Effects on Smear Layer and Debris Removal with Varying Volumes of 17% REDTA after Rotary Instrumentation

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Abstract

The purpose of this study was to quantify the volume of 17% ethylene diamine tetra-acetic acid (EDTA) needed to efficiently remove the smear layer after rotary instrumentation, and to determine if additional irrigation has any effect on debris removal. Forty single canal teeth were instrumented with ProFile GT rotary instruments. Experimental groups were irrigated with 1, 3, or 10 ml of 17% EDTA for 1 min, followed by a final rinse with 3 ml of 5.25% sodium hypochlorite (NaOCl). Samples were scored for debris remaining and examined under SEM to determine quality of smear layer removal. There were no significant differences among groups when comparing either debris remaining or quality of smear layer removal. EDTA irrigation volume greater than 1 ml did not improve debris removal. Efficient removal of the smear layer was accomplished with a final rinse of 1 ml of 17% EDTA for 1 min, followed by 3 ml of 5.25% NaOCl.

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There is no clear consensus in the endodontic community as to whether the smear layer should be removed before obturation (1). Proponents state that removal of the smear layer allows for intimate contact of irrigants and medicaments with potentially infected dentinal tubules. Bystrom et al. showed that 5% sodium hypochlorite (NaOCl) combined with 15% ethylene diamine tetra-acetic acid (EDTA) was significantly more effective in reducing the number of bacteria surviving after instrumentation than 5% NaOCl alone (2). Diffusion of medicaments, such as calcium hydroxide, through the dentinal tubules has been shown to increase when the smear layer is removed (3–5). Other studies demonstrated that smear layer removal increases the bond strength of resin sealers (6), resulting in a significantly better apical seal (7). Opponents to smear layer removal have found that the smear layer acts as a barrier, inhibiting bacterial colonization of the dentinal tubules (8). A major endodontic pathogen in post-treatment disease, *Enterococcus faecalis*, has been shown to rapidly invade the dentinal tubules after smear layer removal (9).

Controversy also exists on how to best remove the smear layer. The most debated elements of smear layer removal are volume of irrigation and contact time. Yamada et al. found that a final rinse with 10 ml of 17% EDTA followed by 10 ml of 5.25% NaOCl was the most effective method (10). Other methods have also been effective, ranging from the use of 2 ml of 15% EDTA as a final rinse (11) to the use of 30 ml of 15% EDTA during instrumentation (12). Gettleman et al. showed that a contact time of 3 min with 17% EDTA was effective for smear layer removal (6). Calt and Serper demonstrated that a 10 ml irrigation with 17% EDTA for 1 min was effective in removing the smear layer, but a 10 min application caused excessive peritubular and intertubular dentinal erosion (13). Increasing contact time and concentration of EDTA from 10 to 17%, as well as using a pH of 7.5 versus pH 9.0 have been shown to increase demineralization of dentin (14).

Another area of interest is the potential for debris removal with additional irrigation. Effective debris removal has been related to volume of irrigation rather than type of irrigant (15). It has also been linked to the depth of needle penetration (16) and a minimum apical preparation of 0.3 mm (17). Max-i-Probe irrigation tips have been shown to be the most efficient irrigating instrument (18). In combination with NaOCl, different irrigating regimens with Glyde File Prep have been shown to be equally effective with 17% EDTA in decreasing debris remaining after instrumentation and in removing the smear layer (19, 20).

Recently, in comparing a mixture of tetracycline isomer, an acid, and a detergent (MTAD) with 17% EDTA for smear layer removal, Torabinejad et al. used 1 ml of 17% EDTA or MTAD on a cotton-wrapped barbed broach placed to working length followed by a 4 ml final flush, with a total contact time of 5 min (21). The EDTA group showed more debris in the apical third and more peritubular erosion in the coronal sections when compared to the MTAD group.

The purpose of this study was to quantify the volume of 17% ETDA needed to efficiently remove the smear layer after rotary instrumentation, and to determine if additional irrigation has any effect on debris removal.

Methods and Materials

Forty single canal anterior and premolar human teeth stored in 0.2% sodium azide were decoronated to a standardized length of 15 mm. A #10 FlexoFile (Dentsply

Maillefer, Johnson City, TN) was placed until just visible at the apex to determine patency and 1 mm was subtracted to establish working length. Rotary instrumentation was performed with ProFile GT 0.08, 0.06, and 0.04 taper rotary files (Tulsa Dental, Tulsa, OK) in a crown-down fashion to a standardized master apical file #40, 0.04 taper, while irrigating with 1 ml of 5.25% NaOCl between files. The teeth were divided into three experimental groups and a positive control group. Group 1, the positive control, did not receive a rinse with 17% REDTA (Roth International LTD, Chicago, IL). The three experimental groups all received a rinse of 17% REDTA with a total contact time of 1 min, with varying volumes as follows: Group 2, 1 ml; group 3, 3 ml; and group 4, 10 ml. All four groups then received a final rinse with 3 ml of 5.25% NaOCl. Irrigation was performed using 28 gauge Max-i-Probe (Dentsply Rinn, Elgin, IL) irrigation tips placed 1 mm from working length. Samples were longitudinally grooved with a diamond disk and split buccolingually. They were then photographed using a Nikon Coolpix 4500 (NIKON, Melville, NY) at X4 and images were imported to Adobe Photoshop 7.0 (Adobe Systems, San Jose, CA). Images were then magnified at X10 by means of the Zoom tool. Using the Lasso tools, canal area and debris were outlined. The histogram function was used to calculate the percentage of debris remaining within the apical, middle, and coronal thirds and the entire canal space. Statistical analysis was performed using one-way ANOVA and the Student Newman-Kuels test for multiple comparisons.

To determine the quality of smear layer removal, four samples were randomly selected from each group, dried for 24 h, and sputter coated in preparation for SEM analysis using standard techniques. SEM was performed using a JEOL JSM-5300 Scanning Electron Microscope (JEOL USA, Inc., Peabody, MA). The smear layer was scored according to the following criteria used by Torabinejad et al. (21):

A score of:
- 1 = No smear layer. No smear layer on the surface of the root canal; all tubules were clean and open.
- 2 = Moderate smear layer. No smear layer on the surface of the root canal, but tubules contained debris.
- 3 = Heavy smear layer. Smear layer covered the root canal surface and the tubules.

Representative photomicrographs of the respective areas were then exposed at various magnifications from ×750 to ×2,000 to show varying levels of detail. Statistical analysis was performed using the Kruskal-Wallis test with subsequent pair-wise comparisons of the individual groups. All statistical analyses were set with a significance level of $p < 0.05$.

Results

Average debris remaining for the entire canal space and each individual canal third is presented in Fig. 1. With one exception, groups 1 through 4 demonstrated no significant difference with respect to debris remaining when comparing the apical, middle, and coronal thirds, or the entire canal. The only significant difference in the debris remaining was between the coronal thirds of groups 1 and 2, with group 2 having significantly less debris than group 1, the positive control.

The results for smear layer removal are presented in Fig. 2. Group 1, the positive control, was heavily smeared in the apical and middle thirds, with a moderate smear layer in the coronal third. Many of the dentinal walls in this group were completely uninstrumented and no smear layer had been generated. Although the dentinal tubules were open, debris usually occupied these regions. In groups 2, 3, and 4, the smear layer was removed equally well with no significant difference between groups. Very little to no peritubular or intertubular erosion was seen in groups 2, 3, or 4. The erosion that was seen was confined to the coronal areas of all samples. Representative photomicrographs of the apical, middle, and coronal thirds of group 2 are shown in Fig. 3.

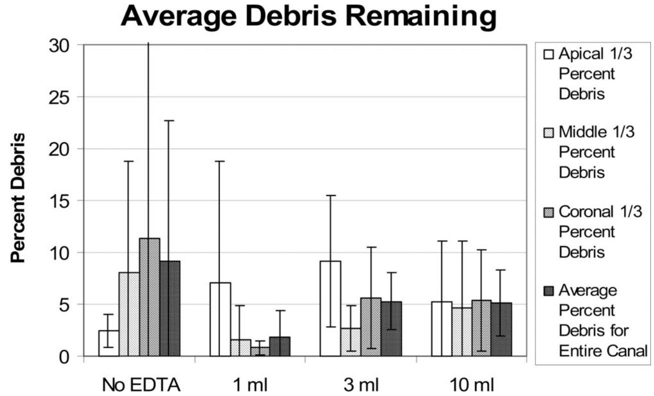

Figure 1. Average remaining debris for the individual canal thirds and the entire canal space after irrigation with varying volumes of 17% EDTA and a final rinse with 3 ml of 5.25% NaOCl.

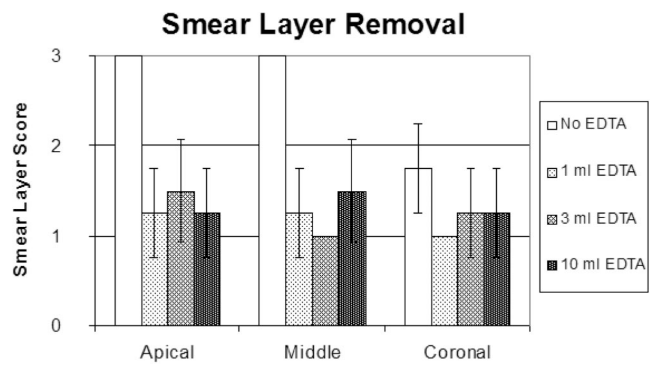

Figure 2. Quality of smear layer removal for individual canal thirds after irrigation with varying volumes of 17% EDTA and a final rinse with 3 ml of 5.25% NaOCl. No standard error bars are seen on four of the columns because all measurements within these groups were the same.

Discussion

Nickel-titanium rotary instrumentation is known to remain well centered within the canal (22), and augers out debris produced during instrumentation (23). Previous studies using passive sonics or ultrasonics after hand instrumentation have shown a significant reduction in the debris remaining after instrumentation. In a study by Jensen et al., debris scores after 3 min of passive sonic or ultrasonic irrigation were 15.1% for the sonic group and 16.7% for the ultrasonic group, while the mean debris score for hand instrumentation alone was 31.6% (24). Sabins et al. found that debris scores in the apical 3 mm of the canal were 19.7% after 1 min of passive sonic irrigation and 15.4% after 1 min of passive ultrasonic irrigation (25). The debris remaining after hand instrumentation alone was 36.7%. Debris scores in the present study were much lower, with rotary instrumentation alone (no smear layer removal) averaging 9.18%. Although not significant, there was a trend for more debris removal with additional irrigation of 1, 3, or 10 ml of 17% REDTA over rotary instrumentation alone. The results of this study are in agreement with the findings of Gambarini and Laszkiewicz in that there was no significant difference between the three regions of the root canal and debris remaining (26).

The amount of debris remaining may be related to the type of instrumentation and internal canal morphology. Teeth with internal

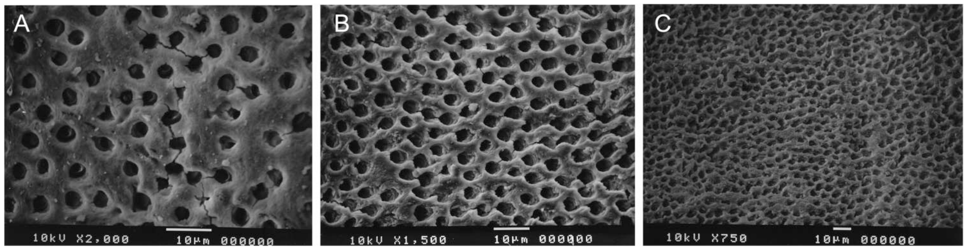

Figure 3. Quality of smear layer removal in Group 2 for (A) Apical third; (B) Middle third; and (C) Coronal third seen with tubular erosion, after irrigation with varying volumes of 17% EDTA and a final rinse with 3 ml of 5.25% NaOCl.

anatomical variations such as resorptive defects, lateral canals, and ribbon-shaped canals demonstrated very high debris scores when compared to other teeth within each treatment group, whereas narrow constricted canals had lower debris scores. This could explain the large standard deviations observed within groups and why statistical significance was only seen between the coronal third of groups 1 and 2. The size of instruments used during instrumentation has also been shown to affect debris remaining in the apical one-third of the canal. Size 20 GT rotary instruments left significantly more debris in the apical third when compared to size 40 GT instruments (27). An area for further study might be to determine if passive sonic or ultrasonic irrigation after rotary instrumentation would further reduce debris remaining, especially in teeth with anatomical variances.

The effects of EDTA within the canal are known to be self-limiting. Seidberg and Schilder determined that EDTA will react with 73% of the available inorganic dentin component, forming an equilibrium within 7 h (28). It may be hypothesized that the effects of EDTA within the canal are a function of contact time with no relation to volume of irrigation. The independent variable for this study, contact time, was chosen based upon the findings of Calt and Serper, in that one minute was sufficient for smear layer removal. In their study, 10 ml of EDTA was the only volume of irrigation used. An observation in the present study was that excessive force, most often requiring the use of two hands, was needed to deliver all of the irrigant during the 1 min time constraint, resulting in operator fatigue.

EDTA has been shown to be a potent inhibitor of macrophage adherence (29), possibly by preventing the binding of VIP to the macrophage, altering the inflammatory mechanisms involved in periradicular lesions (30). Therefore, a controlled delivery of EDTA is important to prevent possible apical extrusion.

This study demonstrated that 1 ml of EDTA with a contact time of 1 min was just as effective as 10 ml. This may allow for faster treatment, more controlled delivery, less operator fatigue, and a potential cost savings. In conclusion, under the parameters of this study, no further debris removal was seen with additional EDTA irrigation over 1 ml, and 1 ml of EDTA was just as effective in removing the smear layer as 10 ml.

Acknowledgment

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References

1. Moss HD, Allemang JD, Johnson JD. Philosophies and practices regarding the management of the endodontic smear layer: results from two surveys. J Endod 2001;27:537–9.
2. Bystrom A, Sundqvist G. The antibacterial action of sodium hypochlorite and EDTA in 60 cases of endodontic therapy. Int Endod J 1985;18:35–40.
3. Foster KH, Kulild JC, Weller RN. Effect of smear layer removal on the diffusion of calcium hydroxide through radicular dentin. J Endod 1993;19:136–40.
4. Han GY, Park SH, Yoon TC. Antimicrobial activity of Ca(OH)2 containing pastes with *Enterococcus faecalis* in vitro. J Endod 2001;27:328–32.
5. Lynne RE, Liewehr FR, West LA, Patton WR, Buxton TB, McPherson JC. In vitro antimicrobial activity of various medication preparations on *E. faecalis* in root canal dentin. J Endod 2003;29:187–90.
6. Gettleman BH, Messer HH, El Deeb ME. Adhesion of sealer cements to dentin with and without the smear layer. J Endod 1991;17:15–20.
7. Cergneux M, Ciucchi B, Dietschi JM, Holz J. The influence of the smear layer on the sealing ability of canal obturation. Int Endod J 1987;20:228–32.
8. Drake DR, Wiemann AH, Rivera EM, Walton RE. Bacterial retention in canal walls in vitro: effect of smear layer. J Endod 1994;20:78–82.
9. Haapasalo M, Orstavik D. In vitro infection and disinfection of dentinal tubules. J Dent Res 1987;66:1375–9.
10. Yamada RS, Armas A, Goldman M, Lin PS. A scanning electron microscopic comparison of a high volume final flush with several irrigating solutions: part 3. J Endod 1983;9:137–42.
11. Ciucchi B, Khettabi M, Holz J. The effectiveness of different endodontic irrigation procedures on the removal of the smear layer: a scanning electron microscopic study. Int Endod J 1989;22:21–8.
12. Baumgartner JC, Mader CL. A scanning electron microscopic evaluation of four root canal irrigation regimens. J Endod 1987;13:147–57.
13. Calt S, Serper A. Time-dependent effects of EDTA on dentin structures. J Endod 2002;28:17–9.
14. Serper A, Calt S. The demineralizing effects of EDTA at different concentrations and pH. J Endod 2002;28:501–2.
15. Baker NA, Eleazer PD, Averbach RE, Seltzer S. Scanning electron microscopic study of the efficacy of various irrigating solutions. J Endod 1975;1:127–35.
16. Abou-Rass M, Piccinino MV. The effectiveness of four clinical irrigation methods on the removal of root canal debris. Oral Surg Oral Med Oral Pathol 1982;54:323–8.
17. Teplitsky PE, Chenail BL, Mack B, Machnee CH. Endodontic irrigation–a comparison of endosonic and syringe delivery systems. Int Endod J 1987;20:233–41.
18. Kahn FH, Rosenberg PA, Gliksberg J. An in vitro evaluation of the irrigating characteristics of ultrasonic and subsonic handpieces and irrigating needles and probes. J Endod 1995;21:277–80.
19. Grandini S, Balleri P, Ferrari M. Evaluation of Glyde File Prep in combination with sodium hypochlorite as a root canal irrigant. J Endod 2002;28:300–3.
20. Lim TS, Wee TY, Choi MY, Koh WC, Sae-Lim V. Light and scanning electron microscopic evaluation of Glyde File Prep in smear layer removal. Int Endod J 2003;36:336–43.
21. Torabinejad M, Khademi AA, Babagoli J, et al. A new solution for the removal of the smear layer. J Endod 2003;29:170–5.
22. Zmener O, Balbachan L. Effectiveness of nickel-titanium files for preparing curved root canals. Endod Dent Traumatol 1995;11:121–3.
23. Reddy SA, Hicks ML. Apical extrusion of debris using two hand and two rotary instrumentation techniques. J Endod 1998;24:180–3.
24. Jensen SA, Walker TL, Hutter JW, Nicoll BK. Comparison of the cleaning efficacy of passive sonic activation and passive ultrasonic activation after hand instrumentation in molar root canals. J Endod 1999;25:735–8.
25. Sabins RA, Johnson JD, Hellstein JW. A comparison of the cleaning efficacy of short-term sonic and ultrasonic passive irrigation after hand instrumentation in molar root canals. J Endod 2003;29:674–8.
26. Gambarini G, Laszkiewicz J. A scanning electron microscopic study of debris and smear layer remaining following use of GT rotary instruments. Int Endod J 2002;35:422–7.
27. Usman N, Baumgartner JC, Marshall JG. Influence of instrument size on root canal debridement. J Endod 2004;30:110–2.
28. Seidberg BH, Schilder H. An evaluation of EDTA in endodontics. Oral Surg Oral Med Oral Pathol 1974;37:609–20.
29. Segura-Egea JJ, Jimenez-Rubio A, Rios-Santos JV, Velasco-Ortega E, Calvo-Gutierrez JR. In vitro inhibitory effect of EGTA on macrophage adhesion: endodontic implications. J Endod 2003;29:211–3.
30. Segura JJ, Calvo JR, Guerrero JM, Sampedro C, Jimenez A, Llamas R. The disodium salt of EDTA inhibits the binding of vasoactive intestinal peptide to macrophage membranes: endodontic implications. J Endod 1996;22:337–40.