ABSTRACT

Purpose: Root fracture is a clinical problem which often is difficult to detect and diagnose. As the root fracture detection is based on demonstration of a fracture line or lines, radiographic examination is important. The aim of this study was to compare diagnostic efficacy of direct digital radiography with conventional radiography for detecting experimental root fractures.

Materials & Methods: This study was based on observational diagnostic method which eighty one extracted single rooted human teeth were endodontically instrumented and divided into two groups, a control group of 40 teeth and a fractured group of 41 teeth in which root fractures were produced with Instron machine. Each tooth was imaged using the parallel technique with a CCD-based digital system and E-speed film. The images were interpreted by three experienced oral and maxillofacial radiologists without prior knowledge of the distribution of the root fractures. Three image groups were taken: conventional film, digital images and enhanced digital images. Sensitivity, specificity, false negative and false positive percentage, accuracy of each method in comparison with golden standard (visual examination of fractured and intact teeth) were analyzed. The degree of agreement in detecting root fractures with each imaging system compared with each other was expressed as the kappa value.

Results: The sensitivity, specificity and accuracy for root fractures in conventional radiography were 73.2%, 87.5% and 80.2% respectively, in direct digital radiography were 78%, 77.5% and 77.8% respectively and in enhanced direct digital radiography were 82.9%, 85% and 84% respectively. The most sensitive was enhanced direct digital radiography and the most specific was conventional radiography. There was fair to good agreement between conventional radiography and digital radiography (k=0.68), fair to good agreement between enhanced digital radiography and conventional radiography (k=0.73) and excellent agreement between digital radiography and enhanced digital radiography (k=0.90).

Conclusions: The diagnostic efficacy of conventional radiography, digital radiography and enhanced digital radiography in detecting root fractures was comparable with each other.

INTRODUCTION

Root fractures comprise between 0.5% and 7% of injuries affecting the permanent dentition. Most root fractures occur in maxillary central incisor teeth. Root fractures occur mostly on either a buccolingual or a mesiodistal plane. Buccolingual fractures are more easily detectable on radiographs whereas mesiodistal fractures are impossible to discern because the line of fracture is parallel to the film.
In the case of a suspected root fracture, a radiograph taken at a certain angulation may fail to disclose the fracture; therefore additional radiographs should be taken from a different angle. Rud and Omnell, using an extracted fractured root, found that the fracture line was within 4° of the fracture plane. However, root fracture can be detected radiographically when there is considerable separation of two root fragments.

Over the past 10 years, the digital imaging system has become an alternative to film-based radiography. Theses systems are based on charged-coupled device (CCD), complementary metal oxide semiconductor (CMOS) or storage phosphor technology. Digital imaging has the advantage of low patient exposure, ease of use, possibility of image manipulation during interpretation, ease of image storage and exchange data. Many studies have found the diagnostic accuracy of digital systems comparable to that of dental films. The diagnostic accuracy of digital systems is equivalent to that of conventional intra-oral radiography for detecting caries, simulated periodontal lesions and simulated periapical lesions.

Also, it is claimed that digital image enhancement greatly improves visibility and increases diagnostic accuracy. The interpretation of root fractures on radiographs is one of the problematic areas in dental care and enhanced digital image may have diagnostic value. Therefore, the purpose of this study was to compare diagnostic accuracy of conventional radiography with digital and enhanced digital images in vitro.

MATERIALS & METHODS

Eighty one extracted single root teeth with closed apices were used in this experimental study. Age, sex and the reason for extraction were not considered among the inclusion criteria. The crown of each tooth was removed 1 mm above the CEJ with a taper-shaped diamond bur and the root canal prepared with file numbers 20 to 80. Debris were removed from root canal and then divided into two groups: a control group with no fractures of 40 teeth and a group of 41 teeth with root fractures. Each tooth was coated with a layer of wax approximately 1 mm thick and invested cold cured acrylic block to the level of CEJ. Pre-fabricated post was placed into the root canal. Each tooth with the post was placed on the load cell table of Instron testing machine (1195, Instron Corp). The testing machine continuously recorded load on a moving graph paper. The load was increased until the tooth was fractured. Determination of fracture was made by sound of sharp ‘crack’ and by a sudden release of load on the post as noted on the Instron recording graph. All radiographic exposures were made with Planmeca prostyle dental x-ray unit at 60 KVP and 8 mA. The exposure time for conventional radiographs was 0.5 s and for the digital radiographs 0.2 s. Conventional film images were recorded on E-speed size no.2 periapical films (Eastman-Kodak co, Rochester NY) and processed automatically for 190 s with Velopax Extrax (Medivance, England), as recommended by the processor manufacture. Digital images were obtained with a Dixi2 (Planmeca, Finland) CCD receptor.

The eighty one radiographs were numbered, mounted in a random order and examined by three observers. The observers had no prior knowledge of distribution of the fractured teeth. The time for the observations was not restricted. For each radiography, presence or absence of a fracture was recorded without any consideration. The same procedure was followed for digital images which were displayed using Dimaxis (v2.3.3) software on a 15” UXGA LCD monitor (Toshiba, 1600x1200). Observers were not allowed to change digital images at this step. Results were recorded. Finally, eighty one digital images with image enhancement were evaluated by observers. Image enhancement filters comprises Emboss, contrast inversion, pseudo-color, magnification, and changing density and contrast. The data were recorded as the number of correct assessments. Incorrect identifications were labeled ‘disagreement’.
The kappa statistic was calculated to evaluate the degree of agreement in detecting root fractures between pairs of techniques. Sensitivity, specificity, percentage of false positive and false negative and accuracy were calculated for each technique.

RESULTS

The diagnostic values of root fracture detection with conventional radiography, digital and enhanced digital images are presented in Table 1. Sensitivity ranged from 82.9% in enhanced digital image to 73.2% in conventional radiography. The respective values for specificity were 87.5%, 85% and 77.5% for conventional radiography, enhanced digital and digital images, respectively. The false positive percentage was 22.5%, 17.5% and 12.5% for digital, enhanced digital and conventional radiography, respectively. The false negative percentage was 26.8%, 22% and 17.1% for conventional, digital and enhanced digital images, respectively. The accuracy values were 84%, 80.2% and 77% for enhanced digital, conventional and digital radiography, respectively.

Table 1. Sensitivity, specificity, false negative and false positive percentage and accuracy for three imaging system.

<table>
<thead>
<tr>
<th>Diagnostic tests</th>
<th>Conventional radiography</th>
<th>Digital radiography</th>
<th>Digital radiography with enhancement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>73.2%</td>
<td>78%</td>
<td>82.9%</td>
</tr>
<tr>
<td>Specificity</td>
<td>87.5%</td>
<td>77.5%</td>
<td>85%</td>
</tr>
<tr>
<td>False Positive</td>
<td>12.5%</td>
<td>22.5%</td>
<td>17.5%</td>
</tr>
<tr>
<td>False Negative</td>
<td>26.8%</td>
<td>22%</td>
<td>17.1%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>80.2%</td>
<td>77.8%</td>
<td>84%</td>
</tr>
</tbody>
</table>

The kappa for the agreement between conventional and digital radiography was 0.68 that indicates a ‘moderate’ concordance in Landis & Koch classification. The kappa between digital and enhanced digital radiography was 0.90 which is an ‘almost perfect’ in Landis & Koch classification.

DISCUSSION

Radiographic evaluation for diagnosis is an extremely difficult task, as a number of factors affect observer performance. These include the imaging system whether analog or digital, image manipulation, the PC monitor and film display characteristics, viewing conditions, observers experience and availability of prior records for comparison. In conventional film-based radiography, attempts to facilitate interpretation are made by improving viewing conditions by means of a magnified view box which is generally limited to 2X magnifying lens. However, there are physiologic limitations to visualization, perception and subsequent interpretation by human eye. The perception of diagnostic features on the digital display may be quite different from film-based images. Many studies have evaluated the performance of digital images in caries, periodontal and periapical lesions. Svanaes et al. reported that enhanced storage phosphor images showed a significantly higher diagnostic accuracy for approximal caries. Higher sensitivity and accuracy of enhanced digital images may be related to changing density and contrast as well as various filters that help observer and increase visual ability. When the images were enhanced, the observers changed their decision from non-fractured to fractured, suggesting that the appearance of pictures related to pixel size and intensity affected interpretation. Using image enhancement had higher effect on specificity (i.e. decreased false negative). The reason is using various filters that give rise to decreasing noise and intensifying pixel boundaries.

Any radiographic system has limitations in detecting root fractures. Fractures will be missed if the X-ray beam does not pass through the fracture line. Multiple radiographs are therefore needed.
Even though this study tried to mimic the clinical situation, differences invariably arose between the *in vitro* and *in vivo* detection of root fractures. *In vitro* studies of an extracted tooth with or without either bone or soft tissue equivalents may react differently to radiation beam than a tooth within the oral cavity. The superimposition of alveolar bone, periodontal ligament fibers, and soft tissue will also affect the clarity of images. Our study simplified interpretation by letting the observers decide whether or not there was a root fracture.

Our study set a gold standard in order to assess the differences between imaging systems in root fracture detection. Clinically, however, no golden standard exists.

**CONCLUSIONS**

1. Conventional radiography, digital radiography and enhanced digital radiography are good diagnostic tools in detecting root fractures.

2. The performance of three systems in detecting root fractures is comparable with each other.

3. The use of image enhancement in diagnosis of root fractures should be regarded as an adjunct to digital radiography that increases sensitivity and accuracy of digital images.

**REFERENCES**


