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Removal of Resin-based Root Canal Filling Materials with K3 Rotary Instruments: Relative Efficacy for Different Combinations of Filling Materials

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Removal of resin-based root canal filling materials may cause serious problems during root canal retreatment. This study compared the working time and amount of canal enlargement when different resin-based root canal filling materials were removed with K3 rotary instruments with or without heat-softening using System B. Root canal sealer/filling point combinations tested were Epiphany/Resilon, SuperBond/Resilon, SuperBond/gutta-percha, and Canals N/gutta-percha. The materials were filled into simulated curved resin canals and removed with K3 instruments in a standardized crown-down procedure. In terms of working time, Epiphany/Resilon required a significantly longer working time than the others. However, heat application with System B significantly reduced the working time for the removal of Epiphany/Resilon. In terms of canal enlargement, there were no significant differences among the tested groups as determined with digital morphometry. It was thus concluded that Epiphany removal with K3 rotary instruments might result in extended working time, but which could be reduced with heat-softening using System B.

Keywords: Resin-based root canal filling material, Ni-Ti rotary instrumentation, Root canal retreatment

INTRODUCTION

A number of studies have assuredly shown that most endodontic treatments yield a success rate of nearly 90%[1]. Nonetheless, failures still occur despite meticulous treatment methods that meet high and stringent standards[2]. Besides iatrogenic factors such as inadequate canal preparation/obturation and procedural errors, other several causes are responsible for these occasional failures. For example, residual post-treatment root canal infection may be inevitable in some cases due to the complexity of root canal anatomy[2]. Reinfection resulting from coronal leakage is also regarded as a major contributing cause[3]. In these cases, non-surgical root canal retreatment may be required to re-disinfect the canals and re-establish healthy periapical tissues[4]. The retreatment procedure requires the removal of pre-existing root canal filling materials, followed by chemomechanical reinstrumentation and refilling of canals.

Presently, gutta-percha — in combination with sealers — is the most commonly used material for root canal filling. However, of late, various resin-based root canal filling materials have been developed to establish a core-sealer-dentin continuum to the end of preventing microleakage and improving the fracture resistance of root-filled teeth[5,6]. For example, Resilon (Pentron, Wallingford, CT) — a synthetic polymer-based core material — is used as an alternative to gutta-percha. It has been claimed that when Resilon was used in combination with Epiphany sealer (a dual-curable resin composite sealer; Pentron), a core-sealer-dentin continuum was established due to the adhesive property of Epiphany sealer[5,6]. Another newly developed resin-based sealer is the SuperBond sealer (Sun Medical, Moriyama, Japan). This is a modified preparation of 4-META MMA/TBB resin-based adhesive material, which is reported to show high bond strength[7] and durable seal[8] to root canal dentin.

Retreatment of roots filled with resin-based materials may cause serious problems due to the difficulty in removing the materials. Resilon can be softened with chloroform. However, there are many reservations and cytotoxicity concerns associated with the use of this chemical owing to its carcinogenicity and mutagenicity. As for Epiphany and SuperBond sealers, no effective and safe solvents have yet been reported.

Several studies have evaluated the efficacy of different engine-driven nickel-titanium (Ni-Ti) file systems in the removal of root canal filling materials, whereby these systems promised reduced working time[9-13]. Removal of Epiphany/Resilon with Ni-Ti rotary files has also been investigated[14-16], although the efficacy of this method has not yet been fully established. Against this background, this study aimed to further investigate the applicability of Ni-Ti rotary instruments in the removal of different resin-based root canal filling materials. Simulated curved canals in resin blocks, which are widely used to evaluate the root canal shaping ability of different instruments[17], were employed for the purpose of standardization.

MATERIALS AND METHODS

Canal preparation and filling

Simulated canals with a 30-degree curvature in resin blocks (Zipperer, Munich, Germany; canal length＝19 mm) were prepared with Ni-Ti instruments to a size 30/.06 taper by a single operator. Working length was set at 18.5 mm and the canals were instrumented with ProTaper instruments (Dentsply Maillefer, Ballaigues, Switzerland) to a 20/.07 taper (SX to 9.0 mm followed by S1, S2, and F1 to the working length), and then with K3 instruments (SybronEndo, Orange, CA, USA; 25/.06 followed by 30/.06 to the working length). The files were rotated at 300 rpm using a 20:1 reduction contra-angle handpiece (Anthogyr. Sallanches, France) set in a torque-controlled electric motor (ATR Tecnika, Advanced Technology Research, Pistoia, Italy).

After preparation, the canals were rinsed with distilled water and desiccated with paper points. They were then filled with a taper-matching, single-cone technique using either Resilon or gutta-percha points (Zipperer) of 30/.06 taper. Sealers used were Epiphany sealer, SuperBond sealer, or Canals N (a zinc oxide non-eugenol sealer; Showa Yakuhin Kako, Tokyo, Japan). Table 1 shows the root canal filling materials used in the present study. The specimens were stored at 37℃ in 100% humidity for seven days before removal.

Retreatment technique

Experimental groups consisted of Epiphany/Resilon, SuperBond/Resilon, SuperBond/gutta-percha, and Canals N/gutta-percha groups (n＝10 each). Retreatment was performed using K3 instruments until a 30/.06 instrument reached the working length. K3 Orifice Openers (25/.12, 25/.10 and 25/.08) and 35/.06, 30/.06, and 25/.06 instruments, rotated at 300 rpm with an ATR Tecnika Endo motor, were used sequentially to reach 13.5, 14.5, 15.5, 16.5, 17.5, and 18.5 mm (working length) respectively. Finally, 30/.06 was used again for the final shaping at the full working length. A single operator performed all the removal attempts in a blinded manner: each canal was masked with an aluminum foil and randomly assigned to each removal attempt. Canals were constantly irrigated with distilled water using a syringe with a 25-gage needle. For five canals in each group, approximately 0.1 ml of d-limonene-based gutta-percha solvent (GP Solvent, Nishika, Shimonoseki, Japan) was applied with every file change. Files were discarded after usage in 10 canals.

Evaluation

The working time that elapsed until the last instrument (30/.06) reached the working length,

Table 1 Root canal filling materials used in the present study

Material		Batch no.	Main components	Manufacturer
Core materials				
Resilon (polyester-based filling material)		07120484	polycaprolactone, glass fillers, bismuth oxychloride, barium sulphate	Pentron Clinical Technologies, Wallingford, USA
Gutta-percha points (gutta-percha-based filling material)		17696	gutta-percha, zinc oxide, metal sulphates	Zipperer, Munich, Germany
Sealers				
Epiphany sealer (dual curable composite resin sealer)			BisGMA, ethoxylated Bis-GMA, UDMA, hydrophilic difunctional methacrylates, calcium hydroxide, barium sulphate, barium glass, bismuth oxychloride, silica	Pentron Clinical Technologies, Wallingford, USA
SuperBond sealer (4-META MMA/TBB resin sealer)	Monomer	KG6	4-META, MMA	Sun Medical Co., Moriyama, Japan
	Catalyst	KE52	TBB	
	Powder	4117	PMMA, zirconium oxide	
Canals N (Zinc oxide non-eugenol sealer)	Liquid	6054MT	higher fatty acids	Showa Yakuhin Kako Co., Tokyo, Japan
	Powder	6056RA	zinc oxide, rosin, barium sulphate, bismuth subcarbonate	

not including the time for instrument changes and irrigation, was measured with a stopwatch.

The amount of canal area removed during retreatment was assessed by digital morphometry. Following initial root canal preparation and retreatment, a red dye was injected into each canal and digital images were taken using a digital camera (Fine Pix S602, Fuji, Tokyo, Japan). Pre- and post-retreatment images were then superimposed. The number of pixels representing the area of canal walls removed was thereby computed with an image analysis software (WinROOF, Mitani, Fukui, Japan).

Statistical analysis was performed with one-way analysis of variance (ANOVA) with multiple comparisons using Scheffe's test.

The frequency of procedural errors (file separation and ledge formation) was also recorded.

Use of System B

Heat was applied using a System B Heat Source (Analytic Technology, Redmond, WA, USA), a device used for warm vertical compaction of gutta-percha[18] and also applied for removing gutta-percha and Epiohany/Resilon[15]. The effect of heat application on working time was evaluated for Resilon-filled canals. Epiphany/Resilon and SuperBond/Resilon groups (n=14 each) were then subdivided into System B/K3 and K3 (control) groups (n=7 each). In K3 (control) group, retreatment was carried out with K3 instruments as described above. In System B/K3 group, System B Heat Source with a Fine Buchanan Plugger was activated at 150℃ and a power setting of 10, and inserted into the canal to 13.5 mm. The last four K3 instruments (35/.06, 30/.06, 25/.06, and again 30/.06) were used as described above. Working time durations for the coronal portion (by means of Orifice Openers or System B to reach 13.5 mm) and apical portion (by means of last four K3 instruments to reach the full working length) were separately measured.

RESULTS

The use of GP Solvent did not significantly influence the outcome in terms of both working time (119.3±18.0 and 132.8±20.9 seconds for GP Solvent-used and non-used groups respectively; mean±SD) and canal morphology (6497.5±1391.9 and 7115.3±1780.3 pixels for GP Solvent-used and non-used groups respectively; mean±SD). In light of these data, pooled data were analyzed.

As shown in Fig. 1, the Epiphany/Resilon group required a significantly longer working time compared with the other groups. No significant differences were detected among SuperBond/Resilon, SuperBond/gutta-percha, and Canals N/gutta-percha groups.

Morphometric analysis revealed that the canal area was increased during removal. However, no significant inter-group differences were detected when the areas were compared (Table 2).

System B reduced the working time for the coronal portion by 55.1% (34.0±8.76 *vs.* 15.3±3.28 seconds; mean±SD) and 60.0% (30.8±4.02 *vs.* 12.3±1.03 seconds; mean±SD) for Epiphany/Resilon and SuperBond/Resilon groups respectively ($p<0.05$). In the Epiphany/Resilon group, the working time for the apical portion was also reduced significantly ($p<0.05$) following the use of System B (Fig. 2).

In the 68 canals examined in this study, file separation and ledge formation occurred in one and three canals respectively. A 30/.06 instrument separated in a canal of the Epiphany/Resilon group when it reached the working length. As for ledge formation, it occurred in Epiphany/Resilon (two canals) and SuperBond/Resilon (one canal) groups.

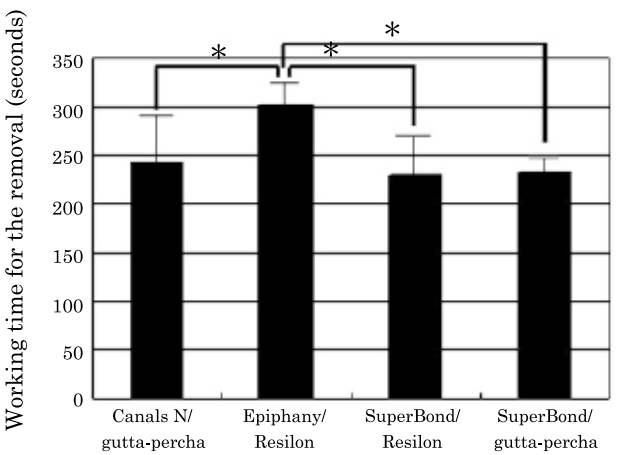

Fig. 1 Working time for the removal of different root canal filling materials using K3 instruments (mean and SD; n=10 each). *: $p<0.05$.

Table 2 Canal areas removed during filling material removal

Group	Mean†	SD†
Epiphany/Resilon	7507.8	3023.2
SuperBond/Resilon	7195.0	3490.6
SuperBond/gutta-percha	4729.8	2875.9
Canals N/gutta-percha	9023.6	1442.8

†Values are expressed as the number of pixels. N=10 each.

No significant differences between groups; $p<0.05$, one-way ANOVA.

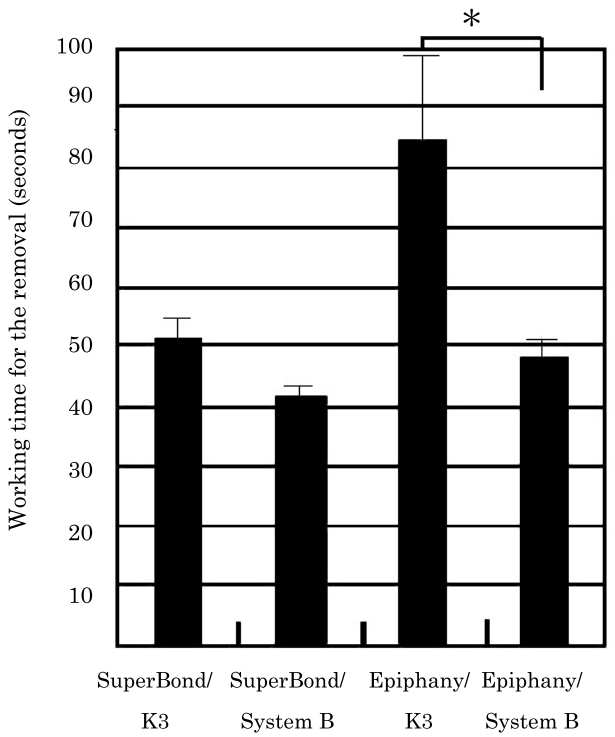

Fig. 2 Effect of heat application with System B on the working time for the removal of the apical portion of resin-based root canal filling materials using K3 instruments (mean and SD; n=7 each). *: $p<0.05$.

DISCUSSION

In this study, we aimed to examine the efficacy of Ni-Ti rotary instruments in the retreatment of canals filled with resin-based filling materials. To this end, we evaluated the working time required for negotiation (reinstrumentation to the original canal size), the amount of canal walls removed during retreatment, and the effect of heat application using a System B Heat Source.

Simulated curved canals in resin blocks were used under strictly controlled laboratory conditions in order to make a reliable comparison by eliminating variables arising from variations in root canal morphology. The taper-matching, single-cone method was employed for root canal filling, which might have created a homogeneous filling with a relatively thin layer of sealer[19]. Moreover, resin-based sealers most likely adhered more strongly to resin canal walls as compared with the dentin surface of root canal wall. Taken together, the present experimental conditions represented a highly challenging situation where a "nearly ideal canal wall-sealer-core monoblock" should be removed from a curved canal. Under such challenging conditions, undesirable instrument effects (file separation, ledging, extended working time, *etc.*) could have been exacerbated in the removal of resin-based materials. However, we believed that with safety issues as our utmost priority and concern, this conservative approach of perhaps obtaining a below-par efficacy of K3 instruments would be far more expedient.

The present results demonstrated that the Epiphany/Resilon group required a significantly longer working time compared with all the other groups (Fig. 1). Conversely, no differences were detected among SuperBond/Resilon, SuperBond/ gutta-percha, and Canals N/gutta-percha groups. Based on the results obtained, it might be interpreted that Epiphany sealer required a longer working time compared with SuperBond sealer and Canals N, and that the removability of Resilon was comparable to that of gutta-percha. Therefore, it seemed that the physical strength of sealers was an important factor influencing these results. In particular, Epiphany being a resin composite material most probably exhibited higher surface hardness and compressive strength compared with all the other sealers tested. Consequently, it required a longer working time for removal from the canal wall.

On the other hand, less-than-ideal resin-dentin adhesion may occur under clinical situations, which may favor the removal of resin-based root canal filling materials. There are several causes that impair resin-dentin adhesion in the root canal system, such as ineffective EDTA conditioning in the deeper part of the canal wall[20], the use of sodium hypochlorite that may adversely affect bond strength[21,22], and the presence of uninstrumented areas[23] that may be unfavorable to adhesion. These could explain, at least in part, why it has been reported that Epiphany/Resilon showed lower adhesive strength to dentin[24,25] and was easier to remove compared with gutta-percha and a conventional epoxy resin sealer (AH Plus)[14-16].

The present results might support the view that K3 instruments were efficient in the removal of gutta-percha[13] and Resilon[14]. Under the present experimental conditions, it was nearly impossible to remove Epiphany/Resilon and SuperBond/Resilon using hand files (data not shown), therefore further supporting the efficiency of K3. Several studies have demonstrated that different Ni-Ti rotary systems required less working time compared with hand instruments for removing gutta-percha[9-13] and Resilon[15], although opposite results have also been presented[16,26]. Rotary instruments may be efficient in disintegrating core materials, since they may effectively auger the materials following softening with frictional heat. On the other hand, removal with hand files may be dependent on the practitioner's ability to remove existing core materials and is hence more technique-sensitive.

This study showed that GP Solvent, which is less effective than chloroform in dissolving gutta-percha[27], was ineffective for the resin-based materials tested. The effect of GP Solvent was not evident even on gutta-percha, most probably because removal was carried out quickly and thus the working time was not sufficient for the solvent. Thus, our data were not necessarily against the use of solvents for gutta-percha removal, although it seemed necessary to find alternatives that are applicable for resin-based root canal filling materials.

The results of the present morphometric analysis were in agreement with the finding that the canal area increased after retreatment[28]. The type of filling material did not influence the mean canal area removed, suggesting that no particular material led to overzealous root canal enlargement. However, the occurrence of ledge formation suggested that the canal centering ability of K3 instruments was impaired due to obstruction by canal filling materials. This agreed with the suggestion that pre-existing gutta-percha may cause and/or aggravate canal transportation[28,29].

The present results seemed to support the view that System B Heat Source was useful for the gross removal of Resilon from the coronal portion of the canal[15]. It should be noted that the working time for the negotiation of the remaining apical segment also decreased significantly following heat application (Fig. 2). This was most likely due to heat transmission to deeper parts, which might have softened Resilon to a certain depth and thereby contributed to quicker negotiation. In addition, the lower melting point of Resilon compared with gutta-percha might have also favored removal using heat. Although the optimal temperature for Resilon removal is not known, we set it at 150℃ as recommended by the manufacturer for thermoplasticizing Resilon during warm vertical compaction. It has been reported that System B set at 200℃ caused a root surface temperature rise of less than 10℃ during gutta-percha compaction[30], suggesting that the heating procedure was not harmful to the periodontal ligament.

Although this study suggested the efficacy of K3 instruments in removing resin-based root canal filling materials, several issues remained to be fully evaluated before routine usage can be recommended. In particular, file separation remained a matter of concern as indicated by previous studies[9,11,31]. This study also showed the occurrence of ledge formation and file separation only in Resilon-filled canals, although relatively low in frequency. Preparation of a "glide path" using small hand instruments in conjunction with heat and/or appropriate solvents prior to the use of Ni-Ti instruments may improve safety. Further, it seemed apparent that rotary instruments alone were not sufficient for the complete removal of root canal filling materials, since a number of studies have demonstrated the remnants of gutta-percha[9-15,26,31] and Resilon[14-16] on the canal wall. Subsequent hand instrumentation after rotary instrumentation might thus facilitate the thorough removal of residual materials.

CONCLUSIONS

It was concluded that Epiphany removal with K3 rotary instruments might result in extended working time, but which could be reduced with heat-softening using System B. K3 rotary instrumentation might be an efficient method for the removal of resin-based root canal filling materials, although safety issues remained to be fully evaluated before routine usage for this purpose can be recommended.

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