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ORIGINAL ARTICLE

Comparison of the accuracy of cone-beam computed tomography, photostimulable phosphor imaging plate, charge coupled device, and conventional intraoral radiography in the diagnosis of internal root resorption: an in vitro study

Comparação da precisão da tomografia computadorizada de feixe cônico , placa de imagem de fósforo fotoestimulável, chargecoupleddevice(CCD), e radiografia intra-oral convencional no diagnóstico de reabsorção radicular interna: um estudo in vitro

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ABSTRACT

Objective: Various radiographic methods are used to identify the internal root resorption. The aim of this study was to assess and compare the diagnostic accuracy of cone-beam computed tomography (CBCT), photostimulable phosphor (PSP) imaging plate, charge coupled device (CCD), and conventional intraoral radiography (CIR), for internal root resorption. **Material & Methods:** This experimental study was conducted in Hamadan in 2012. Fifty seven carries-free single-rooted teeth were divided into three intervention groups of 15 teeth and one control group of 12 teeth. Teeth were split into two parts using a disk. Cavities of 0.5, 1 and 1.5 mm in depth were created in root canal of teeth to simulate internal root resorption artificially. Finally, the teeth fragments were fused. All teeth were examined with four different procedures and the results were compared with known simulated internal root resorption as the gold standard to determine the sensitivity and specificity of the procedures. **Results:** The sensitivity of CBCT, PSP, CCD, and CIR for diagnosis internal root resorption of 0.5 mm in depth was 93%, 73%, 60%, and 53% respectively. The sensitivity of all four procedures for diagnosis of internal root resorption with 1 and 1.5 mm in depth was the same and equal to 100%. Specificity of the four radiology procedures for diagnosis of internal root resorption of any depth was 100%, 100%, 83% and 75% respectively. **Conclusion:** CBCT provides the most accurate information on the depth and location of root resorption followed by the PSP and CCD respectively. Accordingly, conventional intraoral radiography was the least accurate procedure.

KEYWORDS

Radiography; Cone-beam Computed Tomography; Root Resorption; Iran

RESUMO

Objetivos: Vários métodos radiográficos são utilizados para identificar a reabsorção radicular interna. O objetivo deste estudo foi avaliar e comparar a precisão do diagnóstico de reabsorção radicular interna por tomografia computadorizada de feixe cônico (TCFC), placa de imagem de fósforo fotoestimulável(FFE), Charge CoupledDevice(CCD) e radiografia intra-oral convencional (RIC). **Material e Métodos:** Este estudo experimental foi realizado em Hamadan em 2012. Cinqüenta e sete dentes anteriores livres de cárie foram divididos em três grupos de 15 dentes e um grupo de 12 dentes foi utilizado como controle. Os dentes foram divididos em duas partes usando um disco. Cavidades de 0,5, 1 e 1,5 mm de profundidade foram criados nos canais radiculares dos dentes para simular a reabsorção radicular interna artificialmente. A seguir , os fragmentos de dentes foram unidos . Todos os dentes foram examinados com quatro diferentes procedimentos e os resultados foram comparados com um padrão ouro conhecido de diagnóstico de reabsorção radicular interna simulada para determinar a sensibilidade e especificidade dos procedimentos. **Resultados:** A sensibilidade da TCFC, FFE, CCD e RIC para diagnóstico reabsorção radicular interna de 0,5 mm de espessura foi de 93 %, 73 %, 60 % e 53 %, respectivamente . A sensibilidade dos quatro processos para o diagnóstico da reabsorção radicular interna com 1 e 1,5 mm de profundidade foi a mesma e igual a 100 %. A especificidade dos quatro procedimentos de radiologia de diagnóstico de reabsorção radicular interna de qualquer profundidade foi de 100 %, 100 %, 83 % e 75 %, respectivamente. **Conclusão:** A TCFC fornece as informações mais precisas sobre a profundidade e localização da reabsorção radicular, seguido pelo FFE e CCD, respectivamente. Assim, a radiografia intra-oral convencional foi o procedimento menos preciso.

PALAVRAS-CHAVE

Radiografía; Tomografia Computadorizada de Feixe Cônico; Reabsorção da Raiz; Irã

INTRODUCTION

Internal root resorption has been described as the progressive defect of intra-radicular dentin and dentinal tubules along the middle and apical thirds of the canal walls as a result of chronic inflammation and bacterial invasion of the pulp tissue [1]. Internal resorption is a type of root resorption that can result in irreversible pulpitis, so that the dentin and cement substances are dissolved by chelation. Trauma and inflammation are considered to be possible causing factors. Since root resorption is asymptomatic, the untreated internal resorption can progress into external or vice versa which causes fractures of the tooth. Hence, it is important to diagnose this pathological process and institute treatment as early as possible to improve the prognosis of such teeth [2,3].

Various radiology methods are used for early diagnosis on internal root resorption, the most common of which are conventional intraoral radiography (CIR), charge coupled device (CCD), and photostimulable phosphor (PSP) imaging plate. Analog and digital intraoral radiography can be done in two ways. In the analog method, the conventional films are exposed to radiation and fixed in the processing solution. Digital intraoral technique can be done in two ways: directly and indirectly. In the direct method (e.g. CCD), the images are visible immediately after radiography. In the indirect method (e.g. PSP), after radiation, the sensor is placed in a scanner. The scanner is exposed to the laser beam and then the image appears on the monitor. In addition to these conventional methods, cone-beam computed tomography (CBCT) is an innovative technology has recently been extensively used for early detection of dental disease including root resorption. This technique provides three-dimensional images of the maxillofacial structures using Cone beam. [4-6].

Diagnostic information can directly influence clinical decisions. Accurate data offer clinically relevant information and can lead to better treatment-planning decisions and potentially more predictable outcomes [7]. Conventional intraoral radiography offers images that have objects superimposed upon each other and clinician have to make a three-dimensional decision on the basis of a two-dimensional image [8]. Whereas, CBCT technology provides clinicians a three-dimensional view which eliminates the superimposition that is inherent in conventional imaging and offers valuable axial, sagittal, and coronal views [9].

To the best of our knowledge, a few comprehensive study has been conducted to investigate the accuracy of conventional and digital intraoral imaging techniques altogether and with CBCT and to compare the strength and weakness of these imaging procedures for early detection of internal root resorption. The aim of this study was to examine the sensitivity and specificity of four imaging procedures including CBCT, PSP, CCD, and CIR for early diagnosis of internal root resorption.

MATERIAL & METHODS

This experimental study was conducted in Hamadan, the west of Iran, in 2012. Fifty seven single-rooted teeth (including central, lateral incisors, canines and premolars) without root resorption were selected and saved in normal saline serum (Figure 1). The teeth were divided into four groups including three intervention groups of 15 teeth each and a control group of 12 teeth (Figure 2).

Figure 1 - Saving teeth in normal saline solution

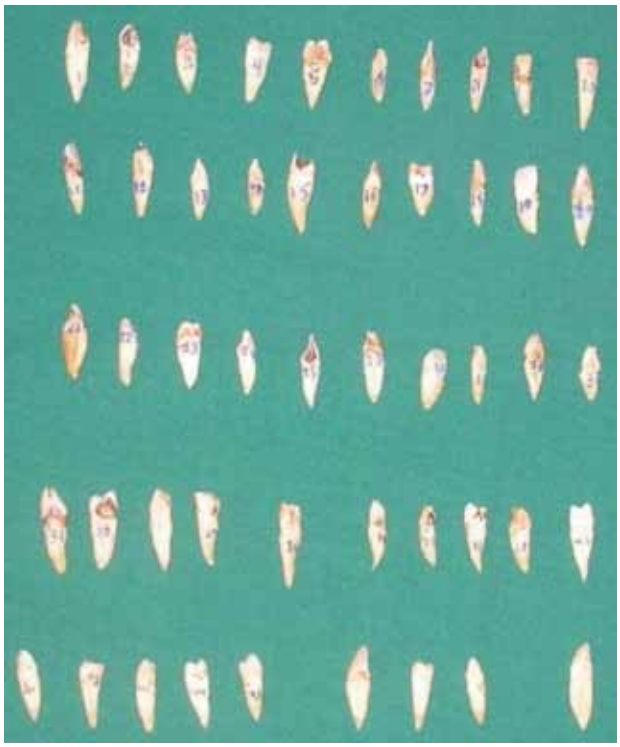

Figure 2 - Teeth used for simulation internal root resorption

Preparing and simulating root resorption

Teeth were split mesiodistally into two parts using a diamond disk (917F220M, SS White, USA). Then, cavities of 0.5 mm in depth were created by round bur (No. 010, Tizkavan, Iran) in first intervention group of the 15 teeth, cavities of 1 mm in depth in the second group, and cavities of 1.5 mm in depth in the third group. In each intervention group, the cavities of different depths were created in the apical (5 teeth), medial (5 teeth), and cervical (5 teeth) areas to simulate internal root resorption artificially at different parts of the root. In order to standardize the root resorption, the depth of cavities was measured by Williams's periodontal probe (Hu-Friedy, USA) to ensure that the depth of the resorption is as it was planned to be. The 12 teeth of the control group were split to be as similar as the teeth of intervention groups but no cavities were created in them. Finally, the teeth fragments were fused using

Figure 3 - Mandible used for fixing the teeth

glue and were fixed in their relevant locations in sockets of one human dry mandible. To simulate facial soft tissue, all surfaces of the mandibles were covered by 2 layers of pink wax, approximately 2 mm in thickness (Figure 3). Then, the teeth were examined with four different imaging procedures.

Imaging techniques

Conventional intraoral imaging system used in this study was Minray x-ray unit (Soredex, Helsinki, Finland) and an E speed film (Kodak, USA) was used. The periapical film was fixed behind the skull with exposure conditions of 60 kVp, 6 mA, and 0.10 s. An automatic processing machine (HOPE, USA) was used to appear the films (Figure 4). Intraoral digital imaging system used in this study was Minray x-ray unit (Soredex, Helsinki, Finland) and captured image with CCD sensor (Sopro, France)and a Digora Optime (Soredex ,Helsinki, Finland) size 2 PSP plate. The sensor was fixed behind the skull with exposure conditions of 60 kVp, 6 mA, and 0.10 s (Figure 5 and 6).

All images were taken parallel and with the same angles using a film holder on the mandible in order to standardize all intraoral images (conventional and digital). The periapical films, sensors, and film holder were

fixed on the mandible with scotch tape. The films, (or sensor), teeth, and x-ray tube were placed in a parallel position. The horizontal and vertical angle of the tube was modified with film holder. The specific software program CCD (Soredex, Helsinki, Finland) was used to view PSP intraoral digital images.

CBCT images were taken by NewTom 3G (Verona,Italy) with a small field of view (FOV) with dimensions of 6 inch and exposure conditions of 110 kVp, 2.8 mA, and voxel size of 0.2 mm for 3.6 seconds. The reconstruction axial sections 0.18 mm thick (pixel size) were performed for axial, coronal, and sagittal sections using NNT viewer software (Figure 7). The CBCT machine which we used in this study had Gantry and couch. So that, the mandible was placed in the same position in which the patient's head is usually placed on the device and then the image was taken.

Figure 4 - Images taken with conventional imaging technique

Figure 5 - Images taken with charge coupled device (CCD) imaging technique

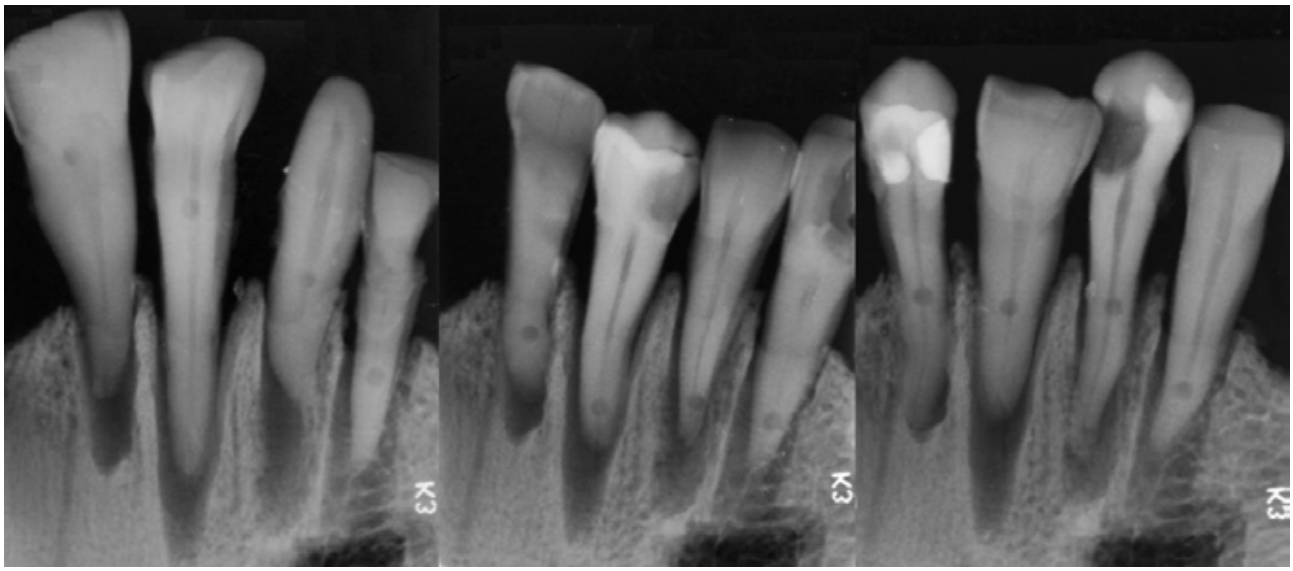

Figure 6 - Images taken with photostimulable phosphor (PSP) imaging technique

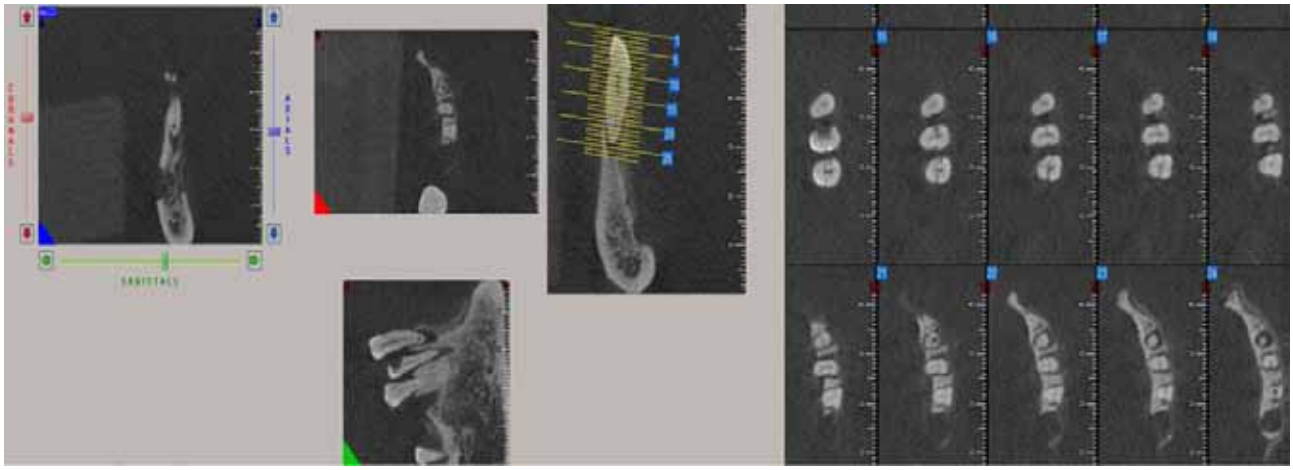

Figure 7 - Images taken with cone-beam computed tomography (CBCT) imaging technique

Interpretation of the images

The images were interpreted by two radiologists independently. They were blind to the presents or absents of root resorption. The observers' judgment on the images was categorized as either positive or negative. A 15-inch liquid crystal display monitor with 1367×768 pixel resolution was used for interpretation of the images. The analog images were evaluated and interpreted using a negatoscope with suitable light condition.

Statistical methods

To estimate the sensitivity and specificity of the imaging methods, we divided the images as positive or negative based on the observers' judgments and reported as a percentage using known simulated internal root resorption as the gold standard. We used kappa statistics to address the inter-technique reliability for each couple of imaging techniques. A kappa statistic below 0.40 was considered poor agreement, a kappa statistic of 0.40 to 0.75 was considered

intermediate to good agreement, and a kappa statistic greater than 0.75 was considered excellent agreement beyond chance [10]. All statistical analyses were performed at the 95% significance level using the statistical software Stata version 11.2 (StataCorp, College Station, TX).

RESULTS

The sensitivity and specificity of CBCT, PSP, CCD, and CIR for diagnosis internal root resorption by resorption depth are shown in Table 1. The sensitivity of the four imaging procedures for diagnosis of internal root resorption of 0.5 mm in depth was 93%, 73%, 60%, and 53% respectively. However, the sensitivity of all four procedures for diagnosis of internal root resorption with 1 and 1.5 mm in depth was the same and equal to 100%. The specificity of the four procedures for diagnosis of internal root resorption of any depth was 100%, 100%, 83%, and 75% respectively. Regardless of depth, the average accuracy of the four procedures based on Kappa statistics was 95%, 81%, 62%, and 53% respectively.

The sensitivity and specificity of CBCT, PSP, CCD, and CIR for diagnosis internal root resorption by location are shown in Table 2. Regardless of the absorption depth, the sensitivity of the four imaging procedures for diagnosis of internal root resorption was 93%, 87%, 87%, and 80% for the apical area, 100%,100%, 93%, and 100% for the medial area, and 100%, 87%, 80%, and 73% for the cervical area respectively. The specificity of all four procedures for diagnosis of internal root resorption in apical, medial, and cervical areas were same and equal to 100%, 100%, 92%, and 75% respectively. Regardless of area, the average accuracy of the four procedures based on Kappa statistics was 95%, 81%, 68%, and 53% respectively.

Table 1 - Sensitivity and specificity of various imaging techniques including cone-beam computed tomography (CBCT), photostimulable phosphor (PSP) imaging plate, charge coupled device (CCD), and conventional intraoral radiography (CIR) for diagnosis of internal root resorption by resorption depth

Resorption depth (mm)	CBCT	PSP	CCD	CIR
Sensitivity %				
0.5	93	73	60	53
1.0	100	100	100	100
1.5	100	100	100	100
Average	98	91	87	84
Specificity %				
0.5	100	100	83	75
1.0	100	100	83	75
1.5	100	100	83	75
Average	100	100	83	75
False negative %				
0.5	3	27	40	47
1.0	0	0	0	0
1.5	0	0	0	0
Average	2	9	13	16
False positive %				
0.5	0	0	17	25
1.0	0	0	17	25
1.5	0	0	17	25
Average	0	0	17	25
Kappa statistics %				
0.5	93	71	42	27
1.0	100	100	85	77
1.5	100	100	85	77
Average	95	81	62	53

Table 2 - Sensitivity and specificity of various imaging techniques including cone-beam computed tomography (CBCT), photostimulable phosphor (PSP) imaging plate, charge coupled device (CCD), and conventional intraoral radiography (CIR) for diagnosis of internal root resorption by location

Location	CBCT	PSP	CCD	CIR
Sensitivity %				
Apical	93	87	87	80
Medial	100	100	93	100
Cervical	100	87	80	73
Average	98	91	87	84
Specificity %				
Apical	100	100	92	75
Medial	100	100	92	75
Cervical	100	100	92	75
Average	100	100	92	75
False negative %				
Apical	7	13	13	20
Medial	0	0	7	0
Cervical	0	13	20	27
Average	2	9	13	16
False positive %				
Apical	0	0	8	25
Medial	0	0	8	25
Cervical	0	0	8	25
Average	0	0	8	25
Kappa statistics %				
Apical	93	85	78	55
Medial	100	100	85	77
Cervical	100	85	70	48
Average	95	81	68	53

DISCUSSION

Remarkable advances support the widespread use of imaging procedures for identification and localization of internal and external resorption, diagnosis of periapical lesions due to pulpal inflammation, the detection of vertical root fractures, and the visualization of accessory canals [11]. Diagnostic information offered by imaging procedures can influence clinical decisions. Accurate data provide clinically relevant information and can lead to better judgment [7].

Early diagnosis of external root resorption is critical for appropriate treatment [12,13]. According to our findings, CBCT offers the most accurate and reliable information about internal root resorption compare to other procedures. de Paula-Silva et al reported that overall sensitivity and specificity of CBCT in the diagnosis of apical periodontitis was 91% and 100% respectively [14]. Murphy et al investigated the accuracy and reliability of forensic information from (CBCT) scans of the jaws and reported a sensitivity of 96.6% and a specificity of 98.4% [15]. On the other hand, Eskandarloo et al compared the sensitivity and reliability of CBCT and PSP for diagnosis of endodontic complications and concluded that CBCT is recommended as a complementary but not routinely used diagnostic method for endodontic complications not usually detected by conventional methods [6].

According to the results of the present study, the average precision of CBCT, PSP, CCD, and CIR for diagnosis internal root resorption of 0.5 mm in depth was 93%, 71%, 42%, and 27% respectively. These results indicate that CBCT has more capability than conventional intraoral imaging techniques in diagnosing internal root resorption in the primary stages. This is due to the adjustment of the contrast and density of digital images as well as using different

software options such systems such as noise reduction, magnification, enhancement, and etc. Among digital intraoral imaging systems, digora Optime PSP has higher precision which is due to its software capability and higher resolution compared to SOPRO CCD. This enables the digital imaging system in diagnosing small internal root resorption. Furthermore, digital systems have less absorption does than conventional systems.

Although CBCT imaging system has higher accuracy than the PSP digital systems (93% versus 71%), but its higher costs and doses compared to PSP has limited its administration for identifying the internal root resorption especially in the early stages. Therefore, the PSP is suggested to be considered as the first choice in diagnosing internal root resorption in patients with trauma because it can detect 71% of the internal root resorption of 0.5 mm in depth. If the results of PSP are negative at this stage, we can follow the patients. If the tooth is inflamed and the inflammation makes progress then, root resorption may be detected. However, CBCT may be used for more precise diagnosis especially when other diagnosis such as fracture is suspected. There is no significant difference between CBCT and PSP in diagnosing internal root resorption of 1-1.5 mm in depth. Indeed, the diagnostic ability of all imaging systems increases with resorption depth.

Regarding the diagnostic accuracy of imaging systems in different regions of origins (cervical, middle and apical), the accuracy of CBCT imaging systems in the apical area is less than middle and cervical areas of the root. The reason is that the root structure is smaller in the apical area and this makes it diagnosis more difficult.

Both intraoral imaging systems (conventional and digital) have the highest accuracy in diagnosing the internal root resorption in the middle area of the root and the least accuracy in that of the apical and cervical areas because the root structure is smaller in the apical area and the superimposition of the concavity of the tooth cycle on the cervical area makes the correct diagnosis of this area difficult.

Similar to the results of the present study, Kamburoglo et al [16] indicated that CBCT systems with small voxels (0.125-0.160 mm3) are more accurate than systems with greater voxels (0.300 mm3) in detecting the internal root resorption. Furthermore, Kamburoglo et al [17] showed that CBCT systems have a high accuracy in detecting and localizing the intraoral and external root resorption as was the case in our study. In addition, Kamburoglo et al [18] studied the ability of the conventional and digital intraoral imaging systems as well as the digitally filtered images in detecting the internal root resorption and concluded that the results of all intraoral imaging systems is the same except the PSP. However, the results were different from the results of our study. The reason was that we used intraoral digital systems which are more accurate than analog or conventional imaging systems which were used by Kamburoglo et al. Furthermore, current digital systems, such as digora Optime with scanora software, have higher software capability and higher resolution than older digital systems used in 2008.

The most important limitation of this study was that we created internal root resorption artificially and used dry human mandible for replacement of the prepared teeth. Although we tried to simulate the natural condition, the inherent difference between the in vitro and in vivo may raise the possibility of measurement bias in our results. Another limitation of this study was that we simulated root resorption in single root teeth and measured the ability of the imaging techniques in that. The results may well be different in multi root teeth, especially the molars.

CONCLUSION

In conclusion, the current study could examine and compare the accuracy of four different radiographic procedures in diagnosing

internal root resorption. Based on our findings, CBCT provides the most accurate information on the depth and location of root resorption followed by the PSP and CCD respectively. Accordingly, conventional intraoral radiography was the least accurate procedure.

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