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.

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

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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 Kruksal-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.

**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...
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 variations.

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.

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References