Original Article

Efficacy of different solutions in reestablishing apical patency during nonsurgical endodontic retreatment: An *ex vivo* study by a senior undergraduate student

Beatriz Fernandes, Ana Cristina Braga[1], Irene Pina-Vaz[2], Inês Ferreira[2]

Faculty of Dental Medicine, University of Porto, Rua Dr. Manuel Pereira da Silva, Porto, [1]ALGORITMI Research Centre, LASI, University of Minho, Rua da Universidade, Braga, [2]RISE-Health, Dental Medicine, University of Porto, Rua Dr. Manuel Pereira da Silva, Porto, Portugal

Abstract

Introduction: This study assessed the effectiveness of different solutions in reestablishing apical patency during nonsurgical endodontic retreatment performed by a senior undergraduate dental student.

Materials and Methods: 54 extracted human mandibular premolars with straight canals were prepared and obturated using a gutta-percha cone placed 2 mm short of the working length, ensuring that the apical 2 mm were filled exclusively with AH Plus sealer. After 5 weeks, retreatment was performed using the ProTaper retreatment system. The teeth were randomly assigned to three groups (n = 18) according to the solution used: 3% sodium hypochlorite (NaOCl – control), orange oil (OOil), and a mixture of methylethylketone (MEK) with tetrachloroethylene (TCE). The data were analyzed using the Kruskal–Wallis and Fisher's exact tests.

Results: Patency was successfully re-established in 100% of the OOil group, 50% of the NaOCl group, and 72.2% of the MEK/TCE group, with the corresponding median times of 36 s, 44 s, and 118 s. No statistically significant differences regarding time were observed between groups. There was a significant association between the groups and the success rate of apical patency reestablishment, with the OOil and MEK/TCE groups showing higher success.

Conclusions: Apical patency in straight canals obturated with AH Plus sealer can be more effectively achieved using solvents such as OOil or a MEK/TCE mixture, by a senior undergraduate student.

Keywords: Apical patency, dental education, endodontics, nonsurgical retreatment, undergraduate students

Address for correspondence: Prof. Inês Ferreira, Faculty of Dental Medicine, University of Porto, Rua Dr. Manuel Pereira Da Silva, 4200-393 Porto, Portugal.
E-mail: inesrvlferreira5@gmail.com

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INTRODUCTION

Nonsurgical endodontic retreatment involves the removal of root canal filling materials – typically gutta-percha and sealer – to thoroughly clean and disinfect the canal system. Among the various regions within the root canal, the apical third is widely recognized as particularly challenging to effectively debride due to its complex anatomy.[1] This represents a significant clinical concern, given that

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retreatment outcomes can approach those of primary root canal therapy if access to the apical infection is successfully regained.[2]

Apical patency refers to the passive cleaning of the apical foramen using small-caliber instruments, aiming to keep it free of dentin debris, residual filling materials, and microorganisms. In primary endodontic treatment, apical patency is achieved by gently extending a small, flexible K-file through the apical foramen passively, without attempting to enlarge it.[3] Although there is no clear consensus on its benefits,[4] and its absence does not necessarily imply treatment failure, maintaining patency appears to help prevent procedural errors such as apical transportation, ledge formation, and perforations.[5,6] It also reduces the risk of losing working length and enhances irrigant penetration, particularly in the apical third.[7] In nonsurgical endodontic retreatment, achieving patency is often more difficult due to residual filling materials or prior procedural complications, such as ledges and apical blockage, that hinder canal cleanliness.[8] It is important to recognize that failure in nonsurgical endodontic retreatment is most often associated with persistent intraradicular infection.[9] Therefore, reestablishing apical patency may play a crucial role in facilitating the reduction or elimination of bacterial populations to levels compatible with periradicular tissue healing.[10,11]

Filling removal involves various techniques, including manual files, solvents, rotary or reciprocating instruments, and adjunctive methods such as ultrasonic or laser activation, often combined.[8,12,13] Among these, nickel–titanium rotary instruments are the most commonly adopted due to their efficiency, even though they might not completely remove obturation material and can increase the risk of canal deviation or perforation.[8,12,14] Solvents are commonly used in the early stages of non-surgical endodontic retreatment to soften gutta-percha, with chloroform and xylene being traditionally employed.[15] However, concerns about their toxicity have led to the search for safer alternatives. Solvents such as tetrachloroethylene (TCE) and essential oils (e.g., orange oil [OOil]) have been suggested.[15] As a complementary approach, recent studies recommend the use of solvents during the final stages of retreatment to dissolve filling material remnants, especially in the apical region.[16,17] Ferreira *et al.* proposed using binary solvent mixtures like methylethylketone (MEK) with TCE to simultaneously dissolve both gutta-percha and sealer residues, while ensuring biocompatibility with periapical tissues.[18] To date, its efficacy in achieving patency has not been assessed.

A successful dental graduate is expected to demonstrate the confidence and competence to perform clinical procedures independently.[19] Although appropriate case selection based on the student's level of training is essential to favorable outcomes,[20,21] exposure to a broader range of procedures – both in preclinical and clinical settings – is equally important for building the confidence necessary for safe, independent practice.[22] While endodontic treatment remains the most commonly performed procedure in undergraduate training worldwide, the inclusion of nonsurgical endodontic retreatment is still only gradually emerging in certain curricula.[23] According to Ba-Hattab *et al.*, although 39.5% of institutions reported that students perform nonsurgical endodontic retreatments during clinical training, only 18.4% include this procedure in their preclinical curriculum.[23] Despite the pedagogical value in introducing students to the complexities of nonsurgical retreatment, it is often omitted from undergraduate training due to its technical difficulty and associated risks. This cautious approach aligns with the idea that students may not yet have the necessary skills for such procedures.[20] Nevertheless, including non-surgical endodontic retreatments, even in limited applications, may enhance students' clinical reasoning, technical adaptability, and readiness to manage more challenging cases in general practice. From an educational perspective, this trend aligns with current curricular guidelines that emphasize not only competence in routine endodontic procedures but also the development of self-efficacy in managing a range of clinical scenarios.[24]

Although the effectiveness of various traditional solvents in non-surgical endodontic retreatment is well documented,[15] evidence on newer alternatives – especially on their use by undergraduate students and their role in reestablishing apical patency in educational settings – remains scarce. For students with limited clinical experience, engaging in retreatment procedures such as regaining apical patency may help develop broader endodontic skills. Evaluating the effectiveness of solvents and students' ability to handle them may offer valuable insights, including the need to update retreatment protocols and reinforce manual file handling techniques from educational and clinical perspectives.

Thus, this study aimed to evaluate the effectiveness of different solutions, including the recently proposed solvent mixture MEK/TCE, in reestablishing apical patency in endodontically treated teeth with straight canals, as performed by a senior undergraduate dental student. The null hypothesis is that the type of solution used would not significantly affect either the frequency of apical patency reestablishment or the time required to achieve it.

MATERIALS AND METHODS

The protocol was approved by the institutional ethics committee (Approval No. 25/2024) and is in accordance with the PRILE (Preferred Reporting Items for Laboratory studies in Endodontology) 2021 guidelines. The research protocol and main findings are presented in the PRILE flowchart in Figure 1.

Sample selection and standardization

The sample size was based on a similar previous study.[25] A total of 54 extracted human mandibular premolars (single-rooted with straight canals) were selected from a pool of teeth extracted for orthodontic or periodontal reasons. Inclusion criteria included teeth with round canals and free of caries, resorptions, significant curvatures, or calcification. Teeth with more than one canal, calcified canals, or unusual internal anatomy were excluded. Buccolingual (BL) and mesiodistal (MD) radiographs were taken to confirm these criteria. The teeth were stored in thymol solution and disinfected with 1% sodium hypochlorite (NaOCl) for 24 h before use. The root canal shape was considered round when the ratio between the BL and MD canal dimensions, measured 5 mm from the radiographic apex on both radiographic projections (BL and MD), was ≤2.5.[26] Across all groups, the mean MD diameter ranged from 0.4 to 0.5 mm and the mean BL diameter from 0.3 to 0.4 mm, resulting in

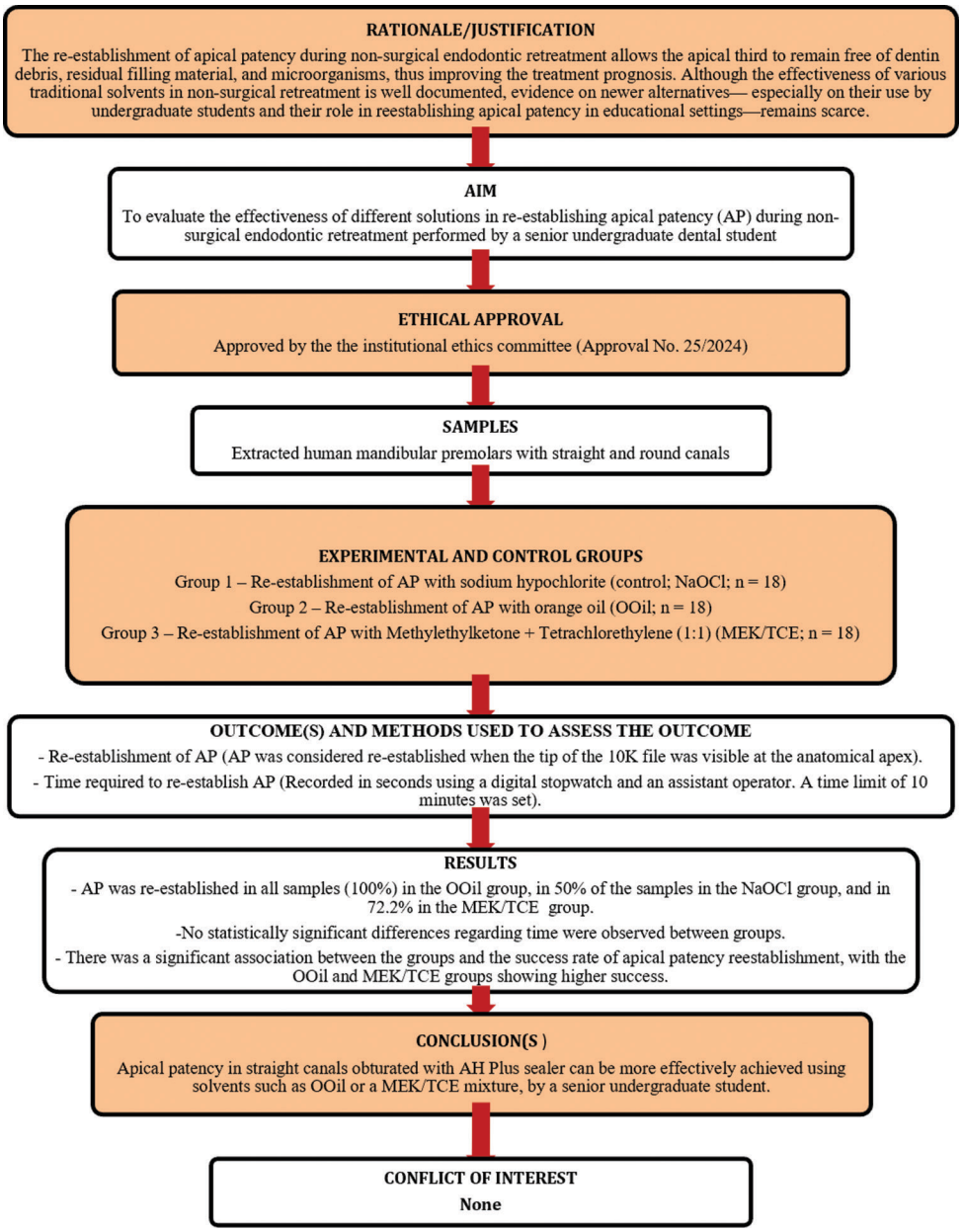


Figure 1: PRILE flowchart

MD/BL ratios between 1.1 and 1.5, confirming round canal morphology. All procedures were performed by a final-year undergraduate dental student who had received preclinical training in nonsurgical retreatment under faculty supervision. To minimize operator-related bias, the same operator performed both the initial treatments and the retreatments. The 54 teeth were randomly assigned to the three experimental groups (n = 18 each) using a computer-generated randomization sequence. Group allocation was concealed, and the operator was blinded to the solution used, ensuring that the sequence of retreatment did not follow a fixed group order.

The teeth were stabilized in a custom support during both preparation and retreatment procedures to maintain consistent positioning, carried out at room temperature.

Chemomechanical preparation of root canals

The coronal portion of the eligible teeth was removed to achieve a standardized length of approximately 20 mm. After creating the access cavity, apical patency and working length determined 1 mm short of the apex were simultaneously assessed by inserting a manual size 10 K-file (Dentsply Sirona, Ballaigues, Switzerland) until its tip was visible at the apical foramen. Moreover, to verify canal patency, a mechanical glide path was created using the WaveOne Gold Glider file (Dentsply Sirona, Ballaigues, Switzerland), following the previously established working length. Root canal shaping was performed up to the working length using the WaveOne Gold reciprocating file system (Dentsply Sirona), following the manufacturer's instructions, up to the WaveOne Gold Primary instrument (size 25, taper 0.07). These procedures were carried out using the WaveOne motor (Dentsply Sirona, Ballaigues, Switzerland) in WAVEONE ALL mode, with reciprocating motion, according to the manufacturer's guidelines. During instrumentation, the canals were irrigated with 5 mL of 1% NaOCl using a 30-G gauge needle. A total of 2 mL of 17% ethylenediaminetetraacetic acid was used, followed by distilled water and a final rinse with 1% NaOCl. The canals were then dried with sterile, absorbent paper points.

Root canal obturation

Apical patency was reconfirmed before obturation. The root canals were obturated using the single-cone technique with calibrated gutta-percha cones, WaveOne Gold Conform Fit Gutta-Percha Primary (Dentsply Sirona, Ballaigues, Switzerland), corresponding to the WaveOne Gold instrumentation system. These cones were intentionally adjusted 2 mm short of the working length to ensure that the last apical millimeters were filled solely with the epoxy resin-based sealer AH Plus Jet (Dentsply Sirona, Ballaigues, Switzerland). Radiographs were taken with the master cone in place to verify its position. After radiographic confirmation, the sealer was first introduced into the canal with the aid of a paper point until extrusion through the apical foramen was observed. Sealer extrusion was intentionally permitted to confirm complete filling of the apical region and to standardize the obturation protocol. Then, the primary gutta-percha cone was inserted. A heated plugger was used to cut and remove the excess coronal gutta-percha, and a vertical condenser (Dentsply Maillefer) was used to compact the gutta-percha inside the root canal. After the obturation of all canals, BL radiographs of all samples were taken to ensure consistency of the root canal fillings. The teeth were sealed with a temporary restorative material (Coltosol F, Coltene/Whaledent AG, Alt-stätten, Switzerland) and stored at 37°C in 100% humidity for 5 weeks.

Nonsurgical endodontic retreatment

After 5 weeks, the temporary restoration was removed, and the ProTaper Re-treatment files D1 (30.09), D2 (25.08), and D3 (20.07) (Dentsply Sirona, Ballaigues, Switzerland) were used to remove the gutta-percha, intentionally leaving 2 mm of obturation material (sealer) short of the working length. A radiograph was taken to confirm the presence of the sealer in the apical zone. Subsequently, the samples were randomly allocated into three groups (n = 18) according to the solution used for reestablishing apical patency:

- Group 1: Control, 3% NaOCl (Coltene/Whaledent AG, Altstätten, Switzerland)
- Group 2: OOil (Citrol, Biodinâmica, Brazil)
- Group 3: 1:1 MEK + tetrachlorethylene (MEK/TCE) (VWR International SAS, France).

Each tooth was identified with a number, and the syringes containing the solutions were covered entirely with paper. In addition, an FFP2 respiratory mask was worn to avoid identifying the solutions by smell. For each group, 0.3 mL of the corresponding solution was placed in the canal. Then, a hand file was used with watch-winding movements. The solutions were refreshed every minute. The time to achieve apical patency through the epoxy resin sealer using a size 10 K-file was recorded in seconds. A time limit of 10 min was set for apical patency reestablishment, which was considered successful when the tip of the file became visible at the anatomical apex.

Statistical analysis

The results of this study were analyzed using IBM SPSS Statistics 29.0 software (SPSS Inc., Chicago, Illinois, USA). The Kolmogorov–Smirnov test determined that the data

Table 1: Descriptive statistics (mean±standard deviation, median, minimum–maximum) and interquartile ranges) for time to apical patency re-establishment (s) and success rate across the three experimental groups

Solution	Mean	SD	Median	Minimum–Maximum	IQR	Success achieving AP, *n*/*N* (%)	*P*
NaOCl	88.11	111.89	44	15–347	100	9/18 (50)	0.001
OOil	88.39	124.85	36	10–498	86	18/18 (100)[a]	
MEK/TCE	175.69	146.127	118	18–500	213	13/18 (72.2)[b]	

*Different superscripts letter were statistically significant ($P<0.05$) – Fisher's exact test. SD: Standard deviation, IQR: Interquartile range, Ooil: Orange oil, MEK: Methylethylketone, TCE: Tetrachloroethylene, AP: Apical patency

were not normally distributed. Regarding the variable "time," statistical analysis was conducted only for cases where apical patency was successfully re-established. The Kruskal–Wallis test was used to compare the time between different groups. The Fisher's exact test was applied to determine the percentage of canals where apical patency was or was not achieved. The significance level was set at 5%.

RESULTS

The mean, standard deviation, median, minimum, maximum, and interquartile ranges for the time required to re-establish apical patency in each group are presented in Table 1.

Apical patency was re-established in all samples (100%) of the OOil group, in 50% of the NaOCl group, and in 72.2% of the MEK/TCE group. No procedural mishaps occurred during retreatment in any group. Concerning the percentage of canals where patency was or was not achieved, a statistically significant association was detected between the groups and the success rate of the apical patency reestablishment (χ^2 (2) = 12.864; P = 0.001). This association was mainly attributable to the higher success observed in the OOil and MEK/TCE groups (P = 0.001).

The median time to re-establish apical patency in the NaOCl, OOil, and MEK/TCE groups was 44, 36, and 118 s, respectively [Table 1]. Regarding the time required to achieve patency [Figure 2], the Kruskal–Wallis test revealed no statistically significant differences among the three groups (χ^2 (2) = 5.244; P = 0.073).

DISCUSSION

This study assessed the effectiveness of three solutions – 3% NaOCl, OOil, and a solvent mixture of MEK/TCE – in reestablishing apical patency in extracted single-rooted mandibular premolars, performed by an undergraduate dental student. The null hypothesis was partially accepted. No statistically significant differences were observed between groups regarding time to apical patency reestablishment. However, a significant association between the groups and the success rate of apical patency reestablishment was found, with the OOil and MEK/TCE groups showing higher success.

Apical patency was restored in most cases, despite the procedure being performed by an inexperienced operator. These findings contrast with those reported by Ferreira *et al*., involving a calcium silicate-based sealer, where consistent patency was achieved independently of the solution.[25] The present results highlight the differences between the solutions studied, as well as the superior performance of OOil as a safe, biocompatible, and adequate solvent targeting endodontic resin sealers.

In clinical practice, selecting an appropriate solvent requires balancing its working time, biocompatibility, clinical safety, and dissolution effectiveness.[15] In this study, NaOCl, commonly used in endodontic procedures, was employed as a control. The MEK/TCE solvent mixture was chosen based on the findings of Ferreira *et al*., who demonstrated its ability to dissolve gutta-percha and epoxy resin sealers.[18] This solution acts on the organic matrix, disrupting the spatial structure of sealers such as AH Plus.[18] In addition, it has shown biocompatibility with osteoblasts,[18] does not affect dentin microhardness,[27] and exhibits increased dissolution capacity over time.[18] OOil is an environmentally friendly, biocompatible solvent derived from citrus peel extracts.[15,28] Its solvent effectiveness depends on the type of filling material used. Martos found that OOil has a similar dissolving capacity to chloroform on resin-based sealers.[29]

Few studies have assessed the performance of undergraduate students in nonsurgical endodontic retreatment procedures. Dimitriu *et al*. highlight the significant challenges beginner operators encounter in performing effective nonsurgical endodontic retreatment.[30] The apical third was identified as the most problematic area for debridement, with markedly lower removal efficiency than the coronal and middle thirds. This difference was mostly attributed to the area's anatomical complexity.[8] Failure to fully regain apical patency can compromise cleaning and shaping ability and may lead to treatment failure in both primary and secondary endodontic treatments.[31] Achieving apical patency, particularly in filled canals, requires fine motor

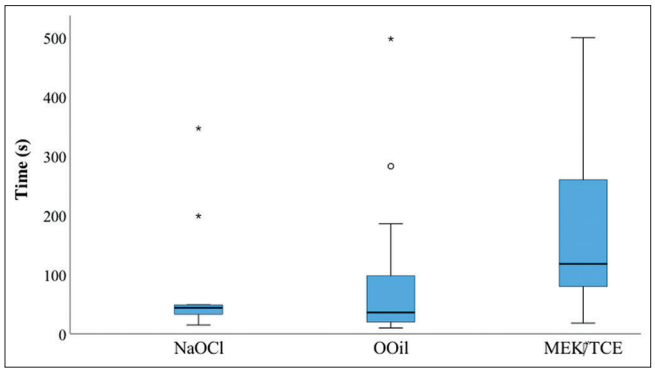


Figure 2: Median time to re-establish apical patency (seconds) across the three groups

control, a deep understanding of root canal anatomy, and the ability to manage procedural complexity – skills still developing in undergraduate students.

A retrospective study by Sunde *et al.* demonstrated a significant increase in the complexity of endodontic cases treated by undergraduate students over the past five decades.[32] The proportion of molars treated rose from 18% in 1971 to 44% in 2019, and retreatments increased from 9% to 15%, indicating a growing trend toward the inclusion of more complex cases in undergraduate clinical training. These findings suggest that contemporary undergraduate dental students are increasingly expected to manage anatomically and biologically complex cases – such as molars and retreatments – which may surpass their current technical and diagnostic proficiency level. As a result, these cases often demand advanced clinical decision-making, enhanced manual skills, and closer supervision, particularly during nonsurgical endodontic retreatment procedures. The most recent edition of the European Society of Endodontology Undergraduate Curriculum Guidelines[24] emphasizes the importance of fostering self-efficacy in students by the end of their training. Self-efficacy is defined as "a practitioner's belief in their own ability to successfully carry out specific clinical tasks, even when faced with real-world challenges."[24] Evidence suggests that the more root canal treatments students perform on patients, the greater their level of self-efficacy.[22] The consensus statement also reaffirms that "students should not perform treatments on patients until they have demonstrated in a pre-clinical setting that they possess the required skills."[24] From an educational perspective, exposing undergraduate students to straightforward, nonsurgical retreatment cases can empower them, boost their clinical confidence, and equip them with the skills needed to manage these increasingly common procedures, especially the less complex cases frequently encountered by newly qualified general practitioners.

One of the main strengths of this study lies in its adherence to the PRILE 2021 guidelines, which ensures methodological rigor and transparency., measures were taken to minimize bias: each tooth was randomly coded with a number, the syringes containing the solutions were fully concealed with opaque paper, and an FFP2 mask was worn to prevent olfactory identification of the solutions. These precautions contributed to effective operator blinding during the patency recovery procedure. Moreover, this study employed standardized criteria for sample selection. It focused on straight, single-rooted premolars with round canals. This minimizes selection bias and potential confounding factors. Thus, it enhances the internal validity and accuracy of the results. However, this homogeneity restricts external validity and limits applicability to other canal morphologies, so the findings herein cannot be directly assumed in curved or multirooted teeth. Another limitation of this study is that it involves a single undergraduate operator in a preclinical setting. Although representative of a realistic training scenario, it also limits the generalizability of the results. A study involving multiple operators at varying levels of training would provide a broader perspective and allow for a more comprehensive evaluation of the educational impact.

In sum, the ability to re-establish apical patency during endodontic retreatment – often considered a technically demanding step – highlights the relevance of including such procedures in preclinical training. When appropriately taught, the management of straight canals can be successfully performed by general dentists, even at the undergraduate level. Furthermore, this study highlights the potential of alternative and safer solvent combinations, which are not commonly employed in the final stages of retreatment, to enhance the success of patency reestablishment. Notably, the favorable outcomes achieved by an operator with limited prior experience in nonsurgical endodontic retreatment cases are promising, reinforcing the need for greater emphasis on this area within undergraduate endodontic curricula.

CONCLUSIONS

Considering the limitations of the present study, apical patency in straight canals filled with an epoxy resin-based sealer such as AH Plus can be more effectively achieved using solvents such as OOil or a MEK/TCE mixture. Further studies are needed to confirm these findings and to support the broader implementation of this protocol within the endodontic undergraduate curriculum.

Contribution details

Conceptualization: Inês Ferreira; Formal analysis and Investigation: Beatriz Fernandes, Ana Cristina Braga, and Inês Ferreira. Methodology: Beatriz Fernandes; Supervision: Irene Pina-Vaz and Inês Ferreira. Writing-original draft: Beatriz Fernandes and Inês Ferreira. Writing-review and editing: Ana Cristina Braga, Irene Pina-Vaz, and Inês Ferreira.

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Conflicts of interest

There are no conflicts of interest.

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