doi: 10.1111/j.1365-2591.2006.01100.x

Retreatment efficacy of hand versus automated instrumentation in oval-shaped root canals: an *ex vivo* study

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Abstract

Zmener O, Pameijer CH, Banegas G. Retreatment efficacy of hand versus automated instrumentation in oval-shaped root canals: an *ex vivo* study. *International Endodontic Journal*, **39**, 521–526, 2006.

Aim To compare the efficacy of hand versus automated instrumentation when retreating oval-shaped root canals.

Methodology Sixty human premolars with single oval canals were instrumented and filled with gutta-percha and sealer and divided into three groups ($n = 20$) – group 1: ProFile .04 taper rotary instruments; group 2: Anatomic Endodontic Technology (AET), and group 3: manual instrumentation with Hedström files. The teeth were split longitudinally and gutta-percha/sealer remnants in the coronal, middle and apical thirds were assessed with light microscopy. The mean percentage of gutta-percha/sealer remnants for each group was calculated and statistically analysed for significance using an ANOVA repeated measures ($P < 0.001$) and Tukey's multiple comparison test. The time required for retreatment was analysed using a one-way ANOVA and Tukey's test ($P < 0.001$).

Results Overall, 10–18% of the canal walls were covered with gutta-percha/sealer remnants after preparation using any technique. Statistical analysis demonstrated that the mean values for remnants of filling material in the ProFile group were significantly higher than for the other groups ($P < 0.001$), except in the apical third where no significant difference occurred. In all groups, the mean values in the middle third were higher than the coronal and apical thirds. The retreatment time for ProFile and AET was significantly shorter compared to manual instrumentation with Hedström files ($P < 0.001$).

Conclusions Under the experimental conditions, AET instruments and manual instrumentation with Hedström files resulted in cleaner canals. However, completely clean root canal walls were not produced with any of the techniques investigated.

Received 14 June 2005; accepted 28 November 2005

Introduction

Retreatment of root filled teeth requires complete removal of the existing filling material as well as repeat instrumentation, disinfection and filling of the root canal system (Bergenholtz *et al.* 1979). Most current techniques use gutta-percha in conjunction with a sealer cement (Taintor & Ross 1978, Nguyen 1991). It has been suggested (Imura *et al.* 2000, Sae-Lim *et al.* 2000, Ferreira *et al.* 2001, Barrieshi-Nusair 2002) that gutta-percha can be effectively removed using ProFile nickel-titanium rotary instruments (Tulsa Dental Products, Tulsa, OK, USA). Unfortunately, the high prevalence of oval-shaped root canals in human teeth (Wu & Wesselink 2001) complicates matters. It has been demonstrated that

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ProFile as well as other nickel-titanium rotary instruments, when used according to the manufacturer's recommendations, were not able to completely clean oval-shaped canals (Short *et al.* 1997, Weiger *et al.* 2002, Zmener *et al.* 2005b) and consequently, their efficacy for gutta-percha/sealer removal may vary.

Recently, a new concept of automated root canal preparation, the Anatomic Endodontic Technology (AET; Ultradent Products Inc., South Jordan, UT, USA) has been introduced (White 2002). This system is composed of two types of flexible stainless steel instruments. The Shaping files are designed to be used in a 30° reciprocating 4 : 1 low-speed hand piece, whereas the Apical files only cut at the tips and are to be used manually to prepare the apical area of the canal. In a previous experiment (Zmener *et al.* 2005a) these instruments were successfully used for root canal retreatment *ex vivo*, however, their efficacy when retreating oval-shaped root canals has not been investigated.

The purpose of this study was to compare *ex vivo* the efficacy of ProFile .04 taper nickel-titanium rotary instruments, AET and manual instrumentation with Hedström files of the removal of gutta-percha/sealer from oval-shaped root canals. In addition, the incidence of instrument failure and the time required for removal of the filling material were recorded.

Materials and methods

Sixty single rooted freshly extracted human maxillary and mandibular premolar teeth, each with one single oval-shaped root canal, were used. If radiographically at the cervical and mid-root level the bucco-lingual to mesio-distal dimension had a ratio of at least 3 : 1, the teeth met the criteria of having an acceptable oval shape. After extraction the teeth were cleaned of soft tissues and hard aggregations and stored in a 0.1% thymol solution. After mounting in a holder simulating an intra-oral set-up, routine access openings were prepared. Size 15-K files were introduced to length in the canal space and radiographs were exposed from the bucco-lingual and mesio-distal aspects of the tooth. The working length was established by deducting 1 mm from the length recorded when the tip of the file was visible at the apex, when viewed at a magnification of 2.5×. All observations and instrumentations were performed by one operator and carried out using 2.5× magnification and confirmed radiographically.

Root canal preparation and obturation

The coronal portion of the canal was flared with sizes 2–3 Gates-Glidden burs (Dentsply Maillefer, Ballaigues, Switzerland). The tooth was then further prepared with a step-back technique using K-files (Dentsply Maillefer) apically to a master apical file size 35 and coronally to a file size 60. Throughout instrumentation, 5.25% NaOCl and 17% EDTA irrigating solutions, followed by rinsing with saline, were used. The canals were filled using laterally condensed gutta-percha cones and AHPlus (Dentsply Maillefer) as the sealer. After the sealer was prepared on a mixing pad according to the manufacturer's recommendations the root canal walls were coated using a 20 K-File and the canal space was filled using a standard master gutta-percha cone fitted to working length with tugback. Lateral condensation was accomplished using finger spreaders and fine–fine or fine–medium accessory cones dipped in sealer. In all teeth the extent of the root canal filling was uniformly limited to 18 mm from the working length. Excess gutta-percha was removed and the access openings were sealed with Cavit (Espe GMBH, Seefeld, Germany). Radiographs were made in bucco-lingual and mesio-distal directions to assess the quality of the root canal filling. If the root canal filling was considered unsatisfactory, a new sample was prepared using the same materials and methods. All teeth were stored at 37 °C in 100% relative humidity for 30 days to allow for complete setting of the sealer.

Reinstrumentation technique

A single operator carried out all retreatment procedures. After removal of the temporary restoration the coronal 2 mm of the canal was enlarged with sizes 4–5 Gates-Glidden burs to create a reservoir for the solvent. A small amount of chloroform (0.1 mL) was placed in the canal to soften the gutta-percha. After the canals were negotiated to the working length with size 20–25 K-files, the teeth were randomly assigned to three groups of 20 teeth each and the canals were retreated with one of the following methods.

Group 1. ProFile .04 taper nickel-titanium rotary instruments

The instruments were used in a crown-down manner without exerting lingual or buccal pressure, but with light apical pressure at a rotary speed of approximately 500 rpm provided by a high torque motor (Nouvag AG,

Goldach, Switzerland). First, a size 4 ProFile was introduced two-thirds to three-quarters followed by a size 5 ProFile to approximately the same depth. The remainder was sequentially instrumented using sizes 3–6 ProFile (equivalent to ISO size 0.36) to the full working length.

Group 2. AET stainless steel instruments
Gutta-percha and sealer were initially removed with Shaping file sizes 1, 2 and 3 with tapers of 2.5%, 4.5% and 6.0% respectively, using a reciprocating 4 : 1 reduction speed hand piece (Ultradent Products Inc.) with a rotational speed of 1500 rpm and a side-to-side/up-and-down motion to approximately 2 mm from the working length. Equivalency in diameter according to ISO sizes for Shaping file is 1 (0.10 mm equivalent to a ISO 10 file), 2 and 3 (0.13 mm), and for apical files the tips were equivalent to a 15, 20 and 30 K-file respectively.

The apical 2 mm was retreated to the working length with apical files no. 1, 2 and 3. Final apical enlargement to the working length was accomplished with Shaping file sizes 1 and 2.

Group 3. Manual circumferential filing with Hedström files
The canals were retreated with sizes 20–35 Hedström files (Dentsply Maillefer) to the working length. They were then stepped-back with Hedström files coronally in 1 mm increments to a file size 60. The files were used in a circumferential motion whilst pressing against the root canal walls.

For all groups throughout the retreatment procedures only two additional quantities of 0.1 mL of chloroform were added to soften the gutta-percha. Each instrument was withdrawn when no resistance was felt followed by the next instrument. Instrument use was limited to two canals. At each change of instrument, the canals were irrigated with 2 mL 5.25% NaOCl solution, followed by rinsing with 2.0 mL saline. Retreatment was considered complete when the master apical file fitted loosely in the root canal at full working length, no debris of gutta-percha/sealer was visible on the files and the canal walls were smooth. Total retreatment time was based on the time required for instrumentation and excluded time for changing instruments, irrigation and control radiographic examination and was recorded in minutes and seconds with a stop watch. If the control radiographs revealed the presence of remaining filling material the procedure was continued until further radiographs showed otherwise. The additional time was also recorded and incorporated in the total time required for retreatment. After completion the specimens were stored in 100% relative humidity at 37 °C until further use.

After preparing grooves parallel to the long axis on the buccal and lingual surfaces the teeth were split into halves. Sections that showed evidence that the groove had penetrated into the root canal space or exhibited an irregular cleavage were discarded and replaced by a new specimen. Both halves were photographed using Kodachrome 25 film (Eastman Kodak, Rochester, NY, USA). The slides were coded and projected at random at a magnification of 10× onto white paper. For practical purposes no attempt was made to distinguish between gutta-percha and/or sealer remnants. The canals were divided into coronal, middle and apical thirds from the crest of the filling to the apex and the presence of gutta-percha/sealer remnants outlined in pencil for both halves of each tooth. The tracings were measured in each third using a LECO 2001-2.02 image analyzer (LECO Corp., St Joseph, MI, USA) by a single operator. The total canal space and remnants of gutta-percha/sealer were quantified. The mean percentage of remaining gutta-percha/sealer was expressed as the ratio between filling materials and the total area of root canal space. To analyse the reliability of the procedure, two area measurements on five randomly selected tracings were made. Throughout the evaluation process the evaluator was blinded as to the treatment of the specimens.

Results were processed with SPSS 10.0 software (Statistical Package for the Social Sciences Inc., Chicago, IL, USA). The mean percentages of gutta-percha/sealer remnants for each group and each one-third segment were analysed using an ANOVA repeated measures and Tukey's multiple comparison test. Statistical significance for the time required for retreatment was determined with a one-way ANOVA and Tukey's multiple comparison test. Significance level was set at $P < 0.001$.

Results

The 10 area measurements on five randomly selected tracings resulted in a variation of less than 1%, which was considered acceptable for validation of the experimental design.

The results of the ANOVA repeated measures analysis for gutta-percha/sealer remnants are shown in Table 1. The two factors analysed as well as their interaction were found to be statistically significant ($P < 0.001$). The arithmetic means and confidence intervals for

Table 1 Analysis of variance (repeated measures) for gutta-percha/sealer remnants

Source	SS	DF	MS	*F*	*P*
Third	405.514	2	202.757	101.214	<0.001
Third × Group	243.098	4	60.774	30.338	<0.001
Error (Third)	228.371	114	2.003		
Group	348.122	2	174.061	82.304	<0.001
Error	120.547	57	2.115		

SS, sum of squares; DF, degree of freedom; MS, mean square.

Table 2 Arithmetic means of gutta-percha/sealer remnants after retreatment

				95% Confidence level	
Group	Third	Mean	SD	LL	UL
ProFile	Coronal	14.20	1.54	13.56	14.84
	Middle	17.90	1.64	17.27	18.52
	Apical	10.98	1.40	10.32	11.64
AET	Coronal	9.73	1.13	9.09	10.37
	Middle	12.49	0.88	11.87	13.11
	Apical	10.86	1.39	10.20	11.52
MI	Coronal	10.44	1.45	9.80	11.07
	Middle	13.44	1.64	12.82	14.06
	Apical	12.34	1.50	11.68	13.00

MI, manual instrumentation; SD, standard deviation; LL, lower limit; UL, upper limit.

gutta-percha/sealer remnants after retreatment are shown in Table 2. All samples displayed some gutta-percha/sealer remnants. The entire canal mean value for ProFile (14.36) was statistically significantly higher (more gutta-percha/sealer remnants) than for AET (11.02) and manual instrumentation (12.07). Furthermore, the mean percentage of remaining gutta-percha/sealer was significantly higher for the ProFile group in the coronal and middle thirds of the canal ($P < 0.001$). However, there was no statistically significant difference ($P > 0.001$) between ProFile, AET and manual instrumentation in the apical third. In all groups the mean percentage of remnants was lower in the coronal and apical thirds than in the mid-root area ($P < 0.001$). The results of the ANOVA and the arithmetic means for retreatment time determinations are shown in Tables 3 and 4 respectively. The time required to retreat the canals using ProFile and AET was significantly shorter than for manual instrumentation ($P < 0.001$), whilst there was no statistically significant difference between ProFile and AET ($P > 0.001$). Although no instruments fractured, 11 ProFile instruments deformed, size 6 most frequently (five instruments), followed by sizes 5 and 4 (respectively four and two instruments).

Table 3 Analysis of variance for time determinations

	SS	DF	MS	*F*	*P*
Between groups	87.575	2	43.787	47.05	<0.001
Within groups	53.049	57	0.931		
Total	140.642	59			

SS, sum of squares; DF, degree of freedom; MS, mean square.

Table 4 Arithmetic means for retreatment time determinations (in minutes and seconds)

Group	*n*	Mean	SD
ProFile	20	9.50	0.65
AET	20	9.96	0.67
MI	20	12.26	1.38

MI, manual instrumentation; SD, standard deviation.

Discussion

One of the most difficult to control parameters in this study was the extent of the anatomical variations that are generally present in human teeth. Variations in original root canal morphology greatly influence the changes that occur after root canal preparation (Peters *et al.* 2001) and as a logical extension, after retreatment procedures. In order to minimize these variables a standardized length of root canal filling was adhered to and only teeth with straight canals were selected. Furthermore, the teeth were assigned at random to one of the three experimental groups. The three groups were compared to each other as it was not possible to add a relevant control group.

The findings demonstrated that the use of AET and manual instrumentation combined with chloroform was significantly more effective than ProFile relative to cleanliness of the entire canal. In contrast to the flute design with flat outer edges (radial lands) of ProFile instruments, AET Shaping files have sharp cutting edges, which may account for a more effective cutting of the gutta-percha. In this study chloroform was used because it is known to be more efficient in dissolving gutta-percha than other chemicals (Tamse *et al.* 1986, Wennberg & Orstavik 1989, Wilcox 1995). According to recent reports by McDonald & Vire (1992) and Vajrabhaya *et al.* (2004) chloroform can be used safely in clinical endodontics providing caution is exercised. However, possible adverse health effects from exposure to chloroform should not be overlooked (Tamse *et al.*

1986, Wennberg & Orstavik 1989) and consequently further research in this area is warranted.

As has been previously demonstrated, it is almost impossible to remove all traces of gutta-percha/sealer from canal walls (Wilcox *et al.* 1987, Barrieshi-Nusair 2002). All groups had significantly less gutta-percha/sealer in the apical third, which is in contradiction with previous reports (Friedman *et al.* 1992, Imura *et al.* 2000, Sae-Lim *et al.* 2000). This may be explained in that the bucco-lingual diameter of oval-shaped canals decreases towards the apex to an almost round diameter at 3 mm from the apex (Wu & Wesselink 2001, Weiger *et al.* 2002), probably resulting in a better contact of the files with the canal walls. It was also demonstrated that significantly less gutta-percha/sealer was present in the coronal third, except for the ProFile group, a finding consistent with other reports (Nearing & Glickman 1999, Imura *et al.* 2000, Sae-Lim *et al.* 2000, Betti & Bramante 2001, Barrieshi-Nusair 2002). This may be explained in that the design of ProFile as well as other nickel-titanium rotary instruments is not suitable for exertion of bucco-lingual or lateral pressure. In this study, the ProFile instruments were strictly used with a light pressure/withdraw motion (pecking) as described by Thompson & Dummer (1997). With this motion the instruments remain centred within the root canal during rotation and generally tend to form round preparations in most oval-shaped canals (Short *et al.* 1997, Weiger *et al.* 2002). This would explain that the polar recesses located at the coronal and middle thirds of oval canals are more prone to be out of reach of ProFile rotary instruments. The more effective removal of debris in the coronal and middle thirds by AET and manual instrumentation may be explained in that the stainless steel instruments are stiffer than nickel-titanium rotary instruments and can be safely directed towards the root canal walls allowing for a better performance in these oval areas of the canal walls. The use of flexible stainless steel instruments in this motion was probably more efficient in following the natural shape of the oval-shaped canals. This possibly resulted in the removal of more dentine thus allowing for an increase in volume of irrigants in direct contact with the root canal walls.

In this study, each instrument was discarded after retreating two canals thus reducing substantially the possibility of instrument breakage. Although no instruments fractured, a large number of ProFile instruments deformed. It has been reported that stainless-steel files are less susceptible to damage during retreatment procedures than nickel-titanium rotary instruments (Zuolo & Walton 1997, Imura *et al.* 2000). It was postulated that the continuous rotation of nickel-titanium instruments caused stresses leading to deformation or fracture (Thompson & Dummer 1997, Imura *et al.* 2000). In the present experiment it was observed that the larger ProFile sizes were more prone to deformation, a finding previously reported (Thompson & Dummer 1997).

The mean values of the retreating time were consistent with other studies (Sae-Lim *et al.* 2000, Betti & Bramante 2001, Hulsmann & Bluhm 2004) showing that engine-driven instruments perform significantly faster than manual instrumentation. It has been suggested that the faster rotation plasticizes the gutta-percha more rapidly thus making it easier to remove (Bramante & Betti 2000).

Under the present experimental conditions AET and manual instrumentation were more effective than ProFile when retreating oval-shaped root canals. However, the design of this study does not allow conclusions as to the clinical success and/or safety using the tested instruments. Further laboratory and clinical evaluations are recommended.

Conclusions

Under the present experimental conditions all techniques were suitable for the removal of gutta-percha/sealer in oval-shaped root canals. However, completely clean root canal walls could not be achieved with any of the three techniques that were tested. The mean percentage of remaining gutta-percha/sealer was significantly higher for the ProFile group in the coronal and middle thirds of the canal ($P < 0.001$). However, in the apical third there was no statistically significant difference ($P > 0.001$) between the three methods. In all groups the mean percentage of remnants was lower in the coronal and apical thirds than in the mid-root area ($P < 0.001$). AET instruments and manual instrumentation with Hedström files produced cleaner canals (fewer remnants of gutta-percha/sealer) than ProFile, whilst ProFile and AET were significantly faster than manual instrumentation in the removal of gutta-percha/sealer. Whilst deformation of instruments was noted no fractures were recorded.

Acknowledgements

The authors thank Dr Ricardo Macchi for the statistical analysis and Mr Dante Gimenes and Pablo Villavicencio for technical assistance.

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