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Accuracy of Working Length Determination in Root Canal Treatment Using Different Algorithms

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Abstract

Background: Determination of working length has great significance in root canal treatments. For this purpose, analog radiography has been replaced by digital radiography. Despite numerous studies, there is still no accurate information about the resolution of these images.

Objectives: The aim of this study was to assess the accuracy of working length determination in root canal treatment using different algorithms in digital radiography.

Materials and Methods: Using an analytical-diagnostic method, an access cavity was prepared in 36 mandibular and maxillary premolar teeth. A file # 15 was inserted into the canal of each tooth until the tip of the file was observed, then the files were retracted 0.5 mm. The teeth were then placed in an acrylic block, and finally, a radiograph was taken of the blocks. Thereafter, the file in each canal was taken out and measured using a digital caliper. The obtained measurement was the real length of the file. The saved images underwent modifications using different algorithms of image processing. The working length was observed on a monitor under standard conditions. Data were analyzed by t- test using SPSS (ver. 17).

Results: Based on the findings of this study, no significant difference was observed between the main image, the images processed with the emboss, enhancement, sharpen, and negative algorithms, and the actual file size regarding the means of error. None of the indices had a statistically significant difference with the actual file length ($P > 0.05$).

Conclusions: According to the results of this study, the accuracy of the file length in improved digital images showed no significant difference in comparison with the actual file length.

Keywords: Radiography, Dental, Digital, Root Canal Therapy

1. Background

Recently, analog and digital radiography have gained a wide use in dentistry. Previous studies have indicated that digital radiography is equal to or better than analog radiography in terms of diagnostic features (1-3). Since digital radiography has several advantages, including lower patient dose, no need for chemical development and stabilization, as well as an improved processing ability, analyzability, image quality enhancement ability, transferability, and particularly, improved ability to manipulate the images (4), it is able to replace analog radiography to a great extent (5-7). One of the top advantages of this type of radiography is its image processing ability. There are several image-processing algorithms, which are mainly used for adjusting the brightness and contrast of images for diagnostic and treatment purposes (4, 8, 9). Studies have shown that correct manipulation of image processing and filtering, by determining the slight differences in density and sharpness, can improve the diagnostic quality and the accuracy of digital images (5, 10).

In endodontic treatment, radiography plays an important role in the treatment of root canal, such as determination of working length, and the number, shape, size and direction of root canals. Radiography is the main tool responsible for working length determination. Since accurate working length determination is a crucial stage in root canal treatment and could affect cleansing, shaping and obturation of the root canal system, radiography is an important aid in this regard (11). Analog radiography has been the most common technique for determination of canal length so far. However, through the introduction of digital radiography, and its recent advances, acceptable changes in typical methods of radiography have been made (12-14).

According to previous studies, it seems that intraoral digital radiography is similar to conventional radiography in common diagnostic tasks (15). Some studies have shown that digital radiography has a lower or equal accuracy in working length measurement than analog radiography methods (15-18). However, several studies have shown that digital enhancement may increase accuracy in detecting carious lesions (19), but according to recent studies the quality of digital images has been improved to some extent (20, 21).

2. Objectives

Based on advances in the software related to radiography and the ability of images to be processed by the available algorithms, this study deals with the accuracy of working length measurement in root canal treatment, using different image processing algorithms in digital radiography.

3. Materials and Methods

This analytical-diagnostic study was done in the Yazd school of dentistry. The study was conducted on thirty six extracted human mandibular or maxillary premolars which had single straight canal, no resorption, closed apex and no apical lesion. Any premolar teeth with curved root, dilacerations, restoration, root canal treatment, two canals or two roots and root fracture were excluded.

The teeth were kept in thymol (Goldaru, Isfahan, Iran). First, the standard access cavity was prepared in the premolar teeth using turbine diamond fissure bur # 8 (NTI, Kahla, Germany) by a dentistry student, and the turbine diamond round or fissure bur # 4 (NTI, Kahla, Germany). The coronal part of the canal was then flared using a glidden gates drill # 2 and # 3 (MANI, Utsunomia, Japan) followed by inserting the K-file # 15 (MANI, Utsunomia, Japan) into the canal to such an extent that the file tip could be seen from the apical foramen (22). The files were retracted 0.5 mm and fixed using self glass ionomer (GC, Tokyo, Japan). then, the teeth were placed in the acrylic block individually (22).

The 24-mm thick acrylic block was placed on the parallel axis to the radiographic tube using a film-holder XCP device (Dentsply Maillefer, Ballaigues, Switzerland). All radiographies were done at a constant SOD (Source Objective Distance) of 32 cm with a horizontal zero angle. To emulate the soft tissue on the acrylic block, two layers of wax were used (22). All of the radiographies were conducted using the periapical radiographic device (Minray, Soredex, Tusuula, Finland) and phosphors storage plates (Soredex, Orion corporation, Tusuula, Finland) under the conditions of 70 KVP and 1.6 MAS. Right after the exposure, the phosphor plates were scanned and the obtained images were saved in a tag image file format (TIFF) format on a personal computer (VAIO, VPCF, China). Thereafter, the file inside each canal was retrieved and measured using a digital caliper. The obtained measures were considered as the actual length of the canal. The saved images were processed by different image processing algorithms, using Digora Optime software (Soredex, Tusuula, Finland 2010). The algorithms of interest were emboss, enhancement, sharpen, and negative (Figure 1).

3.1. Emboss

Emboss is a computer graphics technique in which each pixel of an image is replaced either by a highlight or a shadow, depending on the light/dark boundaries on the original image. Low contrast areas are replaced by a gray background. The filtered image will represent the rate of color change at each location of the original image.

3.2. Enhancement

Computer image editing programs often offer basic automatic image enhancement features that correct color, hue and brightness imbalances, as well as other image editing features, such as redeye removal, sharpness adjustments, zoom features and automatic cropping. These are called automatic, because generally they happen without user interaction or are offered with one click of a button or by selecting an option from a menu. Additionally, some automatic editing features offer a combination of editing actions with little or no user interaction.

3.3. Sharpen

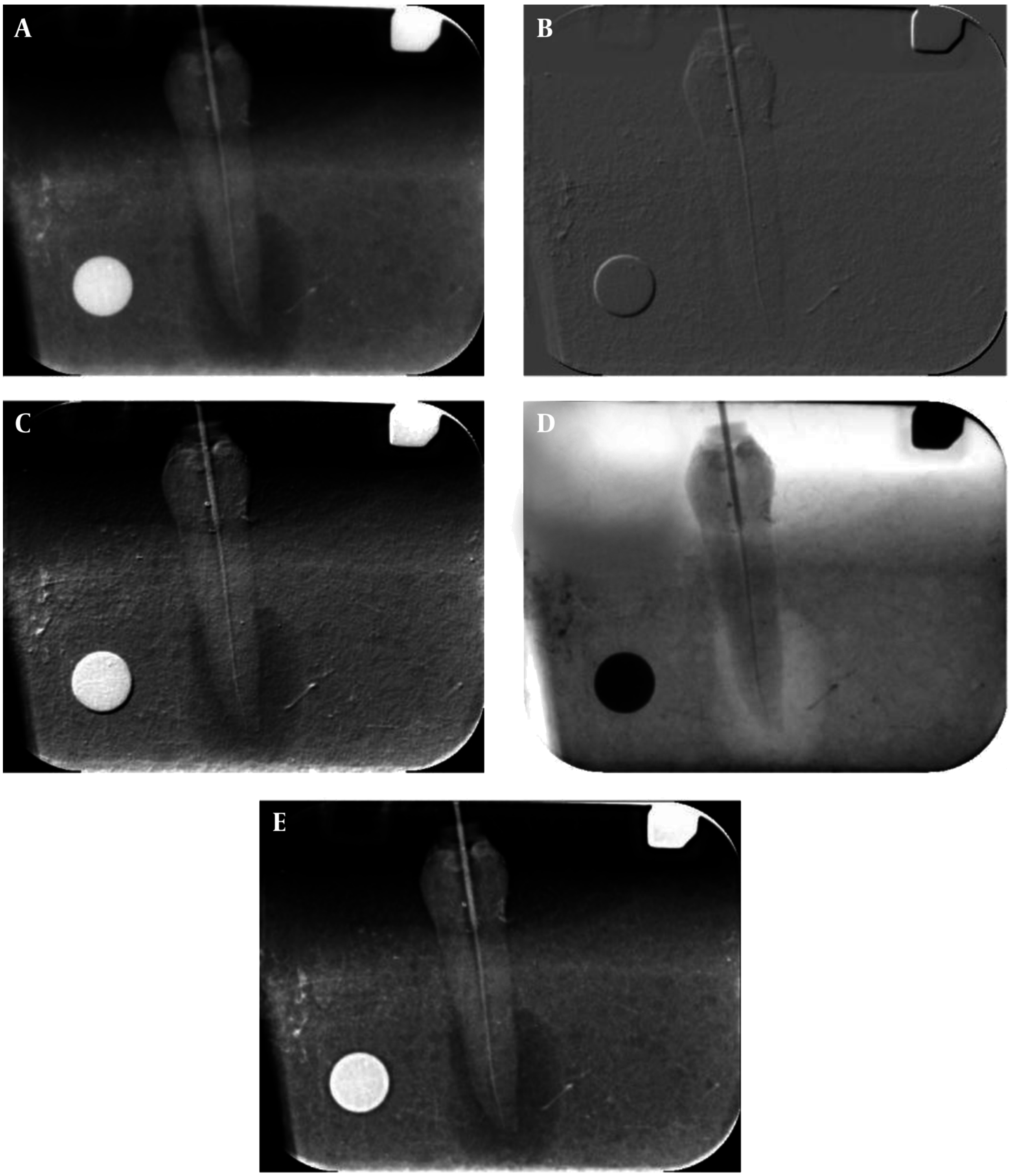
Sharpening is one of the most impressive transformations you can apply to an image, since it seems to bring out image detail that was not there before. What it actually does, however, is emphasizing the edges in the image and make them easier for the eye to pick out. While the visual effect is to make the image seem sharper, no new details are actually created.

3.4. Negative

In the case of color negatives, the colors are reversed into their respective complementary colors. Typical color negatives have an overall dull orange tint due to an automatic color-masking feature that ultimately results in improved color reproduction.

The processed and unprocessed images were analyzed by an endodontist under the standard conditions (semi-dark room) and using a color monitor (LG; pixel of 1024 $\times$ 768). The observed file length was measured using the ruler of the software. Data were analyzed by t-test using SPSS (ver. 17).

Figure 1. Primary and Enhanced Images



A, primary; B, emboss; C, sharpen; D, negative; E, enhancement.

4. Results

Out of 36 primary images, 144 processed images were obtained. Table 1 shows the mean difference of each index with the actual length of the file. Based on this table, the Emboss and Enhancement processed images are closer to the actual length measured by the digital caliper. In the Negative processed images, the read length showed the largest difference compared with the actual length measured by the digital caliper.

Table 1 illustrates the mean length of an endodontic file. As can be seen, the Emboss and Enhancement algorithms are almost in line with the actual length. Table 1 also confirms the closeness of the length measured in these two algorithms with the actual length.

A t-test was used to analyze and compare the mean file lengths, measured by different algorithms, with the actual length. Table 2 indicates the mean comparison of the files' measured length in each of the image processing algorithms versus the actual length mean. According to this table, no significant difference was observed between the main image (P value = 0.61), and those processed with emboss (P value = 0.90), enhancement (P value = 0.87), sharpen (P value = 0.71) and negative (P value = 0.27), and the actual file size regarding the means of error (P value > 0.05).

According to the results of this study, none of the indices had a statistically significant difference with the actual file length (P > 0.05) (Figure 2).

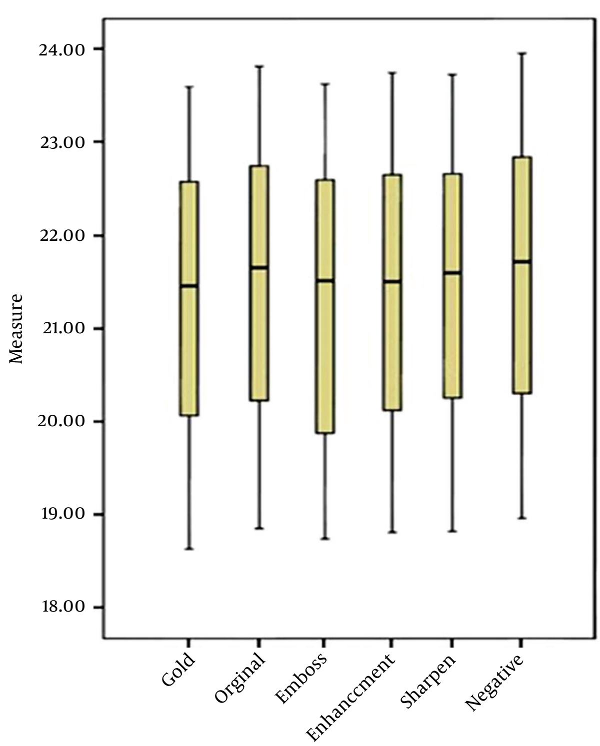


Figure 2. The Error Band of the Mean of Endodontic File Length

5. Discussion

A successful root canal treatment is dependent on the effective cleaning, proper shaping and optimal canal obturation. To date, the accuracy of determining the working length has mostly been dependent on analog radiographies, which were observed and interpreted by endodontists (23, 24). However, through the rapid advances of science and technology, analog radiographies have been replaced with digital images. Regarding the advantages of digital radiography techniques and the convenience of image production by this method, dentists have attempted to improve the quality of images through supplementary and image processing algorithms (16, 25). The main aim of digital processing is improvement of images with sufficient details. This is possible by displaying the data collected during imaging (22). Although the processing should be able to improve diagnostic signs, some information might be lost during the image processing procedure (22, 26). Therefore, investigation of the process type and the amount of improved diagnostic signs is crucial before any digital processing.

The present study compares the effect of different image processing algorithms on working length measurement, using the Digora Optime software. In this study, in order to avoid individual errors, the default settings of the software have been used to change and modify the images so that the results show the direct influence of the processing algorithm on the accuracy of working length determination. To emulate soft tissue, two layers of wax were placed on the acrylic block. Since the wax cannot accurately simulate the tissue around the tooth as normal oral tissue, it cannot be expected that the results obtained from experimental and clinical studies will be the same (27). The majority of studies in this regard are also experimental.

Similarly, in clinical studies, after measuring the root canal length using the device, the tooth of interest has been extracted and the actual length has been measured (28). Use of single-root teeth has enhanced the accuracy and reduced the errors in this study. In a clinic, small files are not very applicable because of the problems in the selection of proper exposure time and the effects of scatter radiation. According to a study by Woolhiser et al., Kal et al., de Oliveira et al. and Mehdizadeh et al. that used other sizes, such as 8 and 10, in addition to 15, the obtained results indicate that measurement accuracy was obtained using file # 15 (21, 22, 29, 30). Therefore, only file # 15 has been used in this study in order to achieve optimal results. After digital imaging, the actual file size was measured by a digital caliper and the canal length was measured in different images by an observer.

Data revealed that there is no significant difference be-

Table 1. The Mean Difference of Every Index With the Actual File Length (n = 36)

Index	Mean[a]	Minimum	Maximum
Original	0.27 ± 0.16	0.07	0.25
Emboss	0.37 ± 0.03	0.15	0.09
Enhancement	0.39 ± 0.03	0.09	0.17
Sharpen	0.28 ± 0.09	0.005	0.18
Negative	0.02 ± 0.27	0.18	0.36

[a]Values are expressed as mean ± SD.

Table 2. The Mean Comparison of Each Index of Interest Based on the Actual File Length (n = 36)

Index	Mean[a]	P Value
Original	21.48 ± 1.48	0.61
Emboss	21.28 ± 1.52	0.90
Enhancement	21.35 ± 1.48	0.87
Sharpen	21.40 ± 1.46	0.71
Negative	21.58 ± 1.49	0.27

[a]Values are expressed as mean ± SD.

tween canal length determination in the main images and enhanced images created by applying different image processing algorithms.

Kal et al. in a similar study, applied Image J 1.34 software for image processing (22). In their results, they found no difference in the canal length accuracy in enhanced images compared with unprocessed images. In this study, for file # 15, the algorithms of inverted, edge enhanced and contrast-brightness have had the highest proximity to the actual file length (22). In another study by Woolhiser et al. (21), the accuracy of intraoral digital image radiographies with a speed of D, F, enhanced and non-enhanced were evaluated for determining the file length. According to the results, there was no significant difference between the measurement accuracy of the various methods, confirming the results of this study (21, 22).

Mehdizadeh et al. (30) investigated the accuracy of file length measurement in periapical digital radiography, after setting noise reduction, followed by digital image enhancement using Scanora software. Their results showed that although noise reduction resulted in removal of subtle details of the image, it had no effect on the accuracy of thin file length measurement in digital periapical radiography. de Oliveira et al. (29) evaluated the combinatory effect of a dedicated filter, spatial resolution and contrast resolution on length determination of endodontic files. In their study, they used DBSWIN 4.5.2 software, and results revealed that 25 lp/mm and 16-bit images accompanied by filtering did not have a significant difference with the actual file length. When file # 15 was used, only the length of 8-bit images was different from the actual file length. However, in the present study, in none of the images was the length of the file significantly different from the main image (29).

In measuring the working length, observation of the thin part of the file, located on the root tip, is of great significance in measurement accuracy. The possible reason for this lack of difference between different images, or even of lowered measurement accuracy, is that none of the image processing algorithms have had a positive effect on enhancing the representation of the thin file inside the root and have, instead, enhanced most of the dental structures and the main part of the file. Even in the study by Javidi et al. (31), who compared the accuracy of canal working length determination with different magnifications of digital radiography, it was observed that the ability of magnification of digital radiography in enhancing the resolution of images is not helpful in canal length determination, particularly when the file is inserted into the canal with a length shorter than the working length. In the current study, all of the image processing algorithms showed a mean working length longer than the actual file length, except for the Emboss method, where the measured working length was shorter than the mean actual length of the file. In addition, image processing using the Emboss and Enhancement methods had the closest mean working length to the actual file length. This has been reported with different results based on file number (21, 22, 30). For example, in the study by Kal et al. (22), the whole working length of the measured images was shorter than the actual file length, except in images of invert, contrast-brightness, and edge enhancement in file # 15, which had the slightest difference with the length of the main file (22).

The reason for the differences among algorithms in various studies could be a result of the application of different image processing software. In the present study, the Negative algorithm had the largest difference between the working length and the actual file length. This demonstrates that small details may be lost in the Negative algorithm; especially, the tips of files were easily blurred in the image. However, Kal et al. (22) reported the largest difference in images processed by Threshold. In a study by Mehdizadeh et al. (30), the noise reduction algorithm had the greatest working length difference with the actual file length. In the Kullendorff and Nilsson (32) and Moystad et al. (33) studies, there was evidence of improving the accuracy and validity of diagnosis and determination of the amount of decayed lesions using the enhancing algorithm. However, regarding determination of working length and the comparison of different image processing algorithms, few studies have been conducted that have shown that image enhancement algorithms have a positive effect on improving the accuracy of working length measurement.

Based on our findings, the accuracy of measurement of the file length in improved digital images has no significant difference in comparison with the actual file length. Furthermore, the file length in enhanced digital images had no significant difference with its counterpart in the main images. Similar studies, using more advanced and up-to-date software, are suggested for further investigations.

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Footnotes

Authors' Contribution: Study concept and design: Sanam Mirbeygi; acquisition of data: Sanam Mirbeygi; analysis and interpretation of data: Sanam Mirbeygi; drafting of the manuscript: Maryam Kazemipor; critical revision of the manuscript for important intellectual content: Maryam Kazemipor; administrative, technical, and material support: Sahar Ghane; study supervision: Simin Shafiei.

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