



Cleaning Efficiency of Anatomic Endodontic Technology, ProFile System and Manual Instrumentation in Oval-shaped Root Canals: An *in vitro* Study

E Sujayeendranath Reddy, Dinapadu Sainath, M Narendrereddy, Srikanth Pasari
Sangeetha Vallikathan, G Sindhureddy

ABSTRACT

Aim: This *in vitro* study is an attempt to compare the effectiveness in cleaning oval shaped root canals using Anatomic Endodontic Technology (AET[®]), ProFile system[®] and Manual Instrumentation with K-files.

Methodology: Sixty oval shaped single rooted maxillary and mandibular premolars with straight canals were divided in to three groups. The root canals were, confirmed as being oval shape by means of radiographs made in a buccolingual and mesiodistal direction. Automated canal preparation was performed using Anatomic Endodontic Technology (group 1) and the ProFile system[®] (group 2). Manual instrumentation (group 3) was performed with k-files. Irrigation was performed using alternatively 3% NaOCl and 17% EDTA, followed by rinsing with normal saline. The roots were split longitudinally into two halves and examined under a scanning electron microscope. The presence of debris and smear layer was recorded at distances 1, 5 and 10 mm from the working length using a three step scoring scale. Mean scores for debris and smear layer was calculated and statistically analyzed for between and within groups significance, using the Kruskal-Wallis non-parametric ANOVA test and Bonferroni's multiple comparison test.

Results: At 1, 5 and 10 mm levels the root canals prepared with AET had significantly less surface debris and smear layer on the canal walls as compared to canals prepared with ProFile system[®] or manual instrumentation. For all three groups significantly lower mean smear layer scores ($p < 0.05$) were recorded at 5 and 10 mm levels compared with the 1 mm level. Significantly lower mean debris scores ($p < 0.05$) were also recorded at 5 and 10 mm levels for the AET group whereas no significant differences were found between the three levels for the ProFile system[®] and manual instrumentation groups.

Conclusion: Although better instrumentation scores were obtained in canals prepared with AET, complete cleanliness was not achieved with any of the techniques and instruments investigated.

Keywords: Anatomic endodontic technology, Oval canals, ProFile, Root canal instrumentation, Scanning electron microscopy.

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INTRODUCTION

Meticulous canal preparation by thorough mechanical debridement coupled with liberal irrigation is the most important objective of conventional root canal therapy. This double-pronged effect is directly related to subsequent disinfection and a three dimensional obturation of the root canal system.¹ A progressive and uniform conical shape, while maintaining the original path of the root canal is often difficult to achieve, because of the high variability of the root canal anatomy.² Cross-sectional variations in the canal shape, anatomy and canal curvature lead to procedural errors such as ledge, zip, elbow formation, canal transportation, perforation, etc.¹

Oval canals which account for nearly 25% of roots have long buccolingual but short mesiodistal diameters. Difficulties have been noted in removing entire inner layer of dentin in these canal walls³ and it is preferable to use an instrument that is able to maintain the original anatomy of the root canal to preserve maximum dentin thickness and further enhance cleaning of buccal and lingual recesses. This also reduces the risk of perforation of the root canal.¹ Conventional methods using circumferential filing and balanced force technique have shown to be ineffective in cleaning oval canals as they do not contact the entire canal wall and thus leave a portion of the wall uninstrumented.³ Even the rotary instruments currently used, such as ProFile and ProTaper systems produced a circular bulge in these

canals while the buccal and lingual extensions remained unprepared with much remaining debris and smear layer.⁴ It is desirable to remove the smear layer formed during instrumentation as it increases dentin permeability, and hence better disinfection.⁵ The cutting efficiency and the ability to clean root canal walls is dependent on the inherent design of the instrument and dynamics used during instrumentation.⁶

Modern preparation techniques such as Anatomic Endodontic Technology along with other new systems should fulfill these tasks and eliminate or at least minimize the degree and types of procedural errors that occur during shaping.¹

Thus, the aim of this study is to compare the cleaning efficiency of Anatomic Endodontic Technology (AET), ProFile system and manual instrumentation in oval shaped root canals.

METHODOLOGY

Sixty freshly extracted single-rooted maxillary and mandibular premolars, each with single straight (5° or less) oval shaped root canal were used.⁷ Single, oval root canal morphology was confirmed by means of radiographs taken in a buccolingual and mesiodistal direction. Canals were determined oval-shaped if the buccolingual to mesiodistal dimensions had a ratio of at least 1.3 to 1.⁶ The teeth were cleaned and stored in a 0.1% thymol solution. After conventional access cavity preparation, size 10 K-files were introduced in the canal space and radiographs were taken. The working length was established by deducting 1 mm from the length recorded when the tip of the file was visible at the apex through magnifying lens ($3\times$). Twenty teeth were randomly allocated to each of the three groups. After the teeth were mounted in plaster blocks, a single operator prepared the specimens using the instrumentation technique designated for each group.

In group 1, the canals were prepared using the AET (Ultra Dent Products Inc., South Jordan, UT, USA) according to the manufacturer's instructions. The operative procedures were as follows. The coronal two-thirds were enlarged with shaping files 1, 2 and 3. Initially, a size 1 shaping file (2.5% taper) was inserted by hand to approximately 4 mm short of the established working length. The file was then used in a reciprocating 4:1 low-speed hand piece and the canal was instrumented to the same length at ± 250 rpm and a side-to-side/up-and-down motion. Intermittently, three to four times, the file was used in a slight lifting motion whilst stroking, to facilitate outward removal of debris. With each stroke, the file was reinserted exerting a buccal to lingual cutting pressure on the outstroke. In teeth in which the mesial and distal aspects provided no resistance, the file was lightly

wiped against these walls for a few seconds. During the reciprocating motion, the canals were constantly flushed with saline. The size 1 shaping file was used until resistance was no longer felt. The same procedures were then repeated for shaping files 2 (4.5% taper) and 3 (6.0% taper). The size 1 shaping file was reinserted by hand to approximately 2 mm from the working length with a quarter turn twist/pull filing motion. Then, the 1, 2 and 3 shaping files were used in the reciprocating hand piece with in-and-out movements to clean and shape the root canal to approximately 2 mm from the working length. For final preparation of the canals, the apical files 1, 2 and 3, which only cut in the apical area and have a 2.5% taper, were then used by hand to the working length with a step-back technique. Files were changed to the next size when no resistance was felt. Preparation of the apical third of the canals was judged complete when the size 3 apical file (equivalent to a size 30 K-file at the tip) could be inserted to the working length without force.

In group 2, the canals were prepared in a crown down manner with ProFile (DentsplyMaillefer, Ballaigues, Switzerland) instruments without exerting lingual and buccal pressure. The instruments were used according to the manufacturer's instructions. Orifice Shapers size 3, 2 and 1 were used sequentially to flare the coronal and middle thirds. ProFile.04 and .06 tapers were then used in the following sequence: 25.06, 20.06 and 25.04 and introduced two-thirds to three-quarters down the canal using light apical pressure at a rotary speed of ± 350 rpm using Anthogyrhandpiece (Kavo). Each instrument was withdrawn when resistance was felt followed by the next instrument. For apical preparation, ProFile 20.04, 25.04, 20.06, 25.06, 30.04 were sequentially used. Final shaping to the working length was achieved with a ProFile 30.06. Instrumentation of the apical third of the canals was considered complete when the size 30.06 ProFile instrument passed to the working length without force. When an instrument failed to go to length, the previous one was used again.

In group 3, the canals were prepared with manual instrumentation, using a step-back technique. The coronal and middle thirds were flared with Gates-Glidden instruments and the apical third was prepared subsequently with sizes 15, 20, 25 and 30 K-files (Mani Inc) to the full working length. Files were used with in-and-out movements in a circumferential manner. Preparation of the apical third was considered complete when a size 30 file could be inserted without force to the working length. Then, K-files from sizes 35 to 60, each size 1 mm short of the preceding instrument, were used for final preparation of the coronal and middle third. The patency of the apical foramen was confirmed with a size 10 K-file.

In all groups, irrigation was performed after each change of instrument using 2.0 ml of a 3% NaOCl solution followed by 2.0 ml of a 17% EDTA solution and a final rinse with 2.0 ml saline. During instrumentation, the canals were flushed with the irrigation solutions using disposable syringes and 30-gauge needles, which were placed to approximately 3 to 4 mm from the working length without binding. Upon completion of instrumentation the needles could be placed to approximately 2 to 3 mm from the working length and the root was finally flushed for 1 min with 2.0 ml of 17% EDTA solution, which was washed with 2.0 ml of 3% NaOCl solution followed by copious irrigation with 4.0 ml saline. Finally the canals were dried with paper points. After preparation, the specimens were stored in 100% relative humidity at 37°C until further use.

A groove was prepared on the buccal and lingual surface of the tooth with a diamond disk, and was then split longitudinally with a chisel. The paired halves of each tooth were coded and mounted side by side on an aluminum stub, coated with 200 Å of gold-palladium and examined under scanning electron microscope. Scanning electron photomicrographs were made at 1000× magnification covering the total circumference of the canal walls at levels 1, 5 and 10 mm from the working length. For evaluation purposes, the total area appearing on the screen at each of the predetermined levels was analyzed.³ When un-instrumented areas were observed they were excluded from evaluation. The amount of debris and smear layer detected at 1000× in each assessment unit was evaluated using a three-step scale.⁶ An independent operator who was unaware of the treatment had performed the scoring. Dentin chips, pulp remnants, larger particles and aggregates appearing haphazardly on the root canal walls were classified as debris. A surface film consisting of remnants of dentin and pulp tissues, with a smeared structured appearance was defined as smear layer.⁶

- Scoring criteria for debris:
 - Score 1: No debris or isolated small particles (+40 micrometers), if present.
 - Score 2: Covering more than 50% of canal walls.
 - Score 3: Almost covering entire canal walls.
- Scoring criteria for smear layer:
 - Score 1: When all dentinal tubules are open and no smear layer is present
 - Score 2: Some dentinal tubules are open and rest covered by smear layer.
 - Score 3: A continuous smear layer covering walls and no dentinal tubules are seen.

Mean scores for debris and smear layer were finally calculated for each group and statistically analyzed for significance ($p < 0.05$) between and within groups, using

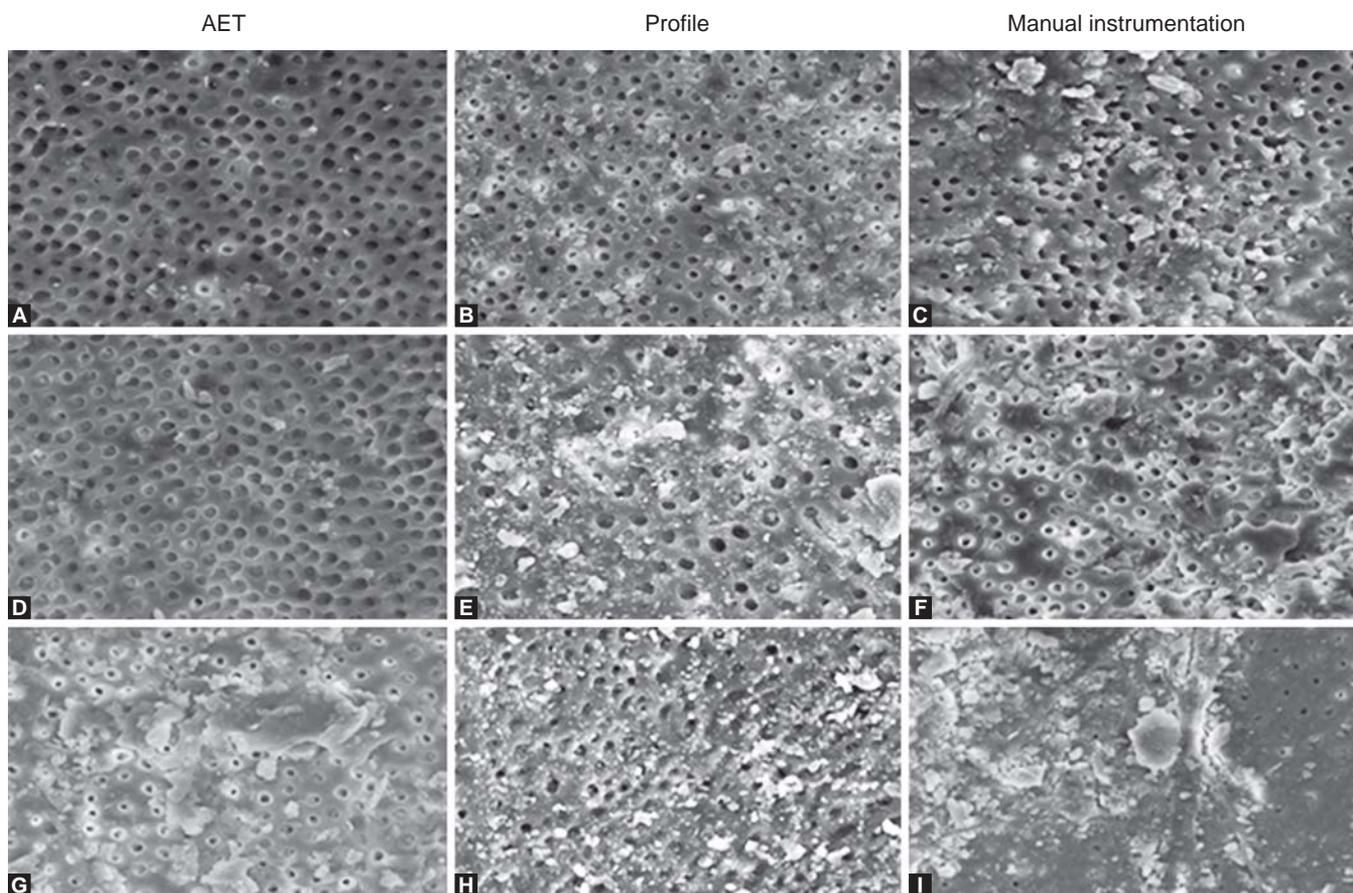
the Kruskal-Wallis nonparametric ANOVA and Bonferroni's multiple comparison test.

RESULTS

At 1000× magnification the instrumented canal walls from all groups exhibited varying amounts of remaining debris and smear layer along the entire length of the root canal. Dentinal walls were seen, which were often partially or totally free of surface debris and/or smear layer with many open dentinal tubules (Fig. 1). The mean scores of debris and smear layer recorded at 1, 5 and 10 mm from the working length are shown in Tables 1 and 2 respectively. It was observed that at the 5 and 10 mm levels for all groups the canal walls were cleaner than at the 1 mm level. However, completely clean root canals were not observed in any group. At the 1, 5 and 10 mm levels, the root canals prepared with AET had significantly less surface debris and smear layer ($p < 0.05$) than the ProFile or manual instrumentation samples. All groups demonstrated significantly lower mean smear layer scores ($p < 0.05$) at the 5 and 10 mm levels compared with the 1 mm level. In addition, significantly lower mean debris scores ($p < 0.05$) were recorded at the 5 and 10 mm levels compared with the 1 mm level for the AET group whereas no significant differences ($p > 0.05$) were found between the three levels for ProFile and manual instrumentation prepared canals.

DISCUSSION

The ultimate goal of root canal preparation is canal debridement to promote apical healing.² The design of this study was to compare the cleanliness of oval-shaped root canals after preparation with two automated devices and a manual instrumentation method using a step-back technique and K-files. It has been shown by several investigators that neither the instruments nor instrumentation techniques in canal preparation achieve complete cleanliness of root canal walls.⁶ The results corroborated these findings. Preparation of oval shaped root canals with rotary NiTi instruments resulted in remaining unprepared areas. This finding seems to be of great value as the prevalence of long oval canals in apical thirds was identified in 25% of teeth of all groups.² Numerous studies have shown that SEM offers high-resolution images and allows the observation of areas covered by debris and/or smear layer as well as the identification of patent dentinal tubules.^{5,8} The use of low magnification can provide representative views of the entire canal, but it does not allow meticulous study of surface details such as remnants of the smear layer or identification of dentinal tubules which need to be observed at higher magnifications.⁸ Hence, for evaluation purposes, the total area appearing on the screen at each of the predetermined



Figs 1A to I: SEM photomicrographs of representative specimens of groups AET, Profile and Manual instrumentation at 10 mm, 5 and 1 mm (in fig from top to bottom) respectively at 1000x magnification

levels was analyzed at 1000x magnification. No assessment as to the presence of smear layer or debris was made in areas that were not instrumented.³

At the 1 mm level, the smear layer covered the root canal walls in the majority of the specimens for all groups and only a few dentinal tubule orifices were discernable. This was probably due to the fact that during instrumentation, the tip of the needle could not be placed closer than 3 to 4 mm from the working length. It has been demonstrated that there is little flushing action beyond the tip of a needle, unless it is binding to the walls of the root canal and the irrigating solution is forcibly expressed. Deeper placement of the needle slowly improved as the instrumentation progressed, however, this only occurred during final flushing and after complete preparation of the apical third of the canals.⁶ Overall, however, at the 1 and 5 mm levels, the canals prepared with AET appeared to have less surface contamination compared with using ProFile or manual instrumentation. Our results are in agreement with previous observations in that the use of ProFile was less efficient in completely cleaning the root canal, leaving many areas untouched by the instruments, especially at 5 and 10 mm

levels. The main reason for the inferior cleaning ability of ProFile system may be the constant helix angles, pitch and burnishing action of radial lands on the root canal walls and not suitable for exertion of lateral pressure to prepare the recesses due to its superelasticity.^{1,5}

When viewed in cross sections, ProFile tends to form round preparations in most oval shaped canals. This was confirmed in the present study in which maxillary and mandibular premolars were used.^{9,11} As reported previously,

Table 1: Mean (SD) scores of debris removal

Groups	n	1 mm	5 mm	10 mm
AET	20	2.0 (0.56)	1.3 (0.47)	1.1 (0.31)
Profile	20	2.2 (0.77)	1.9 (0.64)	1.7 (0.80)
MI	20	2.6 (0.49)	2.0 (0.79)	2.2 (0.83)

Table 2: Mean (SD) scores of smear layer removal

Groups	n	1 mm	5 mm	10 mm
AET	20	2.0 (0.46)	1.3 (0.47)	1.1 (0.31)
Profile	20	2.5 (0.60)	2.0 (0.86)	1.6 (0.59)
MI	20	2.5 (0.51)	1.9 (0.78)	1.8 (0.61)

n: number of samples; SD: standard deviation

the long diameter of oval-shaped canals is more frequently seen at 5 and 10 mm distance from the apex, which logically would indicate that these areas are more prone to be out of reach of the ProFile rotary instruments.¹⁰ However, some isolated areas of unprepared root canal walls were also present in the AET and manual instrumentation groups. There are several reasons that may explain why AET-shaped root canals have lower debris and smear layer scores than canals shaped by means of ProFile or manual instrumentation. In this system, all instruments are made of stainless steel. The instruments for cleaning and shaping the coronal part of the root canal are used in a special handpiece. The Endo-Eze handpiece uses a reciprocal quarter turn motion (oscillating angle of 30°).^{1,2,6}

These instruments are stiffer than nickel-titanium rotary instruments and can be easier and with less risk forced toward the root canal walls and the polar recesses during the side-to-side lifting motion. The use of these instruments, manually pushed in this motion was probably more efficient in following the natural shape of the oval-shaped canals and removing tooth structure.¹ This also yielded a larger preparation with an increased volume of irrigants in direct contact with the root canal walls. In contrast, nickel-titanium instruments used only in a rotary motion and without lingual and buccal pressure tend to partially remove tooth structure leaving untouched areas on the opposite walls.^{1,4} As has previously been demonstrated, the cutting efficiency and the ability to clean root canal walls is dependent on the inherent design of the instrument and the dynamics used during instrumentation.⁶

As nonsquare cross-sectional instruments are generally more efficient than their square counterparts, it was expected that ProFile rotary instruments with their U-shaped cross-section configuration along with their radial lands on the cutting edges, would perform better than AET or hand instruments, which are square in cross section.⁶ Why this did not occur in the current study cannot be determined with certainty, although one might speculate that the better performance of the AET instruments may be related to the flute design and the sharpness (stainless steel instruments) of the cutting edges. Another explanation for the reduced efficiency of the ProFile rotary instruments may be the flat configuration of the outer edges, which may be responsible for packing debris further into dentinal tubules, thus making it more difficult to remove. These explanations are supported by previous findings.⁵ Concerning the efficacy of manual instrumentation, the results suggest that although a step-back technique was used for root canal preparation, the files when used in a circumferential motion were not totally

effective in cleaning the root canal walls at the 1, 5 and 10 mm levels.³ This can be explained by the fact that the file was not sufficiently forced toward the buccal and lingual recesses, thus leaving areas uninstrumented as well as debris and smear layer behind. Another important fact that needs to be emphasized is that efficient cleaning does not necessarily depend only on the type of instrument or instrumentation technique used. In order to dissolve debris and smear layer, chemical irrigation solutions are recommended along with mechanical instrumentation.^{3,8}

Alternating solutions of EDTA with NaOCl was the most effective combination to produce clean root canal walls. Studies have demonstrated the importance of using a chelating agent such as EDTA in combination with NaOCl, to effectively remove the inorganic and organic components of the smear layer.⁸ Therefore, in this study 2.0 ml of 3% NaOCl and 2.0 ml of 17% EDTA was used in an effort to maximize the cleansing of the instrumented canal walls. 2.0 ml of saline as a final rinse was used as an important step to rid the canal of chemicals that had been previously used. To eliminate variables, equal volumes of irrigants were used for all teeth. A potential variable that may have affected the results for all groups is that the use of irrigants appeared to be less effective in areas that were partially or not instrumented.

Although none of the techniques could completely clean the canals it was of the impression that the AET technique was simpler and more effective, followed by ProFile and manual instrumentation.

CONCLUSION

Although better instrumentation scores were obtained in canals prepared with AET, complete cleanliness was not achieved by any of the techniques and instruments investigated. Whether this translates into a clinically more successful treatment cannot be determined from this study. Within the limitations of this study, however, the use of AET is promising and warrants further laboratory experiments and clinical trials.

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ABOUT THE AUTHORS

E Sujayeendranath Reddy

Reader, Department of Conservative Dentistry and Endodontics SVS Institute of Dental Sciences, Mahabubnagar, Andhra Pradesh, India

Dinapadu Sainath (Corresponding Author)

Senior Lecturer, Department of Conservative Dentistry and Endodontics SVS Institute of Dental Sciences, Mahabubnagar Andhra Pradesh, India, Phone: 91-8542-271515, Fax: 91-8542-273111 e-mail: sainathreddy47@gmail.com

M Narenderreddy

Senior Lecturer, Department of Conservative Dentistry and Endodontics SVS Institute of Dental Sciences, Mahabubnagar, Andhra Pradesh, India

Srikanth Pasari

Senior Lecturer, Department of Conservative Dentistry and Endodontics SVS Institute of Dental Sciences, Mahabubnagar, Andhra Pradesh, India

Sangeetha Vallikathan

Senior Lecturer, Department of Conservative Dentistry and Endodontics, Sri Sai College of Dental Surgery, Hyderabad, Andhra Pradesh, India

G Sindhureddy

Senior Lecturer, Department of Conservative Dentistry and Endodontics SVS Institute of Dental Sciences, Mahabubnagar, Andhra Pradesh, India