Original Article

Diagnostic Accuracy of Different Devices and Settings of Cone-beam Computed Tomography in Detecting Intra-radicular Broken File; An in Vitro Study

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Abstract

Background and Aim: The resolution and diagnostic potential of cone-beam computed tomography (CBCT) images can be affected by variations in radiation parameters, including radiation dosage, maximum kilovoltage (kVp), and voxel size. The present study evaluated the diagnostic accuracy of different devices and settings of CBCT in detecting intra-root canal broken files.

Materials and Methods: Seventy-two extracted human single-rooted teeth were used in this in vitro investigation. The samples were randomly divided into two groups based on the type of device: Vatech (n=36) and Newtom (n=36). Additionally, samples from each group were divided into two subgroups according to kVp and radiation exposure. Statistical analysis of the data was performed at a significance level of 0.05 using SPSS 26. The ratios in the two computed tomography scans were examined using the chi-squared test.

Results: The results showed that the parameters of accuracy, specificity, sensitivity, positive and negative predictive values in identifying broken files within the canal for the two CBCT devices were 86.11%, 88.88%, 83.33%, 88.23%, 84.21%, 91.66%, 94.44%, 88.88%, 94.11%, and 89.47%, respectively. The radiation exposure parameters did not significantly affect the detection of broken files within the root canal in any of the two CBCT systems.

Conclusion: The two CBCT devices used in this investigation did not significantly differ in their ability to identify broken files inside the canal.

Key Words: Cone-Beam Computed Tomography (CBCT), Root Canal, Radiation Dosage, Diagnostic Accuracy, Broken Files Detection

- **Cite this article as:** Abdollahi A, Ghaznavi A, Seyyedi A, Purali E. Diagnostic Accuracy of Different Devices and Settings of Cone-beam Computed Tomography in Detecting Intra-radicular Broken File; An in Vitro Study. J Iran Dent Assoc. 2024; 36 (3-4):70-77.

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Received: 7 June 2024
Accepted: 20 Aug 2024

Introduction

It is imperative that dentists recognize the potential for complications, such as the fracturing of stainless steel or nickel-titanium instruments, at any stage of the root canal therapy process [1].

Several factors contribute to the fracturing of files within the root canals, including substandard material quality, flawed file design, improper usage, overuse, application of excessive force in curved or calcified canals during preparation, and the intricate anatomy of the root canal (1,2) [1]. The advent of new nickel-titanium rotary files has heightened the likelihood of these instruments malfunctioning during root canal therapy [2]. Consequently, the failure rate of nickel-titanium files ranges from 0.4% to 4.6%. Separation of these files can occur unexpectedly [3]. The presence of a fractured file within the canal significantly undermines treatment success, with studies indicating a 19% increase in the probability of treatment failure when a fractured file remains [4]. Therefore, it is preferrable to remove fractured files from the root canal to substantially enhance treatment outcomes [2].

Conventional intraoral and panoramic radiography may not always provide sufficient information about endodontic treatment failures. However, numerous studies have investigated the use of CT scans in endodontic treatment, as they offer three-dimensional insights into the anatomy and development of root canals [5]. Compared to CT scans, CBCT images yield sections in the coronal, axial, and sagittal planes, as well as 3D reconstructions, allowing for precise morphological evaluation with high resolution and less radiation exposure [6]. Before identifying the primary issue, it is crucial to locate any fractured files within the root canal. The presence of a broken file inside the canal increases the risk of root canal weakening and perforation during therapy. Identifying a fractured file using periapical and panoramic radiographs can be challenging, especially when the contrast between the broken file and the root canal obturation material is similar. This difficulty is particularly pronounced in teeth where the root canal is filled up to the fracture site [7-10]. For teeth with complex morphology, cone-beam computed tomography (CBCT) has been extensively used during root canal therapy [11]. However, studies have yielded conflicting results regarding the effectiveness of CBCT in identifying broken files [11-13]. These discrepancies can be attributed to variations in the equipment used by CBCT operators and differences in device settings, such as contrast strength, field of view, and voxel sizes [11]. Unlike periapical radiography, CBCT images examine the area in three dimensions, preventing the superimposition of anatomical markers or other root canals. Therefore it is usually advised that using the appropriate imaging equipment is essential to achieving accurate diagnoses and successful treatment outcomes.

Given the discrepancies in results across studies regarding the detection of broken files and the significant influence of device type and specifications on these outcomes, there is a clear need for a study that identifies the most efficient CBCT types and specifications for this purpose. Accurate diagnosis of broken files in the root canal using advanced imaging methods such as cone beam computed tomography (CBCT) is crucial. CBCT offers the ability to examine the complex anatomy of the root canal in three dimensions, precisely determine the exact position of the broken file segment, and evaluate the root canal's length and its relationship with adjacent anatomical structures. Moreover, this imaging technique enhances the dentist's ability to perform treatments with greater care and precision [14, 15]. Therefore, this study aims to address the existing knowledge gap and provide clear guidance on the optimal use of CBCT for detecting broken files, ultimately improving clinical outcomes and patient care.

Materials and Methods

This project received ethical approval from the Urmia University of Medical Sciences Research and Ethics Committee, Urmia, Iran (IR.UMSU.REC.1400.182). Seventy-two extracted human single-rooted teeth were used in this in vitro investigation. The sample size was determined by a 70% accuracy rate identified in the study by Ayatollahi et al. [16] regarding the CBCT device's ability to detect broken files. According to this data, we require 36 samples for each device(total=72). This determination was made using a statistical formula that incorporates an alpha level of 5%, a confidence level of 95%, and a minimum acceptable error (20%p or d = 0.15).

Periapical radiographs were taken from each sample. Teeth without signs of internal or external resorption, prior root canal treatment, fractures, or perforations were included in the research. In each tooth, the access cavity was prepared using a 016 diamond high-speed bur and water coolant. The working length was meticulously measured using a #10 K-file (Mani, Japan), from the incisal or occlusal edge to the apical area. The samples were subsequently divided into two groups (n=36), employing a simple randomization technique with Microsoft Excel 2019. The root canal cleaning and shaping was performed utilizing the crown-down technique and M3 rotary file system (M3, United Dental, Shanghai, China). When cleaning and shaping were completed with a #30/0.06 file in the groups, the file was broken at the end of the process. To make a fracture in the 6% #30 file, a groove was made at the 2-mm end of the file using a round diamond bur with a diameter of 0.8 mm [16]. The root canal was irrigated with 1 mL 5.25% sodium hypochlorite between each instrument. Similar procedures were carried out in the control group except for file breakage. Normal saline was used for the final rinse. The root canal was dried using a #30 paper point (Diadent, Korea). The samples were then obturated using a #30/0.04 gutta-percha as the master cone and AH-26 sealer (Dentsply, DeTrey GmbH, Konstanz, Germany) using lateral compaction technique. To replicate the periapical soft tissues, two layers of sheet wax were applied to each sample at the apical third of each root [16]. Afterwards, the samples were embedded in a paste made of a 1:2 ratio of sawdust to gypsum plaster to replicate hard tissue [16]. Subsequently, each group was divided into two subgroups (n=16) according to the CBCT system used, employing a simple randomization technique with random numbers.

The CBCT devices employed in this study were the Vatech Pax-i3 Green (Vatech Co., Seoul, Korea) and the ProMax 3D Max (Newtom, Finland). The images were captured using a flat panel sensor with 70-90 kVp, radiation doses of 1 and 2 mA, and an exposure time of 1.2 seconds. In the first group, the ProMax 3D Max imaging tool (Newtom, Finland) was used, while the second group utilized the Vatech CBCT instrument under the same conditions. Subsequently, each group was divided into four subgroups (n=4) based on two radiation dose parameters (1 and 2 mA) and kVp settings (70 and 90). Separate images were taken and visualized by a radiologist and an endodontist using a 17-inch LG monitor in a dimly lit room, with a resolution of 1024 x 1280 pixels and 32 bits. The interobserver agreement was evaluated using the kappa coefficient, which was calculated to be 90%, indicating a high degree of agreement between the two observers. If the agreement was below the expected level, the necessary training was provided to the observers until the desired agreement was achieved. The results were presented in terms of specificity, sensitivity, and accuracy. The samples were prepared by a skilled final-year dental student, who coded each sample before delivering them to an oral and maxillofacial radiologist and an endodontist for CBCT imaging. Both the radiologist and the endodontist were blinded to the sample details, and their diagnoses were made independently. If discrepancies arose, additional training was given to achieve consensus.

Data analysis

The data were statistically analyzed using SPSS 26. Quantitative values for accuracy, sensitivity, specificity, positive predictive value, and negative predictive value were calculated to determine the accuracy of the measuring tool as a percentage. Additionally, the chi-squared test was performed to analyze the ratios in the two computed tomography scans, with a significance level set at 0.05.

Results

In the current investigation, the indicators used to diagnose a broken file within the root canal by Newtom CBCT device are listed in Table 1. It was found that 86.11% of cases were correctly classified, with truly negative images identified as negatives and truly positive images identified as positives, demonstrating its effectiveness in

Table 1. Newtom radiographic indicators in the diagnosis of broken file inside the root canal in the present study

Newtom CBCT device	+	-
The file is	15	3
The file is not	2	16

$$Accuracy = \frac{15+16}{15+16+3+2} \times 100 = \frac{31}{36} \times 100 = 86.11\%$$

$$Specificity = \frac{16}{16+2} \times 100 = \frac{16}{18} \times 100 = 88.88\%$$

$$Sensitivity = \frac{15}{15+3} \times 100 = \frac{15}{18} \times 100 = 83.33\%$$

$$positive\ predictive\ value = \frac{15}{15+2} \times 100 = \frac{15}{17} \times 100 = 88.23\%$$

$$negative\ predictive\ value = \frac{16}{16+3} \times 100 = \frac{15}{19} \times 100 = 84.21\%$$

$$Positive\ Likelihood\ ratio = \frac{83.33\%}{1-88.88\%} = 7.49\%$$

$$Negative\ Likelihood\ ratio = \frac{1-83.33\%}{88.88\%} = 18.7\%$$

recognizing broken files. The accuracy of Newtom radiography in detecting a broken file within the root canal was approximately 88.88%, indicating that out of every 100 files without a fracture, 88.88 were correctly classified as negative. Furthermore, about 83.33% of the files with a break were correctly identified as positive. A positive predictive value of around 88.23% was recorded, showing that in 88.23 out of every 100 cases, the broken file was favorably detected. For files without breakage, a negative predictive value of approximately 84.21% was achieved, with 84.21 out of every 100 files accurately diagnosed as unbroken.

Vatech CBCT markers for identifying broken files inside the root canal are displayed in Table 2. Truly negative images were correctly identified as negatives, and truly positive images were identified as positives in 91.66% of cases by the Vatech CBCT device. Specificity in detecting a broken file within the root canal was approximately 94.44%, indicating that about 94.44% of 100 files without a break were recognized as negative. Accuracy in identifying a broken file within a root canal was around 88.88%, meaning roughly 88.88% of 100 files with a break were identified as positive. A positive predictive value of about 94.11% was achieved, meaning a broken file was favorably detected in 94.11 out of every 100 cases submitted for diagnosis. The negative predictive value was about 89.47%, indicating that out of every 100 files submitted for detection without breakage, 89.47 were identified as negative (unbroken) (Table 2).

Table 3 presents a comparative analysis of the indexes for the two CBCT devices utilized in this study—Newtom and Vatech.

There was no significant difference between the two devices in identifying a broken file inside the root canal. However, from a clinical perspective, the Vatech CBCT device exhibited higher percentages for markers of accuracy, specificity, sensitivity, and positive and negative predictive value compared to the Newtom CBCT device (Table 3). Although these differences are clinically important, they were not statistically significant.

Discussion

In the current investigation, we evaluated the accuracy, specificity, sensitivity, and predictive values of the two CBCT devices, Newtom and

Table 2. Newtom radiographic indicators in the diagnosis of broken file inside the root canal in the present study

Vatech CBCT device	+	-
The file is	16	2
The file is not	1	17

$$Accuracy = \frac{16+17}{16+17+2+1} \times 100 = \frac{33}{36} \times 100 = 91.66\%$$

$$Specificity = \frac{17}{17+1} \times 100 = \frac{17}{18} \times 100 = 94.44\%$$

$$Sensitivity = \frac{16}{16+2} \times 100 = \frac{16}{18} \times 100 = 88.88\%$$

Table 3. Comparing the indexes of two CBCT devices in the present study

Indexes	Vatech CBCT device	CBCT device Newtom	p-value
Accuracy	91.66%	86.11%	0.084
Specificity	94.44%	88.88%	0.098
Sensitivity	88.88%	83.33%	0.495
Positive predictive value	94.11%	88.23%	0.096
Negative predictive value	89.47%	84.21%	0.274
Positive Likelihood ratio	15.9%	7.49%	0.006
Negative Likelihood ratio	11.7%	18.7%	0.027

Vatech, in detecting broken files within root canals. Specifically, the accuracy of Newtom was 86.11%, and Vatech was 88.88%. In terms of specificity, Newtom achieved 83.33%, while Vatech reached 88.23%. Sensitivity values were 84.21% for Newtom and 91.66% for Vatech. For positive predictive value, Newtom showed 94.44%, and Vatech indicated 88.88%. Lastly, the negative predictive value was 94.11% for Newtom and 89.47% for Vatech. These results, detailed in Tables 1 and 2, highlight the comparative performance of Newtom and Vatech CBCT devices in accurately identifying the presence of broken files within root canals.

Additionally, no statistically significant differences were observed between the two CBCT devices in terms of identifying a broken file inside the root canal, according to the results presented in Table 3. However, from a clinical perspective, the Vatech CBCT device exhibited higher percentages for accuracy, specificity, sensitivity, and positive and negative predictive values compared to the Newtom CBCT device.

The lack of significant difference in detecting a broken file in the root canal between the Newtom and Vatech CBCT devices can be attributed to several factors. Firstly, image quality and contrast play a crucial role in fracture detection. High contrast in CBCT devices can aid in better diagnosis, and if both devices provide similar image quality, there may be no difference in diagnosis. Secondly, the skill and experience of the operator are also important factors in the accuracy of diagnosis. If the operators of both devices possess similar skills and experience, this could lead to no significant difference in detection. Thirdly, clinical conditions such as root canal curvature and tooth condition can affect the accuracy of diagnosis. In cases where the root canal has severe curvature or special features, both devices may not detect the problem equally. Lastly, the type of file and instruments used in treatment can influence the likelihood of fracture. If both devices are tested under the same conditions and using the same tools, the results may be similar.

Additional research, including larger sample sizes and a range of clinical circumstances, will be necessary to assess how well these two devices function. Chang et al. [17] observed sensitivity in the 95% to 98% range when different CBCT units were tested in analyzing horizontal file fractures within the root canal, which was greater than our findings and consistent with previously described results. The absence of a metal post and the probable size disparity between the two voxels and the two devices were among the factors contributing to the high sensitivity in that investigation. According to a review study by Mayer et al., voxel size and dosage had no bearing on the diagnosis of fractures; however, a variety of CBCT imaging setups and apparatuses are reliable for diagnosing root fractures [18]. Numerous studies on the examination of fractures by various CBCT systems have been published. The variation in their findings is probably related to various factors, such as the impact of varying voxel sizes in the same direction, which aligns with our findings. For example, in a study conducted by Bechera et al. [19], the ProMax3D system showed higher accuracy in identifying file fractures inside the root canal compared to other devices in that study. Additionally, the accuracy was reduced by the artifact removal approach. However, in another research published by Bayrak et al. [20], this approach improved the correct diagnosis, which was unrelated to the fracture of the file inside the root canal. In a study by Sati et al. [21], Vatech CBCT systems outperformed Newtom CBCT in detecting file fractures within the root canal.

Certain studies, such as the one conducted by Hosseini Zarchi et al. [22], have explored alternative systems, including those focused on artifact removal and filtration.

The results showed that these systems had no bearing on the presence or absence of a metal post within the root canal and instead affected the diagnosis and accuracy of CBCT in detecting file fractures within the root canal. There were no false positive diagnoses in the Hosseini Zarchi et al. study [22] due to the 100% specificity of all techniques utilized in identifying file fractures. The observer's extensive knowledge in detecting file fractures inside the root canal contributed to this challenge. According to a study by Kamburg Law et al. [23], it was more difficult to detect file fractures inside the root canal when a metal post was present, as sensitivity and specificity were decreased. The range of specificity in other studies using similar voxel sizes was considerable, ranging between 88% and 100%, consistent with the present study [23, 24].

The limitations of the present study include the varying degree of agreement between observers in interpreting the images, leading to somewhat contradictory results. Additionally, the nature of in vitro studies affects the generalizability of the results. In vitro studies investigate phenomena in a laboratory environment outside the living organism. Although useful for understanding basic mechanisms and discovering new treatments, these studies may not fully simulate natural conditions. The limited number of samples and insufficient diversity may not represent the true population. Therefore, additional in vivo studies are strongly recommended to evaluate the results in natural conditions. The results obtained from clinical settings may differ from those of in vitro studies, and interpreting these results after conducting clinical trials will allow for a more comprehensive analysis.

Conclusion

In conclusion, both CBCT devices demonstrated equal performance in identifying broken files within the root canal system.

Acknowledgments

The authors thank the Research Vice Chancellor of Urmia University of Medical Sciences.

Authors' contributions

AAA and AG designed the study and performed the search and data extraction. SAS analyzed the data. AAA, AG, and ASA wrote the manuscript.

EP edited the draft. All authors read and approved the final manuscript.

Funding
There was no funding for this study.

Availability of data and materials
Please contact the corresponding author for data requests.

Consent for publication
Not applicable.

Competing interests
The authors report no conflicts of interest in this work.

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