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Abstract
The purpose of this study was to describe a new technique by using Adobe Photoshop CS (San Jose, CA) image-analysis software to evaluate the radiographic changes of chronic periapical lesions after root canal treatment by digital subtraction radiography. Thirteen upper anterior human teeth with pulp necrosis and radiographic image of chronic periapical lesion were endodontically treated and radiographed 0, 2, 4, and 6 months after root canal treatment by using a film holder. The radiographic films were automatically developed and digitized. The radiographic images taken 0, 2, 4, and 6 months after root canal therapy were submitted to digital subtraction in pairs (0 and 2 months, 2 and 4 months, and 4 and 6 months) choosing “image,” “calculation,” “subtract,” and “new document” tools from Adobe Photoshop CS image-analysis software toolbar. The resulting images showed areas of periapical healing in all cases. According to this methodology, the healing or expansion of periapical lesions can be evaluated by means of digital subtraction radiography by using Adobe Photoshop CS software. (J Endod 2007;33:493–497)

Key Words
Digital subtraction, periapical lesion, radiograph


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Chronic periapical lesions associated with root-filled teeth are usually monitored by conventional periapical radiography (1, 2). However, the suggested radiographic criteria, including lesion persistence and increase of periapical lesion size, are qualitative and subjective (3). Several methods have been described to measure periapical radiolucencies, including measurement of the diameter, distance between root surface and radiolucency outlines, use of a specific classification, and determination of the area by means of tracing (4).

Digital radiographic techniques and computed analysis methods allow measuring of the periapical lesion area and provide a correlation among the images obtained at different follow-up periods (3).

Digital subtraction radiography with specific software is considered as a valuable tool for evaluation of periapical lesions because they are capable of detecting extremely small bone alterations. It increases the accuracy for assessment of bone gain or loss during or after root canal treatment (5). In addition, this technique almost duplicates the sensibility in detecting lesions in comparison to conventional radiographic interpretation (6).

The importance of digital subtraction radiography as an evaluation tool of the healing process of periapical lesions has been shown in follow-up studies with endodontically treated teeth (7–10). The results of those studies show that image subtraction is a good tool to be used in reliable diagnoses of minimal changes of periapical tissues during short-time intervals. However, the technology involved in digital subtraction radiography together with the need of additional equipment (specific software like X-Poselt [XP, Torben Jorgensen, Lystrup, Denmark] and the EMAGO [Oral Diagnostic Systems, Amsterdam, The Netherlands]) and computer support make this technique complicated for use in daily practice (5).

Nonspecific image-analysis software can represent an alternative for the digital subtraction radiographic technique in the evaluation of healing or increase of periapical lesions. Adobe Photoshop CS image-analysis software allows digital subtraction of two superposed images (11).

The aim of this study was to describe a new technique performed by using Adobe Photoshop CS image-analysis software to evaluate the radiographic changes of chronic periapical lesions after root canal treatment by digital subtraction radiography.

Materials and Methods

Thirteen upper anterior human teeth with pulp necrosis, asymptomatic, in normal masticatory function, and a radiographic image of chronic periapical lesion larger than 5 mm in diameter measured in its largest long axis were selected for this study. Patient written informed consent was obtained after the nature of the procedures and possible discomforts and risks had been fully explained.

In each specific case, the root canal was prepared according to the crown-down technique by using manual instrumentation and irrigation with 2.5% sodium hypochlorite. After biomechanical preparation, a calcium hydroxide-based paste (Calen PMCC; SS White, Rio de Janeiro, Brazil) was placed as root canal dressing for at least 15 days. Final obturation was done by lateral condensation of gutta-percha points and Sealertap root canal sealer (SybronEndo/SDS, Glendora, CA).

Radiographs were taken 0, 2, 4, and 6 months after root canal filling by using Rinn XCP film holder (Rinn Corp, Elgin, IL) stabilized with spherical rubber silicone impression...
material (Optosil Comfort, Heraeus Kulzer, Germany) to standardize image geometry (Fig. 1). All radiographs were taken by using periapical film (Insight; Eastman Kodak Company, Rochester, NY) with GE 1000 X-ray device (General Electric, Milwaukee, WI) at 90 kVp, 10 mA, and 0.12-second exposure time.

The exposed films were automatically developed in an automatic film processor (Dent-X 9000; Dent-X Co, Elmsford, NY) by using 5 minutes of dry-to-dry time and digitized by using a desk scanner (Snap-Scan 1236s Flatbed Scanner; Agfa-Gevaert NV, Mortsel, Belgium) using 2400 dpi acquire resolution. The resulting images were stored in JPEG format at low-compression level.

Radiographs taken 0, 2, 4, and 6 months after root canal treatment were submitted to digital subtraction in pairs by using Adobe Photoshop CS image-analysis software. The radiograph obtained after 2 months of follow-up was subtracted from that taken immediately after root canal therapy. In a sequence, the radiograph obtained after 4 months of follow-up was subtracted from that taken after 2 months, and the 6-month follow-up radiograph was subsequently subtracted from the previous one. Before digital subtraction, both radiographs were moved in horizontal, vertical, or rotational directions applying software tools to reduce geometric distortion. To remove bright and contrast variations, both images were enhanced based on the mean of pixel intensity shown.
in histogram scale. Then, these images were superposed and subtracted. First, “Image” option was selected on the main menu of Adobe Photoshop CS image-analysis software. Next, in the “Image” submenu, the “Calculation” tool was selected by a left click. A toolbar box was opened; the following commands were chosen: “source 1” (later radiographic image), “source 2” (earlier radiographic image), “blending” (subtract) and “result” (new document) (Fig. 2). The images resulting from digital subtraction were enhanced with brightness and contrast tools to facilitate the observation of new bone tissue areas.

Results

The observation of the radiographic images resulting from digital subtraction performed by using Adobe Photoshop CS image-analysis software showed periapical healing areas in all studied cases. Only three cases showed expansion of the radiolucent area between 2- and 4-month controls.

Regions that presented the same pixel intensity in both radiographic images were shown with grayscale on the digital subtraction.
Regions that represent areas of new bone tissue exhibited a radiopaque appearance, whereas regions with bone tissue resorption were radiolucent (Figs. 3–5). A smooth anatomic image in black background was observed on digital subtraction images.

**Discussion**

Digital subtraction radiography has been shown to improve the detection of periapical lesions compared with conventional radiographs (6), and its diagnostic accuracy has been shown (12, 13). In vitro studies have shown that digital subtraction can increase the detection of peripical bone lesions, particularly those confined to cancellous bone (12–14). Razmus (15) reported better findings in initial diagnosis of caries and detection of bone changes in cases of periodontal disease and periapical lesions by using digital methods and radiographic subtraction. The results of the present study also showed that digital subtraction was a reliable method to detect the healing of periapical lesions after root canal treatment, showing periapical bone changes in small time intervals emphasizing the initial period of 2 months after completion of root canal therapy.

The success of digital subtraction radiography depends directly on the reproducibility of the radiographic image, which is associated to contrast, brightness, and geometric distortion. Density standardization can be obtained by careful repetition of technical incidence factors by using the same brand of radiographic film and maintaining a strict control of technical conditions (7, 16). In this study, all radiographs were taken with the same X-ray equipment and using F-speed films that reduce the exposure time by 20% when the films are automatically processed with no detriment to diagnostic efficacy (17). However, Radel et al. (18) used digitized F-speed films and showed lower accuracy than digital systems in endodontic measurement.

According to Van der Stelt (19) and Mikrogorgis et al. (10), the use of the parallel technique for radiographic acquisition is recommended in order to obtain images with good quality and a high degree of reproducibility. Duckworth et al. (20) and Yoshioka et al. (9) used a film holder associated with a custom-made bite block to provide geometric standardization of the radiographs used in digital subtraction. The present study used the Rinn XCP film holding device stabilized with a spherical rubber silicone impression material.

Adobe Photoshop CS image-analysis software is an excellent program for image editing that has different tools and produces good results in digital image manipulation (21). In the finding related by Sargent et al. (11), after conversion into grayscale and alignment of the image. Regions that represent areas of new bone tissue exhibited a radiopaque appearance, whereas regions with bone tissue resorption were radiolucent (Figs. 3–5). A smooth anatomic image in black background was observed on digital subtraction images.

**Figure 4.** (a) Two months of follow-up. (b) Four months of follow-up. (c) Result of the digital subtraction.
digitized images, they were subtracted by using the “subtract” command of the “calculation” tool. In the present study, the same procedure was performed maintaining a standardized radiographic technique because this software is not specific for digital subtraction and has no specific tools to correct any variation of image alignment.

Despite its limitations for this application, Adobe Photoshop CS image-analysis software has shown a great potential for use in dentistry, more specifically in endodontics and radiology.

Conclusions

The radiographic changes of chronic periapical lesions can be evaluated by means of digital subtraction radiography by using Adobe Photoshop CS image-analysis software. The use of nonspecific software for digital subtraction can represent an important tool in follow-up evaluations both in research and in clinical practice.

References