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Effect of Different Final Irrigants Applied on Intraradicular Dentin on the Bond Strength to Fiber Post: A Review

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Abstract

Statement of Problem: Well bonding of fiber posts inside the root canal is based on the formation of hybrid layer (HL). After mechanical post space preparation, final rinse with irrigants before fiber post cementation is used to dissolve the smear layer and encourage the formation of HL. The purpose of this review was to investigate the effects of pretreatment of the root canal using different irrigants on push-out bond strength of luted fiber posts. **Material and Methods:** A computerized literature search for studies based on English-language was conducted on PubMed between 2012 and 2022. **Results:** Thirty-five studies met the eligibility criteria. The most studied surface treatments were NaOCl, CHX, EDTA, and the association NaOCl with EDTA. The results were highly contentious. But most dentin surface treatments and bonding systems used have strengthened the bond between the posts and the dentin surface. **Conclusion:** The review found insufficient evidence to conclude on the best final rinse irrigator. Additional studies with test standardization and well-reported randomized clinical studies considering occlusal forces and tooth position in the arch are required.

Subject Areas

Fixed Prosthodontics

Keywords

Fiber Post, Radicular Dentin, Irrigant, Push-Out, Bond Strength

1. Introduction

Restoration of endodontically treated teeth is one of the problems in dentistry [1].

Using post-core restorations with adhesively luted fiber posts gained more popularity and prospective clinical investigations revealed promising results [2].

Luting of posts inside the root canal is still a challenge due to the limited access, visibility, and moisture control [3].

The use of fiber posts is a suitable treatment because the biomechanical properties of the material, in particular the elastic modulus, are similar to the remaining dentine [4].

The failure risk is significantly affected by the amount of residual tooth structure [5]. The results showed that adhesive failure was the most predominant mode of failure [1].

A routine post space preparation always produces a new smear layer rich in sealer and gutta percha remnants that are plasticized by the friction heat of the drill [6].

The thick smear layer on the post space would impair the effective bonding of adhesive resin into radicular dentin [7].

Well bonding is based on the formation of hybrid layer (HL) with resin monomer infiltration into the demineralized dentin, which requires a clean dentinal surface after mechanical post space preparation with the removal of root canal filling material [8].

Thus, for preventing failure, root canal cleanliness before adhesive luting is indispensable. Sodium hypochlorite (NaOCl), chlorhexidine (CHX) and ethylenediaminetetraacetic acid (EDTA) are widely used with the aim of biofilm removal [9]. The final irrigant might deobstruct the dentinal tubules, clean the intraradicular dentine, and/or inhibit proteolytic enzymes (MMPs).

The main aim of our work was to investigate the effects of pretreatment of the root canal using different irrigants on push-out bond strength of luted fiber posts.

2. Materials and Methods

2.1. Protocol

This review followed the guidelines of the PRISMA Statement "Preferred Reporting for Systematic Review and Meta-Analysis" [10].

2.2. Focused Question and Search Strategy

The focused question was determined according to the well-established PICO strategy: P: Population—Permanent human teeth having undergone endodontic treatment and post space preparation.

I: Intervention—Irrigants were used to treat the surface of radicular dentin before bonding the fiber post.

C: Comparison—The comparison between different root canal irrigants.

O: Outcomes—Evaluation of the bond strength between the post and the dentine surface by using push-out test as well as the fracture mode produced after each surface treatment.

The focused question of the presented review was: "Which surface treatment of radicular dentine (irrigant or combination of irrigants) have more impact on adhesion of fiber post to radicular dentin?"

The search strategy involved carrying out an electronic search through PubMed, based on Boolean equation using 26 anglo-saxon keywords:

("*radicular dentin*") OR ("*dental root*") OR (dentin) OR ("*root dentin*") OR ("*root canal*") OR ("*tooth root*") AND (bonding) OR (adhesion) OR ("*resin cement*") OR (cement) OR ("*dental cements*") OR ("*bond strength*") AND ("*surface treatment*") OR ("*tissue conditioning*") OR (irrigant) AND (post) OR ("*dental post*") OR ("*fiber post*") OR ("*glass fiber post*") OR ("*post and core technique*") OR ("*fiber-reinforced post*") OR ("*endodontic post*") OR ("*post-core restoration*") AND ("*push-out test*") OR ("*push-out*") OR ("*push-out bond strength*")

2.3. Inclusion and Exclusion Criteria

- Articles studying and comparing the bond strength between fiber post and intradicular dentin which have used the push-out test (PBS) measurement.
- Articles written in English, since 2012 and using endodontically treated human teeth, have been included in this systematic review.
- From the investigation were excluded studies testing surface treatment other than irrigants (without any activation protocol).

2.4. Selection of Studies

The scientific articles were read by two persons (M. H and E. N). A first reading was made to select the articles through the title and the abstract according to the eligibility criteria. Then a second full reading of the selected articles was conducted to eliminate articles that did not meet the inclusion criteria. Disagreements between the reviewers during this process were discussed until an agreement was reached.

2.5. Quality Assessment

The quality assessment of in vitro studies included in this work was carried out according to the method described by Sarkis-Onofre *et al.*, Al Fawaz *et al.* and Bin-Shuwaish [11] [12] [13]. Eight parameters were evaluated. The following parameters were considered to rate the overall quality of included studies: randomization of teeth, teeth free of caries or restoration, inclusion of control group, similar dimension samples, description of coefficient of variation, assessment of failure mode, sample size calculation and blinding of the operator testing. The parameter receives a "Yes" (Y) if the particular details have been reported in the selected articles otherwise a "No" (N) in case of missing parameter. Studies covering 1 to 3 items were considered studies at high risk of bias, while those covering 4 to 5 and 6 to 8 were considered studies at medium to low risk of bias, respectively.

3. Results

3.1. Study Selection

The result of the literature search is presented in flow chart (**Figure 1**). A total number of 204 articles were initially found. After assessing the titles and abstracts, 43 articles were selected.

After full-text articles reading, 8 articles [14]-[21] were excluded for the following reasons:

- did not give the unit of measurement of the push-out test;
- the intraradicular irrigants used weren't the final irrigants;
- did not perform endodontic root canal obturation;
- did not compare intraradicular dentine irrigants;
- has associate chemical and mechanical treatment.

3.2. Risk of Bias

Two of the 35 included studies presented a low risk of bias, twenty-eight studies a medium risk of bias, and five studies a high risk of bias. According to the parameters considered during the analysis, the results are presented in **Table 1**.

3.3. General Descriptive of Included Studies

The 35 articles selected are in vitro studies carried out by researchers from different countries. The articles are written in English.

Sample sizes ranged from 28 to 224.

All the studies used the following teeth: central and lateral incisors, canines and single-rooted premolars from the maxillary and mandibular arches.

Regarding root canal filling materials, Garcia *et al.* 2018 [22] and Suzuki *et al.* 2019 [23] used gutta with calcium hydroxide cement. Culhaoglu *et al.* 2012 [24] did not use endodontic cement. The rest of the studies used an epoxy resin cement.

Chemical surface treatments based on the irrigants described in the studies may be applied alone, in combination with two or more irrigants.

Different irrigants used in the 35 studies are: Sodium hypochlorite (**NaOCl**)/ Chlorhexidine digluconate or diactetate (**CHX**)/ Ethylenediaminetetraacetic acid (**EDTA**)/ Ethanol (**EtOH**)/ Saline solution (**NaCl**)/ **Qmix** (association of EDTA, CHX and a detergent)/ Calcium hypochlorite (**CaOCl**)/ Polyacrylic acid (**PAA**))/ Fumaric acid/ Citric acid/ Peracetic acid (**PA**)/ Epigallocatechin-3-gallate (**EGCG**)/ **NISIN** (antibiotic from Lactococcus lactis)/ **MTAD** (mixture of tetracycline, acid and detergents)/ Silver diamine fluoride (**SDF**)/ SmearClear/ **Synthetic chemical solvent** composed of 33% acetone, 33% ethanol and 34% ethyl acetate/ Silver nanoparticle (**SNP**) solution/ Maleic acid/ Phytic acid/ 1-Hydroxyethane-1,1-diphosphonic acid (HEBP)/ Boric acid/ Smear OFF/ Pineapple peel extract (**PPE**).

To carry out the push out test, the roots were sectioned horizontally in several slices according to the root regions studied. The thickness of the slices in this systematic review varies between 1 mm and 3 mm.

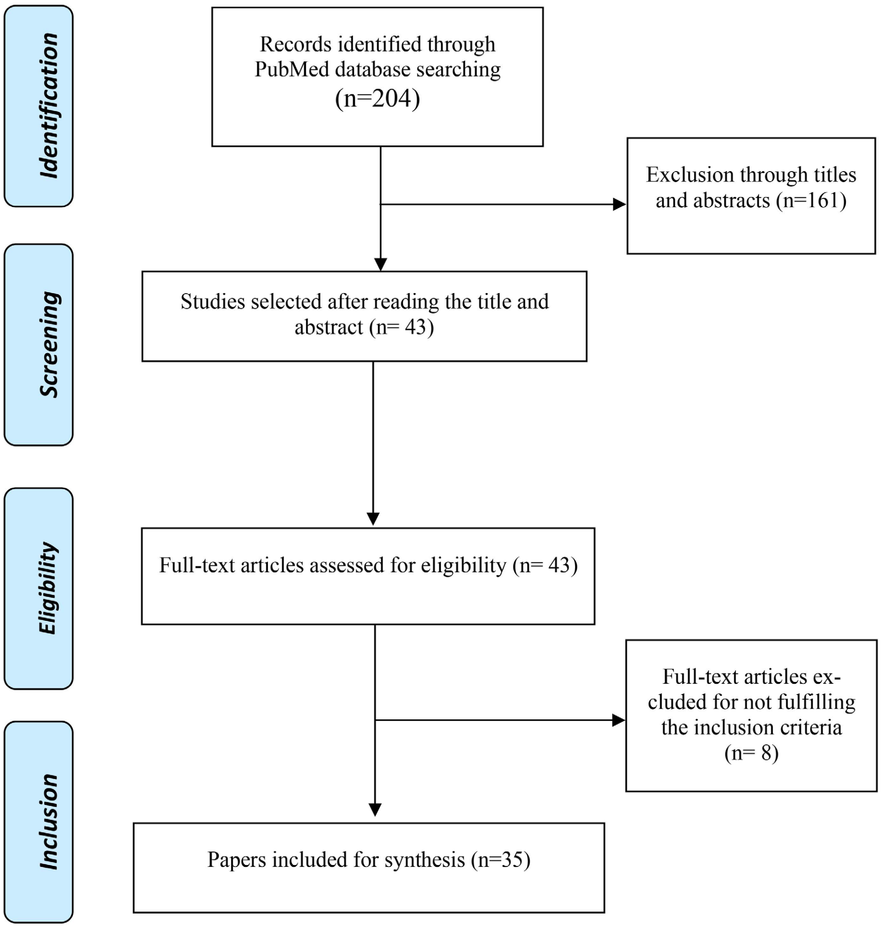

Figure 1. Flow chart illustrating selecting procedures according to the PRISMA statement.

Table 1. Risk of bias of the included studies.

Author, year of study	Teeth randomization	Teeth free of caries or restorations	Control group	Teeth with similar dimensions	Failure mode	Description of the coefficient of variation	Sample size calculation	Blinding of the operator of the testing machine	Risk of bias
Khamverdi *et al.*, 2013 [1]	N	Y	Y	Y	Y	N	N	N	Medium (4)
Bitter *et al.*, 2014 [2]	Y	Y	Y	Y	Y	N	N	N	Medium (5)
Haragushiku *et al.*, 2015 [3]	N	N	Y	Y	Y	N	N	N	High (3)
Garcia *et al.*, 2018 [22]	Y	Y	Y	Y	N	N	N	N	Medium (4)
Suzuki *et al.* 2019 [23]	Y	Y	Y	Y	N	N	N	N	Medium (4)
Culhaoglu *et al.*, 2017 [24]	Y	Y	Y	Y	Y	N	N	N	Medium (5)
Alkhudhairy *et al.*, 2018 [25]	Y	Y	N	Y	Y	N	N	N	Medium (4)
Akman *et al.*, 2016 [26]	Y	N	Y	Y	Y	N	N	N	Medium (4)
Aljamhan *et al.*, 2021 [27]	Y	N	Y	Y	Y	N	N	N	Medium (4)
Alkhudhairy *et al.*, 2016 [28]	Y	Y	N	Y	Y	N	N	N	Medium (4)

Continued

Ciapala *et al.*, 2021 [29]	N	Y	Y	Y	N	N	N	N	High (2)
Erik *et al.*, 2020 [30]	Y	Y	Y	Y	Y	N	Y	N	Low (6)
Abrar *et al.*, 2020 [31]	Y	Y	Y	Y	Y	N	N	N	Medium (5)
Seballos *et al.*, 2018 [32]	Y	N	Y	Y	Y	N	N	Y	Medium (5)
Arisu *et al.*, 2013 [33]	Y	Y	Y	Y	Y	N	N	N	Medium (5)
Khoroushi *et al.*, 2019 [34]	Y	y	Y	Y	Y	N	N	N	Medium (5)
Yu *et al.*, 2017 [35]	Y	N	Y	Y	Y	N	Y	N	Medium (5)
Ertas *et al.*, 2014 [36]	N	N	Y	Y	Y	N	N	N	High (3)
Elnaghy, 2014 [37]	Y	N	N	Y	Y	N	N	N	High (3)
Silva *et al.*, 2021 [38]	Y	Y	Y	Y	Y	N	N	N	Medium (5)
Sheikh Ghaderijani *et al.*, 2021 [39]	Y	Y	Y	Y	Y	N	N	N	Medium (5)
Moura *et al.* , 2017 [40]	Y	Y	N	Y	Y	N	N	N	Medium (4)
Afkhami *et al.*, 2022 [41]	Y	Y	Y	Y	Y	N	N	N	Medium (5)
Fan *et al.*, 2017 [42]	Y	Y	Y	Y	Y	N	N	N	Medium (5)
Belizario *et al.*, 2019 [43]	N	Y	Y	Y	Y	N	N	N	Medium (4)
Jalali *et al.*, 2018 [44]	Y	Y	Y	Y	N	N	N	N	Medium (4)
Kul *et al.*, 2016 [45]	N	Y	Y	Y	Y	N	N	N	Medium (4)
Victorino *et al.*, 2016 [46]	Y	Y	Y	Y	Y	N	N	N	Medium (5)
Saricam *et al.*, 2020 [47]	Y	N	Y	Y	Y	N	N	N	Medium (4)
Alaghemand *et al.*, 2013 [48]	Y	Y	Y	Y	Y	N	N	N	Medium (5)
Yadav *et al.*, 2021 [49]	N	Y	N	Y	N	N	N	N	High (2)
Alkahtany, 2022 [50]	Y	Y	N	Y	Y	N	N	N	Medium (4)
Wan *et al.*, 2020 [51]	N	Y	Y	Y	Y	N	N	N	Medium (4)
Shafiei *et al.*, 2020 [52]	Y	Y	Y	Y	Y	N	Y	N	Low (6)
AlJeaidi, 2020 [53]	Y	Y	N	Y	Y	N	N	N	Medium (4)

On a testing machine, load was applied at a constant rate until bond failure occurred. This fracture is characterized by the extrusion of the root section's post.

4 studies used a speed of 1 mm/min [25] [26] [27] [28]. One study used a speed of 0.1 mm/min [29]. One study used a speed of 0.25 mm/min [30]. The rest of the studies used a speed of 0.5 mm/min except for the study by Abrar *et al.* [31], in 2020 which did not indicate the speed of the test machine.

To express the bond strength in MPa the fracture load recorded in Newton was divided by the area of the bonded interface.

3.4. Push-Out Bond Strength Results

Different types of irrigants were used as root canal pretreatment. 26 studies used a control group.

Nineteen studies used NaOCl [9] [22] [23] [25] [28] [32]-[44] [52] and bond values ranged from 0.65 to 54.21 MPa.

Thirteen studies used chlorhexidine [2] [9] [23] [24] [29] [31] [32] [36] [37] [41] [44] [45] [46] and bond values ranged from 0.03 to 55.23 MPa.

Nine used EDTA [21] [25] [30] [37] [44] [47] [48] [49] [50] and bond values ranged from 4 to 62.1 MPa.

Nine studies used saline solution (NaCl) [28] [29] [30] [32] [34] [36] [39] [42] [44] and bond values range from 2.73 to 43.84 MPa.

Four studies used ethanol [2] [36] [46] [48] and bond values ranged from 6.45 to 35.95 MPa.

Three studies used Qmix [37] [38] [41]. Qmix is an association of EDTA, CHX and a detergent. The bond values ranged from 3.22 to 19 MPa.

Three studies used calcium hypochlorite (CaOCl) [32] [34] [39] and the bond values ranged from 3.24 to 15.5 MPa.

Three studies used MTAD [44] [50] [51] (association of 3% doxycycline, 4.25% citrate and 0.5% polysorbate-80) and bond values ranged from 8.47 to 58.64 MPa.

Two studies [23] [52] used SNP (silver nanoparticles solution). Bond strength values ranged from 0.63 and 19.54 MPa.

Two studies used silver diamine fluoride (SDF) [31] [52]. Bond strength values ranged from 5.88 to 16.72 MPa.

Two studies used peracetic acid (PA) [38] [43] and bond strength values ranged from 1.08 to 14.15 MPa.

Fourteen studies used an association of NaOCl with EDTA [22] [24] [25] [26] [27] [30] [31] [33] [36] [40] [42] [45] [51] [53] and bond strength values ranged from 3.65 to 14.31 MPa.

One study each used polyacrylic acid [23], a chemical synthetic solvent, composed of 33% acetone, 33% ethanol and 34% ethyl acetate [1], boric acid [24], SmearOFF [30], HEBP [30], maleic acid [49], phytic acid [41], PPE [50], SmearClear (EDTA solution with cationic and anionic surfactant) [38], an association of epigallocatechine-3-gallate with sodium hypochlorite [35], fumaric acid (buten-1,4 dioic acid) [47], an association of EDTA with ethanol [48], an association of citric acid with sodium hypochlorite [26], an association of Nisin (antibiotic from Lactococcus lactis) with MTAD [27] (**Table 2**).

4. Discussion

A review including 35 studies was performed.

The majority of the included studies (28 studies) presented a medium bias, five presented a high risk of bias and only two studies presented a low risk of bias.

One limitation of this systematic review was the lack of standardization of the irrigants used in the control groups that were distilled water, NaCl, NaOCl,

Table 2. PBS test values and fracture mode of irrigants used in a single study.

Article	Type of irrigant	Push-out bond strength value (PBS) (MPa)
Khamverdi *et al.* [1]	Chemical synthetic solvent, composed of 33% acetone, 33% ethanol and 34% ethyl acetate.	From 8.2 to 51.39 MPa
Suzuki *et al.* [23]	Polyacrylic acid	From 0.46 to 5.03 MPa
Culhaoglu *et al.* [24]	Boric acid	From 3.03 to 8.34 MPa
Akman *et al.* [26]	Citric acid + sodium hypochlorite	4.46 MPa
Aljamhan *et al.* [27]	Nisin + MTAD NaOCl + MTAD	From 3.62 to 6.91 MPa From 5.51 to 8.21 MPa
Erik *et al.* [30]	SmearOFF HEBP	From 1.1 to 3.98 MPa From 1.41 to 4.77 MPa
Yu *et al.* [35]	Epigallocatechine-3-gallate + sodium hypochlorite	From 5.88 to 17.65 MPa
Saricam *et al.* [47]	Fumaric acid	8.68 MPa
Alaghemand *et al.* [48]	EDTA + Ethanol	35.55 MPa
Yadav *et al.* [49]	Maleic acid Phytic acid	From 52.2 to 79.4 MPa From 42.5 to 93.9 MPa
Alkahtany *et al.* [50]	PPE	11.22 MPa

EDTA and the association NaOCl/EDTA. Thus, the comparison between the different studies was compromised.

Another limitation was the language restriction imposed by the search strategy. Similarly, the variability of cleaning methods, the different concentrations of irrigants and the application times induced differences in the results of studies that evaluated the same surface treatments. Therefore, any general conclusion should be carefully interpreted.

The Push-out test is considered the most appropriate method for measuring post retention, due to its reliability and accuracy [54]. However, fiber post exposure to dislodgement forces during Push-Out test cannot be compared to functional occlusal forces during clinical function. In addition, the process of cutting the roots as well as the root canal filling remnants materials and accessory canals could induce artefacts thus influencing the results of the test [55]. This would explain, at least partially, the high standard deviation observed in some studies.

Among pretreatments presented in this review, NaOCl, CHX, association NaOCl/EDTA and EDTA were most tested irrigants, but controversial results have been observed.

Several studies have reported the negative effect of irrigation with NaOCl on the adhesion of bonding resins to radicular dentin [25] [27] [33] [35] [37] [53]. This can be explained by the fact that the hypochlorite decomposes into sodium chloride and oxygen which can inhibit the polymerization of bonding materials and disturb the infiltration of the resin in the demineralized dentine.

Contrary to the study by Mao *et al.* 2011 [56], which concluded that treatment with NaOCl after etching led to an improvement in bonding forces, thanks to its proteolytic action which made it possible to obtain a porous and irregular dentinal substrate thus allowing complete infiltration of the adhesive resin.

On the other hand, other studies [27] [31] [33] [45] [53] have concluded that the combination NaOCl/EDTA increases the bond strength. This is explained by the fact that in this combination EDTA is antioxidant and reduces the specific disadvantages of NaOCl. EDTA removes the oxidative layer improving penetration of resin cement in dentin [19].

Regarding EDTA, some authors [25] [37] have reported an increase in Push-Out bond strength values. This is due to its effectiveness in the removal of smear layer and the opening of the dentinal tubules, which plays an important role in the penetration of the resin cements into the dentinal tubules [25].

On the other hand, the study by Baena *et al.* [57] indicated that EDTA had reduced the bond strength value. This would be due to the fact that EDTA acts as a calcium chelator and causes the dissolution of hydroxyapatite, which alters the micromechanical bond with the underlying dentin and weakens the chemical reaction produced between the hydroxyapatite of the dentin and the bonding resin.

According to Ertas *et al.* 2014 [36], the use of chlorhexidine alone caused a reduction in the bond strength, unlike the study by Seballos *et al.* 2018 [32] which demonstrated that CHX increases the bond strength by inhibiting collagen-degrading enzymes metalloproteinase (MMPs), which may be responsible for hybrid layer degradation. On the other hand, Elnaghy in 2014 [37], showed that rinsing the root canal with CHX after EDTA improves bond strength due to surfactant in CHX which increases the surface energy of the dentin and therefore its wettability.

Ertas *et al.* in 2014 [36] and Victorino *et al.* in 2016 [46], demonstrated that pretreatment with ethanol improved bond strengths, forming a more stable hybrid layer through its ability to replace dentine water.

Bitter *et al.* 2014 [2] reported using ethanol after rinsing the root canal with water to remove remaining phosphoric acid. Water may remain in the dentinal tubules and increase the potential for hydrolytic degradation of the dentine/adhesive interface. This insufficient humidity control could be compensated by the application of ethanol in combination with a hydrophobic adhesive resin. This can be explained by the action of ethanol which makes the collagen matrix more hydrophobic and thus reduces the micropermeability of the hybrid layers. Ethanol pretreatment significantly increases the number of adhesive fractures between the fiber post and the resin cement, indicating increased adhesion between dentin and resin cement.

The majority of studies have used saline solution (NaCl) as final irrigant for control group because it lacks of chelating and antimicrobial properties. Seballos *et al.* 2018 [32] demonstrated, however, that NaCl induces significantly greater bond strength than CHX, NaOCl, and CaOCl, indicating that saline solution does not contribute to collagen degradation.

Wan *et al.* 2020 [51] reported that MTAD solution improved fiber post bond strength. Aljamhan *et al.* 2021 [27] confirmed this by concluding that irrigation with MTAD after sodium hypochlorite rinsing improved dentin adhesion. This is due to the fact that MTAD functions as a potent antibacterial agent and chelator to eliminate smear layer. MTAD's polysorbate detergent decreases surface tension, thereby enhancing resin penetration into dentinal tubules. This same study assumed that the combination of MTAD/Nisin at a concentration of 10% makes it possible to obtain tubules free of dentinal smear layer, with the persistence of debris in some tubules. In addition, the combination of MTAD/Nisin may accelerate the oxidation of doxycycline in MTAD, thereby accelerating the decrease of bond strength to dentin.

Some authors [37] [38] have established that the Qmix solution's chemical composition and method of action have enhanced the bond strength of the fiber posts. Qmix's chemical composition ensures a low surface tension and good wettability. In addition, Akman *et al.* 2016 [26] found that a last rinse with Qmix for 90 seconds after NaOCl treatment was successful at eliminating smear layer.

According to the findings of Khoroushi *et al.* 2019 [34], irrigation with CaOCl improved the bond strength. It changes the dentin surface's chemical composition by releasing calcium and phosphorus ions, which is advantageous for mineralization and the creation of the amorphous calcium phosphate phase in the hybrid layer. In contrast, the study by Seballos *et al.* 2018 [32] indicated a drop in bond strength as a result of a chelating solution that induces unexpected erosion of the canal walls, thus affecting the root surface's roughness and adhesion ability.

Peracetic acid (PA) increased bond strength, as demonstrated by Silva *et al.* in 2021 [38]. This is due to the release of acetic acid, a mild chelating agent capable of reducing smear layer as effectively as EDTA. However, according to Viola KS *et al.* 2018 [58], PA is more cytotoxic than 2.5% NaOCl, which is a limitation for this solution.

Some authors [31] [52] have found that silver diamine fluoride (SDF) increases bond strength. This result is due to the effect of occlusion of dentinal tubules by silver particles, which restricts the intrinsic flow of fluids at the adhesive interface. However, Shafiei *et al.* 2020 [52] demonstrated that SDF reduced the ability of self-adhesive cement to bond. The silver deposits inhibit the chemical interaction between the acidic functional monomers of the adhesive and the calcium of the dentinal structure.

Shafiei *et al.* 2020 [52] and Suzuki *et al.* 2019 [23] concurred that silver nanoparticle (SNP) solution improves bond strength by increasing dentin surface wettability. In addition, silver has antibacterial and antiviral properties.

The synthetic chemical solvent (acetone 33%, ethanol 33%, ethylacetate 34%) was the subject of study by Khamverdi *et al.* 2014 [1], which concluded that it had no impact on post bond strength. Kosan *et al.* 2021 [59], has shown that the bond strength of fiber post to root dentin was not affected by this chemical solvent.

Akman *et al.* 2016 [26] reached the conclusion that citric acid decreases the bond strength of fiber posts. This can be explained by the incomplete removal of the smear layer, which limits optimal dentin-to-fiber post adhesion.

Silva *et al.* (2021) [38] found that the SmearClear solution (17% EDTA solution combined with cationic (cetrimide) and anionic surfactant, Kerr Endodontics, Orange, CA, USA) does not remove the smear layer more effectively than EDTA alone. Root surface treatment with SmearClear increased adhesive failure at the dentin-cement interface.

Polyacrylic acid (PAA), as demonstrated by Suzuki *et al.* in 2019 [23], contributed to the improvement in bond strength values, in the middle and apical third when used with Adper Scotchbond Universal and RelyX ARC (1.58 ± 1.13 and 1.54 ± 1.34 respectively) compared with chlorhexidine (0.24 ± 0.27 and 0.03 ± 0.08 respectively) and sodium hypochlorite (1.52 ± 1.10 and 0.65 ± 0.61 respectively). Baena *et al.* 2017 [57] found the same results. This is due to its ability to form an intermediate superficial layer that can activate calcium and phosphate ions, thereby promoting a stronger chemical interaction between adhesive and dentin.

Yu *et al.* 2017 [35] reached the conclusion that EGCG increases the bond strength of fiber posts due to its antioxidant properties, which allows adhesive polymerization to proceed without interruption. Moreover, according to Du *et al.* in 2012 [60], the promising effect of EGCG on the stability of bond strength is due to its inhibitory effect on MMPs.

Fumaric acid, according to Saricam *et al.* 2020 [47], enhances the bond strength of fiber posts. This can be attributed to its acidic pH (= 2.6), which ensures effective smear layer removal.

Culhaoglu *et al.* (2017) [24] found that the use of a 10% boric acid resulted in higher bond strengths and concluded that boric acid provides an effective smear layer removal. However, the disadvantage of ensuring high concentrations of boric acid is to warm it to a temperature of 55˚C before use.

Alkahtany *et al.* 2022 [50] demonstrated better bond integrity of glass fiber posts to radicular dentin at all three levels coronal, middle and apical when irrigation with PPE (Pineapple peel extract). This outcome is based on the ability of PPE to remove smear layer. This can be justified by the fact PPE is rich in active ingredients such as saponins, bromelain, polyphenol, and flavonoids which increase the solution surface tension.

Yadav *et al.* (2021) [49] demonstrated that maleic acid and phytic acid (chelating agents) improved fiber post bond strength. This is a result of their efficacy removing smear layer.

Erik *et al.* 2020 [30], showed that SmearOFF (EDTA-based formula recommended for use alone as a final irrigant) had the lowest bond strength values among experimental groups of their study. The important reduction in bond strength observed with SmearOFF may have been originated by the initial reaction failure of self-adhesive luting agent in the presence of residual SmearOFF.

In the same study, another experimental group tested HEDP or HEBP (Etidronic acid or 1-hydroxyethane-1,1-diphosphonic acid) which is a nitrogen-free bisphosphonate, introduced as an alternative chelation agent to its alkalinity and it can be combined with NaOCl without any interacting. HEBP showed no significant difference in bond strength values in comparison with saline and EDTA experimental group.

5. Conclusions

Most dentin surface treatments and bonding systems used have strengthened the bond between the posts and the dentin surface.

PBS values were found to be lower in some studies, particularly with SmearOFF, HEBP and citric acid.

The most studied surface treatments were NaOCl, CHX, EDTA, and the association NaOCl with EDTA. The results were highly contentious.

These differences in strength bond values can be explained by differences in the compositions of different commercial brands, application methods, concentrations, and application times.

Furthermore, while only PBS testing studies were chosen, variations in test application protocols with differences in application load, application speed, plunger diameter, and slice thickness may be related to the large variation in adhesion force values observed between studies.

Furthermore, the included studies are in vitro, which do not replicate clinical conditions, because most studies did not assess the impact of chewing and the teeth were not restored with crowns to ensure loading similar to clinical reality. The application of the test in a dry environment, at room temperature in the majority of studies, cannot be compared to the oral environment, where temperature and pH change frequently.

Finally, additional in vitro studies with test standardization and well-reported randomized clinical studies considering occlusal forces, tooth position in the arch, and evaluating the impact of fiber post surface treatment on bonding coronal-radicular reconstructions are required.

Conflicts of Interest

The authors have no conflict of interest to declare

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