doi:10.1111/j.1365-2591.2007.01254.x

Effectiveness of two nickel-titanium rotary instruments and a hand file for removing gutta-percha in severely curved root canals during retreatment: an *ex vivo* study

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Abstract

Gergi R, Sabbagh C. Effectiveness of two nickel-titanium rotary instruments and a hand file for removing gutta-percha in severely curved root canals during retreatment: an *ex vivo* study. *International Endodontic Journal*, **40**, 532–537, 2007.

Aim To evaluate *ex vivo* the effectiveness of hand files, ProTaper and R-Endo rotary instruments when removing gutta-percha from curved root canals.

Methodology Ninety severely curved teeth were divided into three groups. The root canals were accessed, prepared and filled with vertically condensed gutta-percha and sealer. Removal of gutta-percha was performed with the following devices and techniques: Hedström files (Vereinigte Dentalwerke, Munich, Germany), ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) and R-Endo (Micro-Mega, Besançon, France). All techniques were used with the solvent eucalyptol. The amount of filling material debris remaining on root canal walls was assessed radiographically from two directions: mesio-distal and bucco-lingual. The images were digitized and analysed with AUTOCAD 2000 software. Total canal area, area of the cervical, middle and apical thirds, and area of remaining filling material from both directions were outlined by two different operators and calculated. Statistical analysis of remaining filling material within each third of the canals was performed by the Kruskal–Wallis test.

Results Comparisons of the percentages of remaining filling material in the entire canal did not reveal any significant differences between the methods of removal. However, the canal third was of relevance in all groups; the apical third had the most remaining filling material compared with the middle and cervical thirds ($P = 0.0012$).

Conclusion All instruments left filling material inside the root canal. ProTaper and R-Endo rotary instruments were inadequate for the complete removal of filling material from the root canal system.

Keywords: eucalyptol, gutta-percha, NiTi, ProTaper, R-Endo, retreatment.

Received 2 July 2006; accepted 12 January 2007

Introduction

Safe and efficient removal of filling material from canal systems is essential for optimal root canal retreatment. Ideally, all filling material and sealer should be removed from canal walls to gain access to microorganisms and pulp tissue remnants (Dalton *et al.* 1998).

The most common root canal filling material requiring removal is gutta-percha (Friedman *et al.* 1989). However, its removal from apparently well-condensed root canals may be time-consuming (Ladley *et al.* 1991).

Gutta-percha removal is usually accomplished by the use of hand instruments alone (K-files and H-files), or in combination with rotary instruments with or without solvents (Wilcox *et al.* 1987, Friedman *et al.* 1989). Heat-carrying and ultrasonic instruments are also

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helpful devices to facilitate removal (Shirrmeister *et al.* 2006).

Several reports have confirmed the advantages of hand and rotary NiTi instruments for canal preparation, including maintenance of the canal shape without creating deformation and in a significantly shorter time when compared with hand instruments (Esposito & Cunningham 1995, Bishop & Dummer 1997).

Although Niti rotary instruments have been proposed as an alternative to hand instrumentation for removing gutta-percha, few studies (Hülsmann & Stotz 1997, Bramante & Betti 2000, Barletta & Lagranha 2002, Masiero & Barletta 2005, Shirrmeister *et al.* 2006) have investigated and compared the effectiveness of these instruments in the removal of filling materials. In general, these studies found residual root canal filling material on dentine walls and a high risk of NiTi instrument fracture.

Therefore, the purpose of this study was to compare the cleanliness of root canal walls after retreatment using two engine-driven NiTi rotary instruments ProTaper® (Dentsply Maillefer, Ballaigues, Switzerland) and R-Endo® (Micro Mega, Besançon, France) and hand instruments (Hedström files).

Materials and methods

Specimen preparation

Ninety extracted teeth with severe angles of curvature $25° < \alpha < 70°$ (Shneider 1971) and short radii $r < 10$ mm (Lopez *et al.* 1998) were obtained and stored in 10% buffered formalin. Access openings were prepared into the pulp chamber using a high-speed bur and water spray. A size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was placed into the canal until it was visible at the apical foramen and the working length established 0.5-mm short of this length. For more uniform samples, the crowns were flattened with steel discs and a final dimension of 18-mm working length was achieved for each tooth.

Canal preparation

The same operator, using a standardized technique, prepared all canals. The canals were instrumented to the working length with sizes 15 and 20 K-files using a step back technique. Canals that were larger than ISO size 20 were discarded. In this way, the final size of the apical preparation was standardized as it was intended to instrument all canals to master apical size 20. This was followed by a preparation with two rotary NiTi Hero 642 instruments (Micro-Mega, Besançon, France), 0.5-mm short to the working length. The instruments used had 0.02 and 0.04 taper and had a tip size equivalent to a 20. The instruments were rotated at 300 r.p.m. Thus, following preparation, all root canals had a size 20 with a 4% taper. This was meant to represent narrow and often underprepared root canals, which frequently are found in retreatment cases (Hülsmann & Bluhm 2004). Canals were irrigated between instruments with 3 mL of NaOCl (5.25%) using a disposable syringe on which an Endo-Eze® (Ultradent, South Jordan, UT, USA) irrigator tip was mounted. These irrigator tips have an apical tip diameter of 0.40 mm. Consequently, needle insertion (for the teeth prepared to an apical size K20 and taper 4%) during irrigation was approximately 5-mm short of the working length. When the instrumentation of root canals was completed, 1 mL of EDTA (17%) was applied for 1 min for smear layer removal and the canals flushed again for 3 min with 9-mL NaOCl (5.25%). Finally, the root canals were dried with paper points.

Canal filling

A fine feathered gutta-percha cone (Kerr, Romulus, MI, USA) lightly coated with sealer (Pulp canal sealer EWT, Kerr) was trimmed to fit at the working length with 'tug back'. A System B condenser 0.04 taper tip size 30 (Analytic Technology, Redmond, WA, USA), marked with a rubber stop, was inserted 3-mm short of the working length. The system B unit was set at 200 °C and power 10. All points were seared off initially at the canal orifices. The activated condenser was then pushed apically into the gutta-percha until just short of the pre-measured length. At this point, the condenser was seated to length without heat and apical pressure maintained for approximately 10 s. A second burst of heat was used to remove the condenser. Canals were back filled by thermo-mechanical compaction: a medium-fine gutta-percha was embedded with sealer and placed in the root canal. Then, a gutta condenser (Dentsply Maillefer, Ballaigues, Switzerland) size 35 was used to fill the middle and the cervical canal third. The gutta-condenser was inserted 3-mm short of the working length.

The standard of canal filling was assessed with bucco-lingual and proximal radiographs. A filling was deemed adequate when it appeared to be dense and

contained no voids; inadequately filled canals were recondensed thermo-mechanically. The prepared and filled roots were randomly assigned to one of the three groups. All roots displayed severe angles of curvature between 25 and 45° (mean 30.5 degrees, SD 4.0°). The mean of the radii of all roots was 7.5 mm (SD 3.5 mm). Thus, the three groups had approximately similar angles of curvature and radii. All teeth were stored at 100% humidity and 37 °C for a period of 7 days to allow the sealer to set completely.

Retreatment techniques

The roots were divided into three groups of thirty. Eucalyptol was then placed on the gutta-percha in the orifice for 3 min. All instruments were used in a crown-down technique on a rotary engine driven motor (Teknica Vision, ATR, Pistoia, Italy) with constant speed (400 r.p.m.), low torque (4 N cm^{-1}) and light apical pulses of pressure to remove gutta-percha and sealer.

ProTaper

ProTaper finishing instruments (F3-F2-F1) of 21-mm length were used in a pecking motion (in and out) movement. When the F3 (0.09 taper tip 30) could not progress apically, F2 (0.08 taper tip 25) was used until F1 (0.07 taper tip 20) reached the working length. Adherent material was removed from the file during instrumentation and eucalyptol replenished. Apical enlargement was performed to file F1.

R-Endo

R-Endo instruments (Re, R1, R2 and R3) were used to remove gutta-percha and its sealer in a brushing circumferential movement. All R-Endo files have a 25 tip size but different tapers: 0.12 for Re, 0.08 for R1, 0.06 for R2, 0.04 for R3. During retreatment, when a rotating file could not progress apically, the following file was used until R3 reached the apex. However, apical enlargement was performed to file R2. Therefore, after R3 reached working length, the file R2 was used again to the working length to end with a 6% taper not one of 4%. The 6% taper was more comparable with the 7% taper (F1 ProTaper).

In both groups, if rotating instruments could not reach working length, a stainless steel file MMC 15 (Micro-Mega, Besançon, France) was used to negotiate the canal. After negotiation, rotary instruments were used to working length.

Hedström files: the canals were re-instrumented in a crown-down technique with H-type file sizes 45, 40, 35, 30 and 25 in a circumferential quarter-turn push-pull filing motion to remove gutta-percha and sealer from the canal until the working length was achieved with a size 25 H-type file. This corresponded to the apical diameter established in the mechanical preparation of the R-Endo system.

Eucalyptol was constantly renewed (total volume for each canal was 2 mL) and NaOCl (5.25%) irrigation was used until no filling debris (gutta-percha and sealer) was observed in the instrument flutes or in the irrigation solution. Removal was then considered complete.

Evaluation of remaining material

When filling removal and re-instrumentation of the root canals were concluded, mesio-distal and bucco-lingual radiographs were exposed. The exposure time was 0.15 s and the distance between the X-ray source and film was set at a constant distance of 4 cm. The films used were Kodak Ektaspeed (Rochester, New York, NY, USA) millimetre graduated. The images were digitized by using a scanner with the resolution set at 600 dpi, brightness 132, and contrast at 142. Images were evaluated with the AUTOCAD 2004 software (Mechanical Desktop Power Pack, Microsoft, Redmond, WA, USA). The area of the remaining filling material of the mesio-distal and the bucco-lingual images was measured.

Remaining filling material was identified and outlined by two different operators through the difference of radio-opacity (Figs 1–2). If they did not agree with the outline areas, the measurement was repeated until consensus was reached. Each root canal was then divided in apical, middle and cervical thirds, which were evaluated separately in terms of the remaining gutta-percha/sealer in square millimetres (mm^2) with the same programme AUTOCAD 2004.

Statistical analysis

Statistical analysis was performed by means of the Kruskal–Wallis test for the global null hypothesis to identify any significant differences amongst the three groups. The level of significance was set at 5% (Table 1).

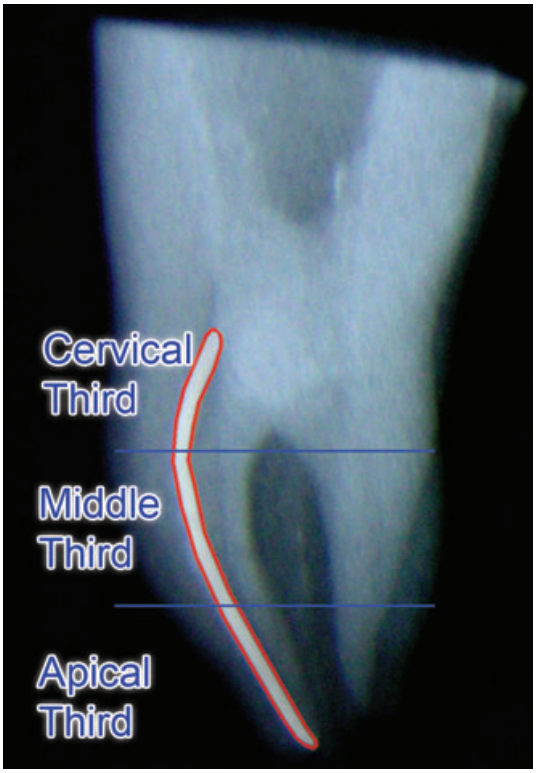

Figure 1 Filling material debris remnants in the canal third (ProTaper system). Note: white areas represent remaining filling material.

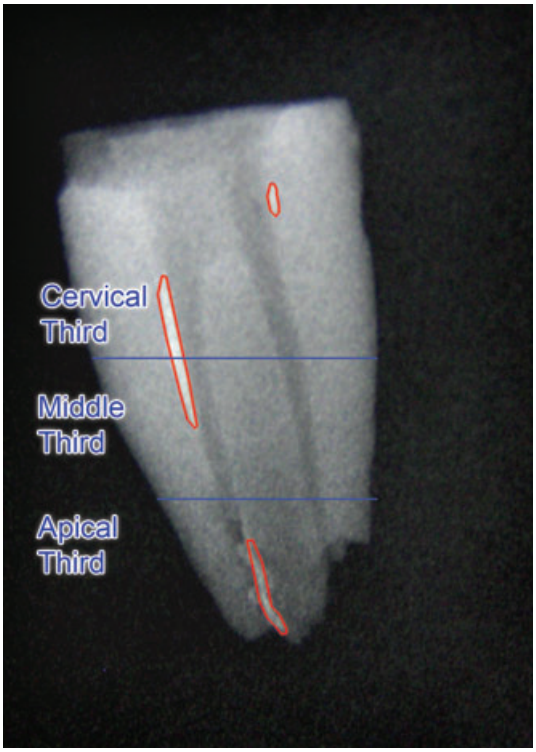

Figure 2 Filling material debris remnants in the canal third (R-Endo system). Note: white areas represent remaining filling material.

Table 1 Areas of remaining obturation material

	A1		A2		A1 + A2	
Method	Mean	SD	Mean	SD	Mean	SD
ProTaper	1.21	1.09	1.39	1.28	2.60	2.37
R-Endo	1.10	1.02	1.14	1.08	2.24	2.10
Hedström	1.14	1.04	1.44	1.05	2.58	2.09

Mean areas (mm^2) and SD (SD, mm^2) of remaining obturation material imaged in bucco-lingual direction (A1) and in mesiodistal direction (A2).
The number of teeth was $n = 30$ in all groups.

Results

All roots displayed severe angles of curvature between 25 and 45° (mean 30.5°, SD 4.0°). The mean of the radii of all roots was 7.5 mm (SD 3.5 mm). There were no significant differences amongst the groups concerning mean angles of curvature ($P = 0.57$; Kruskal–Wallis test) or radii ($P = 0.85$; Kruskal–Wallis test).

A small number of teeth (4/30 for ProTaper® system, 5/30 for R-Endo® system, 3/30 for H-files) had completely clean root canals when evaluated radiographically; the differences were not significant ($P > 0.05$).

The total areas of remaining filling material were not significantly different between the three groups ($P > 0.05$).

The apical third had the most remaining filling material when compared with the middle and cervical thirds ($P = 0.012$). There was no significant difference amongst the groups in mesio-distal and bucco-lingual direction ($P > 0.05$) when evaluating residual gutta-percha/sealer in each canal third.

In the cervical and middle third, no statistically significant difference was observed between the groups ($P = 0.33$).

None of the instruments fractured. Instruments were used (approximately six canals) until deformation was visible. When deformation occurred the instruments were discarded (five instruments for R-Endo®, four for ProTaper®).

Discussion

Removal of sealer and gutta-percha from inadequately prepared and filled root canal systems is essential in root canal retreatment because it is likely to uncover remaining necrotic tissue or bacteria that may be responsible for periapical inflammation and post-treatment disease (Hülsmann & Bluhm 2004, Shirrmeister *et al.* 2006).

Most previous retreatment studies have used teeth filled by lateral condensation, which does not create a homogeneous mass of gutta-percha but tends to entrap pools of sealer between the gutta-percha cones. It also tends to result in better condensation in the middle and coronal thirds rather than the apical third (Nguyen 1994). The thermoplasticized gutta-percha technique used with vertical condensation was found to give consistent homogeneous filling with gutta-percha. By taking radiographs in the bucco-lingual and mesio-distal direction for each tooth, the density and completeness of canal root filling could be checked. The aim was to fill completely the root canals with gutta-percha and sealer and thus provide a greater challenge for its subsequent removal.

Different methodologies have been reported during evaluation of remaining filling material including longitudinal cleavage of teeth (Friedman *et al.* 1993) which may displace filling material remnants (Ferreira *et al.* 2001); association of longitudinal and transverse cleavage for evaluation in thirds (Imura *et al.* 2000); and cleavage and photographic recordings (Wilcox *et al.* 1987). Hülsmann & Stotz (1997) used visual examination through cleavage and photography in association with radiographic examination. The problems with sectioning teeth are that it can disturb the remaining filling material and it is unpredictable (Ferreira *et al.* 2001).

The present analysis was carried out by the method reported by Barletta & Lagranha (2002) without longitudinal cleavage and with radiographs being analysed by means of a software package developed for civil engineering and architecture, the AUTOCAD 2000. This method is more reliable as remaining gutta-percha or sealer might get lost by splitting the roots (Ferreira *et al.* 2001, Masiero & Barletta 2005, Shirrmeister *et al.* 2006). However, this method has limitations as radiographic images provide only two-dimensional information on a three-dimensional structure and may be subject to magnification and distortion. In addition, small volumes of debris may not be visualized.

In the present study, it was only possible to make a semi-quantitative evaluation of the amount of debris remaining. Evaluation was subjective, and observer performance is known to be variable in many cases where diagnosis is required. Complete removal of root canal filling material was difficult to achieve. Less then 20% of the teeth (4/30 for ProTaper® system, 5/30 for R-Endo® system, 3/30 for H-files) had clean root canals. When evaluated radiographically, most of the canals had filling material remaining, a finding that is consistent with previous reports (Wilcox *et al.* 1987, Barletta & Lagranha 2002). The evaluation of total percentage of remaining filling material did not reveal any statistically significant differences in effectiveness for the removal techniques studied.

However, when the analysis was stratified by thirds, a difference was revealed when comparing the apical third with the other two-thirds for both groups ($P < 0.05$).

The apical third had a mean percentage of remaining filling material greater than the middle and the cervical third in both groups. In general, there is increased anatomical variability and difficulty of instrumentation in the area. The existence of curvatures in many planes of deep grooves and depressions on dentine walls in the apical third may well explain the presence of these less instrumented areas making it impossible to direct NiTi instruments against entire root canal walls (Hülsmann & Bluhm 2004, Shirrmeister *et al.* 2006). Reamers and files placed in curved canals will be deflected from their long axes with resultant inequality of cutting and cleaning effectiveness, depending upon the pressure with which the cutting instrument contacts different walls of the root canal. This instrument deflection produces greater cutting and cleaning efficiency in the direction opposite to the curvature of the instrument, and reduces cutting and cleaning efficiency in the direction in which the root canal turns (Schilder 1974).

Removal of filling material was accomplished after 1 week. Other studies using different NiTi rotary instruments for retreatments were performed after a period ranging from 7 days to 1 year (Ferreira *et al.* 2001, Masiero & Barletta 2005, Shirrmeister *et al.* 2006). They were all unable to completely clean root canal walls especially in the apical third.

Conclusion

Under the experimental conditions, both rotary NiTi systems proved to be helpful and safe devices for gutta-percha removal in root canal retreatment.

Nevertheless, the results showed that overall all instruments may leave filling material inside the root canal especially in the apical third.

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