

Effect of digital noise reduction on the accuracy of endodontic file length determination

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ABSTRACT

Purpose: The aim of the present study was to evaluate the measurement accuracy of endodontic file length on periapical digital radiography after application of noise reduction digital enhancement.

Materials and Methods: Thirty-five human single-rooted permanent teeth with canals measuring 20-24 mm in length were selected. ISO #08 endodontic files were placed in the root canals of the teeth. The file lengths were measured with a digital caliper as the standard value. Standard periapical digital images were obtained using the Digora digital radiographic system and a dental X-ray unit. In order to produce the enhanced images, the noise reduction option was applied. Two blinded radiologists measured the file lengths on the original and enhanced images. The measurements were compared by repeated measures ANOVA and the Bonferroni test ($\alpha=0.05$).

Results: Both the original and enhanced digital images provided significantly longer measurements compared with the standard value ($P<0.05$). There were no significant differences between the measurement accuracy of the original and enhanced images ($P>0.05$).

Conclusion: Noise reduction digital enhancement did not influence the measurement accuracy of the length of the thin endodontic files on the digital periapical radiographs despite the fact that noise reduction could result in the elimination of fine details of the images. (*Imaging Sci Dent* 2013; 43: 185-90)

KEY WORDS: Radiography, Dental, Digital; Endodontics; Noise; Radiographic Image Enhancement

Introduction

Recently, digital radiography has superseded film-based radiography because of its advantages. The lower diagnostic dose, no need for chemical development and fixation, the possibility of processing and analysis, image enhancement capacity, and image transfer are the main advantages of digital radiography.¹⁻³ Several studies have shown that digital radiography has equal or better diagnostic accuracy compared to film-based radiography;⁴⁻¹² therefore, digital radiography is widely used in dentistry, especially in endodontics.

Manipulation of images is one of the most important

properties of digital radiography.^{13,14} Several digital processing algorithms are available that enhance the display quality of digital images.^{14,15} Since digital sensors produce a large amount of noise, different image processing schemes have been developed to improve image quality.¹⁶ Noise reduction with the use of different techniques might result in higher signal-to-noise ratios. For medical imaging, a high signal-to-noise ratio is considered essential for clinical diagnosis.¹⁶ Noise reduction, sharpening-smoothing, and edge enhancement are examples of these algorithms. It has been accepted that reduction of the noise value has a significant effect on the improvement of digital image quality. However, this process can lead to loss of some small structures on images.

Several studies have evaluated the use of various digital enhancement algorithms and their effects on diagnostic accuracy.¹⁷⁻²⁵ However, there has been only limited research on the task-specific use of noise reduction algorithms.^{20,26-30}

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Some of these studies have shown that this type of enhancement does not change the diagnostic accuracy;^{20,29} on the other hand, others have shown the opposite.^{26-28,30}

The effect of this enhancement on the measurement accuracy is particularly important in endodontics. The accuracy of measurement can influence the final verification of the outcome of root canal treatment by affecting the precise working length, and consequently, the potentially successful treatment. Therefore, the aim of the present study was to evaluate whether the length measurement of small endodontic files can be affected by application of noise reduction enhancement or not.

Materials and Methods

Thirty-five human-extracted single-rooted permanent

teeth with intact crowns and roots were used in this experimental study. The teeth had only one root canal, measuring 20-24 mm in length. Periodontal or prosthetic problems were the reasons for extraction of the teeth. The samples were cleaned and disinfected by scaling and soaking in 0.5% sodium hypochlorite for 12 h and stored in distilled water at 4°C during the study. Conventional periapical radiography was used to verify any abnormalities or pathologies, such as internal/external root resorption, root canal obliteration/calcification, or severe curvature. An anatomic access cavity was prepared with #008 and #010 fissure burs and an Endo-Z bur (Dentsply Maillefer, Ballaigues, Switzerland) in a high-speed handpiece. Gates-Glidden #3 and #4 drills (Dentsply Maillefer, Ballaigues, Switzerland) were used to enlarge the coronal and middle thirds of the root canals. ISO #08 K-files (Mani Inc., Utsu-

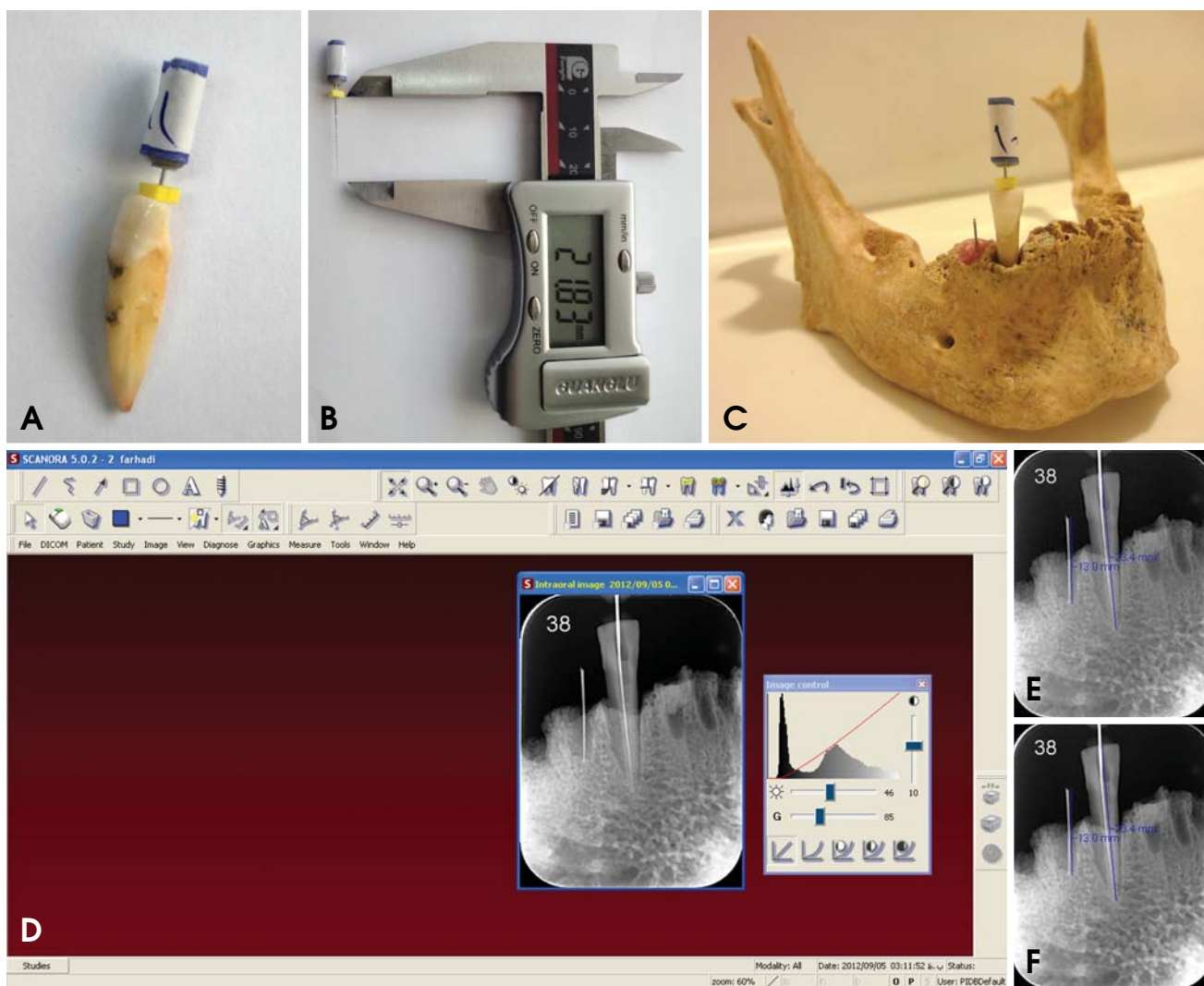


Fig. 1. A. Insertion of an endodontic file into the canal. B. File length measurement (standard value). C. Placement of tooth into cadaver socket. D. Scanora software. E. Original image. F. enhanced image.

nomiya, Japan) were inserted into the canals until the tips of the files were just visible at the apical foramen (Fig. 1A). The file length was measured with a digital caliper to the nearest 0.01 millimeter (Guilin Guanglu Measuring Instrument Co., Ltd., Guilin, China), and the file was shortened by 0.5 mm, which was set as the standard value for the endodontic file length (Fig. 1B). Only teeth with a length of 20-24 mm were included. Then, the files were inserted into the canals again and fixed with flowable composite resin (Tetric® Flow, Ivoclar Vivadent AG, Schaan, Liechtenstein). Afterward, the samples were placed in suitable sockets of a dry human mandible to reproduce the bone density.

In order to eliminate the radiographic magnification, a 10-mm round orthodontic wire was placed in the adjacent dental socket and fixed with wax. A Rinn-Endo-Ray film holder (Dentsply/Rinn Corporation, Elgin, IL, USA) was used to ensure parallelism. The standard geometric configuration was fixed at a 30-cm source-to-object distance. Radiographic images of each sample were obtained with Digora storage phosphor plates (Soredex Corp, Helsinki, Finland) and its special scanner, the Digora Optime (Soredex Corp, Helsinki, Finland), using a Prostyle dental X-ray unit (Planmeca OY, Helsinki, Finland) operating at 63 kVp, 8 mA, and 1.5-mm Al-equivalent filtration for 0.03 s. The digital images were numbered by Scanora 5.0 software (Soredex Corp, Helsinki, Finland) (Fig. 1D) in a semi-dark room and saved in the DICOM format for further processing and analysis (Fig. 1E). The noise of each image was reduced by single clicking on the “noise reduction” option on the diagnostic tools menu bar on the top of the operating window of the Scanora software, and the resultant image was saved again in the same format (Fig. 1F). Then, two blinded radiologists with 5 years or more experience in the interpretation of digital radiographs, identified the endodontic file tip and the most apical portion of the rubber stop of each file in the original and enhanced digital images. They also determined the most coronal and apical point of the orthodontic wire in the adjacent dental socket. The endodontic file and orthodon-

tic wire lengths were measured by a third person using the measurement tool of the software to the nearest 0.1 mm. The magnification coefficient of each image was determined using real and radiographic orthodontic wire lengths. To eliminate the magnification effect of the radiography, the obtained endodontic file length for each image was divided by the magnification coefficient. Then, the mean values of the radiologist measurements were taken as data.

The data were first verified with the Kolmogorov-Smirnov test for the normality of data distribution. Repeated measures ANOVA and the Bonferroni test were used to compare the standard value and radiographic file length with and without enhancement. A SPSS software (ver. 11.0, SPSS Inc., Chicago, IL, USA) was used for analysis. Statistical significance was set at a confidence level of 95%. Also, Cohen’s kappa statistic was used to assess inter-observer reliability.

Results

Repeated measures ANOVA showed significant differences between the standard, original, and enhanced images in the endodontic file length measurements ($P < 0.05$). The

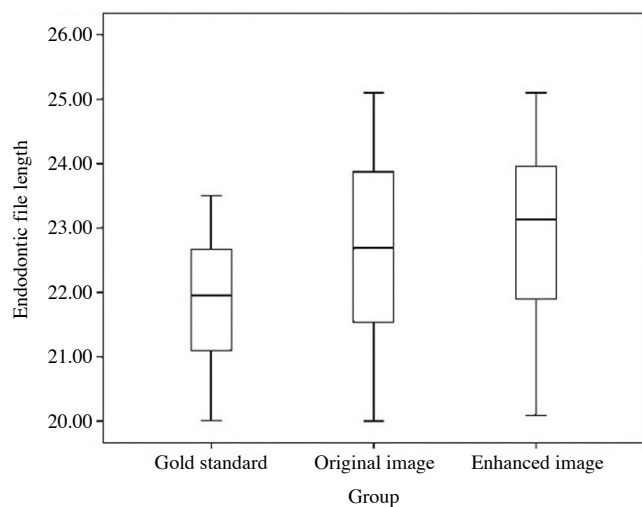


Fig. 2. Box plot of endodontic file length in the standard value and on original and enhanced digital radiographs.

Table 1. Statistical characteristics of the three groups

	Number	Mean	SD	SE	95% confidence interval	
					LB	UB
Standard image	35	21.91 ^a	1.04	0.18	21.55	22.27
Original image	35	22.67 ^b	1.55	0.26	22.14	23.20
Enhanced image	35	22.76 ^b	1.48	0.25	22.25	23.27

Means with different superscript letters are statistically different ($P < 0.05$).

SD=standard deviation, SE=standard error, LB=lower bound, UB=upper bound

Bonferroni test showed no significant differences between the two sets of digital radiographs, suggesting no improvement or reduction in the linear measurement accuracy with noise reduction digital enhancement ($P > 0.05$); however, there was a tendency to overestimate the file length determination by digital enhancement. Additionally, there were significant differences between the two sets of digital radiographs and the standard value ($P < 0.05$). Both the original and enhanced digital images had a tendency to overestimate the file length measurements ($P < 0.05$). The results are summarized in Table 1 and Figure 2.

In addition, inter-observer agreement was excellent for the assessment of digital images with and without enhancement, showing a kappa value of 0.86.

Discussion

The main aim of digital processing is to create images with sufficient detail. This is possible by displaying information that has been collected during imaging but is not visible.¹⁹ Although processing should be able to improve diagnostic signals, some of the information might be lost during the process.^{18,19,23,31} Therefore, digital enhancement should be used with caution, based on the diagnostic task. This task-specific use of enhancements requires accurate investigation. The present study was the first one undertaken to evaluate the influence of noise reduction enhancement on the measurement accuracy of endodontic file length on images acquired using Digora storage phosphor plates. The accuracy was assessed by comparing the position of reproducible landmarks in the original and processed images.

The results of the present study showed that noise reduction does not decrease the accuracy of file length measurement. From the clinical viewpoint, this option does not result in the loss of subtle information, including the position of the tip of a #08 endodontic file. This result is consistent with the results reported by Koob et al²⁰ and Haak and Wicht.²⁹ They showed that noise reduction does not change the diagnostic quality of images in identification of interproximal caries. In addition, Koob et al²⁰ reported that there were no significant differences between images with and images without noise reduction in determination of interproximal caries depth. In contrast, in three studies,²⁶⁻²⁸ Davies demonstrated that the use of noise elimination filters resulted in size and shape distortions. Furthermore, Xu and Lai³⁰ reported that these distortions occurred in fine details such as the tip of endodontic files, particularly with #06 and #08 files. In addition, Brullmann et al^{16,32} evaluat-

ed noise reduction in two different situations. In the first study,¹⁶ it was illustrated that noise filtering had no effect on the accuracy of length measurement of files greater than #10, but this enhancement resulted in underestimation of the length of #10 and smaller endodontic files. This is in contrast with the result of the present study showing overestimation in the length measurement. This controversy may be due to differences in the study design such as the use of charge-coupled device (CCD) digital radiography rather than a PSP system, the use of digital software (Sidexis XG 2.4, Sirona, Bensheim, Germany) with a special filtering program (Borland C-Builder 6.0, Borland GmbH, Langen, Germany) rather than Scanora software, the presence of a marker in the apical portion of the root of the teeth that helps in the identification of the tip of the endodontic file, and the existence of the soft tissue of the mandible resulting in more scatter radiation and noise in that study. In the second study,³² it was shown that this filter was effective in the elimination of noise without the loss of diagnostic information but did not increase the odds of identification of dental root fracture.

Some studies have addressed subjective image quality with and without noise reduction based on observer performance.^{29,33,34} Their major limitation was reliance on subjective assessment of images. For example, Yalcinkaya et al³³ compared the display quality of anatomical structures on conventional and digital periapical and panoramic radiographs. They reported that conventional radiography was superior to unfiltered and noise-reduced filtered digital images, with no statistically significant differences between filtered and unfiltered digital images. However, it has been suggested that it may be more important to use a computable objective measure to predict diagnostic accuracy rather than subjective assessments. Näslund et al³⁴ reported on both objective and subjective evaluations of image quality with and without post-processing noise reduction. The authors basically compared the ability of localization of anatomic landmarks on standard exposed, low-exposed, and a combination of low-exposed and noise-reduced digital cephalograms. They reported that the landmarks were identified more effectively on the low-exposed images than on the images with post-processing noise reduction, although the subjective evaluation of the image quality indicated the opposite. The standard-exposed digital cephalograms were the best in objective and subjective quality evaluations. The results of the objective evaluation contrasted with the result of the present study.

In addition, the results of the present study showed that both enhanced and unenhanced digital images tended to

overestimate the length of endodontic files, consistent with the results of studies by Mehdizadeh et al³⁵ and Williams et al.³⁶ In contrast, Schmitz et al³⁷ and Brito-Junior et al³⁸ reported that the measurement accuracy of digital images was comparable to real measurements.

It is undisputed that the diagnostic impact of digital imaging depends on the task, the quality of source data, and the kind of image processing applied.¹⁹ Therefore, in a clinical situation, discrimination of small file tips may become more difficult. Selection of optimal exposure time is important because under-exposed images have a higher amount of noise.³⁹ In addition, the presence of soft tissues and the increase in the volume and density of hard tissues in the clinical situation results in a greater amount of scattered radiation, increasing the amount of noise. Therefore, clinical studies are suggested for further evaluation of the usefulness of noise reduction digital enhancement in practice.

In addition, although a storage phosphor plate system was used in the present study, most endodontists benefit from the advantages of solid-state detectors to obtain periapical radiographs during root canal treatment. Therefore, the application of solid-state detectors is also recommended for further investigation.

In conclusion, noise reduction enhancement did not change the measurement accuracy of endodontic file length on digital images. Therefore, it could be used, depending on the demands of the practitioner.

References

- Vandenbergh B, Jacobs R, Bosmans H. Modern dental imaging: a review of the current technology and clinical applications in dental practice. *Eur Radiol* 2010; 20: 2637-55.
- Gormez O, Yilmaz HH. Image post-processing in dental practice. *Eur J Dent* 2009; 3: 343-7.
- Parks ET, Williamson GF. Digital radiography: an overview. *J Contemp Dent Pract* 2002; 3: 23-39.
- Almenar García A, Forner Navarro L, Ubet Castelló V, Miñana Laliga R. Evaluation of a digital radiography to estimate working length. *J Endod* 1997; 23: 363-5.
- Kositbowornchai S, Nuansakul R, Sikram S, Sinahawattana S, Saengmontri S. Root fracture detection: a comparison of direct digital radiography with conventional radiography. *Dentomaxillofac Radiol* 2001; 30: 106-9.
- Kamburoğlu K, Barenboim SF, Kaffe I. Comparison of conventional film with different digital and digitally filtered images in the detection of simulated internal resorption cavities - an ex vivo study in human cadaver jaws. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008; 105: 790-7.
- Borg E, Gröndahl K, Persson LG, Gröndahl HG. Marginal bone level around implants assessed in digital and film radiographs: in vivo study in the dog. *Clin Implant Dent Relat Res* 2000; 2: 10-7.
- Syriopoulos K, Sanderink GC, Velders XL, van der Stelt PF. Radiographic detection of approximal caries: a comparison of dental films and digital imaging systems. *Dentomaxillofac Radiol* 2000; 29: 312-8.
- Akdeniz B, Soğur E. An ex vivo comparison of conventional and digital radiography for perceived image quality of root fillings. *Int Endod J* 2005; 38: 397-401.
- Naoum HJ, Chandler NP, Love RM. Conventional versus storage phosphor-plate digital images to visualize the root canal system contrasted with a radiopaque medium. *J Endod* 2003; 29: 349-52.
- Kavadella A, Karayiannis A, Nicopoulou-Karayianni K. Detectability of experimental peri-implant cancellous bone lesions using conventional and direct digital radiography. *Aust Dent J* 2006; 51: 180-6.
- Mohtavipour ST, Dalili Z, Azar NG. Direct digital radiography versus conventional radiography for estimation of canal length in curved canals. *Imaging Sci Dent* 2011; 41: 7-10.
- Li G. Comparative investigation of subjective image quality of digital intraoral radiographs processed with 3 image-processing algorithms. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2004; 97: 762-7.
- van der Stelt PF. Filmless imaging: the uses of digital radiography in dental practice. *J Am Dent Assoc* 2005; 136: 1379-87.
- van der Stelt PF. Better imaging: the advantages of digital radiography. *J Am Dent Assoc* 2008; 139 Suppl: 7S-13S.
- Brüllmann DD, Röhrig B, Sulayman SL, Schulze R. Length of endodontic files measured in digital radiographs with and without noise-suppression filters: an ex-vivo study. *Dentomaxillofac Radiol* 2011; 40: 170-6.
- Castro V, Katz J, Hardman P, Glaros A, Spencer P. In vitro comparison of conventional film and direct digital imaging in the detection of approximal caries. *Dentomaxillofac Radiol* 2007; 36: 138-42.
- Eickholz P, Riess T, Lenhard M, Hassfeld S, Staehle HJ. Digital radiography of interproximal bone loss; validity of different filters. *J Clin Periodontol* 1999; 26: 294-300.
- Kal BI, Baksi BG, Dündar N, Sen BH. Effect of various digital processing algorithms on the measurement accuracy of endodontic file length. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; 103: 280-4.
- Koob A, Sanden E, Hassfeld S, Staehle HJ, Eickholz P. Effect of digital filtering on the measurement of the depth of proximal caries under different exposure conditions. *Am J Dent* 2004; 17: 388-93.
- Sund T, Møystad A. Sliding window adaptive histogram equalization of intraoral radiographs: effect on image quality. *Dentomaxillofac Radiol* 2006; 35: 133-8.
- Møystad A, Svanaes DB, Risnes S, Larheim TA, Gröndahl HG. Detection of approximal caries with a storage phosphor system. A comparison of enhanced digital images with dental X-ray film. *Dentomaxillofac Radiol* 1996; 25: 202-6.
- Raitz R, Assunção Junior JN, Fenyó-Pereira M, Correa L, de Lima LP. Assessment of using digital manipulation tools for diagnosing mandibular radiolucent lesions. *Dentomaxillofac*

- Radiol 2012; 41: 203-10.
24. ShROUT MK, Russell C, Potter B, Powell B, Hildebolt C. Digital enhancement of radiographs: can it improve caries diagnosis? *J Am Dent Assoc* 1996; 127: 469-73.
 25. de Molon RS, Morais-Camillo JA, Sakakura CE, Ferreira MG, Loffredo LC, Scaf G. Measurements of simulated periodontal bone defects in inverted digital image and film-based radiograph: an in vitro study. *Imaging Sci Dent* 2012; 42: 243-7.
 26. Davies ER. Edge location shifts produced by median filters: theoretical bounds and experimental results. *Signal Processing* 1989; 16: 83-96.
 27. Davies ER. Median and mean filters produce similar shifts on curved boundaries. *Electron Lett* 1991; 27: 826-8.
 28. Davies ER. Formulation of an accurate discrete theory of median shifts. *Signal Processing* 2003; 83: 531-44.
 29. Haak R, Wicht MJ. Grey-scale reversed radiographic display in the detection of approximal caries. *J Dent* 2005; 33: 65-71.
 30. Xu Y, Lai EM. Restoration of images contaminated by mixed Gaussian and impulse noise using a recursive minimum-maximum method. *IEE Proc Vis Image Signal Process* 1998; 145: 264-70.
 31. Nair MK, Nair UP. Digital and advanced imaging in endodontics: a review. *J Endod* 2007; 33: 1-6.
 32. Brüllmann D, Witzel V, Willershausen B, d'Hoedt B. Effect of digital noise filters on diagnostic radiographs for the diagnosis of experimental root fractures. *Int J Comput Dent* 2008; 11: 107-14.
 33. Yalcinkaya S, Künzel A, Willers R, Thoms M, Becker J. Subjective image quality of digitally filtered radiographs acquired by the Dürer Vistascan system compared with conventional radiographs. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2006; 101: 643-51.
 34. Näslund EB, Møystad A, Larheim TA, Øgaard B, Kruger M. Cephalometric analysis with digital storage phosphor images: extreme low-exposure images with and without postprocessing noise reduction. *Am J Orthod Dentofacial Orthop* 2003; 124: 190-7.
 35. Mehdizadeh M, Khademi AA, Nasr N. Canal length measurement by digital radiography and conventional parallel radiography. *Res J Biol Sci* 2010; 5: 400-3.
 36. Williams CB, Joyce AP, Roberts S. A comparison between in vivo radiographic working length determination and measurement after extraction. *J Endod* 2006; 32: 624-7.
 37. Schmitz LB, Lima Tde C, Chinellato LE, Bramante CM, Garcia RB, de Moraes IG, et al. Comparison of radiographic measurements obtained with conventional and indirect digital imaging during endodontic treatment. *J Appl Oral Sci* 2008; 16: 167-70.
 38. Brito-Júnior M, Santos LA, Baleeiro EN, Pêgo MM, Eleutério NB, Camilo CC. Linear measurements to determine working length of curved canals with fine files: conventional versus digital radiography. *J Oral Sci* 2009; 51: 559-64.
 39. Macdonald R. Digital imaging for dentists. *Aust Dent J* 2001; 46: 301-5.