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Original Research

Diagnostic Accuracy of Cone-beam Computed Tomography and Conventional Periapical Radiography in Detecting Strip Root Perforations

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Abstract:
Background: Perforations are the one of the greatest cause of failure in endodontics. Early diagnosis of root perforations is a critical factor in treatment outcome. The aim of this study was to compare the sensitivity, specificity, and accuracy of conventional periapical (PA) radiography with cone-beam computed tomography (CBCT) in detecting strip root perforations in filled and unfilled root canals.
Methods and Materials: In this *in vitro* experimental study, mesial root canals of 100 extracted mandibular molar teeth were prepared. Distal wall of the mesiolingual canals were thinned by rotating a Gates Glidden. Then the mesial roots of 51 teeth were randomly perforated. All samples were examined with PA (3 horizontal angles) and CBCT before and after obturation. The images were evaluated for diagnosis of strip root perforations by two observers. Sensitivity, specificity, and accuracy of each technique for detection of strip root perforation were calculated. The data were subjected to statistical analysis using Chi-square and Fisher exact tests.
Results: In unfilled canals, sensitivity, specificity, and accuracy of the techniques for detection of strip root perforation were significantly different ($P < 0.05$). After obturation, PA was significantly more sensitive than CBCT ($P < 0.05$).
Conclusion: Under the conditions of this *in vitro* study, in the absence of root filling materials, CBCT was superior to PA for detection of strip root perforation but for perforation detection in obturated root canals, PA with three different horizontal angulations was more reliable.

Key Words: Cone-beam computed tomography, periapical radiograph, sensitivity, specificity, strip root perforation

Introduction

Root perforation is defined as a pathological or mechanical communication between the root canal system and the external root surface.[1] Strip root perforation which usually occurs when a practitioner is working improperly through a thin wall (danger zone) in the root and creates a challenge due to its difficult diagnosis and management.[1] Several factors influence the outcome of perforated root canals.[2] Perforations that are fresh and small which can be repaired immediately have good treatment prognosis.[1,2] Therefore, early diagnosis of strip root perforations is a critical factor in treatment outcome. Although, an accurate diagnosis of strip root perforations have been very challenging due to lack of definitive clinical symptoms and limitations of conventional periapicals (PAs) radiographs,[3,4] modern endodontic practice promotes diagnosis, and treatment strategies of root perforations.[5-11]

Although, electronic apex locator,[6] operative microscope,[9] and optical coherence tomography scan[12] have been suggested for detection of root canal perforations, none of them were able to diagnose perforations in already filled canals because they are based on imagination of the empty root canal or penetration into it.

Cone-beam computed tomography (CBCT) scans have been used as a valuable diagnostic tool for characterizing the PA lesion and its healing process,[13] diagnosing vertical root fractures,[14] assessing the anatomy of the internal and external aspects of the root,[15,16] and localizing root resorption defects.[17]

In addition, it has been shown that CBCT scans can be used to detect strip root perforation.[18,19]

Considering the fact that total radiation doses from dental CBCT scans are generally higher than conventional dental X-ray exams[19,20] more studies are required to assess superiority of CBCT over conventional PA.

The purpose of this study was to compare the sensitivity, specificity, and accuracy of conventional PA radiography with CBCT in detecting strip root perforations in the absence and presence of root filling materials.

Materials and Methods

This study was approved by the Ethics Committees of Qazvin University of Medical Sciences, Qazvin, Iran.

In this *in vitro* experimental study a total of 100 extracted human two-rooted mandibular molar teeth were selected. For disinfection, the specimens were stored in 5.25% sodium hypochlorite (NaOCl) for an hour and then placed in normal saline before the experiment. All teeth were examined by a stereomicroscope (MBC-2, Russia) under ×16 magnification and teeth with crack, fracture, canal calcification, and root resorption were excluded. After access cavity preparation, real mesial root canal lengths were determined by manually inserting #15 K-files (Dentsply Maillefer, Switzerland) into the canals, until the instrument tips were visible at the apical foramen. Working length was established 1.0 mm shorter than real root canal length. Then, two mesial canals were prepared with ProTaper rotary instruments (DentsplyMaillefer, Switzerland) using the single-length technique. The final file used to prepare the canals was F2. Each canal was irrigated with 5 ml of 2.5% NaOCl before using each file. Distal roots of all teeth were cut out from furcation area, by a diamond disk (Flexilium, Madespa S.A, Spain) and a laboratory hand piece (Marathon Motor, China), to provide access and vision to the danger zone of the mesial root canals. Then the Samples were randomly placed into two experimental groups ($n = 50$).

In Group 1, danger zone of each mesiolingual canal, was thinned by rotating a Gates Glidden drill #3 (DentsplyMaillefer, Switzerland) in distoaxial direction at 1-3 mm below the furcation level.[18] Dentin removal was continued to the point that the drill shadow was evident over the distal area of the mesial root (danger zone). One root in this group was in advertently perforated; therefore, it was added to Group 2. In addition, during root canal preparation, in three teeth, and roots were fractured and excluded. In Group 2, samples were prepared the same as Group 1, but drilling with Gates Glidden was continued to result strip root perforation. Next, coronoapical diameter of each perforation was measured using a digital caliper with precision ±0.001 inch per 6 inch (Mitutoyo Corp., Tokyo, Japan).

Each distal section was reattached to the corresponding tooth with cyanoacrylate adhesive (Mitreapel, Beta Chemical Co. Istanbul, Turkey). Roots were coated with a layer of 0.5 mm green casting wax (AZAR TEB Production Group, Tehran, Iran), to resemble PDL. They were mounted in a mixture of three part saw dust and one part plaster to mimic trabecular pattern of mandibular alveoli.

To simulate soft tissue, samples were coated with layers of modeling wax (Cavex Holland BV, Netherland) to achieve 15 mm thickness.[21]

PA radiographs were made with Planmeca X-ray unit (PlanmecaOy, Helsinki, Finland) using E speed films (Kodak, Rochester, NY, USA), operating at 70 kVp, 0.2 s and 10 mA. The distance between the tooth and X-ray cone was 25 cm. Three radiographs were taken for each tooth (straight and 20° mesial and distal angulations) and they were processed in a peri-pro automatic processor (Air Techniques Inc., USA).

CBCT scans were made using a Promax three-dimensional (3D) unit (84KvP, 10 mA; Planmeca, Roselle, IL, USA) with a field of view of 40 mm × 40 mm and an exposure time of 12 s. The data set consisted of axial, sagittal, and coronal reconstructions; the size of the reconstructed voxels was $0.16\ mm^3$ (Figure 1).

Then, all mesial canals were dried with paper points (Ariadent, Tehran, Iran), and obturated using lateral compaction technique with gutta-percha (Gapadent Co., LTD, Korea), and AH26 sealer (DeTrey, Dentsply, Konstanz, Germany). Again, PA radiographs and CBCT scans were taken from each tooth as described above (Figure 2).

CBCT images were displayed on a 17-inch flat panel screen (Sony Electronics, Inc., Park Ridge, NJ, USA) with a 1024 × 768-pixel resolution and were assessed in axial, sagittal, and coronal planes. PA and CBCT images were evaluated separately by two observers (one endodontist and one radiologist). The observers were not involved in sample preparation and they were blind to the results of the other imaging technique. They were calibrated and instructed to observe the mesial root of each tooth and report their observations as presence or absence of strip root perforation. The interpretation criteria for detecting a strip root perforation were defined as the presence of any communication or discontinuity between the

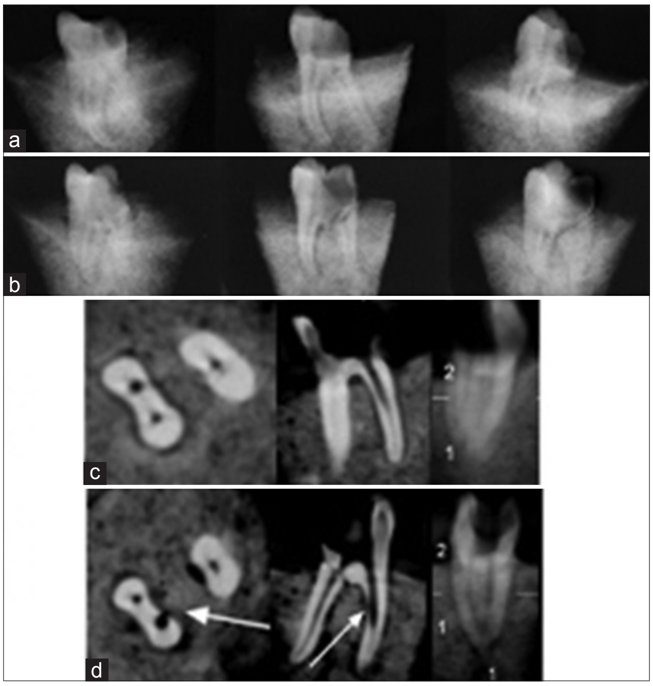

Figure 1: (a, b) Conventional periapical radiographs: Three different angulations, without and with strip perforation, respectively, (c, d) cone beam computed tomography: Sagittal, frontal, and axial views of samples without and with strip perforation, respectively.

mesiolingual root canal and peripheral portion of the root at the furcation area. The overall agreement among observers was evaluated by using Cohen's kappa. When observations of the two professions differed, a consensus was reached after a discussion. Sensitivity, specificity, and accuracy of each technique were calculated.

A two-sided Chi-square, Z-test, Mcnemar, and Fisher exact tests were used to analyze the sensitivity, specificity, and accuracy of both CBCT scans and PAs for detection of strip root perforations, before and after obturation. The data were analyzed with 5% significance level using Statistical Package for Social Sciences (SPSS) 17.0 (SPSS Inc., Chicago, IL).

Results

Sensitivity, specificity, and accuracy of CBCT scans and PAs in detecting strip perforations before and after obturation have been shown in Table 1.

In the absence of root filling materials, the accuracy, specificity, and sensitivity of CBCT were significantly higher than those of PA ($P < 0.05$). In the obturated root canals, the sensitivity of CBCT was significantly lower than that of PA ($P < 0.05$), however, specificity and accuracy of the two techniques were not statistically different ($P = 0.36$ and $P = 0.08$, respectively). In addition, accuracy, sensitivity, and specificity of both techniques after root canal obturation were significantly changed ($P < 0.05$).

Coronoapical size of perforations was in range of 0.3-2 mm, and they were classified into 3 groups of small, 0.3-0.8 mm ($n = 18$); moderate, 0.9-1.4 mm ($n = 16$); and large, 1.5-2 mm ($n = 17$). Frequency distributions of detecting perforations according to size of defects have been demonstrated in Table 2.

By means of CBCT technique, moderate and large perforations have been detected significantly different from small perforations, regardless of the presence of root filling materials ($P < 0.05$). Root canal obturation compromised the ability of CBCT in detecting perforations; however, it was only significantly different for the small perforations ($P < 0.05$).

In the absence or presence of root filling materials, there were no significant differences among detecting small, medium, and large perforations using PA images ($P > 0.05$). After root canal obturation, detection of small perforations using PA technique were significantly different ($P = 0.02$).

In filled root canals, detection of small defects using PA technique was significantly different from CBCT technique ($P < 0.05$). However, in the absence of root fillings, there were no significant differences among detecting small, medium, and large perforations, between two techniques ($P = 0.29$).

The agreement among observers was substantial for CBCT scans in the absence of root filling (k = 0.79); however, after obturation, it was reduced to 0.48. On the other hand, when observers were assessing the PA images, there was a low level of agreement in the absence of root filling materials (k = 0.36), which was increased to 0.73 after root canal obturation.

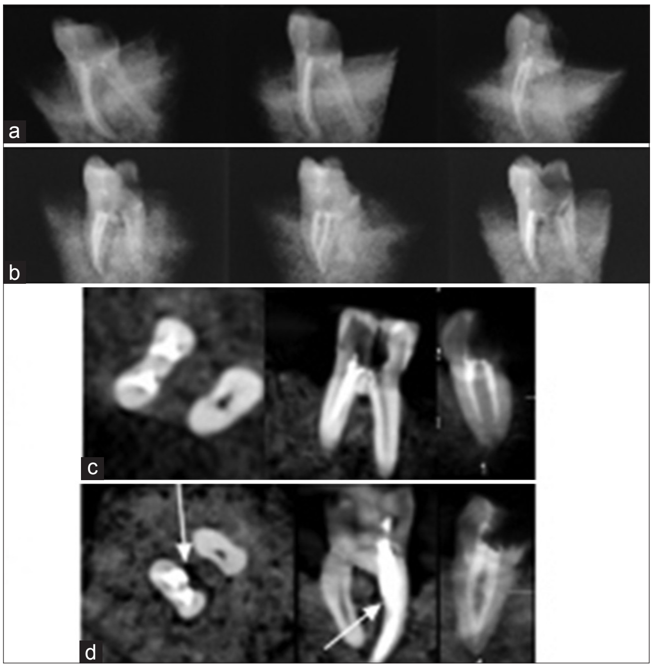

Figure 2: (a, b) Conventional periapical radiographs: Three different angulations, obturated teeth without and with strip perforation, respectively, (c, d) cone beam computed tomography: Sagittal, frontal, and axial views of obturated samples without and with strip perforation respectively.

Table 1: Sensitivity, specificity, and accuracy of PA radiographs and CBCT techniques in detecting strip perforations according to the absence and presence of root filling materials.

Group	Sensitivity (%)	Specificity (%)	Accuracy (%)
PA (unfilled canals)	70.5	69.5	70.1
CBCT (unfilled canals)	90.1	100	94.8
PA (obturated canals)	94.1	89.1	91.7
CBCT (obturated canals)	72.5	82.6	77.3

PA: Periapical, CBCT: Cone beam computed tomography

Table 2: The percentage of root perforation's detection using PA radiographs and CBCT techniques, according to size of defects.

Group	Small (%)	Moderate (%)	Large (%)
PA (unfilled canals)	55.6	81.2	76.5
CBCT (unfilled canals)	72.2	100	100
PA (obturated canals)	94.4	100	88.2
CBCT (obturated canals)	44.4	87.5	88.2

PA: Periapical, CBCT: Cone beam computed tomography

Discussion

This study investigated the sensitivity, specificity and accuracy of CBCT scans and PAs for detection of strip root perforations, in the absence or presence of root filling materials. Although, PA radiography has been a great aid for dental diagnosis in clinical practice, the limitations of these two-dimensional images has long been debated.[22] These limitations lead to geometric distortion, and restrict information regarding the size, extension, and location of defects.[22] To improve ability of conventional radiography, different techniques have been suggested.[23]

CBCT has been particularly designed to create undistorted 3D images of the maxillofacial skeleton, including the teeth and their surrounding tissues.[24] That is why in this study, it was selected as another imaging modality.

In the previous studies, samples in the control group (roots without perforation) had just been prepared conventionally.[18,19,25,26] In our study, to simulate clinical conditions furcal surface of mesiolingual canal of all samples was thinned so the drill shadow was evident over the canal's wall. In so doing, we tried to simulate suspicious clinical cases of strip root perforations in our control group.

On the other hand, our study showed that sensitivity and specificity of PA technique to diagnose strip perforations in empty canals was 70.5% and 69.5%, respectively. It seems that the special location of this type of perforation which might be masked in the root's concavity causes this limitation.[18]

In the present study, root canal obturation significantly increased the accuracy, sensitivity, and specificity of PAs. This could partly be explained by the presence of filling materials inside the perforation area. In a study of Shemesh *et al.*, the sensitivity and specificity of PAs in detecting strip perforations were 13% and 96%, respectively.[18] However, in a recent study conducted by Shokri *et al.*, the sensitivity and specificity of PAs were 81% and 93%, respectively.[19] Higher specificity reported in Shemesh *et al.*'s study could be attributed to their control group and smaller sample size. As mentioned earlier, the control group (roots without perforation) in their study had just been prepared conventionally, and it led to different results. On the other hand, the limited sensitivity of PAs in Shemesh *et al.*'s study could be partly explained by viewing only two mesial and distal angulated PAs and not including the straight one, using digital PA radiographic device instead of conventional one, and smaller sample size.

According to our results, CBCT is a reliable technique for detection of strip root perforations in unfilled canals (sensitivity 90.1%, specificity 100%). Haghanifar *et al.*, also reported similar findings.[26] This result seems perfectly reasonable because we can evaluate samples 3D with CBCT.

Our findings showed that the sensitivity, specificity, and accuracy of CBCT were significantly reduced in the presence of root filling materials. This result is in agreement with previous studies which had reported that ability of CBCT in detecting root canal's defects decreased in the presence of gutta-percha.[26,27] This can be attributed to the fact that gutta-perch*a* and sealer are radiopaque materials that may produce distinct artefacts and decrease observer's ability to detect perforations.[14,24,26-28]

We also found out PA radiography is better for detection of strip root perforation in obturated canals, this finding is in agreement with results of Haghanifar *et al.*,[26] while Shemesh *et al.*,[18] reported that CBCT scans showed a significant higher accuracy than PAs. In their study,[18] the researchers did not consider the size of perforations as an important variable. Moreover, Shokri *et al.*, reported that CBCT had a greater accuracy than PAs.[19] Although they considered the size of perforations and specified the samples into three groups of 0.2, 0.3, and 0.4 mm ($n = 16$), the size of perforations in our study was in a greater range of 0.3-2 mm. However, according to our results, detecting small perforations by PAs was easier than CBCT in obturated canals, because overcoming CBCT's artefacts is much easier when there is a large strip root perforation whereas a small defect is usually difficult to detect. In this study, PAs of each sample were evaluated by an endodontist and a radiologist in three horizontal angulations, however, the other researchers[18,19] evaluated radiographies taken in two horizontal angulations.

The results of our study showed that the difference between the ability of CBCT and PA to detect moderate and large defects are not considerable. In agreement with the results of our study, Shokri *et al.*,[19] D'Addazio *et al.*,[25] and Venskutonis *et al.*,[30] found there were no significant differences between PA and CBCT in the detection of larger perforations.

Our findings showed that artefacts which were produced by filling materials interfered with accurate diagnostic evaluation of CBCT scans. However in the clinical conditions this issue is not as important as *in vitro* studies, because in the clinical practice it is very important to diagnose strip root perforations as soon as possible before root canal filling. Considering the fact that strip perforation just after a short period of time causes a furcation defect which is detectable by PA radiography,[29] using CBCT scans at that time is not reasonable, because they impose higher radiation dose and financial costs on patients. On the other hand, our results showed that PAs have limited ability to detect strip perforations in the absence of root filling materials; thus it seems that the accuracy of CBCT for detection of strip perforations before root canal filling is valuable.

Conclusion

Under the conditions of this *in vitro* study, in the absence of root filling materials, CBCT was superior to PA for detection of strip root perforations. For perforation detection in obturated root canals, PA radiography with three different horizontal angulations was more reliable.

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