Original Article

Effect of Developer Age and Film Speed on Diagnostic Accuracy of Endodontic File Length Measurement on Radiographs

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Abstract

Background and Aim: Radiography has extensive applications in root canal treatment and the developer age plays an important role in making a definite diagnosis. The present study examined the effect of developer age on the diagnostic accuracy of endodontic file length measurement using D-speed, E-speed and E/F-speed films.

Materials and Methods: In this diagnostic study, radiographs were processed weekly by a developer aged for up to 6 weeks. Radiographs were viewed by 5 postgraduate students of endodontics and oral radiology. They determined the file tip position using a 3-point confidence scale. The area under the curve (Az) was calculated and used as a diagnostic accuracy scale. The effects of film type and endodontic file size were analyzed by one-way ANOVA, Tukey's post hoc test and Student's t test.

Results: E-speed and D-speed films had similar diagnostic accuracy higher than that of E/F speed film ($p<0.0001$). The Az values of D, E and E/F speed films were 0.5882, 0.5538 and 0.3578, in fresh developer, 0.5782, 0.5718 and 0.3498 in 2-week old developer and 0.6196, 0.6724 and 0.2080, in 4 - week old developer solution, respectively. Developer age did not decrease the diagnostic accuracy of D and E-speed films but decreased that of E/F films at 4 weeks. Radiographs processed with 6 weeks old developer were not readable. All observers showed higher diagnostic accuracy determining the size of file # 15 than 10 ($p<0.0001$). The mean Az values for endodontic file sizes 10 and 15 using fresh, 2-week and 4-week old developers were 0.3984 and 0.6016, 0.3732, and 0.6268 and 0.2774 and 0.7226, respectively.

Conclusion: The developer aged for up to 4 weeks did not significantly affect the diagnostic accuracy of D-speed and E-speed films. E/F speed films cannot be used with developers older than 2 weeks and their usage was associated with lower accuracy compared to E and D-speed films.

Key Words: Developer, Diagnostic accuracy, Radiographic film, Endodontic file

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Introduction

Considering the adverse effects of X ray radiation on human tissues, reducing the patient radiation dose is a major goal in radiology [1]. One method to decrease the patient exposure dose is to use faster films. At present, radiographic films with two different speeds are commonly used. D-speed films provide higher sharpness and contrast compared to E-speed films; however, they require higher exposure dose (40%) [2, 3]. Use of E-speed films due to lower radiation dose and higher patient protection is more common. E-speed films absorb much of the X-ray beam due to their composition [4]. However, their application

provides a wide range of density and any change in the ideal processing conditions such as thermal changes, altered concentration of developing solutions or developer age can decrease the quality of these films and result in misdiagnosis.

Photographic emulsion is in the form of a thin layer on a clear polyester base. Emulsion contains photo-sensitive, silver halide crystals dispersed in gelatin. Mainly silver bromide and to a lesser amount silver iodide form the crystalline network. By changing the size of these crystals, the film speed may be altered. Faster films have larger crystals and higher amount of silver bromide and thus, they need less exposure for the formation of invisible image. Initial films required 3-4 seconds of exposure. However, at present the same radiographs can be obtained using the same type of x ray beam and the same distance from the device to the patient by using much shorter exposure time [1].

Ekta–speed (E speed) films were introduced in 1982. Their main specification was 50% reduction in patient radiation dose. However, they had lower properties in terms of contrast, fogging, sensitivity, film grain and processing [5]. Ekta-speed Plus films were introduced to improve the properties of the previous generation of films and had characteristics similar to those of ultra-speed (D-speed) films. These properties were confirmed in some studies [5]. However, further investigations are still required in this respect. Thus, using faster, efficient films for usual dental procedures would be a step forward to reduce the patient radiation dose. Moreover, it has been demonstrated that E-speed and D-speed films have similar diagnostic accuracy for detection of proximal caries and also for working length determination in endodontic treatment [6-8].

It appears that D-speed films are less susceptible to developer age [9, 10]. The reaction of dental films to developer age depends on the type of developing solution and the difference in diagnostic accuracy of the three types of films processed in manual processing solutions has reported to be greater than that of films processed by automatic machines [10]. Duration of processing, temperature of the developing solutions, and their exhaustion all affect the density and contrast of radiographic films [9, 11]. This study aimed to assess the effect of developer age on diagnostic accuracy of endodontic file length measurement on D- speed (Kodak), E- speed (Kodak) and E/F speed (Agfa Dentus M2) films.

Materials and Methods

In this in-vitro, diagnostic study, 54 endodontic radiographs of 126 surfaces were evaluated by 5 post-graduate students of endodontics and oral radiology. To simulate oral environment and the human skeletal pattern, the teeth were embedded in acrylic resin to simulate periodontium. Root canals of mandibular first molars (distal root), mandibular second premolars, maxillary first molars (palatal and mesiobuccal roots), maxillary second premolars and mandibular first premolars were prepared. The teeth were arranged in three blocks each containing 2 teeth as follows:

1. Mandibular second premolar and mandibular first molar
2. Maxillary second premolar and maxillary first molar
3. Mandibular first premolar and mandibular second premolar

Canal length was measured primarily by introducing a file into the canal and observing the file tip at the apex. If the obtained value matched the radiographic apex, the respective tooth was entered in the study. Kerr endodontic K files #10 and #15 with different working lengths (1.5 mm short) were prepared using a rubber stop (in order not to lose length). The blocks were radiographed twice: first with #10 files in the root canals and for the second time with #15 files inserted using three types of films: D-speed (Kodak), E-speed (Kodak) and E/F speed (Agfa Dentus M2).

The exposure time was 0.12 seconds for D-speed films, 0.08 seconds for E-speed films and 0.06 seconds for E/F speed films.

All films from the same manufacturer had the same Batch number. Radiography was performed using standard CRANEX® Tome Ceph panoramic and cephalometric X-ray (Soredex) with exposure settings of 60 kVp and 7 mA. Radiographs were obtained using the parallel technique at 20 cm distance.

By using films with the same Batch number and matching the conditions under which radiographs were taken according to the manufacturer's

instructions, the standard conditions for this study were met.

The study followed three trails including fresh solution, and developers aged for 2 and 4 weeks with #10 and #15 files in the canals and using three different films in terms of speed. Each trail included 18 different root canals. Also, 6-week old solution was also evaluated but was later excluded from the study because all the films (in all three groups) were not readable. The first series of films were processed in 1.5 L of fresh solution (Teyf Sazan, Iran) (fresh solution). The same solution was also used after 2 and 4 weeks. Each cycle took 50 seconds, the temperature of the solution was kept at 20°C and the volume of the solution was 1.5 L. Films in each trail were processed simultaneously.

Eventually, 5 observers (2 endodontics and 3 radiology post-graduate students) randomly evaluated radiographs using a viewing box under the same lighting conditions. The observers were blinded to the type of films. Since the observers were acquainted with all types of radiographs, no attempt was made to match them prior to observation. The observers were requested to assess the endodontic file lengths inside the canal and express their opinion regarding the distance from the file tip to the apex using the following 3-point confidence scale:

1. Not-detectable
2. Approximately 1.5 mm under
3. Definitely 1.5 mm under

Observers viewed the radiographs in a quiet room with no time limit. To determine the intra-observer reliability, two of the observers were randomly chosen from the list and 15 days after the first observation, they were requested to re-evaluate 10 of the radiographs. The inter-observer reliability was determined using Cronbach's alpha. One-way ANOVA and the area under the ROC curve (Az) (as dependent variable) were used to determine the diagnostic accuracy. Since the results of one-way ANOVA were significant, Tukey's post hoc test was used for multiple comparisons. The diagnostic accuracy values for observers using films in fresh, 2-week old and 4-week old solutions based on the type of film and size of endodontic file were analyzed using one-way ANOVA and the Student's t-test.

Results

Tables 1, 2 and 3 show the area under the ROC curve (Az values) for different observers. The mean Az in observers was 0.5892 for D-speed film, 0.5952 for E-speed film and 0.3156 for E/F speed film. The results of one-way ANOVA revealed significant differences based on the type of radiographic film in Az values ($p<0.0001$). In general, E/F speed film had lower diagnostic accuracy compared to D and E speed films ($p<0.0001$ for both). The E and D speed films were not significantly different in terms of Az values ($p=0.961$).

In fresh developer, the mean Az was 0.5882 for D-speed film, 0.5538 for E-speed film and 0.3578 for E/F speed film. The difference in the diagnostic accuracy of the three types of films in fresh developer was statistically significant ($p<0.0001$). Pairwise comparison by Tukey's test revealed that the difference between D and E speed films was not significant ($p=0.136$) but D and E speed films had higher diagnostic accuracy than E/F speed film ($p<0.0001$ for both).

Table 1. Az values for each observer based on the type of film

Observer	D	E	E/F
1	0/609	0/631	0/260
2	0/570	0/560	0/369
3	0/601	0/606	0/293
4	0/547	0/595	0/359
5	0/619	0/584	0/297

In 2 week-old developer, the mean Az was 0.5782 for D-speed film, 0.5718 for E-speed film and 0.3498 for E/F speed film; the difference in diagnostic accuracy among the three types of films developed in 2 week-old solution was significant ($p<0.0001$). Pairwise comparison by Tukey's test revealed that the difference in this regard between D and E-speed films was not significant ($p=0.985$) but each of the D and E-speed films had higher diagnostic accuracy than E/F films ($p<0.0001$ for both).

In 4 week-old developer, the mean Az was 0.6196 for D-speed films, 0.6724 for E-speed films and 0.2080 for E/F speed films. Significant differences existed in diagnostic accuracy of radiographic

films in 4-week old developer ($p<0.0001$). Multiple comparisons by Tukey's test revealed that the difference in this regard between D and E-speed films was not significant ($p=0.985$) but each of the D and E-speed films had higher diagnostic accuracy than E/F films ($p<0.0001$ for both).

Table 2. Az values for each of the observers based on the size of endodontic file

Size of endodontic file	
10	15
0.348	0.652
0.387	0.613
0.330	0.670
0.357	0.643
0.369	0.631

The mean Az in observers was 0.6310 for fresh developer, 0.6144 for 2-week old solution and 0.2542 for 4-week old solution. The difference in diagnostic accuracy based on the developer age was significant ($p<0.0001$). Multiple comparisons by Tukey's test revealed that the difference between fresh and 2 week-old solution was not significant ($p=0.809$) but the diagnostic accuracy of films developed by 4 week-old solution was significantly lower than that of films developed by fresh and 2-week old solutions ($p<0.0001$ for both).

Table 3. Az values for each of the observers based on the size of endodontic file

Fresh	Two weeks	Four weeks
0.602	0.624	0.274
0.663	0.635	0.201
0.619	0.620	0.261
0.652	0.646	0.201
0.619	0.547	0.334

The mean Az of observers was 0.3582 when taking radiographs with #10 endodontic files and 0.6418 when taking radiographs with #15 endodontic files. Student's t-test compared the diagnostic accuracy in presence of #10 and #15 files and demonstrated that the diagnostic accuracy was significantly lower when #10 file was used ($p<0.0001$). Such results were also found for different ages of developer.

Cronbach's alpha was calculated to determine the intraobserver reliability. For this purpose, three observers were randomly selected among the five to re-evaluate 10 films and the results showed that the Cronbach's alpha was 0.871, 0.976 and 0.993 in the three, which are all high enough values.

Discussion

Agfa Dentus M2 E/F speed film had the lowest diagnostic accuracy in developers of different ages. The smallest Az belonged to this film in solutions of different ages. D-speed and E-speed films (Kodak) had similar diagnostic accuracy in the three ages of developer and their diagnostic accuracy was significantly higher than that of Dentus D2 films. Az values for D-speed films developed by fresh, 2 week-old and 4 week-old developers were 0.5882, 0.5718 and 0.6724, respectively. These values for E-speed films were 0.5538, 0.5718 and 0.6724, respectively. Despite the lack of significant differences, the diagnostic accuracy of D-speed films in fresh and 2 week-old solutions was slightly higher than that of E speed films. This order was reverse for 4 week-old developer and the accuracy of E-speed film was slightly higher than that of D-speed film.

Syriopoulos et al, in 1999 showed that the diagnostic accuracy of Dentus M2 film decreased as the developer aged but D-speed film maintained its higher accuracy by increased age of developer [12].

The same results were obtained by Syriopoulos et al, in their study in 1999 on the effect of age of developer on detection of proximal caries on three films with different speeds [13]. Our obtained results in this respect are in accord with those of the mentioned two studies. However, the mentioned studies evaluated the developer age by up to 6 weeks and exhaustion of solutions was evaluated after 3 and 4 weeks. In a study by de Carvalho et al, in 2011, it was reported that FV-58 films had stable characteristics in manual aged developers [14]. Our study showed that exhaustion of developer occurred after 4 weeks. It appears that

endodontic files affect the diagnostic accuracy of films by forming high-contrast radiopacities and consequently influencing the exhaustion time of developer. In contrast to our findings, the mentioned studies demonstrated that before exhaustion, the developers did not cause significant differences in diagnostic accuracy of the three types of films. In our study, E/F speed film had lower diagnostic accuracy in fresh, 2 week-old and 4 week-old solutions. The diagnostic accuracy of this film significantly decreased in 4 week-old solution.

The diagnostic accuracy (mean Az) was the highest when using fresh solution followed by two-week and 4 week-old solutions and this difference for the 4 week-old solution was significant. The limited reduction in diagnostic accuracy when using 2 week-old compared to fresh solution was not significant.

Despite the significant reduction in diagnostic accuracy when using 4 week-old solution, it should be noted that this difference was due to the type of film used and not the age of developer; because evaluation of diagnostic accuracy of understudy films based on developer age showed that D and E-speed films developed in 4 week-old solution had the same diagnostic accuracy as in other developers and only the E/F speed film experienced a significant reduction in diagnostic accuracy in 4 week-old solution. In other words, it can be stated that D and E-speed films developed with a 4 week-old developer can have the same diagnostic accuracy as those developed in fresh or 2 week-old developers. But Agfa Dentus M2 E/F films should be only developed in fresh or 2 week-old developers. Some previous studies have evaluated the diagnostic accuracy of films and solutions based on the size of file placed into the root canal [12] and thus, this was also done in the current study. The diagnostic accuracy of radiographs taken with #10 endodontic files in the root canals was significantly lower compared to using #15 files. This result was true for the three types of developers in terms of age ($p<0.0001$).

In a study by Syriopoulos et al, in 1999, endodontic file size significantly affected the diagnostic accuracy of radiographs [12]. All visual stimulations are justified in the context of spatial frequencies. Objects with high spatial frequency show the sharp edges while low spatial frequency shows the details of objects. These objects have rough characteristics providing the observer with valuable information for their detection. Fogging of the visual stimuli decreases the contrast of objects with high spatial frequency but has no effect on objects with low spatial frequency. Based on the results of the current study, aging of the developer and decreased contrast resulted in pale radiographs. Although type of endodontic file and the root (with low spatial frequency) were still detectable, the diagnostic accuracy for detection of the position of endodontic file tip and root apex (with high spatial frequency) decreased. This reduction was more apparent for # 10 endodontic file [15].

Contrast sensitivity function (CSF) enables distinguishing objects better than the visual accuracy [15]. Visual accuracy defines the ability of the eyes to observe small stimuli like alphabets on a sheet but CSF indicates the ability of the eyes to observe spatial details of small and large objects. CSF is the minimum contrast that enables distinguishing similar objects with certain distances (a variable series of light and dark objects). The contrast threshold for an individual is defined as the individual's performance in distinguishing objects with certain distance (number of light and dark objects in a field of view).

Conclusion

The diagnostic accuracy of D- and E-speed films in developing solutions of different ages was equal and also higher than that of Agfa Dentus M2 E/F speed films. Considering the lower radiation dose required for E-speed films (compared to D-speed), they can be processed with up to 4 week-old developers in the clinical setting with no reduction in their diagnostic accuracy. For Agfa Dentus M2 E/F speed films, the developer must be fresh or maximally 2 weeks old and 4 week-old developers must not be used for processing of this type of radiographic films.

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