RESEARCH PAPER

An In Vitro Comparative Evaluation of the Effects of Three Different Solvents on Dentin and in the Retreatment of Teeth Obturated Using Resin Sealer

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Abstract

Aim: To evaluate and compare the efficiency of three solvents – Endosolv, Canalsolve, and xylene – in achieving apical patency in teeth obturated with a resin sealer during non-surgical retreatment, and to assess the effect of these solvents on root canal dentin.

Materials and Methods: Thirty freshly extracted, single-rooted, single-canal human teeth were selected and randomly divided into three groups (n = 10) according to the solvent used: Group I – Endosolv, Group II – Canalsolve, and Group III – xylene. After biomechanical preparation and obturation with gutta-percha and an epoxy resin-based sealer (AH Plus), the specimens were stored for two weeks. In each group, seven teeth were used to record the time required for complete removal of the obturating material and re-establishment of apical patency using a size 10 K-file together with the respective solvent, while the remaining three teeth per group were sectioned longitudinally and examined under a stereomicroscope to assess the erosive effect of the solvent on root dentin.

Statistical Analysis: Sample size was estimated using G*Power software (v.3.1.9.4). The time taken for gutta-percha removal was analysed using one-way ANOVA followed by Scheffe's post hoc test for pairwise comparisons, with the level of significance set at $p < 0.05$ (IBM SPSS Statistics v.22.0).

Results: Canalsolve required significantly less time for complete gutta-percha removal (mean 5.31 ± 0.16 min) than xylene (6.32 ± 0.17 min) and Endosolv (7.27 ± 0.21 min) (one-way ANOVA, $F = 204.10$, $p = 4.28 \times 10^{-13}$). Pairwise comparisons confirmed significant differences between all three groups ($p < 0.001$). Under stereomicroscopic examination, xylene produced the most erosive changes on root dentin, whereas Canalsolve and Endosolv caused comparatively minimal alteration of the dentin surface.

Conclusion: Canalsolve achieved the fastest and most efficient removal of gutta-percha and resin sealer while producing the least erosive change to root dentin, suggesting it may be a safer and more biocompatible alternative to xylene and Endosolv for regaining patency in teeth obturated with resin sealer, without compromising the dissolving capacity required for effective retreatment.

Keywords: *Canalsolve; dentin; endodontic retreatment; Endosolv; gutta-percha solvent; xylene*

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Introduction

The three-dimensional filling of the entire root canal system, as close as possible to the cementodentinal junction, constitutes the goal of obturation, as defined by the American Association of Endodontists (AAE) in 1994.[1] Despite meticulous cleaning, shaping, and three-dimensional obturation, endodontically treated teeth may occasionally fail to heal or may develop new periapical pathology, necessitating non-surgical retreatment. Retreatment has been described as the procedure by which root canal filling materials are removed from the tooth, followed by cleaning, shaping, and re-obturation of the canals (AAE, Glossary of Endodontic Terms).[1] Ruddle further defined non-surgical retreatment as an endodontic procedure aimed at removing materials from the root canal space and, where present, addressing deficiencies or repairing defects of pathologic or iatrogenic origin.[2]

Complete removal of the existing root canal filling material is a prerequisite for successful retreatment, allowing thorough disinfection of the canal system and creation of space for re-obturation. While gutta-percha can often be removed mechanically using hand or rotary instruments, remnants frequently persist within canal irregularities, isthmuses, and dentinal tubules, particularly when the gutta-percha has been used in conjunction with a resin-based sealer such as AH Plus, which bonds more tenaciously to dentin than conventional zinc oxide–eugenol sealers. Chemical solvents are therefore commonly used as adjuncts to soften the filling material and facilitate its removal.

Gutta-percha solvents have traditionally been classified on the basis of their chemical nature, source, and clinical use (Table 1), following early comparative work establishing the relative efficacy of the commonly available solvents.[3] Chloroform and halothane, although highly effective, have been largely abandoned in clinical practice owing to concerns regarding carcinogenicity and hepatotoxicity, prompting the search for equally effective but safer alternatives. Xylene, an aromatic hydrocarbon (C_8H_{10}) existing as ortho-, meta-, and para-isomers, is lipophilic and effectively dissolves the hydrophobic gutta-percha matrix, softening it sufficiently for mechanical removal. Endosolv (Septodont) and Canalsolve (Ammdent) are proprietary tetrachloroethylene-based solvents that have been marketed as alternatives to xylene and chloroform for softening resin- and eugenol-based sealers during retreatment.

Table 1. Classification of Gutta-Percha and Sealer Solvents

Basis of Classification	Category	Examples
1. Chemical nature	Essential oils (natural solvents)	Eucalyptol, orange oil (d-limonene), turpentine oil
	Halogenated hydrocarbons	Chloroform, xylene, chlorobenzene
	Non-halogenated hydrocarbons	Tetrahydrofuran, methyl ethyl ketone, ethyl acetate
	Alcohols	Ethanol, isopropyl alcohol
2. Source	Natural solvents	Eucalyptol, orange oil, turpentine
	Synthetic solvents	Chloroform, xylene, chlorobenzene
3. Clinical use	Primary solvents	Chloroform, xylene, orange oil
	Secondary solvents	Alcohols, acetone, eucalyptol

AH Plus (Dentsply Sirona) is a bisphenol-A epoxy resin-based sealer comprising an epoxy resin paste and an amine-hardener paste filled with zirconium oxide, iron oxide, calcium tungstate, and silicon dioxide. It is widely used in clinical practice owing to its excellent sealing ability, low solubility, long working time, favourable flow characteristics, and minimal polymerization shrinkage.[4] However, these same properties — particularly its low solubility and strong adhesion to dentin — make AH Plus comparatively difficult to remove during retreatment, often requiring the combined use of mechanical instrumentation and chemical solvents.

Direct comparisons of the softening and dissolving efficiency of xylene- and tetrachloroethylene-based solvents on epoxy resin sealers over short exposure intervals have been reported previously.[5,6] However, comparative data on the effect of Endosolv, Canalsolve, and xylene specifically on root canal dentin, together with their combined efficiency in regaining patency in resin-sealer-obturated canals, remain limited. This study was therefore undertaken to

comparatively evaluate the time required by these three solvents to achieve apical patency in teeth obturated with AH Plus resin sealer, and to assess their effect on the dentin of the root canal wall.

Aim

To evaluate and compare the effect of Endosolv, Canalsolve, and xylene on root canal dentin and on the retreatment of teeth obturated using resin sealer (AH Plus).

Objectives

1. To compare the time required by Endosolv, Canalsolve, and xylene to achieve complete gutta-percha removal and regain apical patency in teeth obturated with resin sealer.
2. To evaluate and compare the effect of these three solvents on root canal dentin using stereomicroscopic analysis.

Materials and Methods

This in vitro study was conducted on thirty freshly extracted, single-rooted, single-canal human permanent teeth, extracted for orthodontic reasons and free of caries, cracks, resorption, or previous root canal treatment. Sample size was estimated using G*Power software (v.3.1.9.4, Franz Faul, University of Kiel, Germany) based on data from previous comparative solvent studies. Teeth were cleaned of surface debris and calculus and stored in normal saline until use.

Sample Preparation

All specimens were decoronated at 15 mm from the apex using a diamond disc to standardize root length. The canals were negotiated with a size 10 K-file, and the working length was established 1 mm short of the radiographic apex. Biomechanical preparation was carried out up to a master apical size of 25 with 6% taper, with copious irrigation after each instrument change using 3% sodium hypochlorite (NaOCl) and 17% EDTA; a final rinse with normal saline was used to remove the smear layer and residual irrigants.

Grouping and Obturation

The prepared samples were randomly divided into three groups of ten teeth each (n = 30 total):

Group I – Endosolv (Septodont)
Group II – Canalsolve (Ammdent)
Group III – Xylene

All thirty canals were obturated using the single-cone technique with gutta-percha and AH Plus resin sealer, and the access cavities were temporarily sealed. Specimens were stored at 37°C and 100% humidity for two weeks to allow complete setting of the sealer, simulating the clinical scenario of a previously root-filled tooth requiring retreatment.

Retreatment Procedure

After two weeks, seven teeth from each group were used to assess the time required to remove the obturating material and regain apical patency. The access cavity was reopened, and the coronal gutta-percha was removed mechanically using Gates-Glidden drills. The respective group solvent was then introduced into the canal: Endosolv in Group I, Canalsolve in Group II, and xylene in Group III. A size 10 C-file was used in conjunction with the solvent to progressively soften and remove the remaining filling material and re-establish patency to the original working length. The time from initial solvent application to confirmed apical patency (visual and tactile confirmation of the file tip at the working length) was recorded in minutes for each sample using a stopwatch.

Assessment of Solvent Effect on Dentin

The remaining three teeth in each group were used to evaluate the effect of the respective solvent on root canal dentin. These specimens were sectioned longitudinally in the bucco-lingual direction to expose the canal walls and were immersed in the respective solvent for two minutes. The sectioned surfaces were then examined under a stereomicroscope, and representative areas were further evaluated for surface morphology, including changes in dentinal tubule patency, surface roughness, and evidence of collagen or peritubular dentin loss.

Statistical Analysis

Data for the time taken to achieve apical patency were tabulated and analysed using IBM SPSS Statistics software (version 22.0; IBM Corp., Armonk, NY, USA). Descriptive statistics (mean, standard deviation, minimum, and maximum) were calculated for each group. Comparison among the three groups was performed using one-way analysis of variance (ANOVA), followed by Scheffe's post hoc test for pairwise inter-group comparisons. A p-value of less than 0.05 was considered statistically significant.

Results

The time taken (in minutes) for complete removal of gutta-percha and resin sealer and regaining of apical patency for the seven samples evaluated in each group is presented in Table 2.

Table 2. Time (in minutes) Taken to Regain Apical Patency in Each Group

Sample No.	Endosolv (min)	Canalsolve (min)	Xylene (min)
1	7.16	5.08	6.41
2	6.88	5.19	6.39
3	7.36	5.23	6.42
4	7.24	5.55	6.01
5	7.32	5.42	6.32

Sample No.	Endosolv (min)	Canalsolve (min)	Xylene (min)
6	7.55	5.31	6.52
7	7.40	5.37	6.18

Canalsolve demonstrated the shortest mean time for complete gutta-percha removal, followed by xylene, while Endosolv required the longest time among the three groups (Table 3).

Table 3. Descriptive Statistics for Time (minutes) Taken to Achieve Patency

Solvent	Mean (min)	SD	Minimum	Maximum
Endosolv	7.27	0.21	6.88	7.55
Canalsolve	5.31	0.16	5.08	5.55
Xylene	6.32	0.17	6.01	6.52

One-way ANOVA revealed a highly statistically significant difference in the mean time taken among the three solvent groups ($F = 204.10$, $p = 4.28 \times 10^{-13}$), indicating that at least one group differed significantly from the others.

Post hoc pairwise comparisons using Scheffe's test showed statistically significant differences between all three groups (Table 4). Canalsolve required significantly less time than both Endosolv (mean difference − 1.97 min, $p < 0.001$) and xylene (mean difference − 1.02 min based on the Xylene–Canalsolve comparison, $p < 0.001$), while xylene, in turn, required significantly less time than Endosolv (mean difference − 0.95 min, $p < 0.001$).

Table 4. Post Hoc Pairwise Comparisons (Scheffe's Test)

Comparison	Mean Difference	p-value	95% CI (Lower–Upper)	Significant
Canalsolve – Endosolv	-1.97	< 0.001	-2.22 to -1.72	Yes
Xylene – Endosolv	-0.95	< 0.001	-1.20 to -0.70	Yes
Xylene – Canalsolve	1.02	< 0.001	0.77 to 1.27	Yes

Stereomicroscopic evaluation of the sectioned dentin specimens revealed that xylene produced the most pronounced erosive changes on the root canal wall, including surface roughness and loss of peritubular dentin integrity. Canalsolve and Endosolv showed comparatively minimal alteration of the dentin surface, with the tubular architecture largely preserved in both groups.

Discussion

The present in vitro study was designed to comparatively evaluate the efficiency of Endosolv, Canalsolve, and xylene in regaining apical patency in teeth obturated with a resin-based sealer (AH Plus), and to assess the effect of these solvents on root canal dentin. The results demonstrated that Canalsolve was the most efficient solvent, requiring significantly less time for complete removal of gutta-percha and sealer than either xylene or Endosolv, while producing the least erosive effect on dentin.

The superior dissolving efficiency of Canalsolve observed in this study is consistent with previous reports on tetrachloroethylene-based solvents. Mushtaq et al. similarly found that solvents containing tetrachloroethylene were highly effective in dissolving epoxy resin–based sealers, supporting their use as an alternative to conventional halogenated hydrocarbon solvents.[7] Xylene, an aromatic hydrocarbon with strong lipophilic character, has long been recognised as an effective gutta-percha solvent; Oyama et al. reported that xylene reliably softened both gutta-percha and resilon, facilitating their mechanical removal during retreatment,[8] and comparable dissolving efficiency of xylene against gutta-percha has since been confirmed in other comparative solvent evaluations.[9] In the present study, xylene performed at an intermediate level, dissolving the filling material faster than Endosolv but slower than Canalsolve, in keeping with earlier comparative evaluations of commonly used gutta-percha solvents.[10]

Endosolv demonstrated the least efficiency among the three solvents tested. This finding is in agreement with

Kumar and Madan, who reported that solvents containing amine and ester components — as found in some Endosolv formulations — were comparatively less effective at dissolving epoxy resin–based sealers than halogenated or tetrachloroethylene-based alternatives.[11] Additional comparative work by Dutta et al. and Kapur et al. has similarly reported variability in the efficacy of different endodontic solvents against epoxy resin sealers, reinforcing the observation that solvent chemistry — rather than solvent category alone — governs clinical performance.[12],[13]

Regarding the effect on dentin, xylene produced the most erosive changes in the present study, consistent with earlier reports describing reduced dentin microhardness, increased surface roughness, and disruption of the organic collagen framework of dentin following xylene exposure.[14],[15] The strong lipid-dissolving capacity of xylene, which underlies its efficacy against gutta-percha, appears to similarly act on the lipid and collagen components of dentin, resulting in a more porous, irregular surface with loss of peritubular integrity. In contrast, Canalsolve and Endosolv were associated with comparatively minimal dentin alteration, suggesting a more selective action on the resin and gutta-percha components of the obturating material without substantially affecting the underlying mineralised tissue.

From a clinical standpoint, these findings suggest that although xylene remains an effective and widely available solvent, its erosive potential may compromise dentin integrity and subsequently affect the strength of the retreated root and the quality of bonding for any post-retreatment adhesive restoration, a concern echoed in broader evaluations of the trade-offs involved in solvent-assisted sealer removal.[16] Canalsolve, by offering a favourable balance between rapid dissolving efficiency and minimal dentin alteration, may represent a safer alternative when retreatment efficiency and dentin preservation are both clinically important. Endosolv, while the least efficient of the three solvents in terms of time to patency, caused the least alteration of dentin and may therefore be preferred in situations where a more conservative approach is indicated, such as retreatment of teeth with already compromised root structure.

The results of this study are in general agreement with previous investigations highlighting the efficacy of tetrachloroethylene-based solvents for gutta-percha and resin sealer removal, while corroborating existing concerns regarding the erosive potential of xylene on root canal dentin.[7],[14]

Limitations

This study was conducted under standardised in vitro conditions, which may not fully replicate the clinical variability encountered during retreatment, including canal anatomy, presence of periapical pathology, and previous instrumentation history. The relatively small sample size per subgroup and the qualitative nature of the stereomicroscopic dentin evaluation are further limitations. Future studies incorporating scanning electron microscopy, energy-dispersive X-ray analysis, and micro-computed tomography, along with larger sample sizes and clinically simulated conditions, are warranted to further validate these findings.

Conclusion

Within the limitations of this in vitro study, Canalsolve demonstrated the highest efficiency in achieving apical patency in teeth obturated with resin sealer, requiring significantly less time than both xylene and Endosolv, while producing the least erosive effect on root canal dentin. Xylene, though moderately efficient, exhibited the most pronounced erosive changes on dentin, whereas Endosolv, although the slowest of the three solvents, was associated with minimal dentin alteration. Clinically, the superior overall performance of Canalsolve suggests that it may offer a safer and more biocompatible alternative to xylene and Endosolv for regaining patency during the retreatment of resin-sealer-obturated canals, without compromising dissolving capacity.

Conflict of Interest

The authors declare no conflict of interest.

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Nil.

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