Original Study

ACCURACY OF ROOT CANAL LENGTH DETERMINATION ON RADIOGRAPHS TAKEN USING CMOS AND PSP VERSUS E-SPEED FILMS, USING FIXED AND PORTABLE RADIOGRAPHY UNITS

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ABSTRACT

Aim: Despite the importance of accurate root working length determination, there is no study comparing the diagnostic value of conventional films, PSP receptors, and CMOS receptors or comparing portable versus fixed devices in determination of root canal working length.

Materials & Method: This in vitro experimental study was performed on 234 radiographs (39×6) from extracted teeth. Endodontic files were positioned in roots, at three states of "under, over, and tip-to-tip". A radiologist estimated the working length on radiographs taken by PSP, CMOS, and E-speed films, using a portable and a fixed radiography unit. The diagnostic accuracy of different radiography methods was estimated by comparing radiographic diagnoses with the gold standard. Chi-square test was used to compare success rates of different setups.

Results: The best result belonged to the digital radiographs taken using the fixed device and the CMOS sensor and the poorest result was obtained with fixed / PSP combination. Chi-square test did not show a statistically significant difference between these proportions ($P = 0.4$). There was no significant difference between fixed and portable devices, and between three receiver types ($P > 0.6$).

Conclusion: The accuracy of working length estimation might be rather similar in the case of radiographs taken by both digital receptors and E-speed films. Also the evaluated portable and fixed devices might have similar accuracies.

Keywords [from MeSH]: Digital Radiography; Endodontic Treatment.

Introduction

Root canal working length is the distance between the point where canal preparation and obturation should be terminated and a fixed coronal reference point.[1,2] Working length determination is an essential phase of endodontic treatment,[2,3] and its accuracy highly affects the result of endodontic therapy.[2,3]

Numerous approaches are used to measure the working length accurately, including digital radiography.[2,4] Digital imaging technology is increasingly gaining popularity, because of its several advantages such as ease of image acquisition, storage, and sharing, possibility of image enhancement and editing its size / density, much lower patient doses and exposure time, and no need for dark room or processing equipment.[2,5-11] The digital radiographic method produces images using a sensor instead of radiographic film.[6,7] Digital intraoral radiography benefits from two types of digital image receptors: photo-stimulable phosphor plate receptors (PSP) on which a latent image is constructed and is then scanned, and solid-state receptors including complementary metal-oxide semiconductor (CMOS) which allow direct output of the received image to the computer.[5,12]

However, the literature is not conclusive on whether digital radiographic approaches are more efficient than the conventional method for root canal working length determination.[7,13-20] Besides all these controversies, there is no study comparing the diagnostic value of conventional films, PSP receptors, and CMOS receptors as well as on the comparison of portable versus fixed devices in determination of root canal working length. Therefore, this study was conducted to assess the precision of six radiographic methods in determining root canal working length.

Materials and Methods

This in vitro experimental study was performed on 234 radiographs (39 x 6) in the Dental School of Islamic Azad University. The radiographs were all taken from 3 roots of 13 intact maxillary molars extracted for treatment purposes. Teeth were acquired from orthodontic and surgery clinics. They were stored in 2% sodium hypochlorite for 20 minutes. Then they were inspected visually and radio graphically. The exclusion criteria were the presence of any fractures, external or internal resorption, calcifications, open apices, or apical resorption. Also teeth with any apices larger than K-files #20 and those with 4 canals were later excluded. Canal curvatures were not assessed.

Working Length

All the endodontic procedures were performed by a last-semester dental student (at 13th semester) trained by and under the supervision of an experienced endodontist. The standard access cavity was prepared using high-speed tapered long-shank burs. A K-file #10 was used to confirm the clearance of all canals. As the gold standard, the real canal length was measured using a #15 or #20 K-file: The K-file was inserted into the canal until its tip was exited from the apex for 0.5mm (evaluated using an endometer, with unarmed eyes). Then the K-file was withdrawn for

1mm, in order to mark the length of the canal from the rubber stop to the apical constriction (considered to be 0.5 mm beyond the apex). If the apex was larger than the file #20, the tooth would be excluded.

Randomization of file placement in different lengths

Canals of all 13 teeth were coded with unique numbers (regardless of teeth). Randomization disregarded teeth, and was performed on the canal level.

Based on a random number table, one-third of 39 canals were assigned to **group A** (canals in which files were placed at the correct working length). Another 13 canals were assigned randomly to **group B** (canals in which files were placed 1.0 mm under the proper working length). The remaining 13 canals were assigned to **group C** (canals in which files were placed 1.0 mm over the proper working length). Teeth were not involved in randomization and a particular tooth could have theoretically any number of canals (0, 1, 2, or 3) assigned to any given group (A, B, C).

Gold Standard

K-files were placed in the canals at lengths pre-determined for each canal group (A, B, C). File sizes used were #15 for buccal canals and #20 for palatal canals. The files were fixed at their confirmed lengths using wax. Each tooth was mounted up to the CEJ within a block of plaster mixed with sawdust in a 2:1 ratio .[21] Block size was standardized using a template.

The group (**tip-to-tip [A]**, **under-instrumented [B]**, and **over-instrumented [C]**) of each canal of each tooth was recorded as the gold standard for further evaluation of radiographic diagnostic accuracies.

Radiography

Afterwards, standardized periapical radiographs (using parallel technique) were taken from teeth using different devices and analog / digital receivers, all with an exposure time of 0.2 second. The angle of radiography was calibrated for all methods (in which the parallel technique was used). This duration was estimated by a pilot study, and showed the most appropriate results. The radiographs consisted of:

Group 1. 39 conventional radiographs (E speed, Kodak, Japan) taken by a fixed radiography unit at 70 kVp and 2 mA (Minray, Soredex, Finland)

Group 2. 39 conventional radiographs (E speed, Kodak) taken by a portable radiography unit (Genoray Co., Korea)

Group 3. 39 digital radiographs taken by Minray fixed radiography unit and using a 26.3 Lp/mm size #2 CMOS sensor with 1358*1916 pixel resolution (Toto, Soredex, Finland)

Group 4. 39 digital radiographs taken by Genoray portable radiography unit and using a CMOS sensor (Toto).

Group 5. 39 digital radiographs taken by Minray fixed radiography unit and using a 14.3 Lp/mm size #2 PSP sensor with 1171 x 886 pixel resolution (pixel size= 64 µm), and 14 bit depth (Promax, Soredex, Finland) .

Group 6. 39 digital radiographs taken by Genoray portable radiography unit and using a PSP sensor (Promax).

Radiographic Examination

Digital radiographs were stored as coded JPEG files in a computer with a 15” LCD monitor screen. Conventional radiographs were processed according to the film manufacturers and were coded. A maxillofacial radiologist evaluated 234 canals visible in all conventional radiographs (over a negatoscope) and digital radiographs (on the LCD screen). She determined each canal shown on each image as being either tip-to-tip (file tip over apex), over-instrumented (file tip exiting the root), or under-instrumented (file tip not reaching the apex).

Evaluation of radiographic diagnostic accuracy

The table filled by the radiologist was compared against the table of actual values by the last-semester student. Each canal on each radiograph would receive the value ‘correct’ if the file position determined by the radiologist matched the group of that particular canal (as the gold standard). Otherwise, it would receive the value “incorrect”.

Intraobserver Agreement

The radiologist examined 46 randomly selected radiographs a week later. The intraobserver agreement between the values “tip-to-tip, over-instrumented, and under-instrumented” recorded in both sessions was estimated to be 90% ($p < 0.001$).

Statistical Analysis

Descriptive statistics were calculated for the frequencies of correct answers in different groups of devices / receptors. Chi-square test of SPSS (20.0, IBM, USA) was used to compare success rates of different setups. *P* values smaller than 0.05 were considered statistically significant.

Results

Overall

When taking into account the data pertaining to all specimens in all A/B/C groups, the best result belonged to the digital radiographs taken using the fixed device and the CMOS sensor and the poorest result was obtained with fixed / PSP combination. [Table 1, Figure 1] Chi-square test did not show a statistically significant difference between these proportions (p=0.4). There was no significant difference between fixed and portable devices, and between three receiver types (p>0.6).

Tip-to-tip cases (group A)

There were only 2 significant comparisons in this group: The best results in group A (canals with files placed tip-to-tip) was obtained with E-speed films either using fixed or portable devices. The poorest results differed depending on the used device [Table 1, Figure 1], but they did not reach the level of significance in either device ($p>0.05$).

File position	Unit	Receptor	Correct		Incorrect	
			N	%	N	%
All groups (n = 6 × 39)	Fixed	Film	27	69.2	12	30.8
		CMOS	31	79.5	8	20.5
		PSP	25	64.1	14	35.9
	Portable	Film	28	71.8	11	28.2
		CMOS	27	69.2	12	30.8
		PSP	28	71.8	11	28.2
Group A (tip-to-tip) (n = 6 × 13)	Fixed	Film	11	84.6	2	15.4
		CMOS	10	76.9	3	23.1
		PSP	7	53.8	6	46.2
	Portable	Film	11	84.6	2	15.4
		CMOS	8	61.5	5	38.5
		PSP	10	76.9	3	23.1
Group B (under-filed) (n = 6 × 13)	Fixed	Film	7	53.8	6	46.2
		CMOS	12	92.3	1	7.7
		PSP	11	84.6	2	15.4
	Portable	Film	8	61.5	5	38.5
		CMOS	9	69.2	4	30.8
		PSP	10	76.9	3	23.1
Group C (over-filed) (n = 6 × 13)	Fixed	Film	9	69.2	4	30.8
		CMOS	9	69.2	4	30.8
		PSP	7	53.8	6	46.2
	Portable	Film	9	69.2	4	30.8
		CMOS	10	76.9	3	23.1
		PSP	8	61.5	5	38.5

Table 1. Net and frequency distributions of diagnostic values pertaining to all canals.

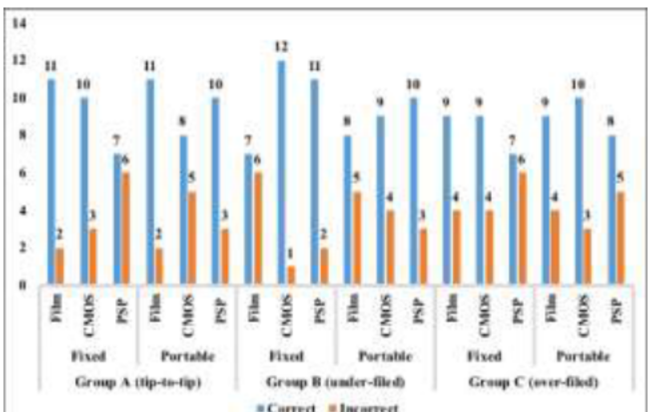

Figure 1. Distribution of correct and incorrect estimations in each subgroup.

Under-instrumented cases (group B)

In group B (under-instrumented canals), the only significant comparison ($P=0.048$) was between the results pertaining to radiographs taken by fixed unit + conventional E-speed film (as the poorest result) and radiographs taken using the same device but with CMOS sensor (as the best result).

Over-instrumented cases (group C)

In group C (over-instrumented canals), no comparisons were significant ($p>0.05$).

Discussion

The current study showed no significant difference between the digital radiographic method and conventional E speed films, in determining the working length correctly. This was in line with studies reporting no difference between two methods.[5,14-16,18,22-24] Burger *et al.*[14] concluded that although all radiographic techniques resulted in erroneous canal length estimations, there was no significant difference between the techniques. Mohtavipour *et al.*[15] observed a high inter-observer agreement regarding working lengths determined by conventional and digital radiographs. They also found both methods reliable and correct, with no significant difference between them.[15] Cederberg *et al*[16] found digital radiography to be more reproducible than conventional technique. In their study, root length determinations pertaining to Ektaspeed Plus films were comparable to those of PSP. However, the positions of file tips, particularly the smaller ones, were difficult to identify on E-speed films. Based on the smaller variations of digital technique, they concluded that conventional file length determination is less accurate than digital technique.[16] Nevertheless, the better accuracy of digital images might be actually attributed to the digital magnification / brightness / contrast enhancements the software provides plus the limitation of the evaluator in reading conventional radiographs.[7,13,17,25] On the other hand, some other studies have shown conventional radiography (especially E-speed films) to be better than digital radiography.[7,13,17,26] According to Akdeniz and Sogur.[17] conventional photography using either E or F speed films was of better quality compared to digital PSP radiography in detecting the working length; however, enhanced digital images were clearer than both conventional films and normal digital images.[17] Through an in vivo study, Orosco *et al* [7] observed an error of 1.11 mm for conventional and 1.20 mm for the digital method and reported the conventional radiographic method as superior in determining the working length. Of course this was not clinically important as both were within the acceptable radiographic limit for the file tip and apex which is about 0.5 and 2 mm.[7,18-20] Friedlander *et al*[13] as well observed the superiority of conventional radiography compared to PSP digital method both regarding the file tip identification and visualizing periapical lesions. Nevertheless, the better accuracy of digital images might be actually attributed to the digital magnification / brightness / contrast enhancements the software provides plus the limitation of the evaluator in reading conventional radiographs.[7,13,17,25] Some other studies have shown conventional radiography (especially E-speed films) to be better than digital radiography. [7,13,17,26]

Various results have been reported with respect to the accuracy of working length determined on images taken with solid state devices and PSPs. This study did not find a significant difference between the accuracy of canal length estimation on radiographs taken by CMOS and PSP receptors. Similarly, Vandenberghe *et al*[27] found both sensors of comparable image quality in root length determination. However, Oliveira *et al*[28] found both CMOS and CCD better than PSP in working length approximation. Farida *et al*,[5] Anas *et al*,[29] and Athar *et al*[30] reported that the other solid-state receptor CCD makes more trustable images than PSP. In the Athar *et al*'s[30] study, CMOS acted also better than CCD. Nevertheless, in the Farrier *et al*'s[31] study, the PSP-based system resulted in more accurate length calculation compared to a CCD-based system.[31] These controversies can be attributed to the differences in the quality of the sensors, their resolutions, the software programs used, and evaluators' eyesight and experience.[12] Considering the advantages of digital radiography and its proper results, it can be recommended for clinical use, although always with the use of image enhancements and especially with solid state receptors.[12,32] Controversy is expected when noting that an even within our sample, there was not an overall consistency between the results observed in different sub-studies (groups A, B, or C). For example, there was no significant difference between any two compared device-receptor combinations when the instrument tip had exited the apex (i.e., in group C). In contrast, when the instrument tip was at the apex level (group A), E-speed films turned out to be the best receptors regardless of the used device; now in this tip-to-tip group, the type of the worst receptor changed from PSP to CMOS depending on the used device (fixed or portable). And when the canal was under-instrumented (group B), the conventional film (E-speed) which had provided the highest accuracy in the case of tip-to-tip canals (in group A) now provided the poorest accuracy; whereas, the CMOS receptors which had provided the poorest results in group A provided the best results in group B. We are not aware of studies explaining this but perhaps a reason for such inconsistencies might be image rendering algorithms used in digital methods but absent in conventional method. Such algorithms might change (in a positive or negative way) the output of digital radiograph rendered on the digital screen, depending on the object arrangements; whereas, conventional films are not affected. Larger samples are needed to compare these sub-studies, and explain potential reasons.

Since there is no standard routine for assessment of different radiographic techniques and various adjustments are allowed, there might appear considerable variations depending on the system used and the observer.[7,17] In vivo studies disallow standardizing further, as digital sensors are not as flexible as film, which this can increase the difference.[7] In this study, the endodontic ruler and a computer mouse-activated curser were used for measurements; digital enhancements might facilitate the assessments and considerably improve the validity and accuracy.[5,8,10,33,34]

Conclusions

This study showed for the first time that overall, the accuracy of working length estimation might be rather similar in the case of radiographs taken by CMOS, PSP, or E-speed receivers. Also the evaluated portable device might be comparable to the fixed device.

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