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Reviews

The effect of post space irrigation protocol and adhesive strategy on push out bond strength to radicular dentin: A network meta-analysis

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Abstract

Introduction: Establishing an effective bond with root dentin remains a complex task, with bond strength diminishing from the coronal to the apical third as a result of reduced dentinal tubule density and limited access to light curing instruments. This network meta-analysis studied the effect of cement and irrigation protocols on push out bond strength to radicular dentin.

Methods: In vitro studies evaluating self- etch, self-adhesive, total etch resin cements, and ethylenediaminetetraacetic acid (EDTA), sodium hypochlorite (NaOCl), distilled water, chlorhexidine (CHX) irrigants were included. A network meta-analysis was performed using a random effect model. The efficacy of the different irrigation and adhesion protocols was ranked using *P* scores. A comprehensive search was carried out in the "Web of Science", "PubMed", "Scopus", and "Embase" databases by October, 2022.

Results: It was shown that the irrigation protocol and adhesive strategy with the greatest chance of producing higher bond strength was EDTA+NaOCL/Total etch (push out MD 6.69 MPa, $P=0.95$) proceeded with CHX/self -adhesive (push out MD 3.70 MPa, $P=0.77$) compared to Distilled water/Total etch as the control group.

Conclusion: Network meta-analyses identified EDTA+NaOCL/Total etch resin cement and self-adhesive cements/CHX as the most efficient protocols for increasing push out bond strength to radicular dentin.

Introduction

A post and core crown represents a dental restoration method employed for endodontically addressed teeth experiencing significant coronal damage, with the durability of the restoration reliant on cementing techniques.[1]

Adhesion to dentin is less reliable compared to enamel, primarily due to the hydrated composition of dentin.[2] Establishing an effective bond with root dentin remains a complex task, with bond strength diminishing from the coronal to the apical third as a result of reduced dentinal tubule density and limited access to light curing instruments.[3]

Research has demonstrated that the quality of the post and core attachment to root dentin relies on numerous factors, including the types of endodontic treatment sealers and luting cements (total etch, self-etch, self-adherent), moisture control, collagen deficiency, dentin hybridization, dentin anatomical positioning, smear layer thickness, friction-based retention, c-factor, core formation approach, etching, and metalloproteinase activity.[3-5]

Following post preparation, dentin walls are coated with a smear layer, as well as residual sealer and gutta-percha materials. It is crucial to eliminate these components to avert leakage and bonding failure.[6] Numerous irrigation solutions are employed to eliminate the smear layer and disinfect the root canal, such as 5.25% sodium hypochlorite (NaOCl), 17% ethylenediaminetetraacetic acid (EDTA), and 2% chlorhexidine (CHX). Regrettably, no single irrigant possesses all ideal attributes.[7]

Residues and byproducts of chemical irrigation agents permeate the dentin tubules, potentially impacting the resin monomer polymerization and cement infiltration into demineralized dentin.[8] Oxygen generated by NaOCl and hydrogen peroxide obstructs the polymerization of resin monomers, adversely influencing the bond strength to root dentin. NaOCl also hinders the in-depth penetration of resin monomers into tubular dentin due to its detrimental effects on dentin collagens.[6-9] Some research

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has revealed that CHX does not harm the organic matrix of root dentin (mainly collagen)[10] and even suppresses matrix metalloproteinases (MMPs) existing in the hybrid layer, enhancing the durability of bonding to root dentin.[11]

Various adhesive resin cements (total-etch, self-etch, self-adhesive) are utilized for attaching fiber posts to root dentin. However, total-etch resin cements are sensitive to technique due to rinsing, drying processes, acid concentration, and moisture management during application.

Self-etch cements streamline the cementing procedure and could be employed on both wet and dry dentin, making them unaffected by post space depth.[12] Nevertheless, the infiltration efficacy of self-etch cements concerning thick smear layers remains a subject of debate.[6]

In recent times, self-adhesive resin cements have offered simpler clinical applications as they do not require any prior dentin treatment.[13]

Baldion et al[14] published the most up-to-date systematic review in 2018, examining various irrigation protocols. However, to our knowledge, a network meta-analysis evaluating the impact of differing endodontic irrigants in conjunction with various adhesive resin cements on push-out bond strength to root dentin has not yet been performed. A network meta-analysis provides practitioners with a ranking of irrigation materials and adhesion methods to achieve optimal bond strength to root dentin. Therefore, this network meta-analysis was undertaken to address the question: "Which irrigation protocol and adhesive method enhance bond strength to radicular dentin?"

Methods

This systematic review followed the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

Eligibility criteria

The selection of studies followed these PICO guidelines: (i) Population: radicular dentin or root canal dentin; (ii) Intervention: "Self-etch", "Total-etch", and "Self-adhesive" resin cements in paired with a range of post-space irrigation solutions such as "CHX", "EDTA", "NaOCL", "NaOCL + EDTA"; (iii) Comparison: "Total-etch" resin cement and distilled water, established as the control group due to its widespread use in clinical environments; and (iv) Outcome: push-out bond strength to radicular dentin.

Studies employing distinct bonding tests, uncommon irrigation methods, post-bond storage longer than 72 hours, or those that failed to disclose the cement or irrigant protocols applied were omitted. Only articles in English were included.

Information sources and search

One author (EJ) conducted an exhaustive search up to October 2022 across four databases: "PubMed/Medline", "Embase", "Scopus", and "Web of Science". Search strategies incorporated free keywords, Medical Subject Headings (MeSH) terms, and Emtree keywords, in combination with the OR and AND Boolean operators. The asterisk () was utilized to enhance search precision. Searches involved the following keywords and their combinations: 'self etch resin cements' OR 'total etch cements' OR 'self adhesive cements') AND ('radicular dentin' OR 'root canal dentin' OR 'glass fiber post' OR 'bond strength' OR 'push out bond strength'/exp OR 'self etch adhesives' OR 'radicular post retention'/exp OR 'Chlorhexidine OR 'NaOCl' OR 'EDTA'/exp OR 'RelyX Unicem' OR 'Relyx ARC' OR 'maxcem elite' OR 'Variolink II' OR 'panavia f2.0' OR 'resin cement')

Further, a comprehensive search was carried out in the ProQuest Dissertations and Thesis; in order to find any relevant gray literature. Furthermore, the reference lists of the selected studies were examined to identify relevant publications.

Study selection and data extraction

Two writers (FPA and EJ) evaluated the headings and summaries of articles to determine if the investigations satisfied the inclusion criteria. Subsequently, the full texts underwent screening by two investigators (FPA and EJ). In case of disagreements, a tertiary researcher (HV) was consulted.

The extraction table encompassed the author, publication date, sample, adhesive cement variety, categories of irrigation solutions, and pertinent results. Two investigators (FPA and EJ) carried out the information-gathering process twice. When multiple concentrations of irrigation substances were utilized, only the most frequently employed one in clinical setup was incorporated into the extraction table.

Risk of bias assessment

The evaluation of potential bias was based on both the Cochrane Collaboration's risk of bias assessment tool[15] and previous studies.[14] Two researchers (EJ and FPA) performed the bias assessment independently, and any disagreements were resolved by consulting a third researcher (HV).

Statistical analyses

HH performed a "frequentist network meta-analysis" using a random effects model by R software's net meta module (version 3.6.2; R Foundation for Statistical Computing). Each node represented a strategy used in the studies incorporated in the network meta-analysis. The connections between nodes represented available direct comparisons, and their width corresponded to the quantity of research assessing these comparisons. Ranking for irrigation and adhesion methods was based on individual *P* values. Higher *P* values indicate a greater probability that the intervention strategy outperforms other comparisons. I^2 represented the network-level inconsistency (comprehensive inconsistency).

Results

The search produced 1982 articles, with 500 being repetitive. Following a review of titles and summaries, 112 articles were chosen for full-text evaluation, and 21 met the inclusion criteria for the network meta-analysis. The "PRISMA" diagram can be seen in Figure 1.

Features of incorporated research

Twenty-one in-vitro experiments were enrolled in meta-analysis. The publication dates of the selected articles ranged from 2008 to 2022. The sample size of studies ranged from 18 to 120 (See Table 1).

Evaluation of risk of bias

Each study exhibited varying bias levels. The most biased aspect of the included studies was the lack of blinding the test equipment operator. Moreover, the method for determining sample sizes appeared largely random across the investigations. Additionally, standard specimen preparation (by a single operator) and standard specimen selection (the process of recognizing and eliminating flawed samples) fields presented a considerable risk of bias (see Figure 2).

Network meta-analysis results

A number of 21 articles were incorporated into the network meta-evaluation. There was significant global network heterogeneity in the push-out network ($I^2 = 96.7\%$), and the subsequent strategies were employed:

(1). CHX/Self-etch resin cement —CHX/SE, (2) CHX/Self-adhesive resin cement—CHX/SA, (3) CHX/Total etch resin cement —CHX/TE, (4) NaOCL/Self-etch resin cement —NaOCL/ SE, (5) NaOCL/Self-Adhesive resin cement —NaOCL/ SA, (6) NaOCL/Total etch resin cement —NaOCL/TE, (7) EDTA/ Self-etch resin cement — EDTA/SE, (8) EDTA/Self-adhesive resin cement — EDTA/SA, (9) EDTA/ Total etch resin cement —EDTA/TE, (10))EDTA + NaOCL/ Self-etch resin cement — EDTA + NaOCL/SE, (11) EDTA + NaOCL/ self -adhesive resin cement —EDTA + NaOCL/SE, (12) EDTA + NaOCL/ Total etch resin cement —EDTA + NaOCL/TE, (13) Distilled water/ Self etch resin cement —DW/SE, (14) Distilled water/ Self-adhesive resin cement —DW/SA, (15) Distilled water/Total-etch resin cement —DW/TE.

In total, 15 methods were part of the push-out bond strength network. Figure 3 displays the forest diagrams, while Table 2 lists the corresponding *P* values. The

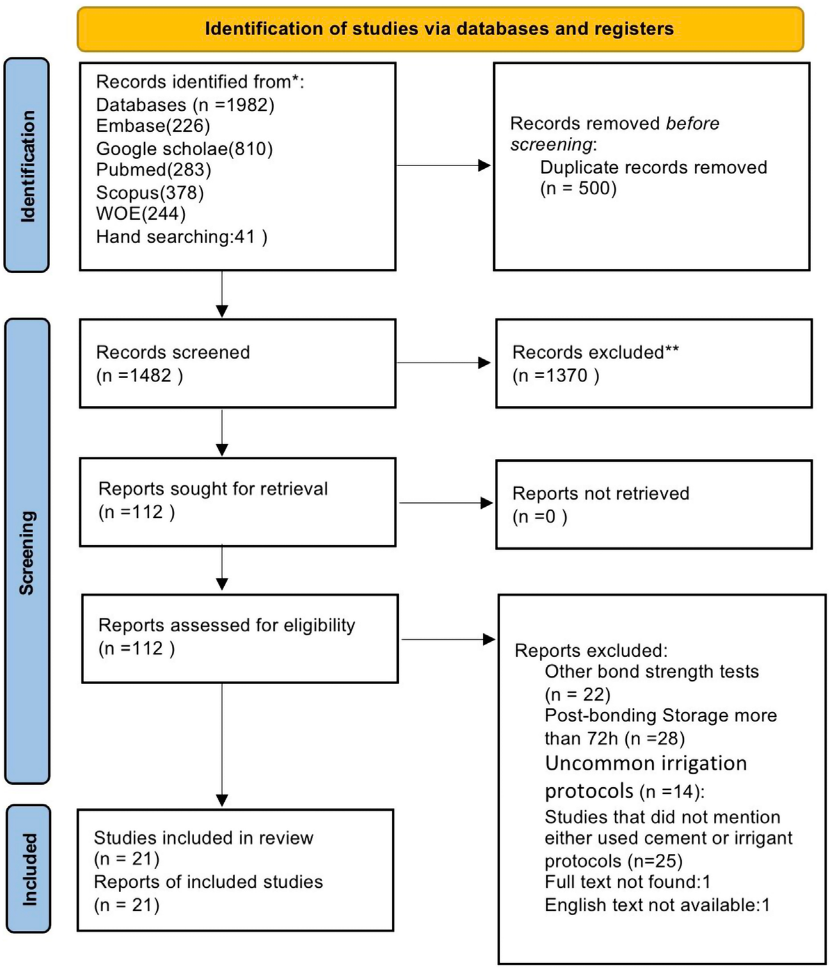


Figure 1. PRISMA flowchart

Table 1. Characteristics of included studies

Study	Specimen	Post space irrigants	Cement	Bond strength
Al-Askary (2013)[16]	80 extracted human lower premolars of single root canal	Gp.1: distilled water (DW) Gp.2: 5.25% NaOCl + DW; Gp.3: 17% EDTA + DW; Gp.4: 5.25% NaOCl + 17% EDTA + DW	A: (PermaCem® Dual) B: (Variolink II) C (LuxaCore® Z-Dual)	1A: 13.13 ± 0.41def 1B: 12.06 ± 1.00efg 1C: 14.22 ± 0.62cd 2A: 13.07 ± 0.45def 2B: 11.79 ± 1.05fg 2C: 14.25 ± 0.28cd 3A: 16.06 ± 0.26bc 3B: 13.79 ± 0.87de 3C: 19.19 ± 0.53a 4A: 19.08 ± 0.34a 4B: 16.63 ± 0.89b 4C: 20.35 ± 0.42a
de Andrade Vilas Boas Motta et al (2015)[17]	60 single-rooted intact upper teeth, extracted for periodontal reasons	1) DW or 2) 1% NaOCl	A) Relyx™ U200 (RU), B) Relyx ARC (RARC)	1A) 23.87(7.91)b 1B) 39.95(10.10)a 2A) 25.96(5.83)a 2B) 25.97(7.57)a
Durski et al (2018)[18]	120 human premolars (n = 120)	Treated with chlorhexidine (N or Y: without or with)	T or S: total etch RelyX ARC or self-adhesive RelyX Unicem	YT: 10.44 ± 1.89 Ka YS: 18.68 ± 2.01 Ea NT: 8.71 ± 0.91 La NS: 16.91 ± 1.72 Fa
Haralur et al (2017)[19]	60 single-rooted premolars extracted for orthodontic, periodontal, and prosthetic reasons were utilized for the study. The inclusion criterion	A: 5.25% NaOCl B: 17% EDTA	1) Total-etch wash (Rely X ARC, 3M ESPE, St. Paul, USA), 2) Self-etch (Panavia f 2.0, Kuraray Medical Inc. Okayama, Japan), 3) Self-adhesive (Rely X Unicem, 3 M ESPE, St. Paul, USA)	A1) 8.273 (1.041) A2) 16.282 (2.073) A3) 10.304 (1.531) B1) 8.493 (0.931) B2) 11.383 (1.782) B3) 9.352 (1.380)
Souza et al (2019)[20]	100 single-root extracted human teeth	1) DW + US 2) 17% EDTA 3) QMix 4) 17% EDTA + US 5) QMix + US	A) Rely-X U200 (#M, St Paul, MN, USA) self-adhesive resin cement B) Rely-X ARC dual-resin;	1A) 5.78 (2.04) A,a 1B) 4.71 (1.98) A,a 2A) 15.91 (2.37) B,a 2B) 14.62 (2.64) B,a 3A) 18.27 (2.18) B,a 3B) 17.62 (2.09) B,a 4A) 24.74 (2.46) C,a 4B) 22.39 (2.55) C,a 5A) 28.88 (3.50) C,a 5B) 27.54 (3.72) C,a
Zhang et al (2008)[6]	48 premolars	G1: Control-water G2: 17% EDTA + 5.25% NaOCl + water G3: Ultrasound þ 17% EDTA þ 5.25% NaOCl þ water silanization	Two self-etch systems (Clearfil SE Bond and Clearfil DC Bond, Kuraray)	1) 9.88 ± 4.14 BCD 2) 10.81 ± 4.56 CD 3) 8.37 ± 3.81 ABC 4) 10.60 ± 4.00 CD
Cecchin et al (2011)[21]	40 freshly extracted bovine incisors	G1: Control – NaCl G2: 2% CHX gel (5 min) þ NaCl (5 min) G3: 100% EtOH (1 min) G4: 2% CHX gel (5 min) þ NaCl þ 100% EtOH (1 min)	Dual resin cement (Rely X ARC, 3 M ESPE)	G1: 6.03 (1.37)a G2: 5.96 (1.08)a G3: 5.94 (1.23)a G4: 5.86 (1.28)a
Crispim et al (2014)[9]	70 freshly extracted mandibular bovine incisors	G1: 5.25% NaOCl (1 min)/17% EDTA (3 min) G2: 5.25% NaOCl (1 min) G3: 17% EDTA (3 min) G4: 2% CHX gel (1 min) G5: 70% EtOH (1 min) G6: 11.5% Polyacrylic acid (30 s) G7: Control- NaCl (1 min)	Self-adhesive RelyX Unicem	G1: 13.1 ± 6.7 G2: 9.0 ± 4.7 G3: 8.6 ± 4.7 G4: 9.4 ± 7.4 G5: 18.5 ± 6.9 A G6: 13.0 ± 5.1 G7: 12.1 ± 5.2
Haragushiku et al (2015)[22]	53 sound human maxillary canines	G1: Control – DW G2: 2.5% NaOCl G3: 2% CHX	Dual resin cement (All-cem, FGM)	G1: 2.70 ± 1.0 G2: 2.67 ± 0.7 G3: 3.76 ± 0.6
Jalali et al (2018)[23]	72 single-rooted premolars	G1: NaCl G2: 5.25% NaOCl (15 s) G3: 17% EDTA (60 s) G4: 2% CHX (5 min) G5: MTAD (5 min) G6: 37% H3PO4 (15 s) and rinse with saline solution. Pre-treatment is not reported	Self-etch (Panavia f 2.0)	G1: 39.82 ± 10.04 G2: 47.15 ± 17.64 G3: 49.08 ± 10.19 G4: 49.8 ± 13.57 MPa G5: 52.47 ± 14.75 MPa G6: 53.21 ± 12.11

Table 1. Continued

Study	Specimen	Post space irrigants	Cement	Bond strength
Erdemir et al (2011)[24]	60 single-rooted human maxillary central incisors and canines	DW	G1) Panavia F 2.0 G2) RelyX Unicem [RU] G3) Single Bond/RelyX Unicem [SBRU])	G1: 13.10 ± 2.89a G2: 12.21 ± 2.40a G3: 11.50 ± 2.24a
Kececi et al[25]	80 human maxillary central incisors	DW	Variolink II RelyX Unicem	3.45 ± 0.62 2.24 ± 1.02
Abrar et al (2020)[26]	40 extracted premolars	1) 5.25% NaOCl + 17 % EDTA 2) CHX	Self-etch (Panavia f 2.0)	1) 9.88 ± 0.12 2) 6.55 ± 1.08
Ali and Kadhim (2021)[27]	Palatal roots of 64 maxillary first molar teeth	1) DW 2) 5.25% NaOCl 3) 2% CHX 4) 17% EDTA	RelyX U200	1) 18.28 /SD:1.36 2) 16.02 /SD:2.43 3) 20.21 /SD:1.09 4) 23.06 /SD:1.87
Dua (2015) [28]	30 extracted human maxillary central incisors	Smear clear solution 3% NaOCl	Group 1 (Variolink II) Group 2 (Panavia F 2.0) Group 3 (RelyX Unicem 2)	1) 13.77 (0.53)a 2) 10.64 (0.33)b 3) 10.36 (0.27)b
Durski et al (2018)[29]	60 human premolar teeth	2% CHX	1) RelyX ARC (ARC), Microbrush 2) RelyX ARC (ARC), elongation tip 3) RelyX Unicem (RU), Microbrush 4) RelyX Unicem (RU), elongation tip 5) RelyX Unicem1etching (RUE), microbrush 6) RelyX Unicem1etching (RUE), elongation tip	1) 10.44 6 1.89 Da 2) 11.13 6 2.40 Da 3) 14.81 6 3.45 Ca 4) 18.68 6 2.01 Ba 5) 21.57 6 3.08 Aa 6) 22.17 6 2.83 Aa
Manhas et al (2020) [30]	60 extracted maxillary central incisor	1) DW 2) 3% NaOCl + DW 3) NaOCl + EDTA + DW	self-etch	1) 24.9727/ Std10.9842 2) 24.4927/Std 12.06 3) 34.7567/Std 13.24
Rodrigues et al (2017) [31]	18 bovine teeth	DW	1) RelyX ARC 2) RelyX Ultimate); 3) RelyX Unicem	1) 5.83 (1.84)Aa 2) 6.52 (3.39)Aa 3) 7.80 (1.83)Aa
Khoroushi (2016)[32]	96 intact single-rooted teeth	1) DW 2) 2.5%NaOCl	A) Duo-Link B) BisCem	1A) 16.04 ± 4.24 1B) 14.97 ± 7.82 2A) 13.12 ± 4.64 2B) 12.11 ± 6.70
Jitumori (2019)[33]	120 single-rooted human teeth	1) DW 2) 2.5% NaOCl 3) 17% EDTA 4) 17% EDTA + 2.5% NaOCl	A) RelyX U200 [3M Oral Care] B) Multilink Speed [Ivoclar Vivadent])	1A) 15.7 ± 2.9 1B) 13.4 ± 4.6 2A) 17.7 ± 3.7 2B) 10.7 ± 2.6 3A) 15.4 ± 3.4 3B) 8.5 ± 2.5 4A) 13.5 ± 3.0 4B) 8.6 ± 2.2
Silva et al (2021)[34]	40 canines	NaOCl EDTA	Self-adhesive resin cement (RelyX U200, 3M ESPE, St. Paul, USA)	11.77 ± 2.5 11. 94 ± 3.7

irrigation process and bonding approach with the highest likelihood of achieving superior bond strength were EDTA + NaOCL/TE (P value = 0.95), followed by CHX/SE (P value = 0.77). According to Egger's test, publication bias was present in the push-out bond strength studies (P < 0.001, see Figure 4).

Discussion

Achieving effective adhesion to root dentin continues to be problematic. Post debonding is regarded as a prevalent failure mode in the restoration of endodontically treated teeth,[35] which is associated with factors such as configuration, cement polymerization shrinkage, inadequate adhesive penetration in constricted and deep canal spaces, and smear layer generation after instrumentation.[36] Further, research indicates that the choice of irrigation and resin adhesive systems might impact bonding efficiency by altering the characteristics and thickness of the smear layer.[37,38] Therefore, this network meta-analysis aimed to examine the effect of various post space irrigant kinds on the push-out bond strength of different adhesive resin cements, and to rank and compare them.

Baldion et al conducted a systematic review exploring the influence of endodontic irrigants on push-out bond strength.[14] However, their conclusions focused on various

Table 2. Irrigation and adhesive protocols ratings by corresponding *P* scores

Rank	Protocol	*P* score
1	EDTA + NaOCl/TE	0.951
2	CHX/SA	0.7721
3	NaOCl/SE	0.7283
4	EDTA + NaOCl/SA	0.6696
5	EDTA/SE	0.5747
6	EDTA/SA	0.554
7	EDTA/TE	0.5416
8	EDTA + NaOCl/SE	0.5215
9	DW/SE	0.4965
10	DW/SA	0.3924
11	CHX/SE	0.3198
12	NaOCl/SA	0.2805
13	NaOCl/TE	0.2702
14	DW/TE	0.2449
15	CHX/TE	0.1828

irrigation substances rather than adhesive resin cement systems. The present research intended to assess the combined effects of irrigants and adhesive resin cement systems. To circumvent the heterogeneity of irrigation protocols, five types were chosen, providing an adequate number of studies for a network meta-evaluation.

EDTA + NaOCL/Total etch adhesive cement yielded the greatest push-out bond strength in comparison with Distilled water/Total-etch adhesive cement as the control group.

Using "Total etch" cement alongside 5.25% NaOCl and 17% EDTA as an ultimate post-space irrigation eliminates both inorganic and organic constituents, enhancing adhesion capabilities to root dentin due to increased resin monomer infiltration within dentinal tubules and encouragement of resin tag production.[16] Irrigation of the canal with EDTA following NaOCl application boosts adhesion strength due to its antioxidative capacity.[39] Although bond strength enhancement is observed when using this combination with total etch systems, additional findings present discrepancies and seem to be influenced not solely by the irrigant solution but also by factors such as concentration, duration of effect, adhesive method, and cementing agent employed.

EDTA + NaOCL/Self-adhesive resin cement demonstrated increased push-out bond strength when contrasted with distilled water/Self-adhesive and distilled water/Total-etch. Silveira and colleagues discovered that employing a combination of 5.25% NaOCl and 17% EDTA used for irrigation purposes, along with self-adhesive bonding agents, resulted in enhanced bonding capacity.[9] However, Barreto et al[40] observed that chelating agents might negatively impact bonding with self-adhesive cements.

The pairing of self-adhesive strategy with CHX emerged as one of the top three most efficient combinations with high push-out bond strength. While some studies suggest that CHX does not hinder adhesion, others argue that 2% CHX application adversely affects the shear bonding capacity of adhesive systems to dentin.[41,42] CHX has unique properties such as great positive ionic charge, easy attachment to phosphate groups, high affinity for tooth surfaces, and increased surface-free energy for enamel, which can extend to dentin. Self-adhesive compounds exhibit mild acidity, minimal demineralization, hybridization of root dentin, and form micromechanical retention and chemical adhesion with hydroxyapatite.[43] These compounds can tolerate moisture in root canals.[28] Therefore, the absorption of CHX into the dentin may promote the resin's penetration through dentinal tubules, potentially accounting for the increased bond strength of self-adhesive compounds combined with CHX.[28] However, total-etch cements did not show improved bond strength when CHX was employed as the ultimate irrigation substance for post space. CHX is known to inhibit MMP, preserving composite-dentin hybridization over time. The included studies assessed immediate bond strength and not long-term strength, which may explain the observed results. Moreover, self-adhesive compounds have a reduced capacity for etching the smear layer, exposing collagen fibrils or endogenous enzymes in the underlying dentin to CHX, which could apply its influence.[21,28] Therefore, it may affect the long-term stability of the hybrid layer and the long-term bond strength rankings might be different.[27]

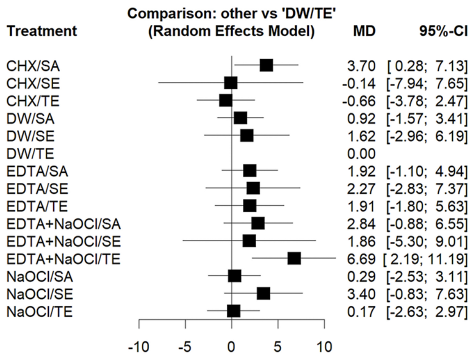
The NaOCL/self-etch resin cement approach exhibited strong push-out bond strength, which was supported by Haralur et al[19] demonstrating that NaOCL irrigation combined with a self-etch bonding method resulted in significant push-out bond strength. NaOCl eliminates the organic matrix within treated dentin, causing alterations to the dentinal substrate and reducing the adhesive system's effective penetration into interfibrillar spaces, ultimately creating a fragile hybrid layer.[31,44] Furthermore, it might lower adhesion quality due to residual oxygen, which could negatively impact adhesive system polymerization. However, this effect appears to be dependent on the adhesive system's composition.[35,45] De Andrade Vilas Boas Motta et al revealed that the total-etch bonding method paired with NaOCl diminished bond strength.[17] Acidic preconditioning, leading to more profound demineralization of collagen fibers and increased NaOCl permeability within dentinal tubules in the coronal region, results in incomplete resin monomer polymerization at the adhesive/dentin interface. NaOCl treatment contributes to a high bond strength through the development of a "reverse hybrid layer" in self-etch adhesive systems.[46]

Irrigation with EDTA in conjunction with self-adhesive and self-etch techniques led to enhanced bonding strength. Ali et al[47] demonstrated that 17% EDTA post-space irrigation substantially increased the bond strength

study	Q1	Q2	Q3	Q4	Q5	Q6
Al-Askary, R (2013)	+	+	−	x	x	−
De Andrade V B (2015)	+	−	−	x	x	−
Durski, M (2018)	+	+	+	x	x	−
Haralur, S (2017)	−	+	−	x	x	−
Souza, M (2019)	+	−	+	−	x	−
Zhang L (2008)	+	−	+	−	x	−
Cecchin D (2011)	+	−	+	−	x	−
Crispim (2014)	+	+	+	x	x	−
Haragushiku GA (2015)	−	−	+	−	x	−
Jalali F (2018)	+	+	+	x	x	−
Erdemir U (2011)	+	+	−	x	x	−
Kececi AD (2007)	+	+	+	−	x	−
Abrar E (2020)	+	+	−	−	x	−
Ali, R.J (2021)	−	+	+	x	x	−
Dua, A (2015)	+	+	+	−	x	−
Durski, M.T(2018)	+	+	+	x	x	−
Manhas, S (2020)	+	−	+	−	x	−
Rodrigues (2017)	−	+	+	−	x	−
Khoroushi(2016)	−	−	+	−	x	−

Figure 2. Risk of bias summary. Q1: Teeth randomization; Q2: Teeth free of caries or restoration; Q3: Teeth with similar dimension; Q4: Endodontic treatment; Q5: Sample size calculation; Q6: Blinding of operator

of fiber posts which were cemented with self-adhesive compounds. This improvement is related to the selective dissolution of dentin's inorganic matrix and smear layer, fostering greater interaction between adhesive resins, luting cements, and root dentin. Additionally, EDTA can potentially increase dentin surface wettability.[48] However, as previously mentioned, chelating agents like EDTA might negatively impact bonding when used with self-



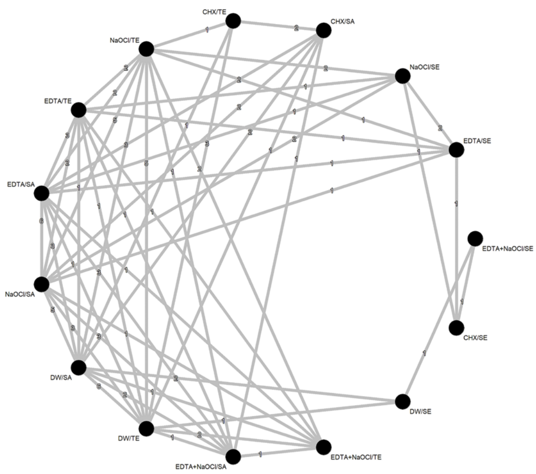


Figure 3. Network map of irrigation and adhesive protocols introduced into the network meta-analysis for push out bond strength by random effects model

adhesive cements.[9]

The outcomes of the current network meta-analysis should be interpreted cautiously as only in vitro bond strength test results were examined, and not all oral conditions could be replicated during the study. The risk of bias summary revealed that some studies did not mention standard sample preparation by a single operator and the selection of standard specimens (teeth without caries, microcracks, similar dimensions, morphological variations, or functional age changes). In none of the experiments was the evaluating machine operator blinded. None of the studies blinded the measuring machine's operator. Unfortunately, paying poor attention to these potential sources of bias is common in laboratory studies, substantially affecting the final results, which needs to be carefully considered in the coming research.

Strength and limitations

The present investigation has the following strengths: it provides a comparative meta-analysis that ranks common endodontic irrigation protocols with adhesive resin cement techniques for improving push-out bond strength in root dentin, despite the lack of direct comparisons, and

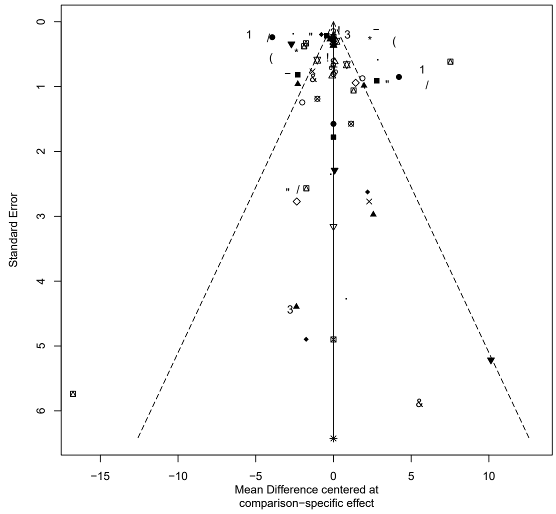


Figure 4. Funnel plots of publication bias tests

narrows down the heterogeneous evaluations by selecting five irrigation methods and focusing on the coronal region. However, the study had certain limitations as the samples from the included studies were not subjected to aging evaluations such as mechanical cycling, thermocycling, or long-term storage.

Conclusion

This analysis, utilizing network meta-analyses, pinpointed EDTA + NaOCl/Total etch resin cement and Self-adhesive cements/CHX as the most effective strategies for augmenting push-out bond strength in root dentin.

Authors' Contribution

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Competing Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

Data Availability Statement

The data used to support the findings of this study are available from the corresponding author upon request.

Ethical Approval

This network meta-analysis was approved by the ethical committee of Tabriz University of Medical Sciences (TBZMED .VCR. REC.1400.314).

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