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A comparison of the efficacy of conventional and new retreatment instruments to remove gutta-percha in curved root canals: an *ex vivo* study

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Abstract

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Aim To compare the efficacy of conventional and new retreatment instruments when removing gutta-percha root fillings in curved root canals.

Methodology A total of 56 curved molar roots were instrumented with ProFile instruments and filled using system B and Obtura II. The root fillings were removed with manual K-files and Hedström files (Dentsply Maillefer), ProFile (Dentsply Maillefer), R-Endo (Micro–Mega) or ProTaper Universal retreatment files (Dentsply Maillefer). Eucalyptol was used as a solvent with all techniques. Bucco-lingual and proximal radiographs of the roots were exposed and the percentage area of the remaining material was calculated by dividing the area of remaining filling material by the area of canal wall. Data were statistically analysed with Kruskal–Wallis and Mann–Whitney *U* tests ($P = 0.05$).

Results None of the techniques completely removed the root filling materials. No significant differences were found amongst the coronal, middle and apical thirds in both radiographic projections ($P > 0.05$). In the bucco-lingual direction, the remaining filling material was significantly less following manual instrumentation than R-Endo and ProTaper instrumentation ($P < 0.05$). In the proximal view, it was significantly less following manual and ProFile instrumentation than R-Endo ($P < 0.05$). Complete removal of filling material occurred only in three specimens (with manual instruments). Manual instruments were significantly faster than R-Endo and ProFile ($P < 0.05$). More procedural errors (five fractured instruments and two perforation) were noted when using ProTaper ($P < 0.05$).

Conclusions In this laboratory study in curved molar roots, ProTaper Retreatment and R-Endo instruments were less effective in removing filling material from canal walls than manual and ProFile instruments.

Keywords: canal wall cleanliness, gutta-percha removal, ProFile, ProTaper, R-Endo, retreatment.

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Introduction

The techniques used to remove gutta-percha from root canals include manual endodontic hand instruments (Imura *et al.* 1996, Schirrmeister *et al.* 2006a), ultrasonics (Ladley *et al.* 1991), lasers (Farge *et al.* 1998), heat carrying instruments (Wolcott *et al.* 1999), as well as NiTi rotary instruments (Imura *et al.* 2000, Sae-Lim *et al.* 2000, Hülsmann & Bluhm 2004, Schirrmeister *et al.* 2006b,c, Gergi & Sabbagh 2007, Saad *et al.* 2007).

In curved root canals, the removal of filling materials, and further cleaning and shaping are more difficult than in straight canals and more likely to cause instrument distortion or breakage. Whilst there are many studies on straight root canals (Imura *et al.* 1996, Imura *et al.* 2000, Betti & Bramante 2001,

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Barrieshi-Nusair 2002, Masiero & Barletta 2005, Kosti *et al.* 2006), studies on the efficiency of removing root filling in curved root canals are rare (Ferreira *et al.* 2001, Schirrmeister *et al.* 2006c, Barletta *et al.* 2007, Gergi & Sabbagh 2007).

Recently, new rotary instruments have been designed for the removal of filling materials in curved root canals: the ProTaper Universal retreatment system (Dentsply Maillefer, Ballaigues, Switzerland) and the R-Endo retreatment (Micro–Mega, Besançon, France). Gergi & Sabbagh (2007) and Taşdemir *et al.* (2008) reported that ProTaper and R-Endo rotary instruments were inadequate for the complete removal of filling material from curved root canals as were Hedström and M-Two instruments. Gu *et al.* (2008) and Somma *et al.* (2008) observed that ProTaper instruments left remnants of filling material from straight root canals as did Hedström, M-Two and K-Flex instruments.

The purpose of this *ex vivo* study was to compare remaining root filling material after the retreatment of curved root canals using manual, ProFile rotary and two new retreatment instruments (R-Endo and ProTaper Universal retreatment files).

Materials and methods

Specimen preparation

A total of 56 extracted maxillary human molar teeth with fully formed apices and no calcification, internal resorption, or previous root canal treatment were used. Soft tissue and calculus were removed mechanically from the surface of the roots. Root canals with apical diameters no greater than a size 15-K file and with a curvature of 20–42° were selected. Only teeth in which a size 10-K file could just be seen through the apex and a size 15-K file tightly fitted at the apical foramen were included. The crowns were flattened to stabilize the reference point and following access cavity preparation the root canal contents were removed with a barbed broach, apical patency was controlled with size 10-K files. The canal length was established visually when the tip of the 10-K file was seen at the apex and the working length was recorded as being 1 mm shorter. The roots were then embedded into acrylic blocks (Orthoacril, Dentarium, Ispringen, Germany) leaving the root apices exposed. A film holder (Hawe-Neos Dental, Bioggio, Switzerland) was modified to allow to exposure of standard digital radiographs. A stainless steel cube was attached to the device in order to ensure that the roots were always positioned in the same orientation (Fig. 1).

A size 10-K file was introduced to working length and standard digital radiographs (Visualix Gendex Dental Systems, Monza, Italy) were taken in bucco-lingual and proximal directions at 65 kVp, using an exposure time of 0.16 s. The images were transferred to a computer and the canal curvatures were calculated according to Schneider (1971). The distance from the orifice of the canal to the apical foramen was calculated as the root length (AUTOCAD 2000, San Rafael, CA, USA).

Preparation of the teeth

All canals were instrumented by the same operator using a crown-down technique with a series of ProFile Ni-Ti rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) in an electric motor (Technika, Dentsply Maillefer) rotating at 300 rpm. The preparation of root canals was completed when a ProFile 0.06 taper with a tip equivalent to size 30 at the working length. Glyde File Prep (Dentsply Maillefer) was used as a lubricant, and 3 mL of 2.6% NaOCl was used as an irrigant at each change of instrument. After the biomechanical preparation, a final rinse with 3 mL NaOCl and 17% EDTA was used for 1 min, followed by distilled water for 1 min. Each canal was dried using size 30 paper points.

Root filling

A fine-medium non standardized gutta-percha cone (SybronEndo, Orange, CA, USA) was trimmed to fit at the working length with tug back. The cone was lightly coated with sealer (AH Plus, De-trey-Dentsply,

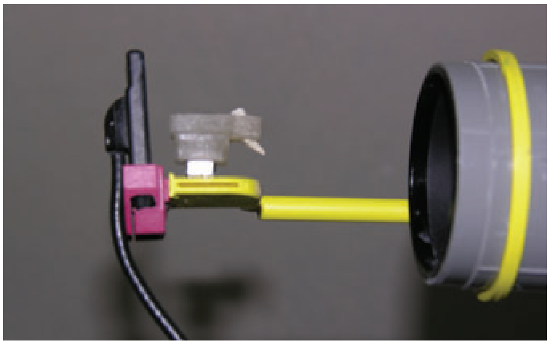

Figure 1 A modified film holder to obtain standard radiographic images.

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Konstanz, Germany) prior to the placement into the canal to the working length. Fine-medium sized system B plugger (Analytic Technology, Redmond, VA, USA) set at 200 °C was introduced into the canal and the cone was seared off at the canal orifice. The tip of the plugger was reactivated and condensation was terminated within 3 mm of working length. The plugger was held in position for 10 s before the system B was activated for 1 s and withdrawn from the tooth. Filling of the coronal portion of the canal was achieved with Obtura II (Obtura Spartan, Fenton, MO, USA) using 23 gauge needle tips at a temperature of 185 °C and condensed with Buchanan Hand Plugger Size 1 (SybronEndo, Orange, CA, USA).

The filling was assessed on digital radiographs in bucco-lingual and proximal directions. When the filling appeared to be dense and contained no voids, it was deemed adequate. Inadequately filled canals were recondensed.

The coronal aspect of the root fillings was covered with a composite resin (Valux Plus, 3M, ESPE, St Paul, MN, USA). The roots were stored in gauze dampened with aqueous solution containing 0.1% sodium azide (NaN_3) for 2 weeks at 37 °C to allow the sealer to set. The roots were randomly assigned to four experimental groups for the different procedures.

Retreatment procedures

Manual instruments

Gates–Glidden (Dentsply Maillefer) size 3 and subsequently size 2 were used to remove coronal filling material and create a reservoir for eucalyptol. After 0.1 mL of eucalyptol was deposited for 3 min, the filling material was removed with K files (Dentsply Maillefer) and Hedström files (Dentsply Maillefer) sizes 30–15 (in descending order) to the working length using a circumferential filling motion. Eucalyptol was replenished up to twice or thrice. Once the working length had been reached with a size 15 file, sizes 20, 25 and 30 were used at the working length. In total, 10 instruments were used in this group.

ProFile ISO rotary instruments (Dentsply Maillefer)

ProFile size 4 and 3 orifice shapers were used to remove the coronal filling material and create a reservoir for 0.1 mL of eucalyptol. After 3 min, size 30, 0.06 taper and size 25, 0.06 taper ProFile NiTi rotary instruments were used in the middle third of the canal. Then, 0.04 tapered size 30 and 25 instruments were used in the apical third; finally a size 30, 0.06 taper instrument was used at working length. Eucalyptol was replenished up to twice or thrice. In total, six instruments were used in this group.

R-Endo retreatment files (Micro–Mega, Besançon, France)

R-Endo retreatment files were used with a rotary electric motor and handpiece (Inget® 06 contra-angle; Micro–Mega, Besançon, France) at 300 rpm. A size 25, 0.04 taper Rm hand file (K-File) was used with 1/4 turn pressure directed towards the apex to create a pathway thus allowing the centering and the alignment of the next instrument. A size 25, 0.12 taper Re NiTi rotary file was used 1 to 3 mm beyond the pulp chamber floor with circumferential filing. Again, 0.1 mL of eucalyptol was deposited into the reservoir created for 3 min. A size 25, 0.08 taper R1 NiTi rotary file was used to penetrate from the coronal third to the beginning of the middle third through repeated apically directed pushing actions. A size 25, 0.06 taper R2 NiTi rotary file was used from the middle third to the beginning of the apical third. A size 25, 0.04 taper R3 NiTi rotary file was used at the working length with circumferential filing action. Finally, the retreatment procedure was concluded with the use of a size 30, 0.04 taper Rs NiTi rotary file at the working length. In total, six instruments were used in this group.

ProTaper Universal retreatment files (Dentsply Maillefer, Ballaigues, Switzerland)

The D1 ProTaper file was used to remove the filling material from the cervical third of the root canal and 0.1 mL of eucalyptol was deposited for 3 min into the reservoir created. A D2 ProTaper file was used in the coronal two thirds of the root canal. The D3 ProTaper file was used with light apical pulses of pressure until the working length was reached and no further filling material could be removed. In total, three instruments were used in this group.

Copious irrigation with 2 mL of 5.25% NaOCl was performed throughout the procedures at each change of instrument. Final irrigation was performed with 10 mL of 5.25% NaOCl. Criteria for the assessment of removal of the filling material were the absence of gutta-percha or sealer on the instrument used last.

To provide similar conditions for all groups, 300 rpm was selected for all rotary files that were used in an electric motor (Technika, Dentsply Maillefer). Each instrument was used for a maximum of five canals. If any deformation or fracture occurred, it was recorded, and the instrument or tooth was replaced.

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Evaluation criteria

The roots were digitally radiographed in bucco-lingual and proximal directions. The images were transferred to a PC and AUTOCAD 2000 was used to evaluate the area of filling material remaining on the root canal walls. Remaining filling material was identified and outlined by a trained operator through a difference in radio-opacity (Fig. 2). The area of remaining filling material as well as the canal wall in each portion was measured in both directions using AUTOCAD 2000. Area fractions of root canal wall covered by remaining filling material was calculated in percentage terms by dividing the area of remaining filling material with the total area of canal wall. Each image was outlined thrice by the same operator to increase the reproducibility and to decrease the intra-operator variability, and then the average of the obtained measurements was taken.

The total removal time was noted for each root. It began with the initial gutta-percha removal and ended when canals were deemed to be clean.

Extrusion of debris or filling material through the apical foramen was evaluated visually and scored as; no debris 0, only sealer 1, sealer and gutta-percha 2.

Fractures and deformations of instruments and ledging and perforations were also recorded.

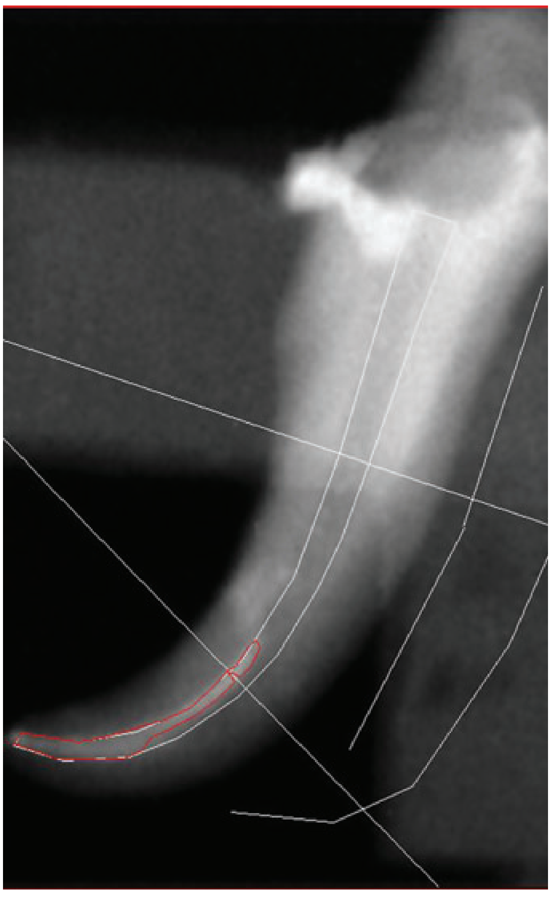

Figure 2 Images of gutta-percha and sealer remaining on the root canal walls and the calculation of the ratios of areas as the percentage of remaining debris using a software program (AUTOCAD 2000).

Statistical analysis

Root canal lengths and the root canal curvatures were analysed using one-way ANOVA and Kruskal–Wallis tests at a significance level of $P < 0.05$ respectively. For the analysis of cleanliness of root canal walls, working time, and extruded materials, Kruskal–Wallis and Mann–Whitney U tests were performed at a significance level of $P < 0.05$.

Results

The mean root canal lengths of the teeth were 12.58 mm ± 1.47 mm. The root curvatures of the teeth ranged between 20° and 42° (mean = 32° ± 4°). There were no statistically significant differences amongst the experimental groups in terms of the root canal length and the degree of curvature ($F = 0.405$, $P = 0.415$, $\chi^2 = 2.850$, $P = 0.750$ respectively).

The working length was obtained in all groups in all teeth except seven teeth that were excluded due to fractured instruments.

Evaluation of remaining filling material

Complete removal of filling material occurred in only three specimens retreated with manual instruments when evaluated radiographically; the differences were not significant ($P > 0.05$).

Considering the whole canal, there were statistically significant differences amongst the groups in terms of the remaining filling material ($P < 0.05$). The remaining filling material in the bucco-lingual direction was less in the group using manual instruments than that in R-Endo and ProTaper groups ($P < 0.05$). In the proximal direction, the remaining filling material was less in groups using manual and ProFile instruments than that in R-Endo ($P < 0.05$) (Table 1).

There were no significant differences in the coronal, middle, and apical thirds in both bucco-lingual and

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Table 1 The area (%) of remaining filling material imaged in bucco-lingual and proximal directions (mean ± SD)*

Groups	Bucco-lingual mean ± SD (n = 14)	Proximal mean ± SD (n = 14)
Manuel instruments	14 ± 25[a]	14 ± 25[a,c]
ProFile	15 ± 20[a,b]	11 ± 15[c]
R-Endo	27 ± 30[b]	23 ± 27[b]
ProTaper	24 ± 28[b]	20 ± 23[a,b,c]

*Groups identified by different letters are significantly different (P > 0.05).

proximal directions amongst the groups ($P > 0.05$) (Table 2) when evaluating the remaining filling material. On the other hand, there were statistically significant differences amongst the coronal, middle and apical thirds of the canal walls irrespective of the technique used. A greater amount of filling material remained in the apical third than in the middle and cervical ($P < 0.05$) (Table 3).

Amount of apically extruded material

No significant differences were found amongst the groups in terms of the apically extruded material ($\chi^2 = 1.538$, $P > 0.05$).

Time required for removal

The time required for removal with manual instruments was significantly lower than when R-Endo and ProFile instrument were used ($P < 0.05$). ProTaper and manual instruments were more rapid than the ProFile ($P < 0.05$) (Table 4).

Procedural errors

No fracture occurred in the manual and ProFile instruments. Five instruments in the ProTaper (3 D3 and 2 D2) and two in R-Endo (R3) groups fractured. Lateral perforation at the outer side of the root was observed in two roots of ProTaper groups. Seven teeth in ProTaper and two in R-Endo groups were replaced. More procedural errors were noted in ProTaper group ($P < 0.05$) (Table 4).

Table 3 The area (%) of remaining filling material in each third of root canals (mean ± SD)*

	Minimum–Maximum	Mean ± SD
Coronal third	0–67	7 ± 13[a]
Middle third	0–78	14 ± 21[b]
Apical third	0–100	34 ± 29[c]

*Groups identified by different letters are significantly different (P > 0.05).

Table 4 Time(s) required for the removal of the filling material* and the number of procedural errors

Groups	Time	Deformed instrument	Fractured instrument	Perforation
Manuel instruments	5.08 ± 2.99[a]	–	–	–
ProFile	8.81 ± 2.65[b]	–	–	–
R-Endo	8.03 ± 3.40[b]	1	2 R3	–
ProTaper	6.02 ± 3.02[a]	–	3 D3, 2 D2	2

*Groups identified by different letters are significantly different (P > 0.05).

Discussion

Different techniques have been used to evaluate remaining filling material (Friedman *et al.* 1993, Imura *et al.* 2000, Schirrmeister *et al.* 2006b,c) and radiographs have been used extensively (Ferreira *et al.* 2001, Masiero & Barletta 2005, Gergi & Sabbagh 2007). Observer performance can vary because root canal wall cleanliness evaluation is subjective and semi-quantitative. However, the remaining filling material is not disturbed, which might otherwise be lost by splitting the roots (Ferreira *et al.* 2001, Masiero & Barletta 2005, Schirrmeister *et al.* 2006a). As radiographs are two dimensional, they cannot distinguish sealer from gutta-percha and may be subjected to magnification and distortion. It

Table 2 The area (%) of remaining filling material imaged in bucco-lingual and proximal directions in each third of root canals (mean ± SD)

Groups	Bucco-lingual direction			Proximal direction		
	Coronal	Middle	Apical	Coronal	Middle	Apical
Manuel instruments	2 ± 5	8 ± 13	32 ± 35	2 ± 7	6 ± 11	34 ± 34
ProFile	5 ± 11	10 ± 13	29 ± 24	4 ± 11	6 ± 11	23 ± 16
R-Endo	14 ± 20	30 ± 29	36 ± 35	10 ± 15	24 ± 26	37 ± 31
ProTaper	10 ± 17	16 ± 24	45 ± 29	7 ± 10	15 ± 22	38 ± 22

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is also known that radiographs do not reveal all remaining material (Schirrmeister *et al.* 2006a). In this study, roots were radiographed digitally in bucco-lingual and proximal directions. In addition, each image was outlined thrice by a trained operator who was unaware of the group assignment and had previously identified and outlined 300 images according to their differences in radio-opacity.

It was not possible to remove all the traces of gutta-percha and sealer from the root canal walls with any of the techniques, which has also been reported in other studies (Wilcox *et al.* 1987, Hülsmann & Bluhm 2004, Taşdemir *et al.* 2008). Complete removal of all filling material as detected radiographically was obtained only in three of the root canals, instrumented with manual instruments. Ferreira *et al.* (2001) and Gergi & Sabbagh (2007) reported that removal of root filling materials in curved canals using Hedström, 0.04 ProFile and R-Endo instruments produced similar levels of remaining material.

As demonstrated in previous studies (Masiero & Barletta 2005, Bueno *et al.* 2006), it was also observed in this study that a greater amount of filling material remained in the apical third than in the middle and cervical thirds irrespective of the technique used. Anatomical variations are greater in the apical third. Although Masiero & Barletta (2005) reported that a rotary system was more effective in removing the filling materials in the apical third, no difference was found in this study amongst the various techniques in curved root canals. This finding was also reported in a previous study (Schirrmeister *et al.* 2006c).

The manufacturer of R-Endo instruments claims that the instrument is designed specially for retreatment as they have three equally spaced cutting edges, no radial land and active tip. Taşdemir *et al.* (2008) reported that R-Endo retreatment files and Hedström files have similar effectiveness in removing filling material in straight root canals. Similarly, Gergi & Sabbagh (2007), in curved root canals, reported no significant difference between R-Endo retreatment and Hedström files. In this study, K-files were used in combination with Hedström files to remove the gutta-percha mass and this combination may have advantages. The good performance of ProTaper Universal retreatment instruments in straight root canals in the study of Gu *et al.* (2008) was attributed to the three progressive tapers and length design of D1, D2 and D3 files. They mentioned that these features may enable the retreatment instruments to cut not only gutta-percha but also the superficial layer of dentine during root filling removal. This aggressive design and active cutting tip of D1 may have caused the lateral perforation at the outer side of two roots in the ProTaper group in this study. As the aim of this study was to assess the efficiency of the instruments designed for removing gutta-percha only, conventional ProTaper rotary instruments were not used. If the finishing instruments had been used, the performance of the ProTaper group would have improved.

In previous studies, rotary instruments were reported to be more rapid in removing gutta-percha than manual instruments (Hülsmann & Stotz 1997, Betti & Bramante 2001, Ferreira *et al.* 2001, Hülsmann & Bluhm 2004). In contrast, Imura *et al.* (2000) found that Hedström files required less time for retreatment than the Quantec group and they attributed it to the removal of gutta-percha in larger pieces. Similarly, it was concluded in this study that the combination of the Hedström and K files required less time than the other techniques. The number and effectiveness of the instruments in the removal process of filling material influenced the working time. Despite the similar effectiveness of manual and ProFile instruments, the removal of gutta-percha in larger pieces by Hedström files may shorten the working time. The number of instruments in ProTaper and R-Endo groups also affected the working time even though they have similar effectiveness. ProTaper groups where three instruments were used, were significantly faster than R-Endo groups. Taşdemir *et al.* (2008), By contrast, reported that R-Endo was faster than Heström files in straight root canals. This conclusion can be explained with the number of files (three files) used in R-Endo groups.

Five instruments fractured in the ProTaper and two in the R-Endo groups. Haïkel *et al.* (1999) noted the taper was a significant factor in determining fracture probability for rotary instruments. The higher rate of fractured ProTaper may be related to the greater tapers of (0.07) the D3 files. In an earlier study investigating the retreatment of curved canals, only F2 and F3 ProTaper finishing instruments were used because of the high fracture rate of the F1 ProTaper finishing files. As reported in earlier studies (Imura *et al.* 2000, Betti & Bramante 2001, Schirrmeister *et al.* 2006c), apical extrusions were observed in all groups but there was no significant difference amongst the groups.

Conclusions

Under the experimental conditions, it was impossible to remove all traces of gutta-percha and sealer from the root canal walls with any of the techniques used.

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However, the full working length was achieved in all root canals. ProTaper Retreatment and R-Endo instruments were less effective in the removal of filling material from curved root canal walls than the Manual and ProFile instruments.

References

Barletta FB, Rahde Nde M, Limongi O, Moura AA, Zanesco C, Mazocatto G (2007) In vitro comparative analysis of 2 mechanical techniques for removing gutta-percha during retreatment. *Journal of the Canadian Dental Association* **73**, 65–65e.

Barrieshi-Nusair KM (2002) Gutta-percha retreatment: effectiveness of nickel–titanium rotary instruments versus stainless steel hand files. *Journal of Endodontics* **28**, 454–6.

Betti LV, Bramante CM (2001) Quantec SC rotary instruments versus hand files for gutta-percha removal in root canal retreatment. *International Endodontic Journal* **34**, 514–9.

Bueno CE, Delboni MG, de Araújo RA, Carrara HJ, Cunha RS (2006) Effectiveness of rotary and hand files in gutta-percha and sealer removal using chloroform or chlorhexidine gel. *Brazilian Dental Journal* **17**, 139–43.

Farge P, Nahas P, Bonin P (1998) In vitro study of a Nd:YAP laser in endodontic retreatment. *Journal of Endodontics* **24**, 359–63.

Ferreira JJ, Rhodes JS, Ford TR (2001) The efficacy of gutta-percha removal using ProFiles. *International Endodontic Journal* **34**, 267–74.

Friedman S, Moshonov J, Trope M (1993) Residue of gutta-percha and a glass ionomer cement sealer following root canal retreatment. *International Endodontic Journal* **26**, 169–72.

Gergi R, Sabbagh C (2007) 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**, 532–7.

Gu LS, Ling JQ, Wei X, Huang XY (2008) Efficacy of ProTaper Universal rotary retreatment system for gutta-percha removal from root canals. *International Endodontic Journal* **41**, 288–95.

Haïkel Y, Serfaty R, Bateman G, Senger B, Allemann C (1999) Dynamic and cyclic fatigue of engine-driven rotary nickel–titanium endodontic instruments. *Journal of Endodontics* **25**, 434–40.

Hülsmann M, Bluhm V (2004) Efficacy, cleaning ability and safety of different rotary NiTi instruments in root canal retreatment. *International Endodontic Journal* **37**, 468–76.

Hülsmann M, Stotz S (1997) Efficacy, cleaning ability and safety of different devices for gutta-percha removal in root canal retreatment. *International Endodontic Journal* **30**, 227–33.

Imura N, Zuolo ML, Ferreira MO, Novo NF (1996) Effectiveness of the canal finder and hand instrumentation in removal of gutta-percha root fillings during root canal retreatment. *International Endodontic Journal* **29**, 382–6.

Imura N, Kato AS, Hata GI, Uemura M, Toda T, Weine F (2000) A comparison of the relative efficacies of four hand and rotary instrumentation techniques during endodontic retreatment. *International Endodontic Journal* **33**, 361–6.

Kosti E, Lambrianidis T, Economides N, Neofitou C (2006) Ex vivo study of the efficacy of H-files and rotary Ni–Ti instruments to remove gutta-percha and four types of sealer. *International Endodontic Journal* **39**, 48–54.

Ladley RW, Campbell AD, Hicks ML, Li SH (1991) Effectiveness of halothane used with ultrasonic or hand instrumentation to remove gutta-percha from the root canal. *Journal of Endodontics* **17**, 221–4.

Masiero AV, Barletta FB (2005) Effectiveness of different techniques for removing gutta-percha during retreatment. *International Endodontic Journal* **38**, 2–7.

Saad AY, Al-Hadlaq SM, Al-Katheeri NH (2007) Efficacy of two rotary NiTi instruments in the removal of Gutta-Percha during root canal retreatment. *Journal of Endodontics* **33**, 38–41.

Sae-Lim V, Rajamanickam I, Lim BK, Lee HL (2000) Effectiveness of ProFile .04 taper rotary instruments in endodontic retreatment. *Journal of Endodontics* **26**, 100–4.

Schirrmeister JF, Hermanns P, Meyer KM, Goetz F, Hellwig E (2006a) Detectability of residual Epiphany and gutta-percha after root canal retreatment using a dental operating microscope and radiographs–an ex vivo study. *International Endodontic Journal* **39**, 558–65.

Schirrmeister JF, Wrbas KT, Meyer KM, Altenburger MJ, Hellwig E (2006b) Efficacy of different rotary instruments for gutta-percha removal in root canal retreatment. *Journal of Endodontics* **32**, 469–72.

Schirrmeister JF, Wrbas KT, Schneider FH, Altenburger MJ, Hellwig E (2006c) Effectiveness of a hand file and three nickel–titanium rotary instruments for removing gutta-percha in curved root canals during retreatment. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **101**, 542–7.

Schneider SW (1971) A comparison of canal preparations in straight and curved root canals. *Oral Surgery, Oral Medicine, and Oral Patholology* **32**, 271–5.

Somma F, Cammarota G, Plotino G, Grande NM, Pameijer CH (2008) The effectiveness of manual and mechanical instrumentation for the retreatment of three different root canal filling materials. *Journal of Endodontics* **34**, 466–9.

Taşdemir T, Er K, Yildirim T, Celik D (2008) Efficacy of three rotary NiTi instruments in removing gutta-percha from root canals. *International Endodontic Journal* **41**, 191–6.

Wilcox LR, Krell KV, Madison S, Rittman B (1987) Endodontic retreatment: evaluation of gutta-percha and sealer removal and canal reinstrumentation. *Journal of Endodontics* **13**, 453–7.

Wolcott JF, Himel VT, Hicks ML (1999) Thermafil retreatment using a new ''System B'' technique or a solvent. *Journal of Endodontics* **25**, 761–4.

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