dentists and the minimum, maximum, and average values were calculated.

RESULTS

Figure 5 shows a graphical representation of the average diagnostic accuracy of the images of a total of 50 teeth roots in five different groups (n=10 per group) evaluated by 30 dentists.

The PPV of periapical radiography, CBCT (0.2 voxel), CBCT (0.3 voxel), and CBCT (0.4 voxel) for the diagnosis of cracked teeth roots ranged from 0 to 0.7, 0.5 to 1, 0.1 to 1, and 0.1 to 0.8, respectively. The mean PPV for the cracked teeth roots was 0.24 for radiography and 0.74, 0.49, and 0.35 for CBCT at voxel values of 0.2, 0.3, and 0.4, respectively. In other words, the CBCT images at 0.2 voxel yielded the best results wherein 74% of the cracked root fractures were diagnosed accurately by all researchers. The PPV of radiography and CBCT (0.4 voxel) for the diagnosis of fractured roots without gaps ranged from 0.3 to 0.9 and 0.9–1, respectively. All researchers evaluating CBCT images at 0.2 and 0.3 voxel made accurate diagnoses for all fractures and hence the PPV of these methods was calculated as 1 for each researcher. For fractured roots without gaps, the overall mean PPV of radiography was 0.73 and that of CBCT (0.4 voxel) was 0.97. The mean PPV of images acquired with a 0.2-mm gap was 0.96 (range, 0.9–1). All researchers made accurate diagnoses for all the images acquired via CBST at 0.2–0.3, and 0.4 voxel values. Therefore, the minimum, maximum, and average PPV for these images were all calculated as 1. Since the diagnoses for the root fractures with gaps of 0.4 mm and 0.6 mm were correct for both imaging methods, they were not included in the calculation of PPV.

In this study, diagnosed all fractures used at the PPV test results for these methods were calculated as 1 for each researcher. The overall mean PPV of radiography and CBCT (0.4 voxel) for fractured roots without gaps was 0.73 and 0.97, respectively.

DISCUSSION

In this study, CBCT images were found to be better and clearer than the traditional intraoral radiography images for diagnosis of root fractures and cracks. Traditional or digital two-dimensional oral radiography is frequently used in clinical settings for evaluation of dental trauma. However, CBCT has increasingly been shown to be the most effective method for radiographic characterization of traumatic dental injuries (TDI). It is particularly effective for imaging of root fractures caused by TDI and for follow-up imaging to assess recovery and evaluate potential complications. However, CBCT is associated with significantly higher radiation exposure as compared to traditional methods and the high cost of the devices limits the routine use of CBCT.¹¹ Despite these limitations, the amount of scientific data pertaining to the effectiveness of CBCT continues to increase in literature.

Several studies have compared the diagnostic accuracy and image quality of CBCT with other imaging methods. Kajan and Taromsari evaluated CBCT imaging for the detection of root fractures; they found that CBCT is an ideal alternative for the diagnosis of root fractures in the field of endodontics. The authors opined that CBCT may help prevent treatment failure in patients with root fractures.¹²

Avsever et al. used 82 extracted maxillary incisor teeth without root canal treatment and fracture. They found that CBCT is the most reliable imaging method for the diagnosis of horizontal root fractures. The authors reported that CBCT imaging methods are superior to the traditional imaging methods for evaluation of all traumatized teeth.¹³

Hassan et al. compared the accuracy of CBCT and periapical radiographs (PR) for the detection of horizontal root fractures. They found that the diagnostic accuracy of CBCT (0.86) was higher than that of PR (0.66).¹⁴ Consistent with their findings, we also observed a high diagnostic accuracy of CBCT for evaluation of horizontal root fractures.

Da Silveira et al. performed PR scans for all teeth from three different horizontal angles followed by CBCT using three protocols with variations of voxel resolution (0.4, 0.3, and 0.2 mm). The specificity, sensitivity, and accuracy was similar for unfilled teeth for both 0.2 and 0.3 voxel resolution scans; however, the accuracy was higher for teeth with root canal treatment or post when a voxel resolution of 0.2 was used. Based on their

findings, the authors suggested the use of radiography with horizontal angle variation to complement the evaluation of vertical root fractures.¹⁵ The best results in our study were acquired at voxel resolutions of 0.2 and 0.3; however, it should be noted that the application time at 0.2 voxel increases the radiation dose that the patient is subjected to.

Khedmat et al. compared the accuracy of digital radiography, multidetector computerized tomography (MDCT), and CBCT for the detection of vertical root fractures in the presence and absence of root filling. The researchers suggested that CBCT should be preferred according to the ALARA (as low as reasonably achievable) principle since the radiation dose of MDCT is higher than that of CBCT.¹⁶ In the light of these findings and the results of our study, CBCT should be considered as the preferred method.

Iikubo et al. examined the sufficiency of CBCT and intraoral radiography (parallel and bisecting angle methods) for the detection of horizontal angle root fractures. The researchers formed grooves in 81 extracted upper central teeth and used 9 teeth without groove as the control group. The results showed a high diagnostic accuracy of CBCT for grooves. In addition, they suggested that additional intraoral radiography from different angles with traditional X-ray imaging methods will increase the diagnostic accuracy.¹⁷ In the light of our findings, CBCT scan should be suggested in patients with suspected root fracture.

The diagnostic accuracy was found to be high in all groups with root fractures. This may be attributable to the fact that all fractures were made in the horizontal plane. In our study, CBCT images acquired at different voxel intervals showed a higher PPV and accuracy for diagnosis of root fractures without gaps and root fractures with 0.2-mm gaps. This is attributable to the fact that CBCT enables a detailed evaluation of the teeth in three different planes with different cross-sections and angles; in contrast, traditional intraoral radiography enables examination in a single plane. The best results for diagnosis of root fractures and cracks were obtained with CBCT images using 0.2 voxel. Even though the difference was not statistically significant, the diagnostic accuracy for root fractures and cracks was found to be lower for 0.4 voxel unit images. No significant difference was observed between CBCT scan images acquired at 0.2 and 0.3 voxels with respect to the diagnostic accuracy for root fracture and cracks.

No significant difference was observed between CBCT images at all voxels and radiography images with respect to the PPV and diagnostic accuracy for groups with 0.4- and 0.6-mm gaps at the site of the root fracture. These findings suggest that the diagnostic accuracy increases with increase in the distance between the fractured fragments due to hemorrhage and formation of granulation tissue with passage of

time after the trauma. Thus, periapical radiography can be the primary choice for evaluation of root fractures that have not been treated for long period of time after the trauma.

CONCLUSION

Our study demonstrates that CBCT is a reliable imaging method for diagnosis of root fractures. It provides detailed characterization of root fractures which may not be diagnosed with traditional radiography. In addition, three-dimensional cone beam dental tomography can be considered as an alternative at 0.3 voxel units in the smallest FOV area based on ALARA principles when traditional radiography is insufficient for the diagnosis of root fractures. CBCT entails lesser radiation exposure as compared to medical tomography. However, traditional radiography methods entail the lowest radiation exposure and should be the first choice in cases where these are sufficient for the diagnosis and treatment of dental trauma. Future advances in CBCT to reduce the radiation exposure may position it as a routine diagnostic modality in dentistry. Currently, routine use of CBCT imaging is not recommended in dentistry practice. Decision-making in oral radiology involves a balance between risk assessment and the diagnostic information needed (indication). Furthermore, the criteria to select the imaging modality during any treatment phase should follow the ALARA principle.

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