Comparison of Accuracy and Observer Agreement in the Detection of Simulated External Root Resorption Using Conventional Digital Radiography and Digitally Filtered Radiography

Original Article

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Recieved: May 21,2014
Accepted: Jun 21, 2014

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Abstract

Introduction: External root resorption is a clinical problem that often cannot be detected clinically. Thus, radiography plays a crucial role in its diagnosis. However, optimal radiographic quality with minimal radiation exposure {2.1 [EN] Verify English word/phrase choice} is an important factor in selecting the appropriate radiographic technique. The aim of this study was the comparison of accuracy and observer agreement in the detection of simulated external root resorption using conventional digital radiography and digitally filtered radiography.

Materials and methods: The study was performed using 100 single rooted teeth in a dry mandibular jaw. The teeth were divided into 5 groups as follows: (1) without resorption, (2) resorption with 0.25 mm depth on buccal surface, (3) resorption with 0.5 mm depth on buccal surface, (4)resorption with 0.25 mm depth on proximal surfaces, and (5) resorption with 0.5 mm depth on proximal surfaces. Digital radiographic images, both conventional and digitally filtered using 3 filters (diagonal, horizontal, and vertical), were obtained. The 2 groups of images were then evaluated by 4 observers in 2 stages, with an interval of 1 week. Thereafter, sensitivity, accuracy, specificity, and Kappa coefficients were calculated to assess observer agreement.

Results: For digitally filtered radiography with diagonal, horizontal, and vertical filters, the accuracy values were 86.5%, 87.2%, and 89.2%; sensitivity values were 93.1%, 92.7%, and 94.3%; and specificity values were 82.5%, 87.5%, and 93.7%, respectively. The accuracy, sensitivity, and specificity values for conventional digital radiography were 86.5%, 91.5%, and 82.5%, respectively.

Conclusion:
Manipulation of images in digital radiographic systems may not always facilitate diagnosis.

Key words:
•Radiography •Dental •Digital •Root Resorption •Diagnosis

Introduction

External root resorption refers to the loss of cementum or dentin, sometimes involving the pulp, and in most cases, the etiology is unknown. However, inflammatory lesions, tumors, high mechanical forces, and occlusal overload can be considered risk factors for this condition. The most common locations of external root resorption are the apical and cervical areas of the root.[1] The lesion is asymptomatic clinically, and typically, its diagnosis is based on radiographic assessment[2]. On the other hand, for demineralization to be visible on the radiograph, 40–50% of the minerals have to be lost; therefore, the penetration depth of the lesion observed in the radiograph is less than the actual depth.[1] Furthermore, overlapping mineralized structures and inherent technical complications make the initial diagnosis difficult.[3]

Digital radiography was introduced in dentistry in 1987 by Dr. Francois Mugnon under the name of RVG system.[4] In digital radiography, a small receptor is placed inside the patient's mouth, and the X-rays strike this receptor. Thereafter, the electronic signals are digitalized and the information is transferred to the computer. The images are processed by the computer and stored in a digital format that can be transformed into images.[5] Digital radiography has advantages such as immediate image display, image-processing facility, and many other improvements.[6]

In the applications of digital imaging systems, there are several facilities, such as various filters that enable manipulation of initial images, which may influence the diagnostic criteria. However, in a study by Kamburoğlu et al. [7], no significant difference was found between conventional and digitally filtered radiographs in the diagnosis of internal root resorption; with increasing depth of the resorption, the diagnostic accuracy increased too.

Borg et al. [8] found that under optimal radiation condition, there was no significant difference between conventional radiography and digital radiography using PSP and CCD systems. Furthermore, detection of the lesions was better in larger cavities with lesser radiation.

In a research by Levander et al. [9], there was no significant difference in sensitivity between conventional radiography and digital radiography in the diagnosis of simulated external root resorption, but the sensitivity increased considerably with increasing lesion size.

The purpose of the present study was to evaluate the effect of various types of imaging (using different filters of SCANORA software) on the accuracy of digital images in the diagnosis of external root resorption.

Materials and Methods

This study was performed using 100 extracted single-rooted human teeth. After extraction, they were kept in 5.25% hypochlorite solution for an hour for disinfection, and thereafter, stored in saline solution until the beginning of the study. Prior to commencement of the study, all soft tissue remnants and calculi were removed from the teeth via polishing.

The teeth were divided into 5 groups of 20 samples each. In Group 1 (control group), no resorption cavity was prepared. In Groups 2 and 3, resorption cavities were prepared on the buccal surface of the roots. In Group 2, external resorption-like lesions of 0.25 mm × 0.25 mm size were created on the buccal surface of the roots using a 1.4 mm round bur. In Group 3, lesions of 0.5 mm × 0.5 mm size were created using a 1.2 mm round bur. In Groups 4 and 5, the resorption cavities were prepared on the distal surface of the roots. In Group 4, external resorption-like lesions of 0.25 mm × 0.25 mm size were created on the distal surface of the roots using a 1.4 mm round bur. In Group 5, lesions of 0.5 mm × 0.5 mm size were created using a 1.2 mm round bur. All these cavities were distributed equally between the coronal, middle, and apical thirds of the root. The sharp edges of the created lesions were rounded using a fissure bur.

Thereafter, the teeth of all 5 groups were placed in a dry human mandible that had sockets fitting the shape of the roots under study. Red wax was used for soft tissue reconstruction, and the radiographs of the teeth were obtained.

The radiation conditions for the digital assessment method (No. 2 CMOS Receptor; Schick Technologies Inc., NY, USA) were selected based on the findings of an initial pilot study under the radiologist's supervision. Thereafter, the device was set for 0.12 s at 60 kVp and 8 mA. The distance between the focal spot and the object was set at 30 cm, and that between the object and the receptor was set at 1 cm.

Subsequently, imaging was completed for all samples of the 5 groups. The images were saved in the JPEG format. Digital radiographs of all the 5 groups were prepared and saved using SCANORA v.4.3.1 software (Soredex, Tuusula, Finland) that enabled image manipulation and filter application. The images were grouped based on the type of filter applied as follows: 1. Diagonal filters, 2. Horizontal filters, 3. Vertical filters, and 4. Filter-less (i.e., conventional digital radiographs). The images thus obtained were randomly coded.

The radiographs were then examined by 4 observers: 2 radiologists and 2 endodontists. All the observers were aware that lesions as small as 0.25 mm and 0.5 mm were created on the coronal, middle, and apical thirds of the buccal and distal surfaces of the roots, and that not more than 1 lesion was created on each tooth. The observers presented their opinions in a ques tionnaire with the following scales: (1) resorption is present, and (2) resorption is absent. The observers were also asked to mention the location of the resorption as apical third, middle third, or cervical third. To check for intra-observer agreement, each observer repeated the examination of all the 4 image groups after an interval of 2 weeks and the results were recorded in a separate file. Thereafter, the observations were checked for accuracy and the data were analyzed. The accuracy of the responses was determined based on the sample codes in the files.

In order to detect significant differences between the 2 methods (with or without filters), chi-square analysis was performed and findings with P values less than 0.05% were considered significant. Thereafter, the sensitivity, specificity, and observer's agreement with the actuals were determined. Agreement between the observers (inter-observer agreement), agreement between the observations of the same observer (intra-observer agreement), and observer's agreement with the actuals were assessed via the Kappa test.

Results

Rates of accuracy for digitally filtered radiographs with diagonal, horizontal, and vertical filters were relatively 86.5%, 87.2%, and 89.2%, respectively, and that for conventional digital radiographs was 86.5%. There was no statistically significant difference between the 2 groups.

Rates of sensitivity for digitally filtered radiographs with diagonal, horizontal, and vertical filters were relatively 93.1%, 92.7%, and 94.3%, respectively, and that for conventional digital radiographs was 91.5%. Again, there was no statistically significant difference between the 2 groups (P = 0.99).

Rates of specificity for digitally filtered radiographs with diagonal, horizontal, and vertical filters were relatively 82.5%, 87.5%, and 93.7%, respectively, and that for conventional digital ones was 82.5%; there was no statistically significant difference between the 2 groups (P = 0.77) (Table 1).

Table 1. Accuracy, sensitivity, and specificity values for conventional digital and digitally filtered radiographic images

	Accuracy	Sensitivity	Specificity
Diagonal Filter	86.5%	93.1%	82.5%
Horizontal Filter	87.2%	92.7%	87.5%
Vertical Filter	89.2%	94.3%	93.7%
Conventional Digital Radiograph(Plain)	86.5%	91.5%	82.5%

The highest rate of intra-observer agreement, in terms of the filter used, was exhibited by the horizontal filter (0.83; excellent), and the lowest was exhibited by the diagonal filter (0.80; excellent). In terms of depth and location of the resorption lesion, the highest rate of intra-observer agreement was found in large resorptions on the buccal surface of the root (0.95; excellent), and the lowest was found in the control group (0.63; good) (Table 2).

The highest rate of inter-observer agreement, in relation to the filter used, was found in the horizontal filter (0.85; excellent), and the lowest was seen with the diagonal filter (0.78; good). The highest rate of inter-observer agreement, in terms of depth and location, was found in large-sized lesions on the buccal surface of the root (0.90; excellent), and the lowest rate was found in the control group (0.64; good) (Table 3).

Table 2. Values of intra-observer agreement based on the depth and location of resorption (Kappa value)

Resorption Depth	Large (0.5 mm)	Small (0.25 mm)	No Resorption	Average (based on the filters used)
Location of the Resorption	Buccal	Proximal	Buccal	Proximal
Diagonal Filter	0.88 Excellent	0.91 Excellent	0.78 Good	0.78 Good
Horizontal Filter	1 perfect	0.93 Excellent	0.81 Excellent	0.83 Excellent
Vertical Filter	0.95 Excellent	0.86 Excellent	0.80 Excellent	0.84 Excellent
Conventional Digital Radiograph	1 Perfect	0.85 Excellent	0.75 Good	0.85 Excellent
Average (based on depth and location)	0.95 Excellent	0.88 Excellent	0.78 Good	0.82 Excellent

Table 3. Values of inter-observer agreement based on the depth and location of resorption (Kappa value)

Resorption Depth	Large (0.5 mm)	Small (0.25 mm)	No Resorption	Average (based on the filters used)
Location of the Resorption	Buccal	Proximal	Buccal	Proximal
Diagonal Filter	0.80 Excellent	0.85 Excellent	0.88 Good	0.70 Good
Horizontal Filter	0.95 Excellent	0.88 Excellent	0.87 Excellent	0.89 Excellent
Vertical Filter	0.91 Excellent	0.85 Excellent	0.81 Excellent	0.83 Excellent
Conventional Digital Radiograph	0.95 Excellent	0.91 Excellent	0.85 Good	0.80 Excellent
Average (based on depth and location)	0.90 Excellent	0.87 Excellent	0.85 Good	0.80 Excellent

A higher rate of observer agreement with actuals was found with the use of filters (for all 3 filter types, Kappa = 0.88; excellent), showing 7% more diagnostic ability than the conventional digital radiographs (Kappa: 0.81; excellent). Nonetheless, the diagnostic ability of both types of radiographs was excellent. As for depth and location of the resorption, regardless of the type of digital radiography used, the highest value for observer ability to diagnose resorption cases was found in relation to large-sized resorption lesions on the buccal surface of the root (Kappa: 0.94; excellent).

The lowest value for the same was found in relation to small resorption lesions on the buccal root surface (Kappa: 0.78; good) (Table 4).

The Kappa values for diagnostic ability in small resorption lesions on the buccal root surface using digital radiography with diagonal, horizontal, and vertical filters were 0.93(excellent), 0.86

(excellent), and 0.87(excellent), respectively, and that for conventional digital radiography was 0.50 (moderate). Therefore, diagnostic ability of digitally filtered radiography using diagonal, horizontal, and vertical filters—with values of 43%, 36%, and 37%, respectively—was relatively better than that of conventional digital radiography.In both digitally filtered and conventional digital radiographs, diagnostic agreement of the observations with the actuals in the detection of large-sized lesions was higher than that for small-sized lesions. The Kappa values for both small- and large-sized lesions for digitally filtered radiography with diagonal, horizontal, and vertical filters were relatively 5%, 12%, and 10%, respectively, and that for conventional radiography was 29%.

Digitally filtered radiographs had more diagnostic agreement with the actuals than conventional digital radiographs in the diagnosis of small resorption lesions. Their superiority using diagonal, horizontal, and vertical filters was 19%, 15%, and 16%, respectively. The observer agreement in the diagnosis of external resorption lesions on the buccal surface of the root using digitally filtered radiography (0.91; excellent) was higher than that using conventional digital radiography (0.73; good).

Diagnostic difference for all observervations in the cervical, middle, and apical thirds of the root for large resorptions, whether on the buccal or proximal surface, was not statistically significant. However, for half of the images, diagnosis of small resorption lesions on the buccal root surface of the cervical thirds of the teeth in both filtered and conventional digital radiographs was significantly better than for lesions on other areas of the root.

In this study, the accuracy of conventional digital and digitally filtered radiography, in which the sharpness of the images were improved using diagonal, horizontal, and vertical filters, were compared in the diagnosis of external root resorption. Further, the intra-observer agreement rate, inter-observer agreement rate, and the rate of observer agreement with actuals were determined.

Discussion

In this study, the resorption of the roots was stud ied under controlled conditions. However, the detection of root resorption clinically is far more challenging than in in vitro conditions, which makes the diagnosis more complicated. Firstly, since the X-rays have to pass through both bone and soft tissue, the image can be affected by any of these tissues. Secondly, in the routine clinical environment, the radiation angle can vary, but under in vitro conditions, this angle is fixed. Thirdly, the pattern of changes in reality is uncontrollable and non-preventable. These factors have to be taken into consideration while determining the accuracy of diagnostic procedures, both in the present study as well as other similar studies. The highest rate of accuracy was found in digital radiographs with vertical filters and the lowest was found in conventional and diagonally filtered digital radiographs. Despite the difference in accuracy between conventional and digitally filtered radiographs, there was no statistical significance.

Mean value of sensitivity for conventional digital radiography, without considering location or size, was 91.5%, and those for digitally filtered radiography with diagonal, horizontal, and vertical filters were 93.1%, 92.7%, and 94.3%,

Table 4. Values of diagnostic agreement of observers with actuals based on the filter, depth, and location of resorption (Kappa value)

Resorption Depth	Large (0.5 mm)	Small (0.25 mm)	Average (based on the filters used)
Location of the Resorption	Buccal	Proximal	Buccal
Diagonal Filter	0.90 Excellent	0.91 Excellent	0.93 Excellent
Horizontal Filter	0.97 Excellent	0.91 Excellent	0.86 Excellent
Vertical Filter	0.95 Excellent	0.91 Excellent	0.50 Excellent
Conventional Digital Radiograph	0.97 Excellent	0.95 Excellent	0.85 Moderate
Average (based on depth and location)	0.94Excellent	0.92 Excellent	0.78 Good

respectively, which showed no significant difference with each other. Also, the sensitivity values of conventional and digitally filtered radiography showed no statistically significant difference in the diagnosis of external root resorption, both in terms of location (buccal or proximal) and size (small or large) of the lesion.

Mean value of specificity for conventional radiographs was 82.5% and those for digitally filtered radiographs with diagonal, horizontal, and vertical filters were relatively 82.5%, 87.5%, and 93.7%, respectively. There was no statistically significant difference between these 2 techniques.

According to the gathered data, it appears that there is no significant difference between conventional digital and digitally filtered radiographs in the diagnosis of external root resorption. These findings are consistent with the results of the Kamburoğlu et al. [7] study in 2007.

The Tofangchiha et al. study [6] in 2012 studied the diagnosis of vertical root fractures and found that the diagnostic accuracy between conventional and digitally filtered radiographs showed no statistically significant difference, thus, corroborating our findings. In the Kositbowornchai et al. [10] and Kamburoğlu et al. [11] studies, magnification of the images in the digital systems did not facilitate the diagnosis of vertical root fractures. In the present study, with an increase in the depth of resorption, regardless of the location of the lesion, the observers' diagnostic agreement with actuals improved. This rise was evident in both conventional and digitally filtered radiographs.

In studies conducted by Levander et al. [9] in 1998, Borg et al. [8], Kamburoğlu et al. [7] in 2007, and Ono E et al. [12] in 2011, it was stated that with an increase in the depth of resorption, the diagnostic ability would increase for conventional, conventional digital, and manipulated digital radiographs. This is consistent with our study.

In this study, most of the correct diagnoses of small resorptions on the buccal surface were made when they were located in the cervical third of the root. In the study by Kamburoğlu et al. [13] 2008, the highest rate of correct diagnosis was found with resorption sites located in the cervical third of the root, which is in agreement with our study.In the present study, Kappa values of observer agreement with actuals in external resorption of the proximal root surface (0.90; excellent) were higher than in lesions on the buccal root surface using conventional digital radiography (0.73; good). Similar results were achieved by Kamburoğlu et al. in 2008 [13], which show consistency with the results of our present study. The observer agreement with actuals for resorptions of the buccal root surface using digitally filtered radiography was higher (0.91; excellent) than with conventional digital radiography (0.73; good). Therefore, digitally filtered radiographs seem to have better diagnostic value than conventional digital ones.

Kravitz et al. [2] in 1992 found no significant difference between conventional digital and digital subtraction radiography in terms of diagnosis of external resorption on the buccal root surface. Nonetheless, in diagnosis of external resorption of the proximal root surface, digital subtraction radiography was markedly better than conventional digital radiography. This finding is not consistent with the present study. In the former study, the image manipulation was different from that of our study in that the digital radiographic images were modified with help of the subtraction method. The differences in the type of digital image receptor, the observer expertise, experience, and knowledge in detecting and diagnosing external root resorption in digital radiographic images could be factors that can explain the dissimilarity between the results of the 2 studies.

The Kappa value of intra-observer agreement for conventional digital radiography was 0.81 (excellent) and those for digitally filtered radiography using diagonal, horizontal, and vertical filters were relatively 0.80 (excellent), 0.83 (excellent) and 0.81 (excellent), respectively.

The Kappa value for inter-observer agreement for conventional digital radiography was 0.82 (excellent). The values for digitally filtered radiography using diagonal, horizontal, and vertical filters were relatively 0.78 (good), 0.85 (excellent), and 0.80 (excellent), respectively.

In the diagnosis of small resorption lesions, digitally filtered radiographs had a higher rate of diagnostic agreement with actuals than conventional digital ones; the average increase for the 3 filters used was 16.6%.

Conclusion

Based on the results of this study, it can be concluded that despite manipulation of the images in digital radiographic systems, changes are not always helpful in diagnosis. In the present study, there were no statistically significant differences in terms of accuracy, sensitivity, and specificity, between conventional digital radiographic images and digital radiographic images that were manipulated using various filters. Hence, these evaluation methods can be viewed only as supplementary.

In the present study, the use of various filters in digital radiography slightly increased the observer's agreement with the actuals for small-sized resorption lesions, and the average increase for all the 3 filters used was 16.6%.

Acknowledgement

The authors would like to thank the Department of Research at Qazvin University of Medicine for supporting this study.

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