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Effect of JPEG compression on the diagnostic accuracy of periapical images in the detection of root fracture

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Abstract – The ability of a periapical radiograph to exhibit the fracture depends on many factors including, but not limited to, the resolution of the image. The quality can be reduced by the image compression. The purpose of this study is to evaluate the effect of Joint Photographic Experts Group (JPEG) compressions on the diagnostic capability of periapical images in the detection of root fractures. Ten dry human mandibles containing 151 teeth were used in this study. Mandibles were radiographed with direct digital imaging sensor using the paralleling technique. Four observers detected root fracture on the images saved in one uncompressed and two compressed formats. Receiver operating characteristic (ROC) and ANOVA analyses were performed to compare the performance of the three different systems and evaluate the effect of the compression on the accuracy of root fracture detection. Results did not show any statistically significant difference between the original, large images presented in tagged image file format (TIFF) and the two compressed images (JPEG medium file and JPEG small file images) in the detection of root fractures. The intra-rater comparison showed a significant consistency in the detection of the fracture. The compression reduced the file size considerably (from 1.77 MB to 453 and 95 Kb), but it did not affect the accuracy of root fracture detection. The file size reduction, on the other hand, is very beneficial for image electronic storage and mainly in teleradiology.

Introduction

Root fractures comprise between 0.5 and 7% of injuries affecting the permanent dentition (1, 2). Horizontal or oblique radicular fractures are more seen in anterior teeth, mainly maxillary ones; they are caused by direct trauma while vertical fractures are usually seen in molars and may be caused by clenching or trauma to the mandible and sometimes can be iatrogenic. A horizontal root fracture is classified based on the location of the fracture in relation to the root tip (apex).

Horizontal root fractures may occur in: the apical third, middle third, or cervical third of the root (1, 3). Vertical root fractures are more difficult to detect and may not be found until extensive tooth and surrounding bone support destruction has occurred. Tooth fractures are often not apparent during a clinical examination and can usually only be diagnosed using appropriate radiographs.

Over the past 10 years, the digital imaging system has become an alternative to film-based radiography (4). Digital imaging has the advantage of real time display with the potential of image enhancement and processing that open the way to endless possibilities for improving the diagnostic capabilities of the image.

Besides the benefits, digital systems create large amount of image data, which require large storage media and prolongs transmission to distant sites. The validity of recent digital radiography systems has been reported for various diagnostic tasks, such as caries detection, implant planning, root resorption, and cephalometry (5). In the vast majority of these diagnostic studies, the digital systems have been found to be as accurate as current dental films for the detection of dental pathology (6).

Currently, the use of solid state detectors (CCD, CMOS, SCMOS) and photostimulable phosphor (PSP) is the two different concepts of photon detection for direct digital image acquisition.

Direct digital imaging refers to the direct acquisition of the image onto a receptor, indirect digital radiographic technology means to take an existing x-ray film and convert it to digital after it has already been exposed and developed.

Many studies have found that the diagnostic accuracy of digital systems is comparable to that of dental films (7–13). The performance of radiologists in detecting various abnormalities on digital images, compared with conventional analog film, has also been evaluated (11, 14–16). It is claimed that digital image enhancement greatly improves visibility and increases diagnostic accuracy (17–20).

Digital images are stored as computer files in picture archive and communication system (PACS). With increasing utilization of digital radiography, storage (hard disk and archival media size) and transmission (bandwidth of computer network) requirements are also increasing. These requirements can be considerably reduced by image compression, which can be either lossless or lossy (21). The use of lossy compression has been accepted by the food and Food and Drug Administration (FDA), but compression method and ratio are left to the radiologist's discretion (22). Use of compressed images varies in between different countries in accordance to their legislation; however, general scientific recommendations are applicable if they are not in conflict with national law.

Compressed digital radiographs must have diagnostic value to interpret root fractures. The aim of this study was to determine the diagnostic values of tagged image file format (TIFF) file format, Joint Photographic Experts Group (JPEG) medium file, and JPEG small file digital images.

Materials and methods

The study protocol was reviewed and approved by the Institutional Review Board of The University of Texas Health Science Center at San Antonio. Ten dry human mandibles with most teeth including anterior and posterior teeth present in socket were used for this study. Age and sex of the individuals were unknown. Of 151 teeth present in all ten mandibles, 43 anterior and posterior teeth were loosened in their sockets, removed, and fractured horizontally and vertically using directed mechanical force (Fig. 1). The fragments were put back together using cyanoacrylate-based fast-acting adhesive (known as super glue).

Each mandible was mounted on a platform and stabilized; images of all the teeth in the mandibles were taken using parallel technique with a dental X-ray machine (Prostyle Intra, Planmeca Oy, Helsinki, Finland) and using conventional direct digital sensor (Dr. Suni, Suni Medical Imaging Inc., CA, USA), size #2 CMOS x-ray detector, with dimensions of 43.5×31.5 mm. According to the manufacturer, the detector can capture the image in 4096 gray levels with 22 lp mm^{-1} resolution.

Parameters used were 63 kVp, 8 mA with an exposure time of 0.16 s, at a focus-to-film distance of 16 inches with a 1-cm plastic material placed between the tube and the mandible to simulate soft tissue scattering.

All digital images were plotted on a 1600×1156 pixels matrix and saved originally in a non-compressed TIFF format with a mean size of 1.77 MB and then saved as JPEG medium file with a mean size of 453 Kb and JPEG small file with a mean size of 95 Kb (Fig. 2).

Images were randomized and read by four experimented readers (two oral and maxillofacial radiologists with more than 20 years of radiology experience, one maxillofacial radiology residents, and one general practitioner with more than 7 years of experience). The readers were not involved with creating root fractures and had no knowledge of the position and distribution of the fractured teeth. All resulting images were displayed on a 17-inch LCD display with an effective resolution of 1024×768 pixels (256 gray levels). The reading was held in a quiet room, and the readers had full control of the room lighting. There was no time restriction for the observation.

Readers recorded their observations of each TIFF file, JPEG medium file, and JPEG small file on a table designed for each tooth number accordingly. The viewer were asked to rate the confidence level of the presence of root fracture for corresponding tooth number on a 1–5 confidence rating scale. The following scale was used: (1) definitely absent, (2) probably absent, (3) unsure, (4) probably present, and (5) definitely present.

Web-based receiver operating characteristics (ROC) analysis software (http://www.rad.jhmi.edu/jeng/javarad/roc/JROCFITi.html) was used to analyze 1572 pieces of data (131 teeth × 3 modalities × 4 readers). This data were compared with 'truth' as determined by an established list of fractures created by the investigators. From this comparison, true positive and false positive fractions were calculated and ROC curves generated (Fig. 3).

The areas under the curves (Az) were computed for each observer and imaging modality and used to evaluate the detection accuracy. Areas under ROC curves (Az) were computed for each modality and each of the four readers then statistically analyzed using ANOVA for repeated measures to test the main effect of modality and observer, and the interaction between observer and modality.

Results

Data from each observation of four observers were pooled together based on each imaging modality. Az values calculated across all imaging modalities varied

Fig. 1. Device used in creating the artificial root fractures.

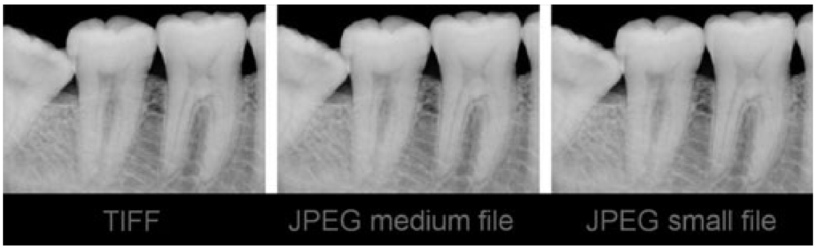

Fig. 2. Series of example images for the same region saved as, from left to right, TIFF, medium sized Joint Photographic Experts Group (JPEG), and small size JPEG.

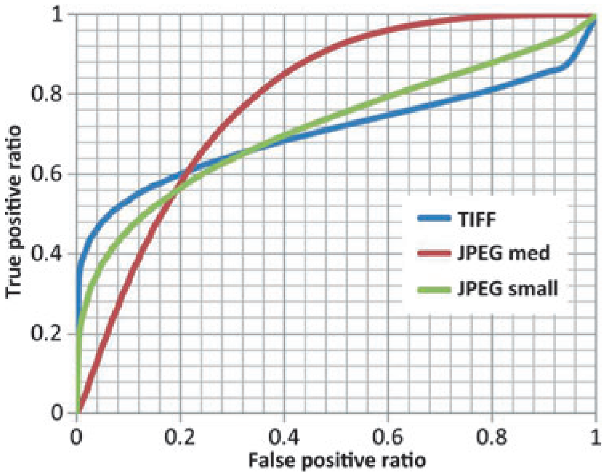

Fig. 3. Receiver operating characteristic curves for TIFF, medium sized Joint Photographic Experts Group (JPEG), and small size JPEG as evaluated by all four readers.

between observers (Table 1). Based on the observed means, JPEG medium file displayed the highest mean Az recorded for all observers combined, but still close to the Az recorded for TIFF and JPEG small file. Sensitivity of TIFF images (65.25%) was higher than both JPEG images 64.05% and 63.4%). The specificity of small JPEG files (79.7%) was higher than TIFF (78.9%) and medium size JPEG (79.1%). The accuracy of all formats was very close, 74.6% for TIFF and JPEG small and 74.4% for JPEG medium files.

The range of Az for modalities was 0.791–0.802 for TIFF, 0.724–0.762 for medium size JPEG, and 0.778–0.851 for small JPEG files. The means for all modalities were calculated and tested with unpaired *t* test to evaluate the significance of the differences between the modalities. The difference was not statistically significant for any of the comparisons (Table 2).

The ANOVA test values indicate that the difference between the readers and between the modalities is not statistically significant (Table 3).

Discussion

Studies evaluating the influence of compression on the efficacy of the radiographic image in detecting a particular condition or disease share almost identical methodology but multiple factors could possibly affect the results. Between these factors, we can count the method of acquisition (digitizing conventional films, storage phosphor plates, or charge coupled device systems), the degree and methods of compression (compression ratio, lossy or lossless), and the degree of information loss (DIL). Development of computer programs is rapid and a large number of compression programs have become available and utilized in subsequent studies in dental radiology. In the majority of JPEG compression software, DIL can be manually adjusted on the compression scale. Even though JPEG is an ISO standard (23), its compression scale is not standardized. The highest acceptable compression rates (CR) reported for different tasks in dental radiography are different and ranged from 3.6% (19) to 15.4% (24).

We decided to use discrete cosine transformation-based Joint Photographic Experts Group (JPEG) because it is by far the most frequently used image compression method in medical and dental radiology.

Different planes of root fractures occur after acute or chronic trauma to the teeth (25). The pattern of fracture lines are unpredictable, and radiographic detection of radicular fractures is indeed a challenging diagnostic task

Table 1. Mean of Az, sensitivity, specificity, and accuracy of all the images

Modality	Az	Sensitivity	Specificity	Accuracy
TIFF	0.750 SD: 0.04185	65.25	78.9	74.6
JPEG med. file	0.780 SD: 0.03837	64.05	79.1	74.4
JPEG small file	0.778 SD: 0.05456	63.4	79.7	74.6

JPEG, Joint Photographic Experts Group; SD, standard deviation; TIFF, tagged image file format.

Table 2. Unpaired *t* test results for the three modalities when compared with each other

Comparison	*P* value	Difference	*t*
TIFF vs medium JPEG	0.23	Not statistically significant	78.9
TIFF vs small JPEG	0.45	Not statistically significant	79.1
Medium JPEG vs small JPEG	0.95	Not statistically significant	79.7

JPEG, Joint Photographic Experts Group; TIFF, tagged image file format.

Table 3. ANOVA analysis showing no significant differences between readers and between compression modalities

Source	df	*P*-Value
Between readers	3	0.0594
Between compression modalities	2	0.4172

that is better facilitated by the sequential examination of the region of interest. Radiography is the most commonly used method to aid in the diagnosis of such fractures.

When interpreting the radiograph, one should look for a radiolucent line between the fragments and discontinuity of the periodontal ligament shadow (25). This feature is not applicable in *in vitro* studies and constitutes an important limitation of this study. Fractures will be missed if the X-ray beam does not pass through the fracture line. Multiple radiographs are therefore needed (26). There are also a number of limitations with an *in vitro* study compared with the actual clinical situation. In clinical practice, the direction of X-ray beam to the fracture line will vary in contrast to the fixed beam angulations that are being used in this study. The X-ray beam will be modified by the adjacent bone and soft tissues. The number, size, and direction of the fracture lines we created may be different from those seen in clinical practice where the source of the trauma varies (27). However, we simplified our experiment because the observers had only to decide whether a fracture was present or absent.

The aim of this study was to conduct a comparative evaluation of diagnostic potential and impact of TIFF and JPEG compression standard *in vitro* root fracture. Use of digital images in this study is justified based on a recent study that showed no differences in diagnostic accuracy for the detection of vertical/oblique root fractures between conventional and digital imaging. One advantage of digital image is that the exposure can be prorated based on the number of images acquired so as not to exceed that required by conventional film-based technique.

Radiographic diagnosis of radicular fractures typically involves acquisition of more than one radiograph employing different projection geometry to facilitate the delineation of the fracture line. The longer the fracture line, the easier it was to detect the signal, regardless of imaging modality used (28).

In this study, observers evaluated three different digital image formats per specimen as opposed to more radiographs that are routinely exposed in clinical practice. The observers did not have access to any clinical information, but they were made aware of the finding root fractures in random teeth.

This study proved that equally reliable and accurate diagnostic decisions could be reached by using JPEG small file. This can be established from the Az values obtained and the ANOVA results showing that there is no statistical difference between large size native images, small size medium compressed images, and extremely small size highly compressed images in the detection of root fractures. In a previous study, it was shown that image compression with typical compression algorithms [uncompressed and 12:1 compressed JPEG (discrete cosine transform) or JPEG2000 (DWT) radiographs] at rates yielding storage sizes of around 50 kB is sufficient even for the challenging task of the radiographic detection of non-cavitated carious approximal lesions (29). Further studies may be needed to compare different formats of digital imaging that is beyond the scope of this investigation.

Because of many advantages, digital imaging is adopted by more practitioners. Consequently, the need for storage space and transmission speed for second opinion has increased, the issue of storage is easy to solve because large hard drives can be purchased for a reasonable price. On the other hand, transmission speeds, though constantly improving, are still limited. JPEG images compressed to remarkably small size files do not appear to have major drawbacks when compared with other image formats; this will facilitate the task of image transmission for administrative purposes or teleradiology.

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