Perceived quality, clarity, and accuracy of manually processed and self-developing radiographs in endodontics

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Abstract:

Objectives:
To evaluate perceived quality, clarity, and accuracy of self-developing films compared to conventional D- and E-speed manually processed films, and to evaluate their ease of use and satisfaction amongst pre-clinical dental students.

Methodology:
Mesiobuccal root canals of 30 extracted mandibular molar teeth were instrumented and size 10 K-files were glued into the canals at 3 different levels. Each tooth was exposed thrice with the same angulation using conventional E-speed, D-speed, and self-developing films. Conventional films were processed manually and self-developing films according to the manufacturer's instructions, which required 50 seconds of contact time with the solution. Radiographs were evaluated by 4 examiners for quality, clarity, and apical position of the file. A questionnaire-based survey was conducted to evaluate the ease of use, quality, and satisfaction of undergraduate students. Data were analyzed using one-way ANOVA and Tukey–Kramer multiple comparison test, significant at $p < 0.05$.

Results:
The quality and clarity of conventional E-speed films was perceived as significantly better than that of D-speed and self-developing films ($p < 0.05$). There was no statistically significant difference amongst the 3 film types for recorded file positions ($p > 0.05$). The results of the student survey corroborated the examiners' views that the self-developing radiographic films were of poor quality.

Conclusion:
Manually processed E-speed films provided significantly superior quality and clarity of images, but for apical file position, no significant differences were found amongst the 3 film types. Conventional E-speed, D-speed, and self-developing films are all adequate for measuring endodontic working lengths.

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Introduction

Establishing an accurate working length is a primary and fundamental step in the debridement of a root canal system. To achieve complete debridement throughout the entire length of the root canal, an accurate measurement of the canal length is required. [1] Methods including radiographic determination, [2] determination by tactile sense, [3] and determination with electronic apex locators [4] have shown some success in providing working length determinations during root canal therapy.

Three radiographic systems currently used to determine working lengths are conventional direct exposure imaging with dental x-ray film, solid-state digital imaging, and digital imaging with a photostimulable phosphor plate (PSP). [5] Currently, conventional intraoral direct exposure radiographs with International Standards Organization (ISO) D-, E-, and F-speed films is the most commonly used method. It is necessary for intraoral radiographs to provide a high degree of clarity and sharpness for accurate visualization of the file tip in relation to the radiographic apex.[6] Furthermore, the observer's ability to ascertain the distance between the file tip and the radiographic apex is also important. The success of endodontic treatment depends on these radiographic measurements that are taken during root canal therapy.

Several recent studies have evaluated the ability of different film speeds to determine radiographic working lengths. Ellingsen et al [1, 6] found that D-speed radiographs were superior to E-speed radiographs both *in vitro* and *in vivo* when conventional radiography using D- and E-speed films was compared with radiovisiography (RVG). Another study evaluating the Kodak D- (Ultra-speed) and E-speed (Ektaspeed Plus) films concluded that the Ektaspeed Plus film could be used for working length radiographs in endodontics. [7] In endodontic practice, intraoral radiographs are often processed manually in the clinic. This requires the presence of a darkroom and continuous replenishment of developing solutions. A self-developing E-speed film (Ergonom-X) has recently been introduced. Self-developing film allows the user to process a radiograph in approximately 1 minute and does not require a darkroom.

The purpose of this study was to evaluate the perceived quality, clarity, and length determination accuracy of self-developing films compared to conventional D- and E-speed manually processed films, and to evaluate the ease of use and satisfaction amongst pre-clinical dental students.

Methodology

Thirty extracted human mandibular molar teeth were used in this study. Access cavities were prepared using round diamond bur in high-speed hand-pieces under copious water irrigation. Root canals were instrumented to their apical foramina and mesiobuccal canals were chosen for radiographs. Size 10 K-files (SDS/Kerr, Orange, CA, USA) were glued into the canals at 3 different levels either 2 mm short of the apex (10 canals), 0.5 mm short of the anatomic apex (10 canals) or 2 mm beyond the apex (10 canals). The apices were covered with luting wax to mimic periapical lesions and teeth were mounted in special molds using a mixture of acrylic and stone.

A Gendex Oralix AC (Gendex, Milan, Italy) x-ray machine was used for all exposures at 65 kVp and 7.5 mA. Each tooth was exposed 3 times with the same angulation using a conventional E-speed film (Eastman Kodak, Rochester, NY, USA) for 0.13 s, D-speed (Ultra-speed) film for 0.16 s (Eastman Kodak), and self-developing Ergonom-X E-speed film for 0.3 s (Dentalfilm, Torinese, Italy). Conventional films were developed manually in GBX concentrate solutions (Eastman Kodak) for 30 s, washed with water and then fixed for 30 s. Self-developing films were processed according to the manufacturer's instructions and required 50 s of contact time with the solution. One investigator performed all the procedures and the films were randomized and coded.

Radiographs were evaluated independently by 4 examiners (1 endodontist, 1 radiologist, 1 general dentist, and an undergraduate student) for quality, clarity, and apical position of the file on a viewbox using 4× magnification loops. Quality and clarity were scored using a 3 point system where 1 = Good; 2 = Diagnostically acceptable; 3 = Poor.

Data were analyzed using one-way ANOVA and Tukey-Kramer multiple comparison test significant at $p < 0.05$. Cohen's Kappa

statistics were used to measure the level of agreement of the 4 evaluators.

A questionnaire-based survey was also conducted amongst the undergraduate dental students enrolled in the pre-clinical endodontic course at the College of Dentistry, University of Dammam, Saudi Arabia to evaluate the ease of use, quality, and satisfaction with using self-developing films compared with manually processed films.

Results

Evaluation by Examiners

The results presented in Tables 1 and 2 demonstrate that overall, the evaluators rated the quality and clarity of conventional E-speed films better than that of D-speed and self-developing films ($p < 0.05$; Figure 1). Self-developing films showed poor quality, which differed significantly from D-speed films, although there was no statistically significant difference between the clarity of the D-speed and self-developing films (Figure 1).

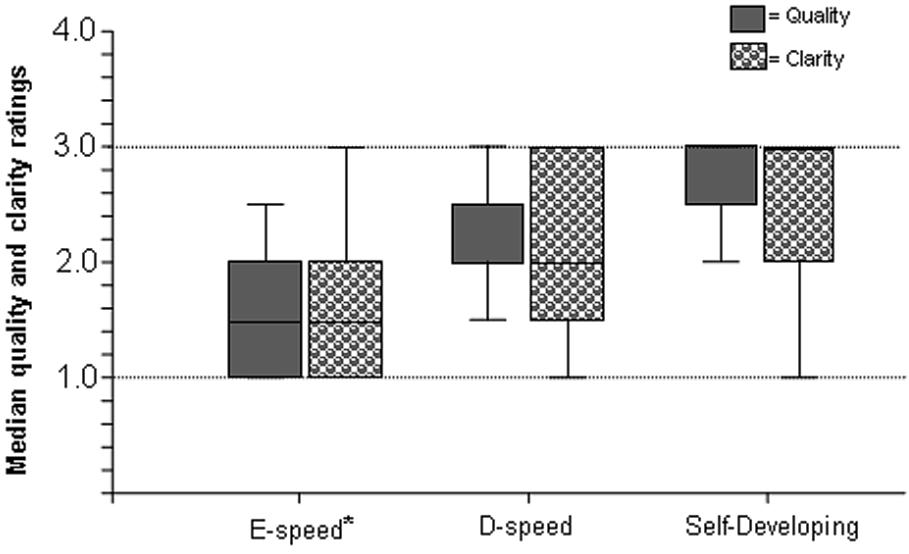

Figure 1: Box-and-Whisker plot of overall median quality and clarity scores for E-speed, D-speed films, and self-developing x-ray films (1 = Good & 3 = Poor). The manually processed conventional E-speed film category scored significantly better than others and is marked with an (*****).

Results of the κ (Kappa) test showed poor to fair agreement among evaluators for quality of E- & D-speed films ($\kappa < 0.20$) and fair agreement ($\kappa < 0.40$) for self-developing films. There was fair to moderate agreement among the examiners for the clarity of all 3 films ($\kappa = 0.28–0.46$).

Overall quality and clarity of conventional E-speed films was ranked as good or satisfactory by all examiners, while the D-speed and self-developing films were ranked as satisfactory or poor.

Table 1: Quality ratings of 30 conventional E-speed, D-speed, and self-developing films by evaluators

Film type	Score	Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4
Conv E-speed	+	6	8	15	20
	=	17	18	15	6
	-	7	4	0	4
Conv D-speed	+	0	4	3	20
	=	21	20	18	5
	-	9	6	9	5
Self-Developing	+	0	1	0	0
	=	7	22	1	4
	-	23	7	29	26

Conv, conventional; +, quality rated as good by the evaluator; =, diagnostically acceptable image quality; –, poor quality radiographs.

Table 2: Clarity ratings of 30 conventional E-speed, D-speed, and self-developing films by evaluators

Film type	Score	Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4
Conv E-speed	+	10	19	12	19
	=	16	8	11	7
	-	4	3	7	4
Conv D-speed	+	6	8	2	9
	=	12	16	10	12
	-	12	6	18	9
Self-Developing	+	2	3	0	5
	=	9	16	6	8
	-	19	11	24	17

Conv, conventional; +, evaluator rated the clarity as good; =, diagnostically acceptable image clarity; –,poor clarity of radiographs.

Errors were observed between the recorded and actual measurements of the apical position of files in the root canals for all 3 film types and for all examiners (Table 3). There was no statistically significant difference between E-speed, D-speed, and self-developing films for the recorded dimensions ($p > 0.05$). Results of the κ (Kappa) test showed good (substantial) agreement among evaluators for apical position of files in the canals ($\kappa = 0.80$).

Table 3: Scores for determination of apical position of files with 30 conventional E-speed, D-speed, and self-developing films by evaluators.

Apical File Position	Score	Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4
Conv E-speed	+	7	7	8	6
	=	13	13	11	14
	-	10	10	11	10
Conv D-speed	+	7	5	9	8
	=	13	15	11	12
	-	10	10	10	10
Self-Developing	+	8	8	11	9
	=	12	12	9	12
	-	10	10	10	9

Conv, conventional; +, the score when file was 2 mm short of the apex; =, the file was 0.5 mm short of the apex, –,the file extended beyond the apex by 2 mm.

Student Survey

A total of 30 students participated in the survey. The survey indicated that 4 of the participants had had previous experience with self-developing films. Although 90% of the participants reported that the speed of self-developing radiographs was good or satisfactory, the films were rated poor for quality when compared to conventional radiographs. A majority of the participants (≥60%) were satisfied with the ease of use and processing speed of conventional radiographs (Table 4 & Figure 2).

Table 4: Responses of students to selected survey questions.

Survey Questions	Student Responses		
	Good (%)	**Satisfactory (%)**	**Poor (%)**
1- How would you rate the speed of self-processed radiographs?	70	20	10
2- After using the self-developing films, how would you rate the quality of radiographs?	17	30	53
3- Compared to conventional radiographs, self-developing radiographs are:	10	23	67
4- How do you rate the speed of processing conventional radiographs?	17	43	40
5- How would you rate the ease of using conventional radiographic films?	17	50	33

A positive preference for using self-developing films in the clinic was expressed by only 20% of the respondents, whereas 54% of them did not recommend the use of self-developing films for their pre-clinical endodontic course.

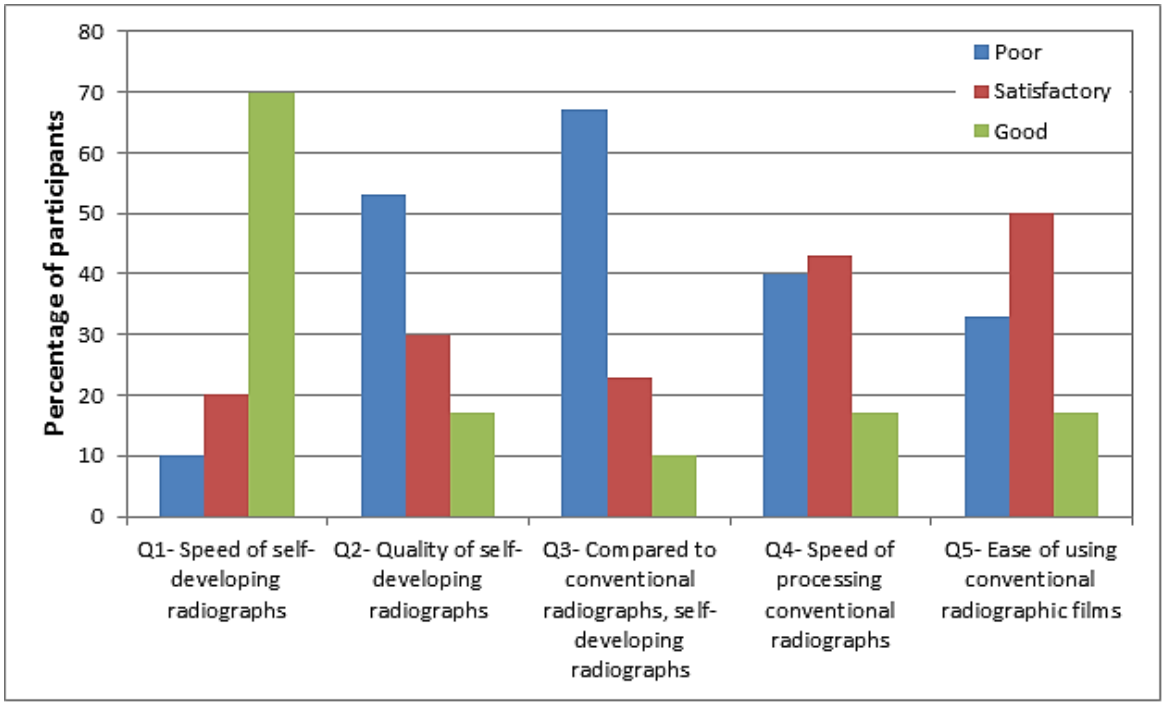

Figure 2: Graphical presentation of participants' responses to survey questions.

Discussion

The evaluation of quality and clarity is a subjective phenomenon that consists of both the technical characteristics of the image and the skill, experience, and perception of the examiners. [8] Various techniques and film types had been compared in the past, however most of these studies evaluated the quality of radiographs by objective criteria. In this study, manually processed E-speed and D-speed films were compared to self-developing x-ray films for quality, clarity, and working length determination during root canal treatment. The results indicated that E-speed films were perceived as superior to D-speed and self-developing films in quality and clarity by the evaluators (1 endodontist, 1 radiologist, 1 general dentist, and 1 undergraduate student). Self-developing x-ray films were rated the poorest in quality and clarity by all evaluators.

In previous *in vitro* [1] and *in vivo* [6] studies, D-speed and E-speed films were compared with RVG for radiographic working length determinations and D-speed films were found to be superior to E-speed radiographs. The results are in contrast to the findings of the present study. However, it is difficult to compare directly the results of present study to those of previous studies because of the differences in methodology and evaluated parameters. In another study, Sheaffer et al [9] compared D-, E-, and F-speed films for endodontic measurements and found no significant difference among these films when image density was held constant. Brown et al [7] evaluated D-speed and E-speed Plus films and reported that E-speed films could be used in endodontics for working length determinations.

The evaluators were blinded in their evaluations among the E-speed, D-speed, and self-developing radiographs. The films were coded and randomly distributed for evaluations. The agreement among the

evaluators varied from poor to moderate for quality and clarity of 3 film types. This could be attributed to the differences in the experience and skill of the examiners. [1] In a clinical study comparing D-speed and E-speed radiographs and RVG, Ellingsen et al [6] reported that examiners with greater experience tended to prefer the E-speed radiographs, whereas examiners with lesser experience tended to prefer RVG. Kawauchi et al [10] reported only minor experience-related differences amongst the examiners (endodontists, radiologists, and new graduates) in a study comparing conventional radiographs and indirect digital images in endodontic treatment. However, in this study all the examiners received prior calibration in relation to the establishment of reference points and manipulation of equipment to set the measurements, while the other studies had utilized only specialists (endodontists and/or radiologists) for evaluations in order to minimize the potential bias. [8, 11]

Another potential source of error could be a lack of uniform radiographic viewing conditions, such as intensity of light and magnification that might influence the examiner's evaluation. [1] In this study, all examiners carried out their evaluations under similar conditions in order to minimize the effect of these variables.

When considering the data from the evaluations of apical file position, it appears that evaluators had perfect agreement (Table 3). However, errors were observed in the actual and determined file positions, and most of the time the examiners underestimated the working length (file position) for all film types. The findings are in agreement with previous studies that have reported that most errors observed during working length determinations are for estimation of file positions that short of the actual foramen. [11, 12] An *in vitro* study compared self-developing and manually processed D-speed films with digital x-ray systems for endodontic file length determination. The results demonstrated significantly less mean error for digital x-ray systems than the film based methods. However, no statistically significant differences were found between manually processed and self-developing films. [12] No other studies could be found that compared self-developing films to manually processed x-ray films.

The second part of our study included an evaluation of the satisfaction of pre-clinical students with ease of use of manually processed and self-developing films via a questionnaire-based survey. Although students reported the processing speed and ease of use of self-developing x-ray films as good, they gave poor ratings for quality when compared to conventional radiographs. Most of the participants were satisfied with the ease of use and processing speed of conventional radiographs and did not recommend the use of self-developing films for pre-clinical endodontic courses. The results of the student surveys corroborated the findings of examiners that the self-developing x-ray films were of poor quality.

Conclusions

Perceived image quality and clarity of manually processed E-speed films were significantly superior to D-speed and self-developing film images for the evaluation of root canal measurements.

Manually processed and self-developing x-ray films did not show significant differences for determination of apical file positions and are adequate for endodontic working length measurements.

Students reported the processing speed and ease of use of self-developing x-ray films to be good, but they rated the quality poor when comparing the films to manually processed conventional films.

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