Original Article

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Efficacy of gutta-percha solvent for removing gutta-percha from curved root canals

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Objectives: The aim of this study was to compare the efficacies of the following gutta-percha removal techniques: NiTi rotary files, hand files, and hand files with solvent. Additionally, the study observed the dentin loss and complications that can occur during the process.

Materials and Methods: Forty extracted human maxillary molars with severely curved mesiobuccal or distobuccal roots were selected. After root canal preparation, the curved canals were filled with gutta-percha and AH Plus sealer. The teeth were randomly allocated into 4 groups with different gutta-percha removal techniques: group 1 - rotary retreatment files, group 2 - hand files, group 3 - hand files with natural gutta-percha solvent, and group 4 - hand files with chloroform. The teeth were scanned by micro-computed tomography after instrumentation, root canal filling, and gutta-percha removal to assess the volume of residual gutta-percha, and percentage of dentin loss and any procedural errors. The statistical analyses were conducted using ANOVA to compare root canal curvatures, and the Kruskal-Wallis and Dunn's tests were employed for comparing the remaining gutta-percha and dentin loss. A significance level of 5% was applied.

Results: The residual gutta-percha in the hand files with chloroform and hand files with gutta-percha solvent groups was 2.56% and 4.34%, respectively, which were significantly ($p < .05$) lower than those of the hand files and rotary retreatment files groups (12.88% and 13.12%). The percentages of dentin loss were not significantly different ($p > .05$) among the groups. Root perforation and instrument separation were not observed.

Conclusion: For retreating severely curved canals, using hand files with solvent was superior to using hand files and rotary files alone for removing gutta-percha.

Keywords: curved root canal, gutta-percha solvent, hand file, retreatment technique, rotary retreatment file

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Introduction

Primary endodontic treatment failure is commonly caused by intraradicular infection, particularly from inadequate disinfection or obturation [1-4]. Non-surgical endodontic retreatment aims to remove the root canal filling material and residual infections [2, 5, 6]. The core gutta-percha root canal filling that is commonly used in combination with root canal sealer, can be heated to become pliable and soft or soluble in various solvents. Gutta-percha removal should be effective without complications. Various gutta-percha removal techniques have been proposed, including heat, hand files with or without solvents, ultrasonic tips, and nickel-titanium rotary retreatment files. Factors influencing gutta-percha removal are the density and extension of gutta-percha, root canal morphology, and the removal technique.

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Well-condensed gutta-percha in a curved or narrow canal, is recommended to be dissolved or softened with solvents to facilitate instrument penetration into the apical portion, reduce the risk of instrument binding to the root canal wall, and prevent ledge formation, canal transportation, instrument separation, canal blockage, root perforation, and excessive dentin loss. Using hand files in combination with gutta-percha solvent and wicking with paper points can prevent ledges and root perforation [5-9]. Some nickel-titanium rotary file systems with high rotational speed and torque can rapidly remove gutta-percha, however, the incidence of instrument breakage was also reported [10]. A specially designed ProTaper Universal retreatment rotary file system with a convex triangular cross-section comprises three instruments: D1 (tip 30 and taper 0.09), featuring an active tip initially penetrating into the coronal third filling material; D2 (tip 25 and taper 0.08), utilized at the middle third; and D3 (tip 20 and taper 0.07), employed at the full working length [11]. When using conventional or retreatment rotary files, none of the instruments completely removed the root canal filling material from the root canals [12-13].

Gutta-percha solvents have been recommended for gutta-percha removal in curved canals [14-15]. These solvents need an appropriate working time to soften gutta-percha with low toxicity to cells. The most potent solvent was found to be chloroform, however, the United States Food and Drug Administration (FDA) prohibited its use in drugs and cosmetics in 1976 due to its carcinogenic potential in animal models and possibility of being a carcinogenic agent in humans [16-17]. Other alternative chemical agents for dissolving gutta-percha are xylene, organic solvents, and essential oils, such as eucalyptol oil and d-limonene [14-15]. D-limonene is a cyclic monoterpene hydrocarbon, a colorless liquid found in the peels of citrus fruits, such as oranges, lemons, limes, and grapefruits. This material has low toxicity and has been shown to be an effective gutta-percha solvent with a softening efficacy comparable to that of eucalyptol oil [15]. The GP-Solvent (Nippon Shika Yakuhin, Shimonoseki, Japan) is one of the most common alternative commercial solvents that is mainly composed of d-limonene. However, GP-Solvent was shown to be toxic to L929 cells [18]. Jantarat et al. found that grapefruit oil and tangerine oil were more effective in dissolving gutta-percha compared with lime oil and lemon oil. The softening and dissolving efficacy of a mixture of essential oils from citrus fruits were also evaluated and found to be comparable to xylene and GP-Solvent [19].

The efficacy of gutta-percha removal, either with hand files or nickel-titanium rotary files, depends on the differences in the instrument systems and the method for evaluating canal cleanliness. Currently, a micro-computed tomography (micro-CT) is used to evaluate the remaining gutta-percha in root canal. A systematic review from 22 micro-CT studies revealed that different instrumentation protocols could effectively, but not completely, remove root canal filling materials from the root canal system. Hand instrumentation was the only method that was not associated with iatrogenic errors. The conventional rotary system and retreatment files exhibited similar abilities to remove root filling materials, and solvents enhanced the penetration of the files to reach the root apex [20]. The objectives of this study were to compare the efficacies of the following gutta-percha removal techniques: NiTi rotary files, hand files, and hand files with solvents, and the dentin loss and complications that can occur were also evaluated.

Materials and Methods

This project received ethical approval from the Ethics Committee of the Faculty of Dentistry and the Faculty of Pharmacy, Mahidol University Institutional Review Board (Certificate of exemption no. MU-DT/PY-IRB 2018/020.2004).

Tooth selection and canal preparation

The sample size calculation was based on assuming a 5% alpha error with 80% study power. The effect size estimation was derived from the means, standard deviations of remaining filling material percentage, and size by each experimental group of a previous study [21]. Using the F test and pooled standard deviation, the sample size was calculated using Gpower 3.1.96 to be 10 specimens per group.

Forty extracted human permanent curved mesiobuccal or distobuccal root maxillary molars without endodontic treatment, cracks, root resorptions or immature apices were chosen. The tooth lengths were 20-22 mm and the separated mesiobuccal and distobuccal curved roots were collected and kept in a 0.1% thymol solution. The soft tissue and calculus on the tooth surfaces were removed, and the teeth were soaked in 2.5% sodium hypochlorite solution for 5 minutes. Digital radiographs of the buccolingual and mesiodistal views were acquired. The root canal curvature was measured using the Schneider method; only teeth with a severe root canal curvature of 25-30° were selected [22]. The teeth were accessed, and the apical foramen size was confirmed and not larger than a size 20 K-file (Dentsply Maillefer, Ballaigues, Switzerland). The tooth cusps were reduced to obtain a flat reference area and to standardize each specimen to a tooth length of 19 mm, and 18 mm was determined as the working length. The root canals were instrumented with a Protaper NEXT system (Dentsply Maillefer, Ballaigues, Switzerland) to the master apical file size X3 (30/07) and rinsed with 5 mL 2.5% sodium hypochlorite (NaOCl) between each instrument change (total of 15 mL). The final irrigation was performed with 5 mL 17% ethylenediaminetetraacetic acid for 1 minute, followed by 5 mL 2.5% NaOCl.

The prepared root canal was dried with paper points and filled with ProTaper NEXT Comfort Fit gutta-percha points (Dentsply Maillefer, Ballaigues, Switzerland) and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) using a continuous wave of condensation technique. A heat plugger size 30/.04 of the System B unit (Analytic Sybron Dental Specialties, Orange, CA) set at 200 °C was pushed on gutta-percha in the root canal and terminated 3 mm from the working length. The plugger was inactivated and held for 10 seconds and then reactivated for 1 second before withdrawing it from the tooth. The excess coronal gutta-percha was removed, and a cold plugger was used to condense the apical gutta-percha. The coronal space of the root canal was refilled with gutta-percha using the thermoplastic injection technique (Obtura, Coltene/Whaledent, Cuyahoga Falls, OH) to the orifice level. The access cavity was filled with temporary filling material (Cavit, Dentsply DeTrey, Konstanz, Germany). Buccolingual and mesiodistal radiographs were acquired to verify the extent and homogeneity of the root canal filling. The filled teeth were stored in a humidified atmosphere at 37 °C for seven days to ensure sealer setting.

Gutta-percha removal technique

The temporary filling was removed. The D1 file of the ProTaper Universal Retreatment System (Dentsply Maillefer, Ballaigues, Switzerland) attached to an electric motor (Endo Mate DT, NSK, Tokyo, Japan) was used to remove the coronal 3 mm

gutta-percha with a constant speed of 500 rpm and 3 Ncm torque. The teeth were randomly divided into four groups, and different techniques were used to remove the middle and apical gutta-percha.

Group 1: Rotary files (RF)

ProTaper Universal Retreatment instruments D2 and D3 were sequentially used to remove gutta-percha from the middle and apical parts of the root canal. Each file was used for five root canals and then discarded. The remaining gutta-percha was removed with hand files. The root canals were irrigated with 15 mL 2.5% NaOCl during each file change.

Group 2: Hand files (HF)

Gutta-percha from the middle and apical root canal was removed by the crown-down technique with pre-curved H-files (Dentsply Maillefer, Ballaigues, Switzerland) sized 30-15 until the working length was achieved. H-files sized 20, 25, and 30 were subsequently rotated not more than 45° at the working length to engage and remove the remaining gutta-percha. The root canals were irrigated with 15 mL 2.5% NaOCl during each file change.

Group 3: Hand files with natural gutta-percha solvent (HF+GC)

Natural gutta-percha solvent (GuttaClear, M Dent, Bangkok, Thailand) (0.1 mL) was dropped into the coronal portion of the root canal and left for two minutes to soften the gutta-percha before the retreatment procedure. The gutta-percha was penetrated with H-files using the same technique as that described for group 2. The solvent was replenished to a total of 0.5 mL during the entire procedure. The root canal irrigation was the same as that for group 2.

Group 4: Hand files with chloroform (HF+CF)

The gutta-percha removal procedure in this group was similar to that in group 3. Chloroform was used as the solvent. This group served as a positive control group.

When there was no visible gutta-percha on the hand file or the procedure reached the maximum 20 minutes, simulating an appropriate clinical chair-time, a radiograph was taken. In some samples, the gutta-percha was completely eliminated from the root canals in less than 20 minutes. If the remaining gutta-percha was observed on the radiograph, the removal procedure was repeated until a duration of 20 minutes was reached. The samples were flushed a final time with 5 mL 2.5% NaOCl to remove debris, and the canals were dried with paper points before acquiring mesiodistal and buccolingual radiographs.

The number of specimens with complications that occurred during the gutta-percha removal procedure, i.e., separation of the instrument or root perforation, were recorded.

Micro-CT evaluation

The root-filled teeth were scanned before and after gutta-percha removal using micro-CT (SkyScan1173, Kontich, Belgium) with an image pixel size of 9 microns, a power voltage of 80 kV, a tube current of 100 µA with an exposure of 500 ms and a 1.0 mm Al filter (Fig. 2). The specimens were scanned 360° with a 0.4° rotation step and reconstructed into a 3-dimensional image with the reconstruction software (NRecon v1.6.4; Bruker-MicroCT, Kontich, Belgium). The micro-CT 3-D images were analyzed with CT analyzer software (CTAn 1.16: Skyscan, Kontich, Belgium). CT volume software (CT Vol: Skyscan, Kontich, Belgium) was used to measure the preoperative and postoperative volumes of gutta-percha and root dentin in mm^3. The remaining gutta-percha and dentin loss were calculated as percentages.

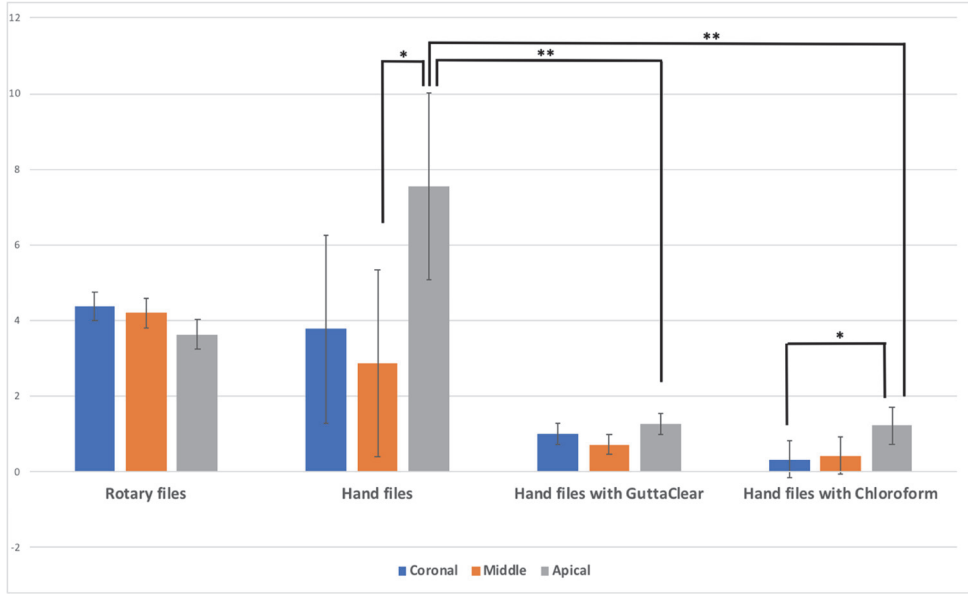

Figure 1 Mean percentages of remaining gutta-percha by volume at the coronal, middle and apical levels of the root canals after its removal in each of the experimental groups.
*Significant difference between root levels in the same group ($p < .05$)
**Significant difference between root levels between the different groups ($p < .05$)

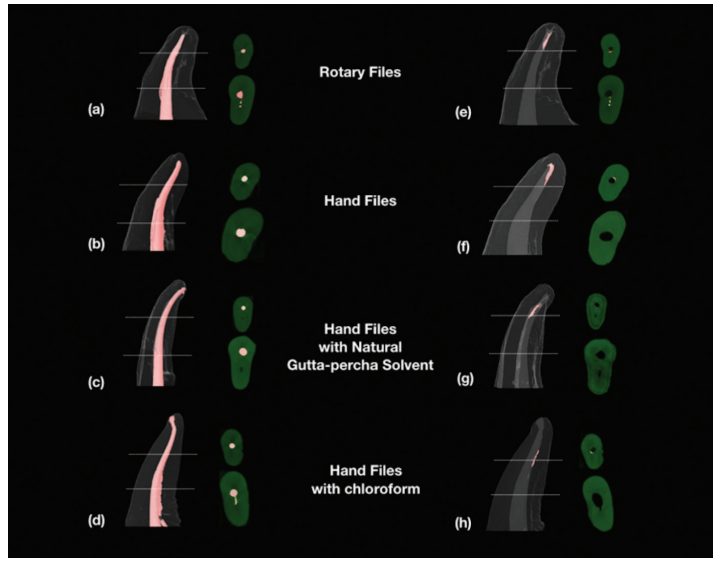

Figure 2 Microcomputed tomography reconstructions and cross-sectional slices at 4 mm (upper) and 7 mm (lower) from the apical foramen of representative samples before (a-d) and after (e-h) the gutta-percha removal procedures in each of the experimental groups.

Statistical analysis

The statistical analysis was performed with IBM SPSS Statistics for Mac, version 23 (IBM Corp., Armonk, N.Y.). The data distribution and equality of variances were determined by the Shapiro-Wilk test and Levene's test. The one-way ANOVA test was used for comparing root canal curvatures. Due to the non-normally distributed data, the Kruskal-Wallis test and Dunn's test were utilized to identify differences in remaining gutta-percha percentage and dentin loss percentage among the four experimental groups. Furthermore, differences in remaining gutta-percha percentage at the coronal, middle, and apical levels of each experimental group were also identified using the Kruskal-Wallis test and Dunn's test. The level of significance was set at 5% ($p < .05$).

Results

The root canal curvature of the experimental teeth ranged from 25.14°-29.97° (mean = 27.97° ± 1.44°). There were no significant differences in root canal curvature among the experimental groups ($p > .05$) (Table 1).

The median percentage of residual gutta-percha volume in the root canals was 2.56%, 4.34%, 12.88%, and 13.12% in the HF + CF, HF + GC, HF, and RF groups, respectively. The HF + GC and the HF + CF groups had significantly less gutta-percha remaining than the RF and HF groups ($p < .05$). There was no significant difference in the remaining gutta-percha between the HF + GC and HF + CF groups ($p > .05$) or the RF and HF groups ($p > .05$) (Table 2). The remaining gutta-percha was mostly located at the apical part of the root canals, in which the HF group had significantly more than the HF + GC and HF + CF groups ($p < .05$) and was not significantly different from the RF group ($p > .05$) (Table 3, Fig. 1). When considering the remaining gutta-percha between root levels within a group, the apical level demonstrated significantly more gutta-percha than the middle level in the HF group ($p < .05$) and the apical level presented significantly more gutta-percha than the coronal level in the HF + CF group ($p < .05$) (Table 3, Fig. 1). The remaining apical gutta-percha in the HF + GC group and HF + CF group were not significantly different ($p > .05$). In the coronal and middle parts of the root canals, the HF + CF group had significantly less remaining gutta-percha than the RF group and HF group ($p < .05$), but was not different from the HF + GC group ($p > .05$) (Table 3).

Table 1 Means of the degree of canal curvature of the experimental groups. No statistically significant differences were found between the groups ($p > .05$).

Group	N	Canal curvature (degrees) Mean (±SD)
1. RF	10	28.27 (26.97±29.57)
2. HF	10	27.52 (25.95±29.09)
3. HF + GC	10	27.92 (26.41±29.43)
4. HF + CF	10	28.16 (26.68±29.64)

Table 2 Percentages of remaining gutta-percha by volume after its removal in each of the experimental groups. Different superscript letters indicate a significant difference ($p < .05$) between groups.

Group	N	Remaining gutta-percha (%) Median (min, max)
RF	10	13.12[a] (3.85, 27.57)
HF	10	12.88[a] (9.44, 37.91)
HF + GC	10	4.34[b] (0.61, 12.75)
HF + CF	10	2.56[b] (1.00, 15.12)

Table 3 Percentages of remaining gutta-percha by volume at each root canal level after its removal in each of the experimental groups. Different superscript capital letters (A, B) in each row indicate significant differences in the levels in the same group ($p < .05$). Different superscript lowercase letters (a, b) in each column indicate significant differences in the same level between experimental groups ($p < .05$).

Group	Median (min, max) of remaining gutta-percha (%)		
	Coronal	Middle	Apical
1. RF	4.37 (0.44, 10.95)$^{A, a}$	4.20 (0.25, 9.43)$^{A, a}$	3.63 (0.92, 18.21)$^{A, a, b}$
2. HF	3.77 (0.69, 5.75)$^{AB, a}$	2.87 (1.19, 7.11)$^{A, a}$	7.54 (2.12, 10.60)$^{B, b}$
3. HF + GC	1.01 (0.05, 4.12)$^{A, a, b}$	0.72 (0.13, 7.07)$^{A, a, b}$	1.26 (0.08, 11.60)$^{A, a}$
4. HF + CF	0.33 (0.00, 2.19)$^{A, b}$	0.43 (0.07, 2.11)$^{AB, b}$	1.22 (0.63, 4.70)$^{B, a}$

The median percentage of dentin loss from retreatment procedures was 7.30%, 7.38%, 18.80%, and 19.56% in the HF + CF, HF, RF, and HF + GC groups, respectively, which were not significantly different ($p > .05$) (Table 4). Root perforation and instrument separation was not observed in any of the specimens in the experimental groups.

Table 4 Percentage of dentin loss after gutta-percha removal in each of the experimental groups. No significant differences were observed between groups ($p > .05$).

Group	N	Dentin loss (%)
		Median (min, max)
RF	10	18.80 (9.04, 35.68)
HF	10	7.38 (1.77, 27.63)
HF + GC	10	19.56 (1.13, 35.92)
HF + CF	10	7.30 (1.52, 35.46)

Discussion

In the present study, micro-CT was used because it is non-destructive and a three-dimensional assessment, enabling accurate analysis of the remaining volume of gutta-percha and the amount of dentin loss. The severely curved root canals, ranging from 25-30° for the retreatment procedure, made the study more challenging. The mesiobuccal or distobuccal roots of the maxillary molars are considered good specimens to evaluate because these roots are often curved and have thin root canal walls, which pose difficulties for retreatment and frequently lead to complications. The remaining gutta-percha, which ranged from 2.56–13.12%, was comparable to those of the previous experimental micro-CT studies in curved root canals [23-27]. The results revealed that the root canal filling could not to be completely removed, regardless of the technique used, which was mainly due to the difficulty in approaching the apical part of the curvature of the root canal. A supplemental technique may be required to remove the remaining gutta-percha in a future study.

The 20 minute limitation for the retreatment procedures was an adequate duration to remove the bulk of the gutta-percha from curved root canals, making it more clinically relevant to actual clinical procedures. In addition, the limited 20 minute removal time was used to control the effectiveness of the treatment.

The hand files along with either chloroform or natural gutta-percha solvent groups had the lowest remaining gutta-percha in the root canal. The appropriate amount of solvent was allowed to interact for an optimal length of time to soften the gutta-percha and easily negotiate with hand files [9]. In curved canals, less resistance during negotiation facilitated the tactile sense of the operator to locate and engage the gutta-percha. After engagement, the gutta-percha was pulled out from the canal in pieces. The hand file could then be advanced apically. Many studies have reported that less time is required to reach the apex and less gutta-percha remained in the root canal when using gutta-percha solvent [14-15]. Thus, the solvent played an important role in removing gutta-percha, especially in curved canals and well-condensed gutta-percha. Chloroform is the most effective solvent for gutta-percha removal. It has been widely accepted as the optimum method in several studies [6, 14-15]. However, the use of chloroform has been prohibited by the U.S. Food and Drug Administration due to its carcinogenic potential in animal models and possibility of being a carcinogenic agent to humans [16-17]. Horvath et al. found that copious solvent use led to more gutta-percha and sealer remnants on the root canal walls and inside the dentinal tubules. The chloroform group had a higher ratio of obturated dentinal tubules/total dentinal tubules by scanning electron microscopy than the natural solvent and no solvent groups [26]. The natural gutta-percha solvent used in this study was a mixture of organic solvents and was comparable to chloroform.

The rotary file and hand file groups had limitations during gutta-percha removal from the densely filled curved root canals. These groups left significantly three- to five-fold more remaining gutta-percha than the hand files with solvent groups. In the rotary files group, the spiral blade and helical formation cut the root canal to form a round cross section [23, 27]. Gutta-percha remained in untouched areas, such as an oval canal, which was difficult to detect and remove with hand files. Due to the spring-back effect of the rotary file, it tended to engage the gutta-percha at the outer curve rather than at the inner side of the curved canal [28]. In the hand file group without solvent, the densely packed gutta-percha was difficult to penetrate, and the procedure was time-consuming. Removing the gutta-percha below the curve of the root canal with hand files was difficult because the files tended to stretch to bind the outer dentin wall, often causing deviation or perforation. Thus, it was difficult to engage the gutta-percha with hand files in this area of the severely curved root canals.

Most retreatment technique studies have been performed in straight root canals [8, 10]. Studies in curved root canals would be more clinically relevant, because treatment failure is often caused by complex root canal anatomy. Curved root canals with densely filled gutta-percha are one of the most challenging retreatment procedures [29-30]. In the present study, the apical level often had higher percentages of remaining gutta-percha than other levels when using the same technique. To approach the apical level in a curved root canal and remove the gutta-percha below the canal curvature, the gutta-percha above the canal curvature needs to be removed first. The visible gutta-percha in the coronal part was definitively removed. However, in some areas, it was not visible. In the coronal part, which had the largest root canal

diameter, the instrument could not adequately fit the root canal diameter. This led to incomplete gutta-percha removal, particularly without solvent. We found that the groups with higher gutta-percha remnants in the coronal and middle levels, i.e., the rotary file and hand file groups, demonstrated more gutta-percha remnants in the apical region.

Although removing as much root canal filling material as possible would increase the effectiveness of root canal disinfection, the potential for substantial damage to the root canal walls should be considered [30]. In the current study, dentin loss among the experimental groups was not significantly different. There were no root perforations or instrument separations. These results might be due to the use of correct techniques and instruments by an experienced operator.

Conclusion

For retreating a severely curved root canal, hand files in combination with solvent were superior to the use of hand files and rotary files to remove gutta-percha.

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