ORIGINAL ARTICLE

Turk Endod J 2025;10(3):151–157
doi: 10.14744/TEJ.2025.43650

Effects of solvents on the adhesion of glass fiber posts to root canal dentin: An in vitro study

Evren Sariyilmaz,[1] Ersan Celik,[2] Elif Bahar Cakici,[3] Fatih Cakici,[3] Oznur Sariyilmaz,[1] Dogu Omur Dede,[2] Ayca Tulga[4]

[1]Department of Endodontics, Çanakkale Onsekiz Mart University Faculty of Dentistry, Çanakkale, Türkiye
[2]Department of Prosthodontics, Ordu University Faculty of Dentistry, Ordu, Türkiye
[3]Department of Endodontics, Ordu University Faculty of Dentistry, Ordu, Türkiye
[4]Private clinic, Doç. Dr. Ayça Tulga Muayenehanesi, Antalya, Türkiye

Purpose: This study compared the effects of solvents (chloroform, orange oil, turpentine, eucalyptol, Endosolv R) and irrigants (5.25% sodium hypochlorite [NaOCl], distilled water) on the adhesion of glass fiber posts luted with dual-cure resin cement to root canal dentin, testing the hypothesis that solvents and NaOCl would impair bond strength.

Methods: In this in vitro study, 128 extracted human mandibular premolars were prepared, filled, and retreated using NiTi files with assigned solvents/irrigants. Post spaces were prepared, and glass fiber posts were cemented with dual-cure resin. Push-out bond strength (MPa) was measured on 1-mm-thick root slices using a universal testing machine. Data were analyzed via ANOVA and Tukey tests ($p<0.05$).

Results: Turpentine significantly reduced bond strength compared to control and other solvents ($p<0.05$). NaOCl also decreased bond strength ($p<0.05$), while Endosolv R, chloroform, eucalyptol, and orange oil showed values comparable to the control. The highest bond strength was observed with eucalyptol.

Conclusion: Turpentine and NaOCl adversely affected glass fiber post adhesion, likely due to solvent penetration or oxygen radical interference. Clinicians should avoid turpentine during retreatment and consider antioxidants with NaOCl. Further research on solvent-dentin interactions is warranted to optimize post-retreatment outcomes.

Keywords: Endodontic retreatment; glass fiber post adhesion; push-out bond strength; solvent effects.

Introduction

Retreatment is generally preferred as the first treatment option when primary root canal therapy fails. The first step of retreatment involves the removal of the previous root canal filling, which typically consists mainly of gutta-percha and root canal sealer. Various gutta-percha solvents have been recommended to facilitate the removal of gutta-percha to date (1).

Chloroform has been reported in various studies as a very effective and fast gutta-percha solvent (2,3). However, re-

Cite this article as: Sariyilmaz E, Celik E, Cakici EB, Cakici F, Sariyilmaz O, Dede DO, et al. Effects of solvents on the adhesion of glass fiber posts to root canal dentin: An in vitro study. Turk Endod J 2025;10:151-157.

Correspondence: Oznur Sarıyılmaz. Department of Endodontics, Çanakkale Onsekiz Mart University Faculty of Dentistry, Çanakkale, Türkiye

Tel: +90 505 – 241 63 90 e-mail: oznur.sariyilmaz@comu.edu.tr

Submitted: May 14, 2025 Revised: May 21, 2025 Accepted: May 27, 2025 Published: December 09, 2025

searchers continue to search for safer alternatives due to the potential carcinogenicity of chloroform (2).

Orange oil, an essential oil, has been recommended as a biocompatible alternative to chloroform for gutta-percha dissolution (4). Eucalyptol is another non-carcinogenic and less aggressive gutta-percha solvent; however, Wourms et al. (2) reported that its solvent effect was weaker compared to chloroform.

Turpentine is an organic solvent extracted from pine trees. It can partially soften gutta-percha within a few minutes at body temperature, thus facilitating the removal of gutta-percha bulk from root canals (5). Furthermore, Kaplowitz suggested that the partial softening effect of turpentine might provide an advantage during post preparation procedures (5).

Endosolv R is a synthetic root canal filling solvent composed of 66.5g of formamide and 33.5g of phenylethyl alcohol per 100g of Endosolv R. It is recommended for the removal of phenolic resin-based root canal fillings (6).

Endodontically treated teeth are more susceptible to biomechanical failures than vital teeth (7). Consequently, these teeth may lose their coronal structure due to recurrent caries or even the regular mechanical stresses of daily function. In such cases, post systems are required to support core restorations, particularly when endodontically treated teeth have suffered extensive structural loss.

Currently, glass fiber posts are preferred due to their superior esthetic properties compared to metal alloy posts, which tend to corrode over time and may cause gingival discoloration (8). Moreover, the elastic modulus of glass fiber posts is similar to that of dentin and resin cements (9), resulting in more homogeneous stress distribution compared to metal posts (10), thereby reducing the risk of root fracture (11).

Furthermore, glass fiber posts are capable of transmitting light along their length, which enhances the polymerization quality of dual-cure resin cements (12).

Resin cements are commonly used to bond glass fiber posts within root canals, and the success of this adhesion depends on multiple factors, including the complexity of the root canal system, adequate cleaning of the post space, and the proper manipulation and delivery of resin cement throughout the canal (13).

For the removal of root canal fillings, H-type files and various endomotor-assisted NiTi retreatment file systems can be used, either with or without solvents (1). Copious irrigation is also necessary to flush out remnants of root canal filling material during the removal process.

However, previous studies have shown that the bonding strength of resin-based dental materials may be affected by chemical agents used in root canal treatment, such as sodium hypochlorite (NaOCl), EDTA, and chlorhexidine (14-16). Moreover, one study reported that the root canal solvent chloroform interfered with the adhesion of root canal sealers to root dentin (17). Similarly, Shokouhinejad et al. (18) demonstrated that retreatment procedures detrimentally affected the adhesion of Resilon/Epiphany root canal filling materials.

The aim of the present study was to compare the effects of different solvents, chloroform, orange oil, turpentine, eucalyptol, and Endosolv R, and commonly used irrigants, sodium hypochlorite and distilled water, on the adhesion of glass fiber posts luted with a dual-cure resin cement, using a push-out bond strength test in retreatment-required cases.

The null hypothesis stated that the use of different solvents and sodium hypochlorite does not affect the bond strength of glass fiber posts to root canal dentin.

Materials and Methods

The study protocol was approved by the Clinical Research Ethics Committee of Ordu University (protocol number 2015/12). The protocol of this study was carried out in accordance with the guidelines outlined in the Declaration of Helsinki.

A total of 128 extracted human mandibular premolars with fully formed apices and straight root canals were used in this study. Teeth with calcified canals, extensive caries involving the roots, previous endodontic treatment, internal or external root resorption, or any signs of previous root canal treatment were excluded.

The crowns were removed using a high-speed bur under water cooling, leaving a standardized root length of 17 mm. A #10 K-file (Dentsply Maillefer) was inserted into the canal until it became visible at the apical foramen. Working length was established by subtracting 1mm from this measurement. Teeth that did not allow sufficient working length for standard post preparation were replaced at this stage.

Root canals were prepared using primary WaveOne Gold files (#25/.07) mounted on an X-Smart Plus endomotor operating in WaveOne Gold mode. During preparation, canals were irrigated with 5 mL of 5.25% sodium hypochlorite (NaOCl) using a syringe and a 30-gauge needle (NaviTip; Ultradent, South Jordan, UT, USA). Each WaveOne Gold file was used for a maximum of three canals before being discarded.

Final irrigation was performed sequentially with 1 mL of 17% EDTA, 1 mL of distilled water, 1 mL of 5.25% NaOCl, and finally 1 mL of distilled water to remove any residual irrigants. The canals were then dried with #25 absorbent paper points.

Sixteen roots were randomly selected as the control group, and their canal orifices were sealed with a temporary restorative material (Cavit G; 3M ESPE, Germany).

The remaining teeth were obturated using an epoxy resin-based sealer (AH Plus; Dentsply Maillefer), a primary WaveOne Gold gutta-percha master cone, and #25 accessory gutta-percha cones (Diadent, Almere, Holland) using the cold lateral condensation technique. The coronal 1mm of the root canal filling was removed, and the space was sealed with temporary restorative material (Cavit; 3M ESPE, Seefeld, Germany).

All specimens were wrapped in pieces of sponge and stored at 37 °C in 100% humidity for two weeks.

At the end of the storage period, the specimens were randomly divided into eight groups as described below:

Control Group: Specimens without root canal filling (n=16)

Distilled Water Group: Root canal filling removal using NiTi retreatment files with distilled water as the irrigant (n=16)

NaOCl Group: Root canal filling removal using NiTi retreatment files with 5.25% sodium hypochlorite as the irrigant (n=16)

Endosolv R Group: Root canal filling removal using NiTi retreatment files with Endosolv R as the solvent (n=16)

Eucalyptol Group: Root canal filling removal using NiTi retreatment files with eucalyptol as the solvent (n=16)

Orange Oil Group: Root canal filling removal using NiTi retreatment files with orange oil as the solvent (n=16)

Turpentine Group: Root canal filling removal using NiTi retreatment files with turpentine as the solvent (n=16)

Chloroform Group: Root canal filling removal using NiTi retreatment files with chloroform as the solvent (n=16)

Retreatment phase

The D-Race NiTi retreatment file system (FKG Dentaire, La Chaux-de-Fonds, Switzerland), consisting of D1 (15mm length, .10 taper, size 30, active tip; operated at 1000 rpm and 1.5 Ncm torque) and D2 (25mm length, .04 taper, size 25, inactive tip; operated at 600 rpm and 1.0 Ncm torque) files, was used during the retreatment phase for all specimens.

In the distilled water group, the D1 file was advanced 1–2mm into the root canal filling, followed by irrigation with distilled water. The D1 file was then reintroduced into the canal until resistance was felt. Upon encountering resistance, the file was removed, cleaned with gauze moistened with distilled water, and the canal was irrigated again with distilled water. These steps were repeated until complete removal of the coronal root filling. The remaining root filling material was subsequently removed using the D2 file, following the same procedure.

In the NaOCl group, the root canal filling was removed following the same protocol described for the distilled water group, except 5.25% NaOCl was used as the irrigant.

In the groups utilizing solvents, the D1 file was first advanced 1–2mm into the root canal filling, followed by irrigation with 5.25% NaOCl. The access cavity was then dried with paper cones and cotton pellets. A drop of the tested solvent was applied to the root canal filling for 30 seconds, after which the coronal root filling was removed using the D1 file operated at 1000 rpm and 1.5 Ncm torque. If resistance was encountered, the file was removed, cleaned with gauze moistened with distilled water, and the canal was irrigated with NaOCl. After drying, another drop of the tested solvent was placed for 30 seconds, and instrumentation was continued until the coronal root filling was completely removed. The remaining root filling was removed using the D2 file operated at 600 rpm and 1.0 Ncm torque, following the same steps.

Following the retreatment procedures, all specimens, including the control group (which had not been obturated), were instrumented using a WaveOne Gold Medium file (35/.06) (Dentsply Maillefer) mounted on an X-Smart Plus (Dentsply Maillefer) endomotor operating in WaveOne Gold mode.

Refilling of the specimens

A Medium 35/.06 WaveOne Gold gutta-percha cone (Dentsply Maillefer) was coated with AH Plus (Dentsply Maillefer) root canal sealer and placed into the root canals of all specimens. A size 0 Buchanan heat plugger, mounted on the down-pack unit of the ElementsFree obturation system, was used to remove the gutta-percha above 5mm from the apical foramen. The remaining apical 5mm of gutta-percha was then condensed using the same heat plugger.

Post placement

The post space was prepared up to 1.8mm in diameter using a Piezzo Reamer canal drill set (Cytec Blanco; Hahnenkratt GmbH, Königsbach, Germany). The post space was irrigated with distilled water after each drill change, and an EndoActivator (Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) with a large-sized tip (35/.04) was used for final irrigation to eliminate any remnants from the post space.

A self-etch adhesive system (Clearfil SE Bond 2; Kuraray Co., Inc., Osaka, Japan) was applied to the post cavities of all specimens according to the manufacturer's instructions. Glass fiber posts were then cemented into the cavities using a dual-cure resin cement (RelyX U200; 3M ESPE, Minnesota, USA).

Obtaining slice samples

The specimens with placed glass fiber posts were embedded in autopolymerizing acrylic blocks measuring 2.5 cm in height and 10mm in diameter. From the coronal region of the posts, located 14mm from the root apex, 1-mm-thick slices were obtained using a water-cooled diamond saw mounted on a low-speed precision cutting machine (Mecatome T180; Presi, Eybens, France) operating at 750 rpm. The coronal side of each slice was marked with a fine-tipped indelible marker for the push-out tests and then stored in a 1.5 mL Eppendorf tube.

The push-out tests

The slices were placed on a plastic holder with a 1.7mm diameter hole, allowing the passage of a 1.1mm cylindrical stainless steel pushing tip. The pushing tip, mounted on the head of a universal testing machine (Autograph AGS-X; Shimadzu Co., Japan) equipped with a 5000 N load cell, was positioned at the center of the glass fiber post within the slice. A compressive force was applied at a crosshead speed of 1 mm/min until the post was dislodged from the surrounding dentin. The required force was recorded and automatically converted to megapascals (MPa) by the software of the universal testing machine.

Table 1. Mean and standard deviation values of bond strength (MPa) between glass fiber posts and dentin after the use of different solvents. Different lowercase letters indicate statistically significant differences between groups ($p<0.05$).

Groups	n	Mean (STD)
Control	16	43,87±10,36[a]
Distilled water	16	33.86 ±20.79[abc]
Sodium hypochlorite	16	23.26±10.37[bc]
Endosolv	16	37.46±16.86[ab]
Eucalyptol	16	44.1±16.08[a]
Orange oil	16	33.4637±14.52[ab]
Turpentine	16	16.85±12.67[c]
Chloroform	16	36.07±16.47[ab]
p		0.000

Statistical Analysis

The normality of the data distribution was assessed using the Shapiro-Wilk test. One-way ANOVA and post hoc Tukey tests were used to evaluate the significance between groups at a 95% confidence level. All statistical analyses were performed using SPSS version 21.0 software (SPSS Inc., Chicago, IL, USA).

Results

Turpentine significantly reduced the bonding strength of the glass fiber post to dentin compared to other the solvents tested in this study. Whereas, Endosolv R, chloroform and eucalyptol were statistically similar to the control group. ($p>0.05$).

Table 1 presents the mean and standard deviation values of the bond strength between glass fiber posts and dentin following the use of different solvents.

Bond strength in the control and eucalyptol groups was found to be significantly higher than in the sodium hypochlorite and turpentine groups ($p<0.05$). The bond strength observed in the distilled water group was similar to that of all other groups. Bond strength in the turpentine group was significantly lower than in the control, eucalyptol, Endosolv R, chloroform, and orange oil groups ($p<0.05$). Among all groups, the lowest bond strength was observed with the use of turpentine. The highest bond strength was recorded in the eucalyptol group. Bond strengths in the eucalyptol, Endosolv R, chloroform, and orange oil groups were comparable to that of the control group.

Discussion

Endodontic retreatment, which has an approximate success rate of 80%, is a preferred treatment option when conventional root canal therapy fails (19). The main goals of this procedure are to regain access to the apical region by removing the existing root canal filling, disinfect the root canal system, and subsequently perform proper obturation. Achieving these objectives requires the effective removal of the often-infected root canal filling material (20). Various methods—relying on the use of ultrasonic devices, lasers, solvents, and heat-transfer systems, either alone or in combination—have been recommended to enhance removal efficacy (4, 21-24).

The persistence of apical periodontitis after initial root canal treatment remains a significant clinical challenge, often necessitating endodontic retreatment. With a reported success rate of approximately 80% (19), retreatment is the preferred option when conventional root canal therapy fails. The primary objectives of this procedure are to regain access to the apical region by removing the previous root canal filling, thoroughly disinfect the canal system, and ensure a hermetic re-obturation.

Achieving these goals largely depends on the effective removal of the existing root canal filling materials, which are frequently associated with persistent microbial contamination (20). To enhance the efficacy of filling material removal, various adjunctive techniques have been proposed, including the use of ultrasonic devices, laser systems, chemical solvents, and heat-assisted approaches (4, 21-24).

Despite these advancements, complete removal of filling materials remains a challenge, and the choice of solvent may influence not only the cleaning efficacy but also subsequent procedures, such as glass fiber post placement. In this context, the present study aimed to evaluate how different solvents used during retreatment affect the bond strength between glass fiber posts and root dentin.

Post systems are required to restore endodontically treated teeth with extensive loss of coronal structure. Among these systems, glass fiber posts are frequently preferred by clinicians due to their advantageous properties, including an elastic modulus similar to that of dentin (9), favorable esthetics (8), and a reduced risk of root fracture (11). One of the key determinants of the long-term success of post systems is the bonding strength between the post and root dentin, which can be assessed by various mechanical tests such as push-out (25), pull-out (26), and microtensile tests (14).

While the microtensile test is highly sensitive, it is associated with a high risk of premature failure. The pull-out test, although useful for evaluating the bond strength of the entire root, does not allow regional comparisons. The push-out test, on the other hand, is considered more suitable for studies like the present one, as it enables the evaluation of bond strength at different levels of the root and can better simulate clinical conditions by adjusting the direction of the applied load (13). However, this method may produce inaccurate results with thicker slices due to uneven stress distribution. To overcome this limitation, the use of 1 mm-thick slices has been recommended (25). Therefore, in this study, 1 mm-thick slices from the coronal region of the root were used to evaluate the bonding strength of glass fiber posts to root dentin.

Previous studies have shown that root canal irrigants such as NaOCl, EDTA, and chlorhexidine affect the bonding strength of resin-based materials to root dentin by altering both the organic and inorganic components of dentin or leaving remnants such as oxygen radicals (14-16). In addition, Morris et al. (27) also reported that NaOCl interferes with the infiltration of resin-based materials into demineralized dentin, thereby detrimentally affecting the bonding strength. Similarly, the root canal filling solvent chloroform has been shown to interfere with the adhesion of root canal sealers to root dentin (17). In line with these findings, Shokouhinejad et al. (18) reported that the retreatment procedure negatively impacted the adhesion of resilon/epiphany root canal fillings. A previous study by Kaufman et al. (28), which reported that root canal filling solvents such as chloroform, xylene, and Endosolv E could affect the calcium and phosphorus levels in dentin, may provide an explanation for these effects.

This study was based on a case scenario involving the resin-post requirements of a retreatment case. The commonly recommended root canal solvents, including Endosolv R, eucalyptol, orange oil, turpentine, and chloroform, were compared to determine their effect on the bonding strength of glass fiber posts. Additionally, a previous study showed that root canal sealers could detrimentally affect the bonding strength of glass fiber posts to root dentin (29). Thus, a control group was created using specimens of posts cemented into prepared, but not filled, root canals. Another important consideration is the detrimental effect of the commonly used irrigant NaOCl on resin-based dental cements due to the degradation of NaOCl into chloride and oxygen radicals. Subsequently, the released oxygen radicals inhibit the polymerization of the resin and interfere with its penetration into the demineralized dentin (27). Therefore, these findings led us to include the “distilled water” and “NaOCl” experimental groups in this study.

In this study, comparison of distilled water and the control group shows no statistical differences in bonding strength. On the other hand, the NaOCl decreased the bonding strength. The coronal third of the root has a larger surface area than the other regions of the root so, more irrigant circulated in the coronal third of the root. Thus, the coronal region of the root encountered more oxygen radicals released from NaOCl, which might be responsible for the decrease in bonding strength in the coronal region (27). Clinicians might consider the use of antioxidant agents such as Sodium thiosulfate ($Na2S2O3$) for improve the decreased bonding strength due to NaOCl.

Previous studies revealed that solvents used for retreatment have an effect on the mineral levels of dentin (28,30), which may have affected the bonding strength of resin-based dental materials. Additionally, solvent residues in the root canal might interfere with the chemical setting reactions of resins, negatively affecting the bonding strength of resin post systems. Furthermore, solvents may cause remnants of gutta-percha to remain, as they dissolve the material and potentially coat the dentin walls of the canal, thereby compromising the bond strength between resin post systems and dentin by forming a physical barrier.

The results of this study showed that the use of turpentine as a retreatment solvent resulted in a statistically significant decrease in the bonding strength of glass fiber posts. However, the other tested solvents did not show a statistically significant reduction in bonding strength. The removal of dentin affected by solvents during post space preparation up to 1.8mm in diameter using a Piezzo Reamer canal drill set (Cytec Blanco) may explain why a significant reduction in bonding strength was not observed for the other solvents. On the other hand, turpentine may have penetrated the dentinal tubules more deeply than the other tested solvents, and could not be completely eliminated during the post preparation process, resulting in decreased bonding strength. Further research is needed to evaluate the penetration of different solvents into dentin and the alterations they cause on the root canal dentin surface for a more precise explanation.

One of the primary limitations of this study is that it was conducted using extracted human teeth. The physiological changes that occur in dentinal tubules post-extraction, such as dehydration, collapse of the tubule structure, or altered permeability, may influence the interaction and bonding performance of resin-based materials. Consequently, the results obtained under these in vitro conditions may not fully reflect the clinical behavior of the materials under in vivo circumstances.

Within the limitations of this in vitro study, it can be concluded that the type of solvent used during endodontic retreatment may influence the bonding strength of glass fiber posts to root dentin. Among the tested solvents, turpentine caused a statistically significant decrease in bond strength, likely due to deeper dentin penetration and incomplete removal during post space preparation. In contrast, other commonly used solvents did not adversely affect bonding performance under the tested conditions. Additionally, sodium hypochlorite negatively impacted adhesion, possibly due to the release of oxygen radicals, suggesting that the use of antioxidant agents may be beneficial. These findings underscore the importance of careful solvent selection during retreatment, particularly in cases where post placement is planned.

Based on these results, the null hypothesis was partially rejected, as only turpentine and sodium hypochlorite were found to have a significant negative effect on the adhesion of glass fiber posts.

Conclusion

Further in vivo research is warranted to comprehensively evaluate the interactions between endodontic solvents and the dentin substrate, particularly in terms of their depth of penetration and long-term effects on adhesive bonding and clinical outcomes. Additionally, potential chemical interactions between residual solvents and adhesive systems may also impact bond strength, highlighting the need for further investigation into this aspect.

Authorship Contributions: Concept: E.S., E.C., E.B.C., F.C., A.T., D.O.D.; Design: E.S., E.C., F.C., D.O.D.; Supervision: E.S., D.O.D.; Funding: E.S., E.C., E.B.C., F.C., A.T., D.O.D.; Materials: E.S., E.C., F.C., E.B.C., A.T., D.O.D.; Data: E.S., E.C., F.C., E.B.C., A.T., D.O.D.; Analysis: E.S., E.C., O.S.; Literature Search: E.S., E.C., A.T.; Writing: E.S., O.S.; Critical Revision: E.B.C., A.T., D.O.D.

Use of AI for Writing Assistance: Not declared

Source of Funding: This study utilized data from the BAP Project coded AR-1523, which was financially supported by Ordu University.

Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Clinical Research Ethics Committee of Ordu University (protocol number 2015/12).

Informed consent: Written informed consent was obtained from patients who participated in this study.

References

1. Duncan HF, Chong BS. Removal of root filling materials. Endod Topics 2008; 19: 33–57. [CrossRef]
2. Wourms DJ, Campbell AD, Hicks ML, et al. Alternative solvents to chloroform for gutta-percha removal. J Endod 1990; 16: 224–6. [CrossRef]
3. Roda RS, Gettleman BH. Nonsurgical retreatment. In Hargreaves KM, Berman LH, eds. Cohen's pathways of the pulp. 11th ed. Toronto: Elsevier; 2016. p. 324–86.
4. Scelza MF, Oliveira LR, Carvalho FB, et al. In vitro evaluation of macrophage viability after incubation in orange oil, eucalyptol, and chloroform. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006; 102: 24–7. [CrossRef]
5. Kaplowitz G. Clinical uses of rectified turpentine oil. Int Endod J 1996; 29: 93–4. [CrossRef]
6. Gambrel MG, Hartwell GR, Moon PC, et al. The effect of endodontic solution on resorcinol-formalin paste in teeth. J Endod 2005; 31: 25–9. [CrossRef]
7. Hansen EK, Asmussen E, Christiansen NC. In vivo fractures of endodontically treated posterior teeth restored with amalgam. Dent Traumatol 1990; 6(2): 49–55. [CrossRef]

8. Cecchin D, de Almeida JF, Gomes BP, et al. Influence of chlorhexidine and ethanol on the bond strength and durability of the adhesion of the fiber posts to root dentin using a total etching adhesive system. J Endod 2011; 37: 1310–5. [CrossRef]
9. Plotino G, Grande NM, Bedini R, et al. Flexural properties of endodontic posts and human root dentin. Dent Mater 2007; 23: 1129–35. [CrossRef]
10. Coelho CS, Biffi JC, Silva GR, et al. Finite element analysis of weakened roots restored with composite resin and posts. Dent Mater J 2009; 28: 671–8. [CrossRef]
11. Santos AF, Meira JB, Tanaka CB, et al. Can fiber posts increase root stresses and reduce fracture? J Dent Res 2010; 89: 587–91. [CrossRef]
12. Yoldas O, Alacam T. Microhardness of composites in simulated root canals cured with light transmitting posts and glass-fiber reinforced composite posts. J Endod 2005; 31: 104–6. [CrossRef]
13. Faria-e-Silva AL, Mendonça AA, Garcez RM, et al. Adhesion strategy and early bond strengths of glass-fiber posts luted into root canals. Braz Oral Res 2012; 26(5): 485–7. [CrossRef]
14. Ari H, Yasar E, Belli S. Effects of NaOCl on bond strengths of resin cements to root canal dentin. J Endod 2003; 29(4): 248–51. [CrossRef]
15. Hayashi M, Takahashi Y, Hirai M, et al. Effect of endodontic irrigation on bonding of resin cement to radicular dentin. Eur J Oral Sci 2005; 113(1): 70–6. [CrossRef]
16. de Araújo DF, Chaves LP, Bim O Jr, et al. Influence of 2% chlorhexidine digluconate on bond strength of a glass-fibre post luted with resin or glass-ionomer based cement. J Dent 2014; 42: 735–41. [CrossRef]
17. Topcuoglu HS, Demirbuga S, Tuncay O, et al. The bond strength of endodontic sealers to root dentine exposed to different gutta-percha solvents. Int Endod J 2014; 47: 1100–6. [CrossRef]
18. Shokouhinejad N, Sabeti MA, Hasheminasab M, et al. Push-out bond strength of Resilon/Epiphany self-etch to intraradicular dentin after retreatment: A preliminary study. J Endod 2010; 36: 493–6. [CrossRef]
19. Kang M, Jung HI, Song M, et al. Outcome of nonsurgical retreatment and endodontic microsurgery: A meta-analysis. Clin Oral Investig 2015; 19: 569. [CrossRef]
20. de Oliveira DP, Barbizam JV, Trope M, et al. Comparison between gutta-percha and Resilon removal using two different techniques in endodontic retreatment. J Endod 2006; 32: 362–4. [CrossRef]
21. Hunter KR, Doblecki W, Pelleu GB Jr. Halothane and eucalyptol as alternatives to chloroform for softening gutta-percha. J Endod 1991; 17: 310–1. [CrossRef]
22. Hülsmann M, Stotz S. Efficacy, cleaning ability and safety of different devices for gutta-percha removal in root canal retreatment. Int Endod J 1997; 30: 227–33. [CrossRef]
23. Farge P, Nahas P, Bonin P. In vitro study of a Nd:YAP laser in endodontic retreatment. J Endod 1998; 24: 359–63. [CrossRef]
24. de Carvalho Maciel AC, Zaccaro Scelza MF. Efficacy of automated versus hand instrumentation during root canal retreatment: An ex vivo study. Int Endod J 2006; 39: 779–84. [CrossRef]
25. Uzun I, Keskin C, Özsu D, et al. Push-out bond strength of oval versus circular fiber posts irradiated by erbium-doped yttrium aluminum garnet laser. J Prosthet Dent 2016; 116(3): 425–30. [CrossRef]
26. D'Arcangelo C, Cinelli M, De Angelis F, et al. The effect of resin cement film thickness on the pull-out strength of a fiber-reinforced post system. J Prosthet Dent 2007; 98: 193–8. [CrossRef]
27. Morris MD, Lee KW, Agee KA, et al. Effects of sodium hypochlorite and RC-prep on bond strengths of resin cement to endodontic surfaces. J Endod 2001; 27: 753–7. [CrossRef]
28. Kaufman D, Mor C, Stabholz A, et al. Effect of gutta-percha solvents on calcium and phosphorus levels of cut human dentin. J Endod 1997; 23: 614–5. [CrossRef]
29. Rosa RA, Barreto MS, Moraes Rdo A, et al. Influence of endodontic sealer composition and time of fiber post cementation on sealer adhesiveness to bovine root dentin. Braz Dent J 2013; 24(3): 241–6. [CrossRef]
30. Erdemir A, Eldeniz AU, Belli S. Effect of gutta-percha solvents on mineral contents of human root dentin using ICP-AES technique. J Endod 2004; 30: 54–6. [CrossRef]