Efficacy, cleaning ability and safety of different rotary NiTi instruments in root canal retreatment

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Abstract

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Aim To evaluate the efficacy, cleaning ability and safety of three different rotary nickel-titanium instruments with and without a solvent (eucalyptol) versus hand files in the removal of gutta-percha root fillings.

Methodology Eighty extracted single-rooted anterior teeth were enlarged to size 35 and obturated with laterally condensed gutta-percha using AHPlus as the sealer. Removal of gutta-percha was performed with the following devices and techniques: FlexMaster, GT Rotary, ProTaper and Hedström files. All techniques were used with and without the solvent eucalyptol. The following data were recorded: time taken to reach the calculated working length and time required for the removal of gutta-percha. The teeth were split longitudinally and photographed. Cleanliness of the root canal walls was scored using the projected slides with a total magnification of approximately 70×. Statistical analysis was performed using the two-way ANOVA ($P < 0.001$) for the analysis of working time.

Results The technique that reached the working length most rapidly was that using ProTaper instruments and eucalyptol (+E), followed by FlexMaster + E, ProTaper, FlexMaster, Hedström files + E, GT Rotary + E, Hedström files, and GT Rotary. No significant differences were found for retreatment with or without a solvent in all groups. ProTaper and FlexMaster worked significantly more rapidly than Hedström files and GT Rotary (ANOVA, $P < 0.001$). Time for complete removal of gutta-percha was again shortest with ProTaper + E, followed by FlexMaster + E, ProTaper, FlexMaster, GT Rotary + E, Hedström files + E, Hedström files, and GT Rotary. ProTaper and FlexMaster again worked significantly faster than the other techniques (ANOVA, $P < 0.001$). There was no visible filling material extruded apically. Root canal cleanliness proved best following the use of FlexMaster + E, and Hedström files + E, followed by ProTaper + E, and GT Rotary + E.

Conclusion Under the experimental conditions, FlexMaster and ProTaper NiTi instruments proved to be efficient and time-saving devices for the removal of gutta-percha. The use of eucalyptol as a solvent shortened the time to reach the working length and to remove the gutta-percha, but this was not significant.

Keywords: eucalyptol, FlexMaster, GT Rotary, gutta-percha removal, Hedström files, NiTi instruments, ProTaper, root canal retreatment.

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Introduction

The results of many cross-sectional epidemiological studies report a high percentage of root filled teeth with radiographic signs of apical periodontitis (De Cleen *et al.* 1993, Saunders *et al.* 1997, Weiger *et al.* 1997, Kirkevang *et al.* 2000, 2001) indicating a substantial need for endodontic retreatment. The main causes of endodontic failure making retreatment necessary are thought to be insufficient cleaning and inadequate obturation (Abou-Rass 1982, Siqueira 2001). Additionally, teeth with inadequate obturation, unfilled or untreated root canals, or underextended root fillings may require retreatment before coronal restoration, as failure may occur in the future (Friedman & Stabholz 1986). Among several treatment alternatives

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orthograde retreatment should be considered as the first choice of treatment (Abou-Rass 1982, Taintor *et al.* 1983, Friedman & Stabholz 1986, Lovdahl & Gutmann 1997). The success rates for orthograde retreatment are reported to range from approximately 65% (Molven 1974, Allen *et al.* 1989) to more than 80% (Strindberg 1956, Selden 1974, Sjögren *et al.* 1990).

The main goals of orthograde retreatment are complete removal of the root canal filling material in order to regain access to the apical foramen thus facilitating sufficient cleaning and shaping of the complete root canal system (Stabholz & Friedman 1988). Although numerous materials have been described for obturation of root canals, gutta-percha in combination with a sealer is the most frequently used material. Techniques described for gutta-percha removal include the use of rotary instruments, heat carrying instruments and solvents (Taintor *et al.* 1983, Lewis & Block 1988, Stabholz & Friedman 1988, Friedman *et al.* 1989, 1990, Mandel & Friedman 1992, Teplitsky *et al.* 1992, Imura *et al.* 1996, Hülsmann & Stotz 1997). In many cases the combined use of different techniques may be the most efficient and time-saving method (Wilcox *et al.* 1987, Teplitsky *et al.* 1992, Lovdahl & Gutmann 1997). Nevertheless, removal in many cases is a tedious and time-consuming operation, especially in narrow and curved canals or when the filling material is well condensed (Wilcox *et al.* 1987, Wilcox & Swift 1991, Wilcox & Van Surksum 1991).

Recently, the use of NiTi instruments has been recommended for gutta-percha removal and various studies have reported their efficacy, cleaning ability and safety (Barrieshi *et al.* 1995, Zuolo *et al.* 1996, Bramante & Betti 2000, Imura *et al.* 2000, Sae-Lim *et al.* 2000, Betti & Bramante 2001, Ferreira *et al.* 2001, Baratto Filho *et al.* 2002, Barrieshi-Nusair 2002).

The aim of the present study was to investigate the efficacy, cleaning ability and safety of three different rotary NiTi systems FlexMaster (VDW Antaeos, München, Germany), GT Rotary (Dentsply Maillefer, Ballaigues, Switzerland), ProTaper (Dentsply Maillefer), compared to hand instrumentation with Hedström files (VDW Antaeos), with and without the use of a solvent (eucalyptol) in the retreatment of gutta-percha root fillings.

Materials and methods

Eighty straight root canals in extracted single-rooted anterior teeth were selected. Following preparation of a coronal access cavity and removal of pulp tissue apical patency was assured with a size 10 reamer. Working length was defined as 1 mm short of the root tip. The root canals were enlarged with FlexMaster rotary NiTi instruments to size 35 and .02 taper at working length. Root canal preparation was performed using copious irrigation with sodium hypochlorite (5%). Apical patency was ensured by slight overinstrumentation with a size 10 reamer following each NiTi instrument. The root canals were dried with paper points and sealed with laterally condensed gutta-percha and AHPlus (DeTrey Dentsply, Konstanz, Germany) as the sealer. Regardless of root length the extension of the root filling was uniformly limited to 15 mm from the apex by sectioning the coronal surplus using a heatened hand plugger so that the volume of the gutta-percha filling was approximately equal for all teeth. The access cavities were sealed with Cavit (DeTrey Dentsply) and the teeth stored at 37 °C in a hygrostat for 2 months to allow complete setting of the sealer. The teeth were coded and randomly divided into eight groups with 10 specimens each. The temporary filling was removed and the root canal was reopened.

Gutta-percha and sealer were removed using the following techniques:

(a) FlexMaster rotary instruments (VDW Antaeos) used with an electric motor with constant speed and low torque (EndoStepper, S.E.T., Olching, Germany) were used to remove the gutta-percha and sealer from the canals. FlexMaster instruments sizes 45–20 were used in reverse sequence in a crown-down technique to reach the working length and to remove the root filling materials. Apical enlargement was performed to size .02/45. The maximum rotary speed was 300 r.p.m. Eucalyptol was applied as solvent with a cotton pellet. The amount of applied solvent was not controlled.

(b) FlexMaster rotary instruments were used as described above but no solvent was applied.

(c) GT Rotary (Dentsply Maillefer) rotary instruments and an electric motor (EndoStepper, S.E.T.) with a maximum speed of 300 r.p.m. were used to remove the root filling materials. The instrument sizes 45–20 were used in a crown-down technique. Apical enlargement was performed to size .04/45. Eucalyptol was applied as solvent with a cotton pellet.

(d) GT Rotary instruments were used as described above but without a solvent.

(e) ProTaper (Dentsply Maillefer) rotary instruments and the electric motor (EndoStepper, S.E.T.) with a maximum speed of 300 r.p.m. were used in a crown-

down technique. Only the finishing files (F3–F1) were used for the retreatment. Apical enlargement was performed to file F3. Eucalyptol was used as a solvent.
(f) ProTaper rotary instruments were used as described above but no solvent was applied.
(g) Hedström files (VDW Antaeos) sizes 45–20 were used for the retreatment of gutta-percha and sealer. The hand instruments were used in reverse sequence in a crown-down technique. Apical enlargement was performed to size 45. Eucalyptol was applied as a solvent.
(h) Hedström files were used as described above but without a solvent.

All instruments were discarded after use in three root canals.

Time was recorded until the working length was reached. Following this apical enlargement was performed to instrument size 45 for Hedström files, GT Rotary and FlexMaster, and to Finishing File no. 3 with ProTaper (tip diameter approximately size 30), respectively.

Gutta-percha removal was judged complete when the working length was obtained and no more gutta-percha could be removed with the instruments used. Radiographs were taken from two directions. If the radiographs revealed remaining gutta-percha the root canals were instrumented again until no more gutta-percha was removed. Time was recorded again and added to the first measurement. All teeth were treated by the same operator.

The teeth were grooved with a diamond bur, split longitudinally and both root halves photographed under a light microscope. The slides of the split root halves were projected which resulted in a total magnification of approximately 70×. The coronal, middle and apical thirds of the specimens were evaluated separately for remaining gutta-percha using seven categories:
1 Gutta-percha completely removed.
2 Small remnants of sealer (<2 mm extension).
3 Large remnant of sealer (>2 mm extension).
4 One to three small (<2 mm extension) remnants of gutta-percha.
5 More than three small (<2 mm extension) remnants of gutta-percha.
6 Large remnant of gutta-percha (>2 mm extension).
7 Gutta-percha covering more than 4 mm.

The evaluation of the coded specimen was performed by two operators who could not identify the techniques and devices used for retreatment. Extrusion of debris or root canal filling material through the apical foramen was controlled visually using loupe with 5× magnification. Procedural incidents (perforations, blockages, loss of working length, ledging, instrument fractures) were recorded.

Statistical analysis

Statistical analysis was performed using the ANOVA test ($P < 0.001$) for the analysis of working time.

Results

Time taken to reach the working length

Working length could be regained in all specimens. The shortest time to reach the working length was found with ProTaper and eucalyptol, followed by FlexMaster and eucalyptol, ProTaper, FlexMaster, Hedström files and eucalyptol, GT Rotary and eucalyptol, Hedström files, and GT Rotary (Fig. 1). The rotary devices ProTaper and FlexMaster proved to be significantly faster than the other techniques (ANOVA, $P < 0.001$). No significant differences existed between the treatments with or without the use of eucalyptol.

Time for complete removal of gutta-percha

The fastest technique to remove gutta-percha completely again was ProTaper with eucalyptol, followed by FlexMaster and eucalyptol, ProTaper, FlexMaster, GT Rotary and eucalyptol, Hedström files and eucalyptol, Hedström files, and GT Rotary (Fig. 2). ProTaper and FlexMaster were significantly faster than the other techniques (ANOVA, $P < 0.001$). No significant differences existed between the treatments with or without the use of eucalyptol.

Apical extrusion

No apically extruded gutta-percha was detected in any of the specimens.

Working safety

No obvious procedural incidents such as perforations, blockages, loss of working length, ledging, or instrument fractures occurred.

Cleanliness of root canal walls

The results for root canal cleanliness are summarized in Tables 1–3. In the coronal part of the root canals

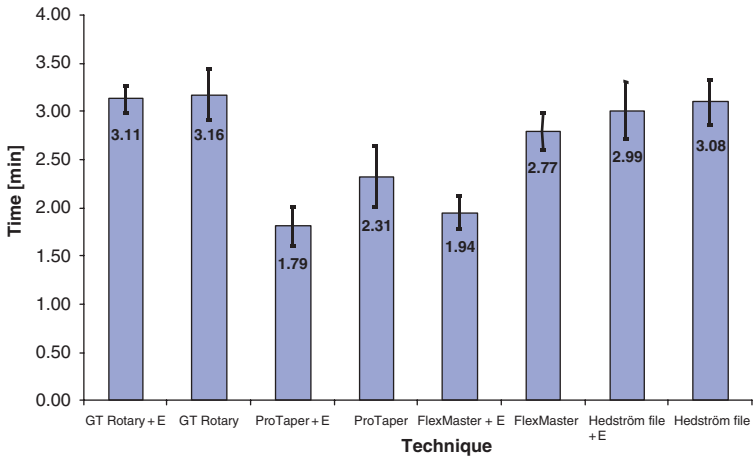

Figure 1 Time needed to reach the working length.

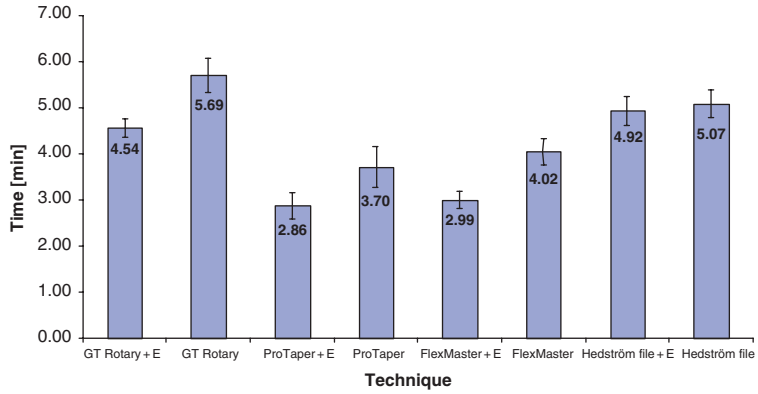

Figure 2 Time needed for complete removal of gutta-percha.

Table 1 Scores for root canal cleanliness in the coronal third of the root canals

	Scores						
Technique	1	2	3	4	5	6	7
GT Rotary + E	1	2	6	0	1	0	0
GT Rotary	2	5	2	1	0	0	0
ProTaper + E	7	2	0	1	0	0	0
ProTaper	6	2	0	1	0	0	1
FlexMaster + E	8	1	0	1	0	0	0
FlexMaster	7	1	2	0	0	0	0
Hedström files + E	5	2	2	1	0	0	0
Hedström files	5	3	1	0	0	0	1

FlexMaster and ProTaper independently from the use of a solvent showed the highest number of scores 1 and 2. Preparation with GT Rotary with and without eucalyptol resulted in the lowest number of scores 1 and 2. In general, only minor remnants of gutta-percha and sealer were found in this part of the root canal (Figs 3–5).

In the middle part of the root canals again ProTaper and FlexMaster with and without eucalyptol showed the highest number of scores 1 and 2; the use of Hedström files with solvent resulted in comparable cleanliness.

In the apical part of the root canals FlexMaster and Hedström files, both in combination with a solvent, produced the cleanest root canal walls. In general, the results for the apical third were worse than for the coronal and the middle thirds, leaving larger amounts of filling material. In the apical part of the root canals the use of a solvent in most groups improved the degree of cleanliness, whereas this effect was less pronounced in the coronal or middle parts of the specimens.

Table 2 Scores for root canal cleanliness in the middle third of the root canals

	Scores						
Technique	1	2	3	4	5	6	7
GT Rotary + E	4	2	2	1	0	1	0
GT Rotary	4	2	0	2	0	2	0
ProTaper + E	9	1	0	0	0	0	0
ProTaper	8	1	0	0	0	0	1
FlexMaster + E	5	3	0	1	0	0	1
FlexMaster	5	1	1	2	0	1	0
Hedström files + E	8	1	0	1	0	0	0
Hedström files	0	4	2	3	0	0	1

Table 3 Scores for root canal cleanliness in the apical third of the root canals

	Scores						
Technique	1	2	3	4	5	6	7
GT Rotary + E	3	1	2	1	0	2	1
GT Rotary	2	0	0	4	1	3	0
ProTaper + E	3	1	2	4	0	0	0
ProTaper	3	2	0	3	1	0	1
FlexMaster + E	7	2	0	1	0	0	1
FlexMaster	2	5	1	2	0	0	0
Hedström files + E	6	0	2	1	0	1	0
Hedström files	3	1	3	1	0	1	1

Figure 3 Split specimen demonstrating completely removed gutta-percha and a small amount of sealer in the apical part of the root canal (score 1 for all coronal and middle parts of the root canal and score 2 for the apical part).

Discussion

All root canals in this study were prepared initially to size 35 with a 2% taper. This was assumed to represent rather narrow and often underprepared root canals, which frequently are found in retreatment cases. Probably, preparation to sizes of 30 or even 25 may have been more appropriate from a clinical prerogative, but this would have resulted in of some of the instruments used for gutta-percha removal cutting not only gutta-percha but also dentine. As a consequence, working time for some instruments could have been longer than when only cutting gutta-percha.

In the present study eucalyptol was used as a solvent. Although chloroform is known to be more efficient in dissolving gutta-percha (Tamse *et al.* 1986, Wennberg & Ørstavik 1989, Wilcox 1995) it has been reported to be locally toxic in contact with periradicular tissues, to be hepatotoxic and nephrotoxic and has been classified as a carcinogen (Wennberg & Ørstavik 1989, Zakariasen *et al.* 1990, McDonald & Vire 1992). Eucalyptol was selected from a variety of different solvents already recommended for endodontic retreatment which also include xylol, methyl chloroform, tetrahydrofuran, halothane and others (Wennberg & Ørstavik 1989, Kaplowitz 1990). Eucalyptol has been reported to be safe and efficient (Kaplowitz 1990, Wourms *et al.* 1990, Hunter *et al.* 1991). The use of eucalyptol in the present study with one exception (GT Rotary) resulted in shorter working times for all groups and in marginally better root canal cleanliness. Nevertheless, these differences were not statistically significant. These results are in accordance with similar studies reporting on reduced working time when using a solvent (Wilcox 1995, Sae-Lim *et al.* 2000). Whether this effect is more or less pronounced for solvents other than eucalyptol needs to be clarified.

In this study a low-torque motor with constant speed was used. This might be one reason for the lack of instrument fracture. Comparable studies on the use of NiTi instruments reported a varying incidence of instrument fractures (Bramante & Betti 2000, Imura *et al.* 2000, Betti & Bramante 2001, Baratto Filho *et al.* 2002).

Figure 4 Split specimen demonstrating completely removed gutta-percha but a large amount of remaining sealer in the coronal and apical parts of the root canal (score 3) and only small amounts of sealer in the middle part (score 2).

Figure 5 Root half showing large amounts of remaining gutta-percha. This specimen was rated score 6 for the coronal and score 7 for the middle and apical third.

Working speed in the present study was kept constant at 300 r.p.m. Using Quantec SC instruments working time was shortest when the rotary speed was increased to 1500 r.p.m. instead of 350 or 700 r.p.m. (Bramante & Betti 2000). The number of instrument fractures in that study decreased with increasing speed (350 r.p.m.: six fractures; 700 r.p.m.: four fractures; 1500 r.p.m.: one fracture). In accordance with the present study the use of NiTi instruments has been reported to decrease working time for gutta-percha removal. ProFile with and without use of chloroform proved to be faster than hand instrumentation with chloroform (Sae-Lim *et al.* 2000, Ferreira *et al.* 2001).

The use of FlexMaster and eucalyptol and ProTaper and eucalyptol was significantly faster than using GT Rotary and eucalyptol or Hedström files and eucalyptol. FlexMaster and ProTaper took nearly 2 min to reach the working length whereas GT Rotary and Hedström files took 3 min. In the present investigation the time needed to reach the working length was similar to that found by Bramante & Betti (2000) who used Quantec SC rotary instruments. In their study, a speed of 1500 r.p.m. proved to be the fastest technique to reach the working length and remove the gutta-percha. This probably will be due to the fact that the higher rotational speed plasticized the gutta-percha more rapidly. The plasticized gutta-percha would also have presented less resistance to removal (Bramante & Betti 2000). Ferreira *et al.* (2001) compared the efficacy of gutta-percha removal using ProFiles and K-Flexofiles with and without chloroform. The rotary methods were considerably faster than the hand methods.

Quantec SC without a solvent performed significantly faster than hand instruments with xylol as a solvent (Betti & Bramante 2001) whereas Imura *et al.* (2000) reported a significantly shorter working time for Hedström files than for Quantec SC. Barrieshi-Nusair (2002) found a shorter working time for hand instruments when compared with ProFile .04, both used with chloroform as a solvent.

In the present study GT Rotary had the longest working time amongst the NiTi systems. As all NiTi instruments were used with the same rotational speed of 300 r.p.m. the difference will be due mainly to instrument design. FlexMaster and ProTaper instruments have negative cutting angles and a convex diameter which will result in a combination of softening the gutta-percha by rotation and cutting the gutta-percha, whilst GT Rotary instruments with their radial lands and U-type cross-section may not cut the filling material. This is in accordance with several studies reporting on a higher efficacy of cutting instruments such as FlexMaster or Hedström files when compared to files with radial lands such as ProFiles or GT Rotary (Imura *et al.* 2000, Barrieshi-Nusair 2002). On use, it was observed that FlexMaster and ProTaper instruments frequently removed large amounts of gutta-percha in spirals around the instruments, whereas Hedström files and GT Rotary mainly removed the gutta-percha in small increments that did not adhere to the instruments.

Barrieshi-Nusair (2002) tested the effectiveness of nickel-titanium rotary instruments versus stainless steel hand files in gutta-percha retreatment. That study revealed no significant difference with both techniques in the amount of gutta-percha and sealer left in the canal system.

The results for hand instrumentation with Hedström files reconfirm earlier findings from the literature (Wilcox *et al.* 1987, Wilcox & Swift 1991, Wilcox & Van Surksum 1991, Wilcox & Juhlin 1994, Wilcox 1995, Hülsmann & Stotz 1997). The use of Hedström files without a solvent is more time consuming than other techniques but results in better cleanliness compared with hand instrumentation and the use of a solvent (Wilcox 1989).

Hülsmann & Stotz (1997) removed gutta-percha with five different devices and techniques. Gates-Glidden drills and the XGP gutta-percha remover were time-saving and relatively save devices for the removal of the bulk of gutta-percha from straight root canals; nevertheless complete removal could not be achieved. It was concluded that the use of rotary devices, heat or solvents in endodontic retreatment procedures should be followed by thorough hand instrumentation to achieve optimal cleanliness of root canal walls.

It was not possible to remove all traces of gutta-percha and sealer from the root canal walls with any retreatment technique when using ProFile .04 nickel-titanium rotary files with or without chloroform (Sae-Lim *et al.* 2000). The ProFile .04 system partially removed filling material from the root canal system allowing the working length to be achieved rapidly without a solvent. However, complete cleaning was not achieved and complementary manual instrumentation would be required (Baratto Filho *et al.* 2002). Ferreira *et al.* (2001) compared the efficacy of gutta-percha removal using ProFiles and K-Flexofiles with and without chloroform and found no significant difference between ProFiles with chloroform and K-Flexofiles with chloroform at all three levels of the roots in terms of cleanliness.

Imura *et al.* (2000) in a comparative evaluation quantified the amount of remaining gutta-percha or sealer on the walls of root canals following retreatment with two engine driven NiTi instruments (Quantec and ProFile) and two hand instruments (K-File and Hedström file). The results revealed that all instruments left filling material inside the root canal.

The use of ProTaper resulted in reduced cleanliness in the most apical part of the root canals compared with FlexMaster and Hedström files. This is likely due to the fact that the final size of preparation using the F3 instrument (tip diameter approximately size 30) was less than with the other systems (size 45). In the middle and coronal parts of the root canals ProTaper performed better than in the apical part, which was probably due to the variable taper of the instruments. The results for GT Rotary showing the worst results in all three parts of the canal may be explained by the file design; the radial lands probably not cutting but rather smearing or burnishing the softened gutta-percha onto the walls.

From a clinical point of view it proved to be difficult if not impossible to direct the NiTi instruments to a certain aspect of the root canal wall at least in the apical region. Manually operated Hedström files allowed better preparation of isolated root canal wall areas which is in accordance with the results of a recent comparative study on NiTi and hand instruments in the preparation of oval canals (Rödig *et al.* 2002). For the ProTaper system it proved to be impossible to penetrate the gutta-percha with the shaping files S1–S3 without fractures of the file tip.

From the results of the present investigation using straight root canals no conclusions may be drawn on the retreatment efficacy of these instruments in curved root canals. Further studies are necessary to evaluate the usefulness of rotary NiTi instruments in root canals with a more complex and complicated root canal anatomy.

Conclusions

Under the experimental conditions all three rotary NiTi systems proved to be helpful and safe devices for gutta-percha removal in orthograde endodontic retreatment.

NiTi systems with a negative cutting angle such as FlexMaster or ProTaper performed better than hand instrumentation and a NiTi system with radial lands such as GT Rotary in terms of working time and canal cleanliness.

The use of eucalyptol as a solvent helped to reduce working time and to enhance root canal cleanliness. Nevertheless, completely cleaned root canal walls could not be achieved with any of the techniques under investigation.

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