A Scanning Electron Microscopic Evaluation of the Effectiveness of the F-file versus Ultrasonic Activation of a K-file to Remove Smear Layer

Sonia Chopra, DDS, Peter E. Murray, PhD, and Kenneth N. Namerow, DDS

Abstract

The objective of this study was to compare the effectiveness of F-files and ultrasonics to remove the smear layer from instrumented root canals when irrigated with sodium hypochlorite and EDTA. Sixty healthy human premolar teeth were instrumented with ProTaper file series to F3, and the canals were enlarged with Profiles 35/.06, 40/.06, and 45/.06. The canals were then instrumented with either the F-file or an ultrasonically activated #20 K-file with or without EDTA. The removal of smear layer was visualized using blind scanning electron microscopic micrographs. There appeared to be little difference between the F-file and the ultrasonically activated #20 K-file in removal of the smear layer with or without EDTA. The effect of ultrasonic activation appeared to be self-limiting with high-volume flushes of irrigant. It appears the F-file was not any more beneficial in removing smear layer. Conversely, smear layer removal appears to be mostly influenced by the introduction of an EDTA rinse. *(J Endod 2008;34:1243–1245)*

Key Words

Endodontics, irrigants, root canal, scanning electron microscope

From the Nova Southeastern University, Fort Lauderdale, FL.

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Address requests for reprints to Dr Kenneth Namerow, Department of Endodontics, College of Dental Medicine, Nova Southeastern University, 3200 South University Drive, Fort Lauderdale, FL 33328-2018. E-mail address: knamerow@nova.edu.

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The mechanical instrumentation of the root canal creates an irregular layer of debris, known as the smear layer, which is formed on the dentinal walls (1, 2). The advantages or disadvantages of the presence of smear layer are still controversial (3–6). The smear layer has been shown to prevent the penetration of intracanal disinfectants (7) and sealers (8) into the dentinal tubules, which may result in compromising the seal of the root filling (9, 10). A systematic review and meta-analysis (11) observed that the overall consensus has moved toward favoring the removal of the smear layer, which requires the use of a chelating agent or acid conditioner, the most common agent being EDTA.

Sodium hypochlorite (NaOCl) has become the most widely used irrigating solution in endodontics (12, 13). The effectiveness of the irrigating solution to remove infected tissues from the root canal system may be enhanced by ultrasonic activation (14). Ultrasonics was first introduced by Richman in 1957 (15). Some studies have shown that the acoustic streaming of the irrigant can produce cleaner root canal surfaces (16), particularly in areas of complex root anatomy when compared with the routine syringe delivery of the irrigant (17). The enhanced effectiveness of an irrigating solution to remove infected tissues by ultrasonic activation can be beneficial because 35% to 53% of the root canal surfaces appear to remain untouched after mechanical instrumentation (18). The use of ultrasonics in endodontics has been claimed to enhance the overall quality of treatment and be an important adjunct in the treatment of difficult cases (19).

Recently, a new plastic rotary finishing file has been developed called the F-file. This presterilized, single-use, plastic rotary file has a unique design with a diamond abrasive embedded into a nontoxic polymer. This file was designed to remove dentinal wall debris and agitate the sodium hypochlorite without further enlarging the canal (20). The file tip is equivalent to a size #20 K-file, and it has a .04 taper. The F-file was designed to be as effective as sonic and ultrasonic instrumentation and to be used as a replacement (20). However, the cutting effectiveness of different endodontic rotary file systems has proved to be controversial (21). There appears to be a need to investigate the effectiveness of the F-file.

The objective of this study was to compare the effectiveness of the F-file with an ultrasonically activated #20 K-file in removing the smear layer after biomechanical instrumentation and irrigation with sodium hypochlorite, with or without a flush of EDTA.

Materials and Methods

Sixty extracted human premolar teeth with a single canal were used in this study following institutional review board approval. The presence of a single canal was verified with two digital radiographs in a mesiodistal and a buccolingual direction. The teeth were decoronated at the cementoenamel junction with a rotary bone saw (Buehler, Lake Bluff, IL).

All teeth were prepared with rotary instruments in order to produce a smear layer. Working length was determined by passively placing a #10 K-file (Dentsply Tulsa, Oklahoma City, OK) in the canal until the tip of the instrument visibly penetrated and was adjusted to the apical foramen. The actual canal length was measured, and the working length was calculated by subtracting 1 mm from this measurement. The teeth were instrumented with ProTaper (Dentsply Tulsa Dental, Oklahoma City, OK) file series to

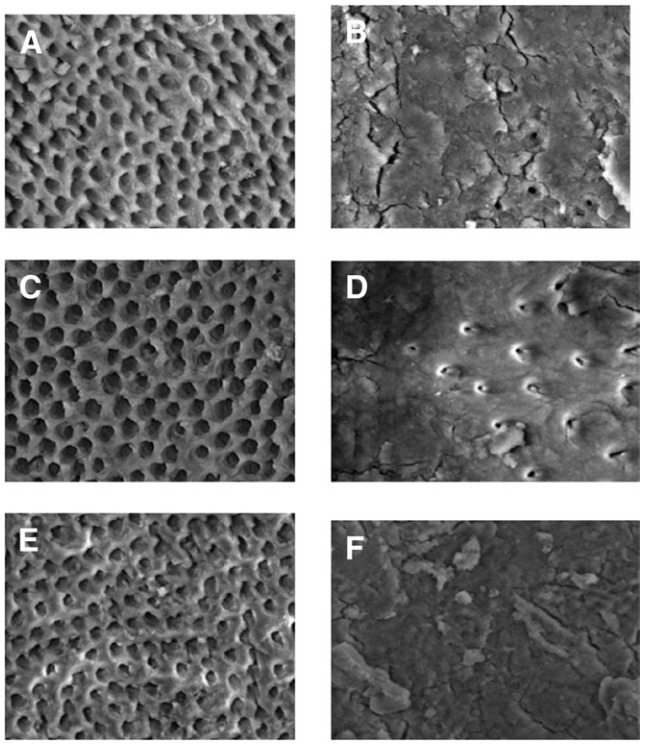

Figure 1. Scanning electron micrographs of the middle aspect of root canals. (*A*) F-file: 6% NaOCl and 17% EDTA, (*B*) F-file: 6% NaOCl, (*C*) ultrasonics: 6% NaOCl and 17% EDTA, (*D*) ultrasonics: 6% NaOCl, (*E*) 6% NaOCl and 17% EDTA, and (*F*) saline.

F3, and the canals were further enlarged with Profiles (Dentsply, Tulsa Dental) 35/.06, 40/.06, and 45/.06. The canals had a final preparation of 45/.06, and the teeth were irrigated with 10 mL of 6% NaOCl (Clorox, Oakland, CA) during preparation except for the control group. After canal preparation, the teeth were randomly divided into six equal groups. Groups 1, 2, and 3 were irrigated according to the protocol developed by Yamada et al. (6) with a final flush of 10 mL 17% EDTA (Vista Dental Products, Racine, WI) and 10 mL 6% NaOCl. In group 1, the F-file (PlasticEndo, Buffalo Grove, IL) was used to activate the 17% EDTA for 30 seconds at 600 rpm in the electric slow speed rotary handpiece (Dentsply Tulsa Dental). A new F-file was used for every tooth. In group 2, a #20 K-file under ultrasonic vibration (Enac; Osada Electrical Co Ltd, Tokyo, Japan) was used to activate the 17% EDTA for 1 minute. In group 3, the irrigants were introduced into the canal by needle syringe delivery (Luer-Lock; Sherwood, St Louis, MO). In group 4, 10 mL saline was introduced into the canal by needle syringe delivery during preparation, no final flush was used, and this served as the control group. In groups 5 and 6, the teeth were irrigated with a final flush of 10 mL 6% NaOCl only. No 17% EDTA was used in these groups. In group 5, the 6% NaOCl was activated with the F-file for 30 seconds at 600 rpm in an electric slow-speed rotary handpiece. In group 6, the 6% NaOCl was activated with a #20 K-file under ultrasonic activation for 1 minute.

After preparation and irrigation, the specimens were fractured with a chisel and prepared for the scanning electron microscopy (SEM) (22). The samples were then viewed in their entirety in a Quinta 200 SEM (FEI, Hilsboro, OR). SEM micrographs were obtained at a ×2,000 magnification of the coronal, middle, and apical areas of each root canal using digital image analysis software (22). Each micrograph was scored blind for the amount of smear layer using a semiquantitative scale by two independent evaluators using a 4-step scale as follows: (0) all tubules visible, (1) more than 50% of tubules visible, (2) less than 50% of tubules visible, and (3) no tubules visible. The removal of smear layer from the root canals was analyzed by using chi-square statistics tests (Statview; SPSS, Cary, NC).

Results

The most effective treatments to remove smear layer was observed when a flush of EDTA was used: the combination of the F-file/NaOCl/EDTA removed smear layer (Fig. 1*A*), whereas the same treatment without EDTA did not (Fig. 1*B*). The combination of the ultrasonics/NaOCl/EDTA removed smear layer (Fig. 1*C*), whereas the same treatment without EDTA did not (Fig. 1*D*). The combination of the NaOCl/EDTA removed smear layer (Fig. 1*E*), whereas NaOCl without EDTA did not (Fig. 1*F*).

There were differences in the effectiveness of smear layer removal between the six root canal treatment groups (χ^2, $p < 0.0001$). The first three treatment groups had some complete removal of the smear layer in 3.3% to 6.6% of the visualized root canal surfaces (Fig. 2). The majority of the visualized root canals in these treatment groups, 43.4% to 56.7%, were less than half covered with smear layer (Fig. 2). A large proportion, 30.0% to 40.0%, of the root canals was more than half covered with smear layer (Fig. 2). A few of these root canal treatments, 6.6% to 10%, appeared to have no removal of smear layer. There was little difference in the effectiveness of the first three root canal treatments to remove smear layer (χ^2, $p < 0.9302$).

In the final three treatment groups, only the ultrasonics/NaOCl treatment removed more than half of the smear layer, but this was only in 3.3% of the root canals visualized (Fig. 2). A large proportion, 13.3% to 36.7%, of these root canals was more than half covered with the smear layer (Fig. 2). The majority; 60.0% to 86.7%, of the visualized root canal surfaces were completely covered with smear layer (Fig. 2). In the absence of a flush of EDTA, there was little difference in the effectiveness of the final three root-canal treatments to remove smear layer (χ^2, $p < 0.0614$).

The semiquantitative analysis of smear layer removal found that the first three treatment groups were the most effective to remove smear layer, all with a flush of EDTA (Fig. 3). Overall, for all six categories, the removal of smear layer from the apical, middle, and coronal regions were similar (χ^2, $p > 0.05$). Slightly more smear layer appeared to be visible in the apex of the root canals in the first and third treatments (Fig. 3), but the difference was not significant (χ^2, $p > 0.05$). The most

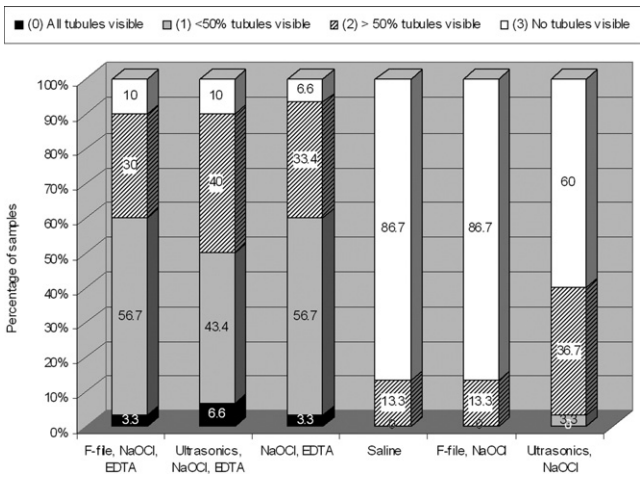

Figure 2. Smear layer removal after root canal instrumentation.

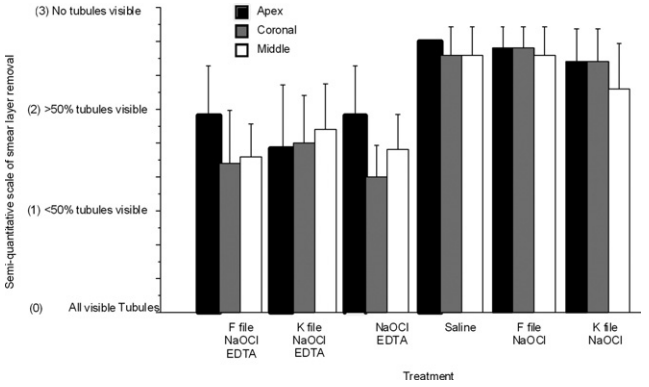

Figure 3. Bar chart of smear layer removal from the apex, middle, and coronal aspects of root canals.

important treatment variable for the removal of smear layer from the root canal was a flush of EDTA (χ^2, $p < 0.0001$).

Discussion

The effectiveness of endodontic files, rotary instrumentation, irrigating solutions, and chelating agents to clean, shape, and disinfect root canals underpins the success, longevity, and reliability of modern endodontic treatments. Nevertheless, controversy still exists regarding the effectiveness of a myriad of file systems, ultrasonic irrigation, irrigating solutions, and chelating agents needed to accomplish the chemomechanical cleansing of the root canal system (23).

The present study used the high-volume irrigant flushing protocol developed by Yamada et al. (6). It was found that incorporating a final flush with 10 mL 17% EDTA followed by 10 mL 5.25% NaOCl resulted in cleaner canals with greater numbers of visible dentinal tubules in SEM micrographs (6). When the volumes of irrigating solutions were equalized in the present study, the ultrasonic activation of the K-file (group 2) removed a similar amount of smear layer as the F-file (group 1) and the controls (group 3). The results suggest that flushing the root canals with high volumes of EDTA has a greater potential to remove smear layer than ultrasonic activation. Further research is needed to measure the effectiveness of ultrasonic irrigation in combination with different flushing volumes of NaOCl irrigant as part of root canal cleaning and shaping.

In the present study, the most effective treatments in removing smear layer were the F-file or ultrasonics with NaOCl irrigation in combination with a flush of EDTA. In the absence of EDTA, the smear layer was observed to cover the root canal surface, even when using the F-file or ultrasonic K-file activation. These observations are in agreement with previous studies that have shown that EDTA or other chelating agents, such as SmearClear (SybronEndo, Orange, CA), 17% EDTA, or 10% citric acid, are needed to remove the smear layer after NaOCl irrigation (24, 25). The effect of the volume of EDTA used to remove smear layer has been found to be self-limiting (23). According to manufacturer instructions, the F-file was used in the canal for 30 seconds with an exposure of EDTA compared with 60 seconds in the ultrasonic K-file treatment group. The difference in the time of EDTA exposure between the treatment groups did not influence smear layer removal in the present study. The results of the present study and the previous studies all emphasize the need to use EDTA to accomplish smear layer removal. Several modifications of EDTA has been attempted to improve its ability to remove smear layer, including the addition of surfactants, but these have not proved to be successful (26). Future research is needed to compare smear layer removal with the F-file in comparison with ultrasonic activation from more curved canals and prepared to smaller sizes.

Conclusion

This study did not identify any increase in smear layer removal by using the F-file when comparing it with the ultrasonically activated K-file, with or without a rinse of EDTA. The present study suggests that the F-file is not beneficial in removing the smear layer. Further investigation of the effectiveness of the F-file is required to justify its expense and the extra working time necessary for its use.

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