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Post-Space Treatment Influences the Bond Strength In Endodontically Treated Teeth: A Systematic Review and Meta-Analysis of *In Vitro* Studies

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Clinical Relevance

Several factors can influence the retention of posts to root canal dentin. Post-space treatment is one of these factors, which can improve the bond strength of the post to dentin.

SUMMARY

Objectives: This systematic review of in vitro studies investigated the influence of the post-space treatment used to remove the smear layer on the bond strength of the post to root canal dentin.

Methods and Materials: In vitro studies included in this study were identified from PubMed/MEDLINE, Lilacs, and Scopus databases up until March 2019, without limits on publication year or language. Two reviewers independently selected the studies based on the inclusion and exclusion criteria, extracted the data, and evaluated the risk of bias of all studies. A random effects model was used for pairwise meta-analyses (control vs. post-space preparation groups) at a significance level of $p<0.05$.

Results: Of the 2,832 potentially eligible studies, 453 studies were selected for full-text analysis, and 75 were included in this systematic review. Only

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one study was considered to have a low risk of bias. Overall, post-space treatment significantly improves the bond strength to root canal dentin (p<0.00001).

Conclusion: Post-space treatment has a positive influence on the bond strength of the post to root canal dentin. In this review, the post-space treatments that improve the adhesive resistance of the post were ethanol, sodium hypochlorite, and ethylene diamine tetra-acetic acid (NaOCl + EDTA), NaOCl + EDTA + ultrasound, erbium-doped yttrium aluminium garnet laser (Er:YAG laser), neodymium-doped yttrium aluminium garnet laser (Nd:YAG laser), and diode laser.

INTRODUCTION

For restoration success in endodontically treated teeth with extensive coronal loss, the use of intraradicular posts is indicated to retain the restoration.[1] The post system choice to be used is based on the amount of dental structure remaining, the esthetics, and functional considerations.[2,3]

Effective adhesion among the intraradicular post, dentin, and cement is necessary for the success and longevity of the restoration.[4] However, failures associated with post adhesion have been reported in the literature, especially for fiber posts.[2,5,6] Several factors can influence the retention of the intraradicular post such as the root anatomy itself, the materials used in the endodontic treatment, and techniques and materials used for post luting.[1,2,4,7] Moreover, obliteration of dentinal tubules resulting from the preparation of the post-space can also influence the adhesion between the intraradicular retainer and root dentin due to modifications in the dentin hybridization.[5,6,8-10]

Studies have been performed to find the ideal treatment for the post-space, promoting better retention of the intraradicular retainer.[5,11-16] Among the post-space treatments, ethylenediaminetetraacetic acid (EDTA) is a valid option for smear layer removal.[17] Sodium hypochlorite (NaOCl) is the most common irrigating solution used and can dissolve organic matter in the canal.[17]

Moreover, Zhang and others[18] suggested the use of 35% phosphoric acid as a post-space treatment as the increased bond strength is associated with its potential to remove the smear layer in the post-space. Also, some studies have shown that the use of ultrasound and Nd:YAG, Er:YAG, Er, Cr:YSGG, and diode lasers within the post-space can contribute to disinfecting this space and eliminating the smear layer, thus improving the retention of the intraradicular post.[19-22]

Some studies have reported that post-space treatments improve post-adhesive resistance,[11-13] while other studies have shown that these treatments decrease their resistance.[14-16] Thus, there is no consensus in the literature whether the treatments used in the post-space are favorable for adhesion of this retainer.

Therefore, although several studies have attempted to point out the best treatment to be used in the post-space, some controversy remains. Thus, this study aimed to systematically review the literature to verify the influence of the post-space treatments on the bond strength of posts to root canal dentin. The hypothesis tested was that there would be no difference in bond strength to root canal dentin when the post-space is or is not treated.

METHODS AND MATERIALS

This study was conducted and reported according to the Cochrane Handbook and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement.[23,24] The protocol of this systematic review was not registered in any platform, because no platforms exist at this time to register reviews of *in vitro* studies.

The systematic review was performed by compiling all available *in vitro* studies to answer the following question: Is there an influence of the post-space treatment on the bond strength of post to root canal dentin in endodontically treated teeth?

Thus, the population, intervention, comparison, and outcomes (the PICOs) for this review included: tooth (population); post-space treatment (intervention); no treatment (comparison), and bond strength (outcome).

Literature Strategy

The PubMed/MEDLINE, Lilacs, and Scopus databases were searched to identify relevant studies up to March 2019 with no limits on publication year or language.

The search strategy used in PubMed/MEDLINE and adapted for other databases was a combination of specific medical subject headings (MeSH) and keywords, as follows: ((((((((((((((((((((((Tooth, Endodontically Treated) OR Endodontically-Treated Tooth) OR Tooth, Endodontically-Treated) OR Teeth, Endodontically Treated) OR Endodontically-Treated Teeth) OR Teeth, Endodontically-Treated) OR Nonvital Teeth) OR Teeth, Nonvital) OR Devitalized Teeth) OR Teeth, Devitalized) OR Pulpless Teeth) OR Teeth, Pulpless) OR Pulpless Tooth) OR Tooth, Pulpless) OR Devitalized Tooth) OR Tooth, Devitalized) OR Nonvital Tooth) OR root canal dentin) OR dentin) OR root canal) OR endodontic) OR post

space)) AND ((((((((((((((((((((Canal Irrigants, Root) OR Irrigants, Root Canal) OR Root Canal Medicaments) OR Canal Medicaments, Root) OR Medicaments, Root Canal) OR Acid, Ascorbic) OR Sodium Ascorbate) OR Ascorbate, Sodium) OR citric acid) OR qmix) OR edta) OR chlorhexidine) OR lasers) OR Hypochlorite, Sodium) OR Sodium Hypochlorite (Solution)) OR Pretreatment) OR Ethanol) OR post space irrigation) OR ultrasonic activation) OR diode laser) OR irrigation protocol)) AND (((((((push out bond strength) OR push-out bond strength) OR dislocation*) OR push-out) OR push out) OR adhes*) OR bond strength). All the identified studies were then imported into Mendeley software (Elsevier Inc, New York, United States) to remove duplicates.

Study Selection

Two reviewers (TB and PF) independently assessed the titles and abstracts of studies that were included if the following inclusion criteria were fulfilled: 1) studies that evaluated the influence of any post-space treatment; 2) studies in which the post-space treatment was applied to root canal dentin; and 3) *in vitro* studies.

The final decision about the study selection was made after a full-text reading of the previous selected studies, according to the following exclusion criteria: 1) studies in which the treatment was not in the post-space; 2) studies which did not present a control group (solution that has no interference in the adhesion; for example, water); 3) studies that did not provide bond strength values as mean and standard deviation in megapascals (MPa); 4) studies that used experimental materials; 5) studies with contaminated specimens; 6) studies that did not present immediate bond strength data. If any data were not described or were unclear in the primary study, it was requested of the authors by e-mail (at least twice), and the study was excluded if they did not reply. In the case of multiple publications with the same data, only one study was considered. The group data were excluded from studies in which the aged group was stored in a solution other than water. Reference lists of all included studies were also manually checked in order to retrieve all relevant papers.

Disagreements between the reviewers were resolved by consensus or arbitration by an independent review (OBK). The inter-examiner agreement regarding the inclusion criteria was excellent (kappa coefficient=0.88).

Data Extraction

Data extraction was independently performed by two researchers using standardized extraction sheets. The extracted information included the study characteristics (title, authors, year and country), study methodology (sample size, type of tooth, endodontic sealer used, post-time waiting for post luting, post-space treatment used, type of post used, resin cement used, post-time waiting for bond strength test and type of bond strength test) and the outcome (mean bond strength [MPa]) and standard deviation).

Risk of Bias

The risk of bias assessment was evaluated according to the description of the following parameters suggested by previous studies:[25,26] randomization of the teeth, sample size calculation, materials used according to the manufacturer's instructions, specimens (roots) with similar dimensions, endodontic treatment performed by a single operator, post-space treatment performed by a single operator, post luting procedures performed by a single operator, blinding of the operator to the testing machine, and failure analysis.

If the study presented a clear description of the parameter, it received a "yes"; if not, it received a "no." Studies that reported 1 to 3 items were classified as high risk of bias, 4 to 6 as medium risk, and 7 to 9 as low risk. Disagreements between the reviewers were solved by consensus for the final risk of bias classification.

Data Analyses

Meta-analyses were performed using Review Manager software (RevMan version 5.3 software, Cochrane Collaboration; Copenhagen, Denmark). The mean difference with a 95% confidence interval was calculated for the bond strength means from each included study, taking into account two groups: experimental (post-space treatment) and control (no post-space treatment). The pooled-effect estimates were obtained using an inverse variance method and the random effect model (Z-test; $p<0.05$).

The overall analysis was performed by comparing any post-space preparation with the control group. For studies that evaluated more than one post-space treatment, the type of endodontic sealer, post-time waiting for post luting, type of post, type of cement, thirds of the root, test time, or type of drills, one bond strength mean of each group (experimental and control) was calculated using a formula according to the Cochrane Statistical Guidelines.[23]

Prespecified subgroup analyses by type of post-space treatment, type of endodontic sealer, post-time waiting for post luting, type of post, type of cement, thirds of the root, test time and type of drills used to prepare the post-space were performed to assess whether these variables modify the bond strength of post to root canal dentin.

Forest plots were created to illustrate the meta-analyses. A modified chi-squared test (Cochran Q test) and the inconsistency I^2 test was used to calculate the statistical heterogeneity of the treatment effect among studies.

RESULTS

Search and Selection

The study selection process, conducted according to the PRISMA statement, is depicted in Figure 1. From 2832 potentially eligible studies, 2379 were not included for full-text reading, mainly because the post-space treatment was not applied to root dentin. Thus, 75 studies from 453 screened for full-text analysis were included in the systematic review.[5,8,11-16,18,27-92] The main reasons for the exclusion of studies were: studies in which the treatment was not in the post-space and studies that did not present a control group.

Descriptive Analysis

Descriptive analysis of the included studies is shown in Table 1. All studies were published between 2005 and 2018, with the majority of studies being performed in Brazil (n=35) and Turkey (n=13).

Regarding language, 70 studies were published in English, two studies in Chinese, two studies in Portuguese and one study in Spanish. Among the included studies, 56 used human teeth and 19 used bovine teeth.

Nine different endodontic sealers were used in the included studies, including epoxy resin-based sealers (n=37), calcium hydroxide-based sealers (n=17), and zinc oxide and eugenol-based sealers (n=6). Most of the studies used AH Plus sealer (n=30), while 14 studies had no information about the endodontic sealer used.

Forty-three (43) different post-space treatments were evaluated in this review, with chlorhexidine being the most used solution (n=28). All post-space treatments in studies included in this systematic review that filled the root canal with epoxy resin-based sealer were evaluated, while only 19 post-space treatments were evaluated in studies using calcium hydroxide sealer. Only 10 post-space treatments were evaluated for studies using zinc oxide and eugenol-based sealer.

Regarding the storage time before post luting, most of the studies stored the specimens for one week (n=32), while the maximum storage period was two weeks and the minimum was 24 hours. Moreover, 16 studies did not have any information about the storage time before post luting.

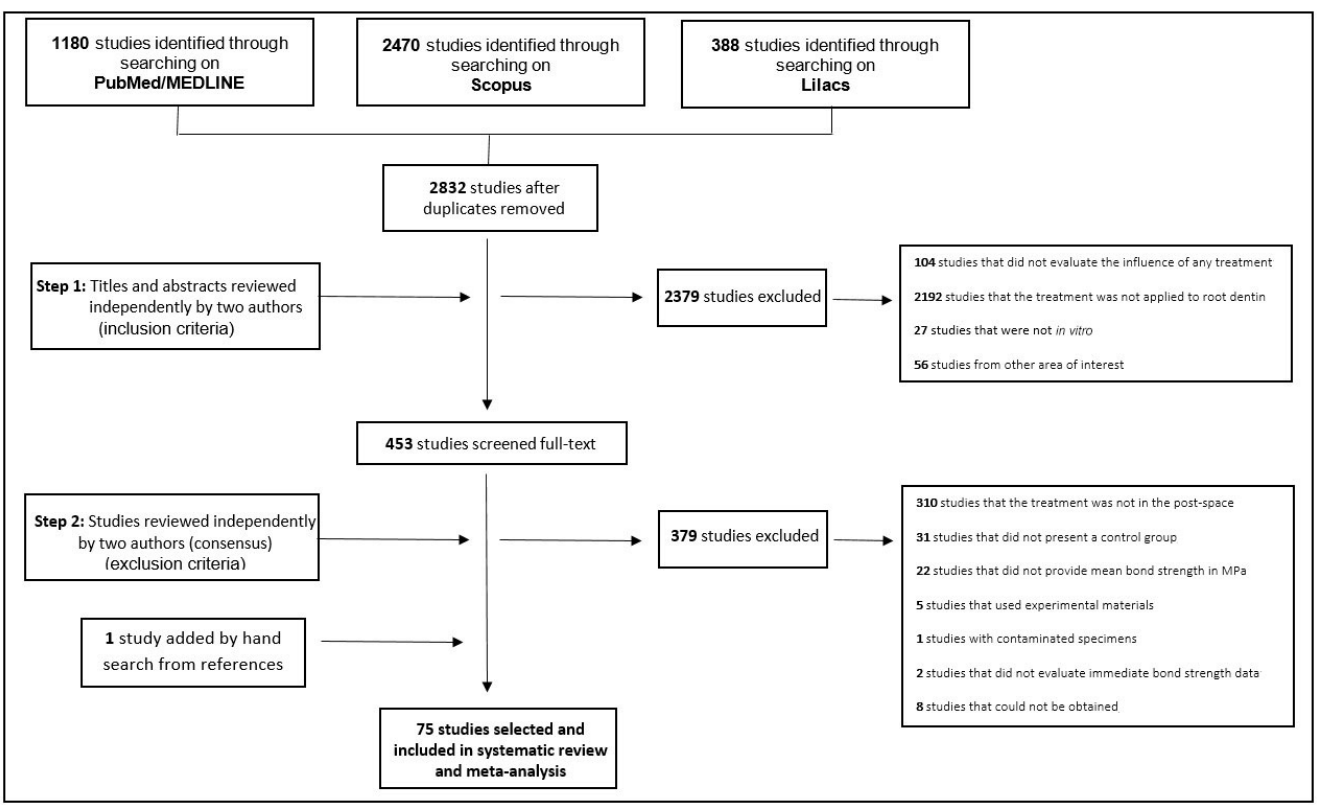

Figure 1. *Flow diagram of study selection according to PRISMA statement. Abbreviations: MPa,* megapascals.

Table 1: *Description of Included Studies*

Authors/Year	Country[a]	Language	Type of Teeth	Endodontic Sealer	Storage Time Before Luting	Post Space Treatments	Drills Used to Make Post Space	Type of Post	Cement	Storage Time Before Test	Bond Strength Test
Alaghemand & others[27]	Iran	English	Human upper central incisors & canine teeth	AH Plus	24 h	0.1 M EDTA; 99.6% Ethanol; 0.1 M EDTA + 99.6% Ethanol	2 DT light drill	DT light-post system	Panavia F 2.0	24 h	Push-out test
Alfredo & others[28]	Brazil	English	Human maxillary permanent canines	Sealer 26	2 d	17% EDTA +1.0% NaOCl; Er:YAG laser irradiation	No. 6 Largo burr (1.7 mm diameter)	Cast post	Panavia F or zinc phosphate cement	3 d	Tensile strength test
Alkhudhairy & others[11]	Saudi Arabia	English	Human maxillary permanent central & lateral incisors	AH 26	—	5.25% NaOCl; 2.5% NaOCl	Sequential reamers (3M ESPE)	RelyX Fiber Post, size # 3	RelyX-Unicem or MultiCore Flow	—	Push-out bond
Angeloni & others[29]	Italy	English	Human incisors	AH Plus	—	2% CHX	Calibrated burs (3M ESPE or Voco)	RelyX Fiber Post, size: yellow or Rebilda Post, size: green	RelyX Unicem or Bifix SE	24 h/6 mo/1 y	Micro-push-out bond strength test
Arana & others[30]	Brazil	Spanish	Human mandibular premolar	AH Plus	1 wk	24% EDTA	Gates Glidden #2 & drill #2 provided by the post system's manufacturer	Exacto, size nº 2	Rely X U100 or Para Core Automix	24 h or Thermo-cycling 5000 cycles	Expul-sion test
Arisu & others[31]	Turkey	English	Human mandibular premolar	AH 26	24 h	2.25% NaOCl; 2.25% NaOCl+ 17% EDTA; diode laser (1.25 W)	Low-speed drill provided by the post system's manufacturer (Mirafit White Reamer)	Mirafit White, 1.35 mm in diameter	Panavia F 2.0	1 wk	Push-out test
Arslan & others[32]	Turkey	English	Human mandibular premolar	AH Plus	1 wk	5% NaOCl;5% NaOCl + Ultrasonic irrigation; 5% NaOCl + Er:YAG laser (0.3 W, 15 Hz); EDTA + Er:YAG laser (0.3 W, 15 Hz); Er:YAG laser (0.3 W, 15 Hz)	Gates-Glidden drills & 1.4-mm size drill (Cytec Carbon)	Cytec Carbonsize 2 (1.4 mm diameter)	RelyX U200	24 h	Push-out test
Baena & others[33]	Spain	English	Single-rooted human teeth	AH Plus	1 wk	35% H3PO4; 17% EDTA; 25% Polyacrylic acid	Gates-Glidden drills 2, 3 & cali-brated drills corresponding to the conical RelyX glass Fiber Post size #1 or #2	RelyX glass Fiber Post size 1 or 2	RelyX Unicem 2	1 wk	Push-out test
Bitter & others[34]	Germany	English	Human maxillary central incisors	AH Plus	24 h	5.25% NaOCl + ultrasonic irrigation; 1% NaOCl + ultrasonic irrigation; 5.25% NaOCl + EDTA; 2% CHX	Drill provided by the manufacturer of the fiber post system X Post size 4, or drill of the system FRC Post size 3	Fiber post system X Post size 4 or FRC Post size 3	Multicore Flow or SmartCem2 or CoreX Flow	-	Push-out test
Bordim & others[35]	Brazil	English	Bovine incisors	—	—	100% ethanol	—	White Post DC, size 4	AllCem dual-cure	24 h or 1 y	Push-out test
Carvalho & others[36]	Brazil	English	Human single-rooted & single-canal premolars	AH 26	24 h	99.6% ethanol	Drill recommended for RelyX Fiber Post size 2	RelyX Fiber Post, size 2	Dual Link	24 h	Push-out test

Table 1: *Description of Included Studies (cont.)*

Carvalho & others[37]	Brazil	English	Bovine incisor	AH Plus	1 wk	2.5% NaOCl; 100% ethanol; 2.5% NaOCl +100% ethanol	Largo burrs 3 & 4	Reforpost RX 2	RelyX ARC or RelyX U200	1 wk	Push-out test
Cecchin & others[5]	Brazil	English	Bovine incisors	—	—	2% CHX in gel; 100% ethanol; 2% CHX in gel + 100% ethanol	—	Fiber post relining with resin composite was made with a fiber-glass post (Angelus) & composite resin (B0.5, Z250)	Rely X ARC	24 h or 1 y	Push-out test
Cecchin & others[38]	Brazil	English	Bovine incisors	—	—	2% CHX	—	Fiberglass posts no. 3 (Angelus) relined with composite resin (B 0.5, Z250)	Rely X ARC	24 h or 1 y	Push-out test
Cecchin & others[8]	Brazil	English	Bovine incisors	—	—	2% CHX in a gel; 100% Ethanol; 2% CHX in a gel +100% ethanol	—	Fiber posts relined with resin composite was achieved with a fiber-glass post (Angelus 3) & composite resin (B0.5, Z250)	Rely X ARC	24 h or 250,000 cycles of mechanical fatigue (1 y of clinical function)	Push-out test
Cintra & others[39]	Brazil	Portuguese	Human premolars	Sealapex	1 wk	2.5% NaOCl; 2% CHX; 17% EDTA	Drill 2 of fiber glass post system (Exacto)	Exacto 2	RelyX Unicem Aplicap	1 wk	Push-out test
Clavijo & others[40]	Brazil	English	Bovine incisors	Sealer 26	3 d	17% EDTA	Drills designated for the quartz coated carbon fiber post Aestheti Post	Aestheti Post	RelyX ARC or RelyX U100 or Multilink	—	Push-out test
Crispim da Silveira & others[41]	Brazil	English	Bovine incisors	Sealer 26	24 h	5.25% NaOCl + 17% EDTA; 5.25% NaOCl; 17% EDTA; 2% CHX in gel; 70% ethanol; polyacrylic acid;	Gates Glidden 4 drill & Largo drill 5	Reforpost	RelyX U100	24 h	Push-out test
Culhaoglu & others[42]	Turkey	English	Human incisors	—	—	2% CHX; 5.25% NaOCl+17% EDTA; 5% boric acid; 10% boric acid	—	Panavia Post (18 mm long & 1.44 mm in diameter)	Panavia F 2.0 or Panavia SA	1 wk	Push-out test
da Cunha & others[14]	Brazil	English	Bovine incisors	Sealer 26	1 wk	5.25% NaOCl; 5.25% NaOCl + 10% ascorbic acid	Drills supplied by the manufacturer of the fiber posts (Exacto 3)	Exacto 3	RelyX U100 or RelyX ARC	24 h	Push-out test
Da Silva & others[43]	Brazil	English	Human maxillary canines	Sealer 26	3 d	2% CHX in gel; 20.3% EDTA +1% NaOCl; Xylene	First (1) & second (2) drills of the 2 C-Post carbon fiber post system	C-Post #2	Hi-X cement	24 h	Tensile-bond-strength test
De Araújo & others[44]	Brazil	English	Bovine roots	Sealer 26	1 wk	2% CHX; 11.5% polyacrylic acid; 11.5% polyacrylic acid + 2% CHX	Gates-Glidden drill 2 & low-speed drill provided by the post system's manufacturer	Exacto 2	RelyX ARC or RelyX Luting 2	1 wk or 6 mo	Push-out test

Table 1: *Description of Included Studies (cont.)*

de Oliveira & others[45]	Brazil	English	Bovine incisors	Endofill	1 wk	70% ethanol; acetone; 70% isopropyl alcohol	Using a heated Rhein instrument (1) followed by Largo burs 3	Glass fibre posts (Angelus) were relined with composite resin (Z250)	RelyX ARC	1 wk	Push-out test
Duski & others[46]	USA	English	Human premolars	AH Plus	—	2% CHX	A series of sequential reamers provided for the post (Rely-X Fiber Post 2)	Rely-X Fiber Post 2	RelyX ARC or RelyX Unicem	Imediate or Thermocycling 20,000 cycles or 40,000 cycles	Push-out test
Ekim & Erdemir[47]	Turkey	English	Human maxillary central teeth	AH Plus	1 wk	2.5% NaOCl + 17%EDTA; 2.5% NaOCl + 17%EDTA + ULTRASONIC; 2.5% NaOCl + 17%EDTA +apical negative pressure; 2.5% NaOCl + 17%EDTA + diode laser; 2.5% NaOCl + 17%EDTA + Nd:YAG laser; 2.5% NaOCl + 17%EDTA + Er:YAG laser; 2.5% NaOCl + 17%EDTA + Er:YAG laser + photon-induced photoacoustic streaming	Post drills (White Post DC, drill, 1)	White Post DC, 1	Panavia F 2.0	24 h	Push-out test
Elnaghy & others[48]	Egypt	English	Human teeth	AH Plus	1 wk	5.25% NaOCl; 2% CHX; 17% EDTA; 17% EDTA + 2% CHX; Qmix	Drill provided with the post system (Rebilda post)	Rebilda post, Ø 1.5	i Cem	1 wk	Micro-push-out bond strength
Ertas & others[15]	Turkey	English	Single-rooted human teeth	AH Plus	24 h	5.25% NaOCl; 2% CHX; 100% ethanol; 5.25% NaOCl + 17% EDTA; 5.25% NaOCl + 17% EDTA + 2% CHX; 5.25% NaOCl + 17% EDTA + 100% ethanol; 5.25% NaOCl + 17% EDTA +PAD (FotoSan Agent, photoactivated disinfection).	Post drill	UniCore, 1.5-mm	Bifix SE	—	Push-out test
Fan & others[49]	China	English	Human single-canal premolars	AH Plus	1 wk	2.5% NaOCl; 17% EDTA + 2.5% NaOCl; 7% maleic acid + 2.5% NaOCl	Drill provided with the post system until size 3	Fiber posts (3M ESPE)	Rely X U200	1 wk	Micro-push-out
Faria-e-Silva & others[50]	Brazil	English	Bovine incisors	Sealer 26	3 d	5% NaOCl; 17% EDTA; 11.5% polyacrylic acid	Drills available in the post kit	White Post DC3	RelyX Unicem or BisCem	1 wk	Push-out test
Feng & Gao[51]	China	Chinese	Human mandibular canines or premolars	—	3 d	35% H3PO4; primer Clearfil SE Bond; 35% H3PO4 + Single Bond 2; primer Clearfil SE Bond + bond Clearfil SE Bond	Drills of post	Macro-Lock Post 3	Embrace Core Resin Cement	24 h	Push-out test

Table 1: *Description of Included Studies (cont.)*

Furuse & others[52]	Brazil	English	Bovine incisors	Sealer 26	1 wk	5.25% NaOCl; 5.25% NaOCl + 10% ascorbic acid	3 Largo & burs provided by the post manufacturer (Exacto)	Exacto 3	RelyX ARC	24 h	Push-out test
Garcia & others[53]	Brazil	English	Human maxillary canines	EndoFill	2 d	Diode laser (power of 1.5 W & a frequency of 100 Hz)	Low-speed post preparation bur was used (FibreKor Post System)	FibreKor Post System 2	Rely-X Unicem or Cement-Post	—	Push-out test
Garcia & others[54]	Brazil	English	Human maxillary canines	Endofill	2 d	Diode laser (1.5 W/100 Hz); diode laser (1.5 W/ continuous wave); diode laser (3.0 W/100 Hz); diode laser (3.0 W/ continuous wave);	Post preparation bur (FibreKor Post System)	Parallel fiberglass posts 2 (Angelus)	Cement-Post	—	Push-out test
Garcia & others[55]	Brazil	English	Human mandibular premolars with single canals	Sealer 26	1 wk	5% NaOCl; 17% EDTA +5% NaOCl; 17% EDTA	Low-speed drill provided by the post system manufacturer	White Post - DC 2	RelyX U100	24 h	Push-out test
Gomes França & others[56]	Brazil	English	Bovine roots	—	—	2% CHX; 100% ethanol	Largo Peeso Reamers at increasing diameters until reaching 4	Reforpost 2	Rely X ARC	2 d or 6 mo	Push-out test
Gorus & others[57]	Turkey	English	Single-rooted & single-canaled human teeth	—	—	Er: YAG laser (15 Hz/0.6 W) + 0.5% NaOCl	Drill of the post system (Snow-fiber post-drill, 1.0)	Snowpost	Clearfil SA	24 h	Push-out test
Jain & others[58]	India	English	Single-rooted human teeth	AH Plus	24 h	10% sodium ascorbate; 10% hesperidin; 1% riboflavin 5 phosphate	Drill for Hi-Rem posts size #1	Hi-Rem, size #1	Rely X ARC	—	Push-out test
Kirmali & others[59]	Turkey	English	Single-rooted human maxillary incisors	AH Plus	1 wk	Er,Cr:YSGG laser (20 Hz/1W); Er,Cr:YSGG laser (20 Hz/2W); Er,Cr:YSGG laser (20 Hz/3W)	Drill by the manufacturer with a 1.5 mm tip diameter.	Rebilda, 15	Grandio Core Dual Cure	1 wk	Push-out test
Kul & others[60]	Turkey	English	Mandibular premolar human teeth	AH Plus	1 wk	5.25% NaOCl+17% EDTA; 2% CHX; 35% H3PO4	1 Peeso reamer, & preparation of the post was completed with a number 1 drill (DT Light-Post System	DT Light-Post System	RelyX U200	24 h	Push-out test
Lacerda & others[61]	Brazil	English	Bovine teeth	Sealer 26	1 wk	2% CHX; 2.5% NaOCl; ultrasound; 2% CHX + ultrasound; 2.5% NaOCl + ultrasound	Burs of the system of glass fiber post (White Post DC3 & DC4)	White Post DC3 & DC4	Bifix QM	1 wk	Push-out test
Lacerda & others[12]	Brazil	English	Single-rooted human premolar teeth	—	—	1% NaOCl; 2% CHX gel	Largo burs 2, 3 & 4	Reforpost	RelyX ARC or RelyX U100	1 wk or 6 mo	Push-out test
Leitune & others[62]	Brazil	English	Human upper central incisor teeth	—	—	0.2% CHX; 2% CHX	2 drill from the Exacto post system	Exacto	RelyX ARC	24 h or 6 mo	Push-out test
Lima[63]	Brazil	English	Bovine incisors	AH Plus	2 d	17% EDTA; 11.5% Polyacrilic acid; NaOCl	Gates-Glidden 3 & post drill 3	White post DC 3	Variolink II or RelyX U100 or Maxcem Elite	24 h	Push-out test

Table 1: *Description of Included Studies (cont.)*

Mao & others[64]	China	English	Human maxillary central incisors	AH 26	1 wk	10% NaOCl; 17% EDTA + 5.25% NaOCl	D.T. Pre-Shaping Drills 3	D.T. light-post 3	Duo-Link or LuxaCore Dual	1 wk	Push-out test
Martinho & others[65]	Brazil	English	Bovine incisors	Sealer 26	1 wk	2% CHX; 2.5% NaOCl; ultrasound; Nd:YAG laser (15 Hz/ 1.5 W); 2% CHX + ultrasound; 2% CHX + Nd:YAG laser (15 Hz/ 1.5 W); 2.5% NaOCl+ ultrasound; 2.5% NaOCl + Nd:YAG laser (15 Hz/ 1.5 W)	—	White Post DC4	Bifix QM	1 wk	Push-out test
Mathew & others[66]	India	English	Uniradicular human teeth	AH Plus	24 h	5% NaOCl + 17% EDTA; diode laser (3W)+5% NaOCl	(0.70 mm) peeso reamer 1, & preparation was completed using drill number 1 (Hi Rem Endod Drill 201)	Hi Rem Over, size 1	G Cem or GC Pro	24 h	Push-out test
Mohammadi & others[67]	Iran	English	Human maxillary central incisors	AH 26	24 h	Er,Cr:YSGG laser (0.5W+ 20% water & air level) +(2.5W + 50% air & water level)	Peeso reamers 4, 3, 2 & he special drills provided by the manufacturer fiber posts (Endolight Post)	Endolight Post	Maxcem Elite	24 h	Push-out test
Neelakantan & others[68]	India	English	Human single-rooted maxillary central incisors	AH Plus	1 wk	3% NaOCl; 3% NaOCl + 17% EDTA; 6% NaOCl + 18% etridronic acid; 3% NaOCl + Qmix	This was accomplished using a warm plugger (E&Q Plus). Post-space preparation was performed using the post-specific drill (Rely X fiber post)	RelyX fiber post	Rely X Unicem or Fusion Ultra DC	24 h or 4 mo	Push-out test
Oral & others[69]	Turkey	English	Human single-rooted maxillary anterior teeth	—	—	2.5% NaOCl + Er:YAG Laser; 2% CHX + Er:YAG Laser; Slurry Bioactive Glass Granules; Silane-based Primer+ Er:YAG Laser; Slurry Bioactive Glass Granules + Silane-based Primer + Er:YAG Laser	ParaPost up to diameter of 1.75 mm with increasing drills of 1.14, 1.25, 1.40, 1.50 & 1.75 mm from 1 mm coronal level of apices.	EverStick POST (1.5mm)	ParaCem	—	Push-out test
Parčina Amižić & others[70]	Croatia	English	Single-rooted human premolars	AH Plus	1 wk	Er:YAG laser with photon-induced photoacoustic streaming (PIPS) tip; Er,Cr:YSGG laser with radial-firing (RFT2) tip	Gates Glidden 4 burs	everStick POST, diameter 1.2 mm	G-Cem	—	Micro push-out bond strength
Ramos & others[71]	Brazil	English	Human canines	AH Plus	1 wk	Photodynamic therapy	2 bur (White Post DC System)	White Post DC System 2	Relyx ARC or Relyx U200	24 h	Push-out test

Table 1: *Description of Included Studies (cont.)*

Ramos & others[72]	Brazil	English	Human canines	AH Plus	1 wk	Photodynamic therapy	# bur (White Post DC System)	White Post DC System #2	RelyX U200 Automix or Gold Label 1	24 h	Push-out test
Santos & others[73]	Brazil	English	Bovine incisors	—	—	2% CHX; 100% Ethanol; 100% Ethanol+ 2% CHX	—	Reforpost	Rely X U200	1 wk after obtain slices, the specimens were tested in time intervals of 2 d & 6 mo	Push-out test
Scotti & others[74]	Italy	English	Human single-rooted teeth	Pulp Canal Sealer EWT	24 h	32% H_3PO_4	—	Fiber post	Bisfill 2B	1 wk	Push-out test
Scotti & others[75]	Italy	English	Single-rooted human teeth	Pulp Canal Sealer EWT	1 wk	10% EDTA; 10% EDTA + Teethmate Desensitizer; Teethmate Desensitizer	Largo drills 1 & also dedicated drills (EasyPost 3)	Radix 3	Panavia SA	1 wk	Push-out test
Seballos & others[16]	Brazil	English	Single-rooted premolars human	AH Plus	1 wk	2%CHX; 1% NaOCl; 2.5% NaOCl; 5% NaOCl; 1% CaOCl; 2.5% CaOCl; 5% CaOCl	2, 3, 4 Largo drills & fiber post bur	Exacto Translúcido N2	RelyX U200	48 h	Push-out test
Shafiei & others[76]	Iran	English	Human maxillary central incisors	AH26	1 wk	EDC (1-ethyl-3-(3-dimethylaminopropyl) carbodiimide pretreatment was included in the adhesive; 18%EDTA; 18%EDTA +EDC;	Drills (2) from the respective post manufacturer	FRC Postec Plus No. 2	Variolink II or Panavia F2.0 or Clearfil SA	1 wk or 1 y	Push-out test
Shafiei & others[77]	Iran	English	Human maxillary central incisors	—	1 wk	2% CHX; Chlorhexidine diacetate added to a mixture of ED primer; 2% CHX; Chlorhexidine diacetate incorporated Clearfil SE Bond	Drills provided by the post manufacturer	Glassix Post	Panavia F2.0	1 wk or 2 y	Push-out test
Shafiei & others[78]	Iran	English	Human maxillary central incisors	AH26	1 wk	1% NaOCl; 17%EDTA	Drills from the post manufacturer	Fiber posts	Duo-link	1 wk	Push-out test
Silv[a79]	Brazil	Portuguese	Bovine incisors	Sealer 26	24 h	2% CHX	Drill with 1.5 mm diameter from post manufacturer	Exacto 2	RelyX ARC	1 wk or 6 mo or 1 y	Push-out test
Simões & others[80]	Brazil	English	Single-rooted human premolars	Sealer 26	24 h	17% EDTA; 35% H_3PO_4	Exacto drill 2	Exacto 2	RelyX ARC or RelyX U200 Automix	24 h or 6 mo	Push-out test
Simões & others[81]	Brazil	English	Single-rooted human premolars	Sealer 26	24 h	11.5% polyacrylic acid	Drill number 2 was used (Angelus)	Exacto # 2	RelyX ARC or RelyX U200 Automix	24 h or 6 mo	Push-out test

Table 1: *Description of Included Studies (cont.)*

Tuncdemir & others[82]	Turkey	English	Human maxillary central incisors	AH Plus	1 wk	5.25% NaOCl; 17%EDTA; 37% orthophosphoric acid; Diode laser (wavelength of 660 nm, output power of 75 mW)	Matching drill	Snowlight Post 14	Clearfil SA	—	Push-out test
Uzun & others[83]	Turkey	English	Human mandibular premolars	AH Plus	2 d	Er:YAG laser (1.5-W, 15-Hz)	(1) Oval fiber post + Ellipson tip group: An oval sectioned ultrasonic tip (Ellipson tip) mounted in Suprasson; (2) Circular fiber post + Unicore drill group: A dedicated drill (Unicore)	Oval posts (Ellipson posts), circular posts (Unicore posts size 2)	RelyX Unicem	24 h	Push-out test
Victorino & others[84]	Brazil	English	Human canines	AH Plus	1 wk	1% CHX diacetate; 1% CHX diacetate + 99% ethanol; 99% ethanol; 2% CHX	Unicore Drill 2	Unicore Post	PermaFlo DC	24 h	Push-out test
Wang & others[85]	Brazil	English	Bovine roots	Sealer 26	1 wk	2% CHX	Gates drill 2 & drill provided by the manufacturer of the post-system	Exacto posts, (2)	Rely X ARC	1 wk	Push-out test
Wu & others[86]	China	English	Human incisors & premolars	—	—	Irradiation unit in conjunction with a transparent light-guiding attachment; 17% EDTA+ 5% NaOCl + irradiation unit in conjunction with a transparent light-guiding attachment	Diameter of 1.5mm using preparation drills (Para Post Drill #6	Para Post Fiber White	DC Core Automix Dentin	24 h	Microtensile bond strength
Xia & Cheng[87]	China	English	Human premolars	RealSeal SE	3 d	2.5% NaOCl; 17% EDTA + 2.5% NaOCl; 17% EDTA+2.5% NaOCl+ ultrasound	Size 3 universal drill (RelyX Fiber Post system)	RelyX Fiber Post system	RelyX Unicem	24 h	Push-out test
Yaman & others[88]	Turkey	English	Permanent human lower premolars	AH Plus	24 h	Clearfil SE Primer; 37% H_3PO_4; ≥99.5% Ethanol; 2% CHX	Largo Peeso Reamer & drill corresponding to the size of the FP (ICELight reamer)	ICELight, 1.4 mm	Clearfil SA Cement Automix	24 h	Microtensile bond strength
Yu & others[89]	China	English	Human premolars	AH Plus	3 d	5.25% NaOCl; 5.25% NaOCl +EGCG irrigant; 5.25% NaOCl +anhydrous ethanol *EGCG was dissolved in anhydrous ethanol at the concentration of 400 μg/mL to prepare the EGCG irrigants	Rely X Fiber Post drill 3	Rely X Fiber Post	Clearfil DC Core Auto-mix	24 h or thermocycling for 10,000 cycles	Push-out test
Zhang & others[18]	China	English	Human premolars	AH Plus	3 d	35% H_3PO_4; 17% EDTA+ 5.25% NaOCl; 17% EDTA+ 5.25% NaOCl + ultrasound	#2 Peeso reamer & #3 DT drill from DT Light-Post system	#3 DT Light posts	Clearfil SE Bond or Clearfil DC Bond	—	Push-out test

Table 1: *Description of Included Studies (cont.)*

Zhou & others[90]	China	English	Human maxillary anterior teeth	VitaPex	—	0.5% CHX; 1% CHX Different amounts of 20% chlorhexidine digluconate were added directly into ED primer to prepare mixtures containing three different concentrations of chlorhexidine: 0%, 0.5% & 1.0%	Gates-Glidden drills #2 & post drills provided by the post manufacturer	LuxaPost, 1.5 mm diameter	Panavia F	24 h or 18 mo	Push-out test
Zhu & others[91]	China	Chinese	Human mandibular premolars	AH 26 or AH Plus	1 wk	17% EDTA + 5.25% NaOCl; 17%EDTA + 5.25% NaOCl + ultrasound	—	Fiber posts	RelyX Unicem	1 wk	Push-out test
Çökük & others[13]	Turkey	English	Human maxillary central incisors	MM Seal	1 wk	5% NaOCl; 2% CHX; 1.5W Er, Cr: YSGG laser; 1.25W Er, Cr: YSGG laser	Exacto drill 2 of fiber glass post system	Exacto	Panavia F2.0	1 wk	Push-out test
Šimundić Munitić & others[92]	Croatia	English	Anterior single-rooted permanent human teeth	AH Plus	2 wk	Er:YAG (pulse energy 20 mJ, pulse duration 50 µs, pulse repetition rate 15 Hz, energy density 2.06 J/cm^2.); Er:YAG + QMiX solution; Er,Cr:YSGG (power 1.25 W, repetition rate 20 Hz, pulse duration 140 µs, pulse energy 62.5 mJ); Er,Cr:YSGG + QMiX solution; Nd:YAG laser (pulse energy 100 mJ, repetition rate 10 Hz, medium power 1.5W, pulse duration: 100 µs, energy density 140.85 J/cm^2)	Drill, size 1 (diameter 0.8 mm at the tip), provided by the post system's manufacturer	FRC Postec Plus size #1	Speed CEM	1 wk	Push-out test

[a]*Country of the first author. Abbreviations: EDTA, ethylene diamine tetra acetic acid; NaOCl, sodium hypochlorite; CHX, chlorhexidine digluconate; H3PO, phosphoric acid; EGCG, flavonoid produced in large amounts as a secondary metabolite by the Camellia sinensis plant, green tea; Er:YAG, erbium-doped yttrium aluminium garnet laser; Er,Cr:YSGG, erbium, chromium-doped:yttrium, scandium, gallium, & garnet; Nd:YAG, neodymium-doped yttrium aluminium garnet; CaOCl, calcium hypochlorite. " — " signifies information is unclear in the paper.*

In analyzing the type of drills used to make the post-space, most of the studies only used the drill of the post systems (n=43), and nine studies did not have this information. Sixty-eight studies (68) used fiber post, four studies used fiber post relining, two studies used carbon fiber post, and one study used cast post.

In total, 41 commercial cements were used, and three of them were not resin cement, as follows: one zinc phosphate cement, one glass ionomer cement, and one resin-modified glass ionomer. The resin cement most used was RelyX ARC (3M Oral Care, St Paul, MN, USA) resin cement (n=19).

The maximum storage time before the bond strength test was two years, and minimum storage time was 24 hours. The most commonly employed method for evaluating bond strength was the push-out test (n=66).

Meta-Analyses

Post-space treatment improved the bond strength of posts to root canal dentin, as significant differences were found between the control and experimental groups (p<0.00001) (Figure 2). A subgroup meta-analysis also showed improved bond strength when post-space treatment was done using ethanol (p<0.0001), NaOCl

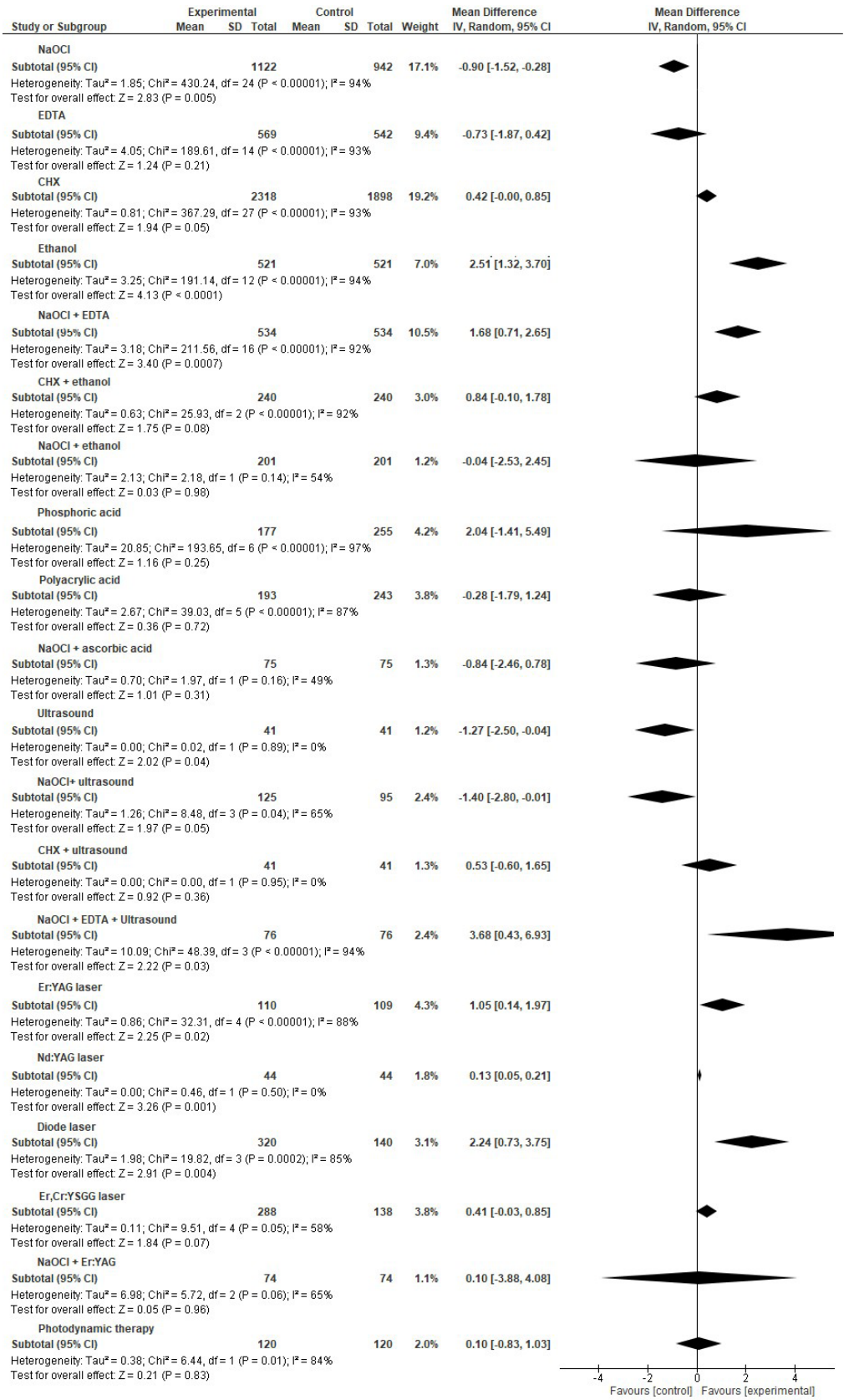

Figure 2. *Forest plot of global meta-analysis. Abbreviations: CI, confidence interval.*

+ EDTA (p=0.0007), NaOCl + EDTA + Ultrasound (p=0.03), Er:YAG laser (p=0.02), Nd:YAG laser (p=0.001), and diode laser (p=0.004) (Figure 3).

Moreover, subgroup analyses (endodontic sealer, post-time for post luting, type of post, drills used to make post-space, resin cement, post-waiting time for the test, and thirds of root) were performed (Figure 4). Most factors in the subgroup analyses affected the results of the meta-analysis, except for resin cement, post-waiting time for tests, and different thirds of the root canal.

High heterogeneity was found in the global meta-analysis and subgroup meta-analyses (I^2>50%).

Risk of Bias

The majority of the included studies were scored as having a high risk of bias (n=52),[a] whereas only one study was scored as low risk of bias.[16] The items which were not described in the majority of studies were blinding of the operator of the test machine (97.33%), sample size calculation (97.33%), post luting procedures performed by the same operator (94.67%), and post-space treatment performed by a single operator (90.67%) (Table 2).

DISCUSSION

This systematic review and meta-analysis aimed to verify whether post-space treatments would improve the bond strength of posts to root canal dentin. In general, the post-space treatment has a positive influence on the bond strength of intraradicular posts compared to the control group. A meta-analysis of the data leads to rejecting the null hypothesis, as bond strength to root canal dentin was higher when the post-space was treated.

The formation of debris and residues in the canal during the post-space preparation can affect intraradicular posts adhesion.[5,6,8-10] In addition, endodontic sealer residues might also interfere on degree of conversion of cement used for post luting.[26,97] Moreover, the presence of the smear layer impairs adequate contact between adhesive systems/cement used for bonding the post and the root canal.[94] In this sense, the use of post-space treatment can improve the post adhesion in root canal dentin, removing partial or total debris of the root canal, and promoting the opening of dentinal tubules.[18]

In total, 43 post-space treatments were evaluated by studies included in this systematic review, but not all treatments increased the bond strength values. Among the post-space treatments analyzed, the treatments that improved the bond strength values were: ethanol (in concentrations ranging between 70% and 100%), NaOCl (1% to 5.25%) + EDTA (17% to 20.3%), NaOCl (2.5%) + EDTA (17%) + Ultrasound, Er:YAG laser, Nd:YAG laser, and diode laser.

Ethanol was used in 13 studies. It is considered a bipolar solvent and may be a good option for dentin cleaning because it dissolves both polar and non-polar compounds.[45] Furthermore, this substance acts in controlling humidity in the depth of the root canal, making the collagen matrix from the post-space more hydrophobic due to the substitution of water by ethanol, and thus can improve the adhesive strength of the post and reduce the degradation of the adhesive layer.[10] Moreover, the combination of NaOCl + EDTA treatment was evaluated in 17 studies, and this treatment is indicated for smear layer removal due to the intrinsic properties of these two solutions. NaOCl is an excellent proteolytic agent promoting a greater dissolution of organic compounds, thereby cleaning the root canal.[17] In addition, EDTA has also shown to be effective in removing this smear layer. EDTA is a demineralizing agent, and has the ability to chelate calcium ions, to dissolve inorganic material such as hydroxyapatite, and it has little or no effect on the organic material.[17] The use of ultrasound activation associated with NaOCl + EDTA in this study does not seem to affect the efficacy of this treatment, and the dentist may choose to use or not use this additional treatment.

The post-space preparation with lasers could be able to improve bonding to root canal dentin compared to the control group; however, few studies evaluated laser treatment; only four studies considered Er:YAG laser, two considered Nd:YAG laser, and four compared the diode laser. The treatment with Er:YAG laser increased dentinal permeability, had a thermomechanical effect on the hydrated component of surface dentin leading to ablation and water evaporation, and micro explosions eject organic and inorganic tissue, promoting clean dentinal walls and open tubule orifices.[83,95] Studies in the literature showed that Nd:YAG laser irrigation promoted morphological alterations such as melting, resolidification, and formation of small globules in dentin surface.[92,96] Furthermore, the diode laser has been recommended in the literature because it is efficient in removing the smear layer and debris from root canals.[97,98]

Despite not increasing the bond strength of the post to root dentin, chlorhexidine was the most used treatment among the studies included in this meta-analysis. Chlorhexidine has antibacterial action, substantivity, and biocompatibility.[29,38,42,44] Also, it is a non-toxic MMP inhibitor, intending to preserve the stability of the bond strength over time.[29,56] However,

[a] *11-15, 18, 28, 30-32, 34, 36, 38, 40-44, 46-52, 55-63, 66-71, 73-75, 80-82, 86, 88-92*

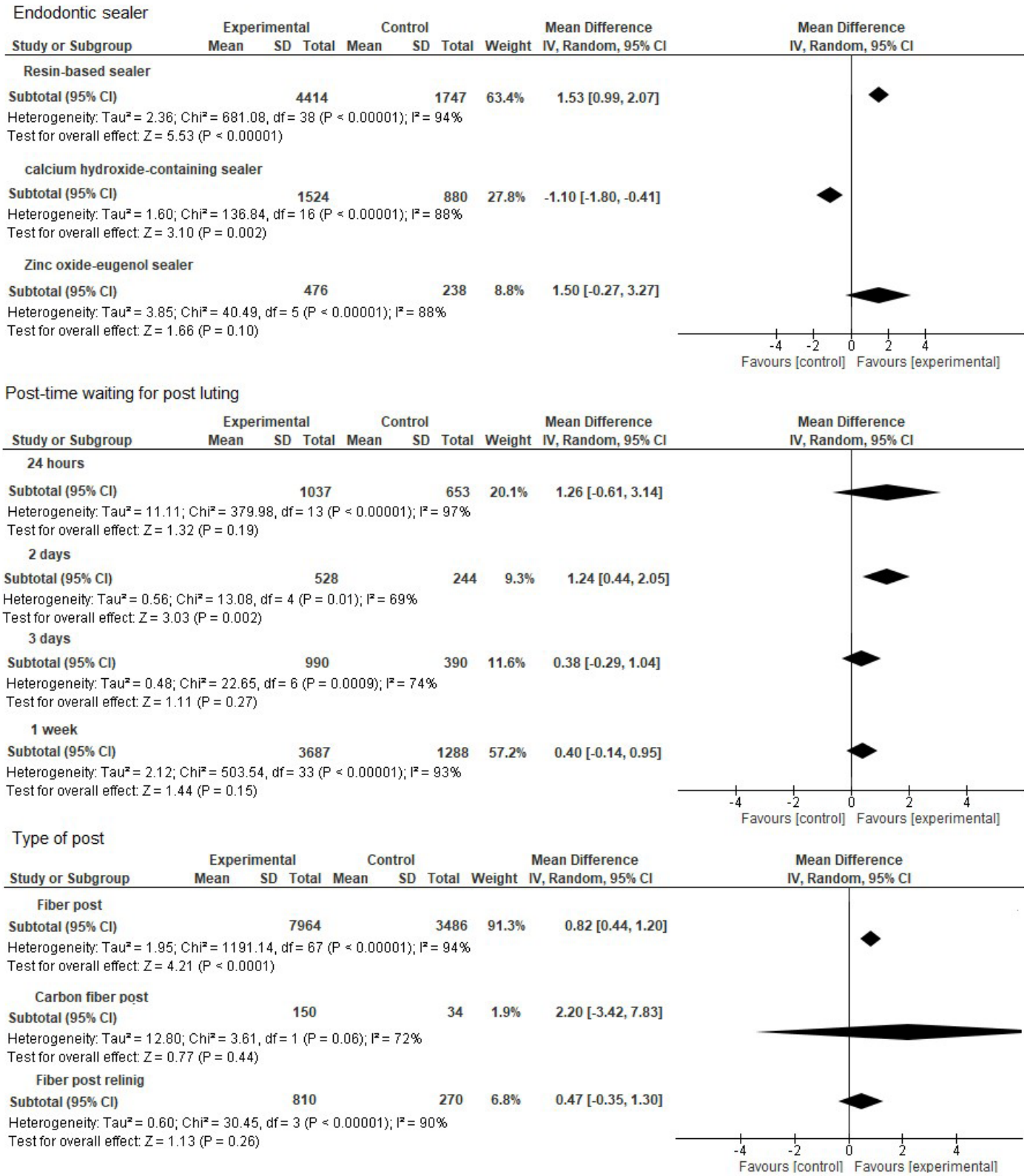

Figure 3. *Forest plot of post space treatments analyzed separate. Abbreviations: CI, confidence interval.*

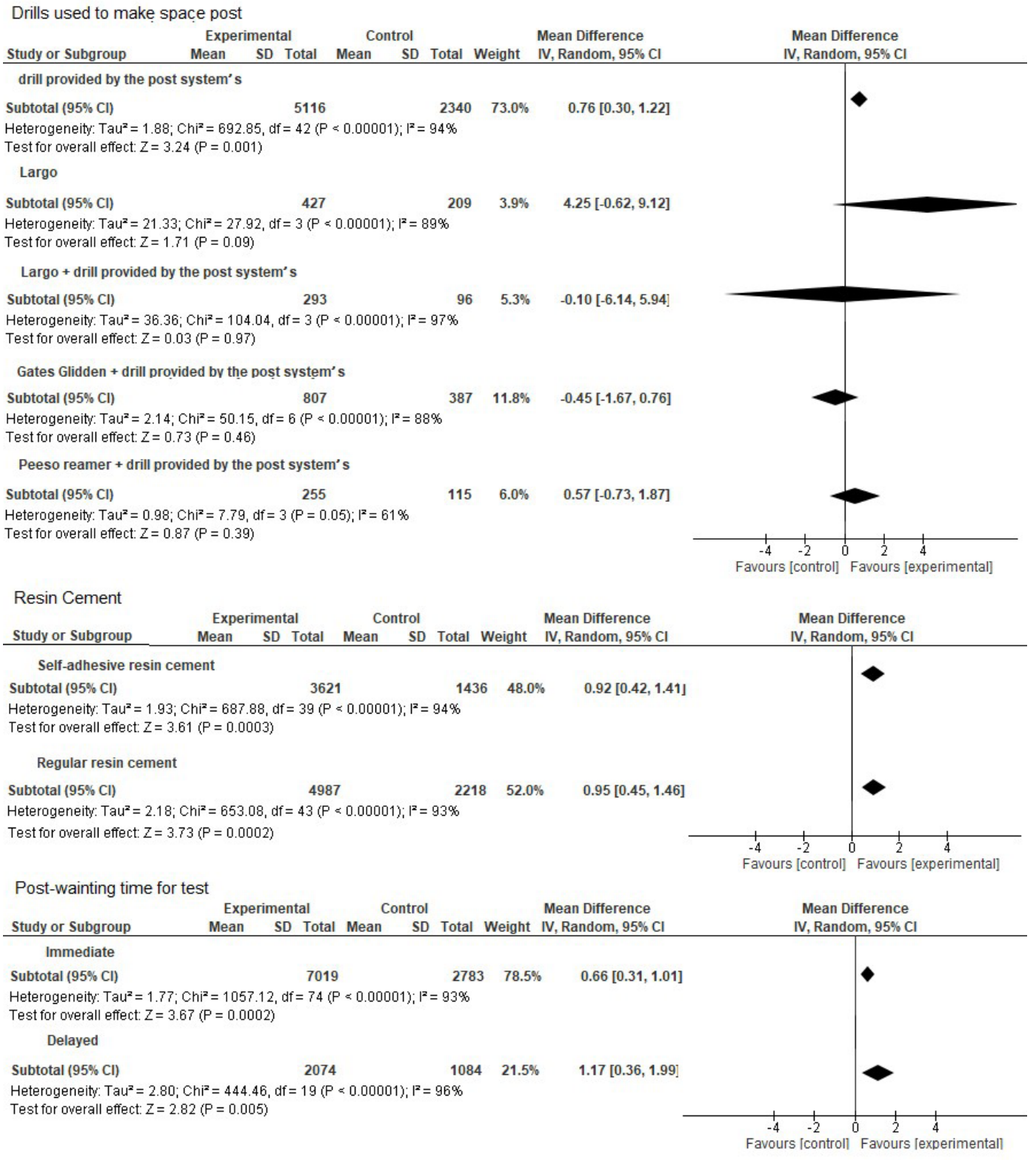

Figure 3. *Forest plot of post space treatments analyzed separate. Abbreviations: CI, confidence interval. (cont.)*

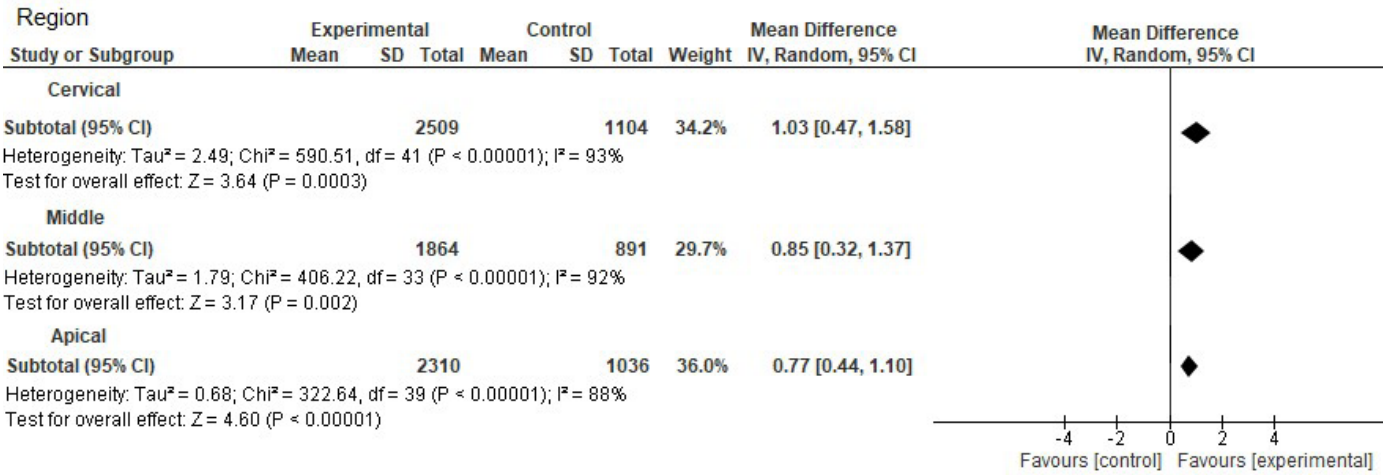

Figure 3. *Forest plot of post space treatments analyzed separate. Abbreviations: CI, confidence interval. (cont.)*

for the post-space treatment, chlorhexidine does not seem to be effective.

Moreover, subgroup analyses were performed evaluating different factors that can affect the efficiency of post-space treatments. For the overall data, the type of endodontic sealer used seems to affect the treatment action. Also, other studies in the literature showed that the type of canal sealer can affect the bond strength of the fiber post.[26,93] For the resin-based sealers, the post-space treatments are effective in improving the post bond strength. The resin-based sealer is considered in the literature as the gold standard because this sealer does not affect the post retention.[99]

On the other hand, different treatments decreased or showed no difference in the bond strength for calcium hydroxide sealers and zinc oxide-eugenol sealers, respectively. In contrast, the literature showed higher bond strength values of a post in root canals filled with a sealer containing calcium hydroxide compared with other sealers; this can be explained by the isobutyl salicylate present in this sealer, which reacts with calcium creating a physiochemical barrier that may have influence on cement adhesion.[93,100] However, this sealer seems to affect the post-space treatment because the control group achieved the highest bond strength values of the post. Eugenol-based sealers have lower bond strength values than other sealers because they interfere with polymerization of cement used for post luting.[99] The post-space treatment evaluated with this sealer does not seem to affect the post retention. However, this result should be evaluated with caution since only 10 treatments were evaluated for this sealer.

Regarding the storage time before post luting, there is no difference between post-space treatment and the control group, except for the two-days subgroup. However, it should be considered that they do not have a long storage period, and only five studies used two days of storage. This analysis is essential because the prolonged contact of endodontic sealer with dentin walls may affect the adhesion of the post through the penetration of molecules of endodontic sealer in dentinal tubules.[101,102] A more extended storage period and more endodontic sealer molecules would be able to penetrate dentin walls, and post-space treatments would be necessary for the removal of these molecules. Therefore, the post-time waiting for post luting is influenced by the type of endodontic sealer used for filling the root canal.[103]

In the subgroup analysis of the type of post, the fiber post showed that the post-space treatment improved the post retention. In the literature, one systematic review found the same result for fiberglass posts; this study shows that the root canal cleaning can affect the bond strength of the fiberglass post and that NaOCl + EDTA was recommended.[104] Other types of posts should be analyzed with caution, as there are few studies included in this present review that used carbon fiber post (n=2), fiber post relining (n=4), or cast post (n=1).

Post-space preparation may interfere in the post retention due to the effect of the drill used, which may remove variable amounts of gutta-percha and dentin, and generate a temperature increase on the root surface, which may form cracks or fractures in the intraradicular dentin.[105-108] In this systematic review, the post-space treatment was only efficient for drills provided by the post system's subgroup. Other types of drills should be considered with caution due to the presence of few studies that used each of the following drills: Largo drill (n=4), Largo drill + drill provided by the post system (n=4), Gates Glidden drill + drill provided by the post system (n=7) and Peeso Reamer drill + drill provided by the post system (n=4).

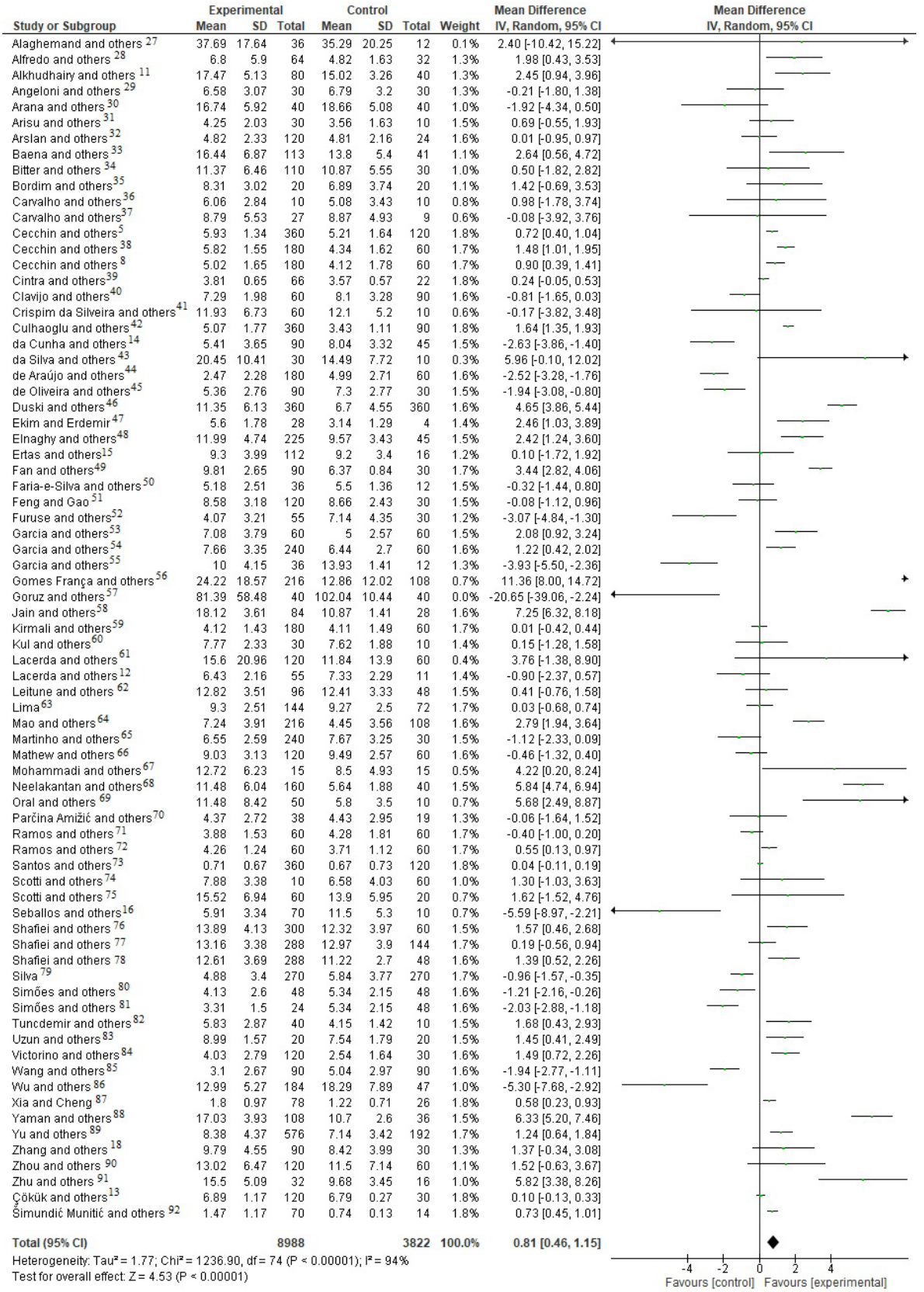

Figure 4. Forest plot of analysis subgroup of global data. Abbreviation: CI, confidence interval.

Table 2: *Risk Bias of the Studies Considering Aspects Reported in Methods & Materials Section*

Article	Randomization Teeth	Sample Size Calculation	Used Materials According to the Manufacturer's Instruction	Teeth with Similar Dimensions	Endodontic Treatment Performed by a Single Operator	Space of Post Treatment Performed by a Single Operator	Luting Post Procedures Performed by the Same Operator	Blinding of the Operator of the Test Machine	Failure Analysis	Risk of Bias
Alaghemand & others[27]	YES	NO	YES	NO	YES	NO	NO	NO	YES	MEDIUM
Alfredo & others[28]	YES	NO	YES	YES	NO	NO	NO	NO	NO	HIGH
Alkhudhairy & others[11]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Angeloni & others[29]	YES	NO	YES	NO	NO	NO	NO	NO	YES	MEDIUM
Arana & others[30]	NO	NO	YES	NO	NO	NO	NO	NO	NO	HIGH
Arisu & others[31]	NO	NO	YES	YES	NO	NO	NO	NO	YES	HIGH
Arslan & others[32]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Baena & others[33]	YES	NO	YES	NO	YES	NO	NO	NO	YES	MEDIUM
Bitter & others[34]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Bordin & others[35]	YES	NO	NO	YES	YES	NO	NO	YES	NO	MEDIUM
Carvalho & others[36]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Carvalho & others[37]	YES	NO	YES	YES	YES	NO	NO	NO	YES	MEDIUM
Cecchin & others[5]	YES	NO	NO	YES	YES	NO	NO	NO	YES	MEDIUM
Cecchin & others[38]	NO	NO	NO	YES	NO	NO	NO	NO	YES	HIGH
Cecchin & others [8]	NO	NO	YES	YES	YES	NO	NO	NO	YES	MEDIUM
Cintra & others[39]	YES	NO	YES	YES	NO	YES	NO	NO	NO	MEDIUM
Clavijo & others[40]	YES	NO	YES	NO	NO	NO	NO	NO	NO	HIGH
Crispim da Silveira & others[41]	YES	NO	YES	YES	NO	NO	NO	NO	NO	HIGH
Culhaoglu & others[42]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
da Cunha & others[14]	NO	NO	YES	YES	NO	NO	NO	NO	NO	HIGH
Da Silva & others[43]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
De Araújo & others[44]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
de Oliveira & others[45]	YES	NO	YES	NO	YES	YES	NO	NO	YES	MEDIUM
Durski & others[46]	YES	NO	YES	NO	NO	NO	NO	NO	NO	HIGH
Ekim & Erdemir[47]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Elnaghy[48]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Ertas & others[15]	NO	NO	YES	YES	NO	NO	NO	NO	YES	HIGH
Fan & others[49]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Faria-e-Silva & others[50]	NO	NO	NO	YES	NO	NO	NO	NO	NO	HIGH
Feng & Gao[51]	YES	NO	NO	YES	NO	NO	NO	NO	YES	HIGH
Furuse & others[52]	NO	NO	YES	YES	NO	NO	NO	NO	YES	HIGH
Garcia & others[53]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM
Garcia & others[54]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM
Garcia & others[55]	YES	NO	NO	NO	YES	NO	NO	NO	NO	HIGH
Gomes França & others[56]	YES	NO	NO	YES	NO	NO	NO	NO	YES	HIGH
Gorus & others[57]	YES	NO	NO	NO	NO	NO	NO	NO	NO	HIGH
Jain & others[58]	NO	NO	NO	NO	NO	NO	NO	NO	NO	HIGH
Kirmali & others[59]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Kul & others[60]	NO	NO	YES	NO	NO	NO	NO	NO	YES	HIGH

Table 2: *Risk Bias of the Studies Considering Aspects Reported in Methods & Materials Section (cont.)*										
Lacerda & others[61]	NO	NO	YES	NO	NO	NO	NO	NO	NO	HIGH
Lacerda & others[12]	YES	NO	NO	YES	NO	NO	NO	NO	NO	HIGH
Leitune & others[62]	YES	NO	NO	NO	YES	YES	NO	NO	NO	HIGH
Lima[63]	NO	NO	NO	YES	NO	NO	NO	NO	YES	HIGH
Mao & others[64]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM
Martinho & others[65]	YES	NO	YES	YES	YES	NO	NO	NO	YES	MEDIUM
Mathew & others[66]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Mohammadi & others[67]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Neelakantan & others[68]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Oral & others[69]	NO	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Parcina & others[70]	NO	NO	NO	YES	NO	NO	NO	NO	NO	HIGH
Ramos & others[71]	YES	NO	NO	YES	NO	NO	NO	NO	YES	HIGH
Ramos & others [72]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM
Santos & others[73]	NO	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Scotti & others[74]	YES	NO	NO	NO	NO	NO	NO	NO	NO	HIGH
Scotti & others[75]	YES	NO	NO	NO	NO	NO	NO	NO	NO	HIGH
Seballos & others[16]	YES	NO	YES	YES	YES	YES	YES	YES	YES	LOW
Shafiei & others[76]	YES	NO	YES	YES	NO	YES	NO	NO	YES	MEDIUM
Shafiei & others[77]	YES	NO	YES	YES	NO	NO	YES	NO	YES	MEDIUM
Shafiei & others[78]	YES	NO	YES	YES	NO	YES	YES	NO	YES	MEDIUM
Silva[79]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM
Simões & others[80]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Simões & others[81]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Tuncdemir & others[82]	YES	NO	NO	NO	YES	NO	NO	NO	YES	HIGH
Uzun & others[83]	YES	NO	YES	NO	YES	YES	YES	NO	YES	MEDIUM
Victorino & others[84]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM
Wang & others[85]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM
Wu & others[86]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Xia & Cheng[87]	YES	NO	YES	NO	YES	NO	NO	NO	YES	MEDIUM
Yaman & others[88]	YES	YES	NO	NO	NO	NO	NO	NO	YES	HIGH
Yu & others[89]	YES	YES	NO	NO	NO	NO	NO	NO	YES	HIGH
Zhang & others[18]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Zhou & others[90]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Zhu & others[91]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Çökük & others[13]	NO	NO	YES	NO	YES	NO	NO	NO	YES	HIGH
Šimundić Munitić & others[92]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH

The type of post most used in our systematic review was the fiber post. The main reason for the failure of this type of post is post debonding;[109] therefore, the type of cement used for post luting is important. Different types of cement have been analyzed in the literature; however, adhesive cementation achieves higher bond strength than other types of cement.[110,111] All the included studies in this review used resin cement for post luting, and the post-space treatment improves the post retention for all types of resin cements. Regarding the post-treatment before luting, most of the papers included in the meta-analysis used silano for post-treatment. Some papers[b] do not explain what was used for the post-treatment and one[67] paper used only alcohol for post-treatment.

[b] *5, 51, 61, 70, 74, 82, 88, 89, 91*

For the post-waiting time for test analysis, the immediate (stored between 24 hours and one week) and delayed subgroups (stored between four months and two years) obtained higher results for post retention when the post-space treatment was used compared with the control group. Although there was no difference between the subgroups (immediate and delayed), it is important to take into account length of storage time because studies in the literature suggested the integrity of cement-dentin bonds over time decreased the post bond strength.[112] In addition, some treatments were available in the post-space to increase the bond strength value in the delayed condition.[5,8,38]

The bond strength test most used among the included studies was the push-out test.[92] One reason for this is promoting shear stresses at the interface between cement-root dentin and cement-post, and the push-out test generates the best evidence available in the literature.[113,114]

It is reported in the literature that root thirds affected the bond strength of the post due to regional differences in the concentration, volume, and direction of dentinal tubules in different thirds,[115] although others did not show any difference between thirds.[44,84] In the present review, the use of post-space treatment was better than the control group, independent of tooth third.

High heterogeneity among studies was found in the meta-analyses, and heterogeneity is expected because this review only considered *in vitro* studies. There are many differences among experimental designs in *in vitro* studies such as bond strength test, type of teeth, number of specimens per group, and specific variables such as the endodontic sealers, type of post, type of cement, and post-space treatments. Moreover, a small number of samples and consequently high standard deviations also contribute to heterogeneity.[25,116] Among the evaluated studies, only one[16] had a low risk of bias. The parameters of sample size calculation, treatments performed by a single operator, and blinding the operator of the testing machine were the most frequently missed or unclear parameters. These findings usually occur in a systematic review of laboratory studies.[25,26,97,116]

The present study is a systematic review of only *in vitro* studies, which impacts the interpretation of the findings, thus constituting a limitation of the study. The literature search only being conducted in the PubMed/MEDLINE, Scopus, and Lilacs electronic databases is also a limitation despite the number of obtained studies that can be considered as representative and reasonable. Nevertheless, the obtained results could be considered as a recommendation for clinicians regarding the post-space treatment.

Thus, despite the study limitation, the post-space treatment with ethanol should be preferred due to the the simplicity of the technique and similar results as the more complex techniques, mainly in the situations that the root canal is filled with a resin-based sealer, post-waiting of 2 days using fiber post, and when the post-space preparation was done with the drill provided by post system.

CONCLUSION

This systematic review of laboratory studies indicates, under the limitations of the present meta-analysis, that post-space treatments improve the bond strength of posts to root canal dentin. The treatments with ethanol, NaOCl + EDTA, NaOCl + EDTA + ultrasound, Er:YAG laser, Nd:YAG laser, and diode laser provide higher bonding to root canal dentin. Thus, the clinician can choose the most appropriate treatment to be used among those described above.

Conflicts of Interest

The authors certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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REFERENCES

1. Manicardi CA, Versiani MA, Saquy PC, Pécora JD, & de Sousa-Neto MD (2011) Influence of filling materials on the bonding interface of thin-walled roots reinforced with resin and quartz fiber posts *Journal of Endodontics* **37(4)** 531-537.

2. Schwartz RS & Robbins JW (2004) Post placement and restoration of endodontically treated teeth: a literature review *Journal of Endodontics* **30(5)** 289-301.

3. Santos Pantaleón D, Morrow BR, Cagna DR, Pameijer CH, & Garcia-Godoy F (2018) Influence of remaining coronal tooth structure on fracture resistance and failure mode of restored endodontically treated maxillary incisors *Journal of Prosthetic Dentistry* **119(3)** 390-396.

4. Aleisa K, Alghabban R, Alwazzan K, & Morgano SM (2012) Effect of three endodontic sealers on the bond strength of prefabricated fiber posts luted with three resin cements *Journal of Prosthetic Dentistry* **107(5)** 322-326.

5. Cecchin D, de Almeida JF, Gomes BPFA, Zaia AA, & Ferraz CCR (2011) Effect of chlorhexidine and ethanol on the durability of the adhesion of the fiber post relined with resin composite to the root canal *Journal of Endodontics* **37(5)** 678-683.

6. Pashley DH (1984) Smear layer: physiological considerations *Operative Dentistry* **(Supplement 3)** 13-29.

7. Dimitrouli M, Günay H, Geurtsen W, & Lührs AK (2011) Push-out strength of fiber posts depending on the type of root canal

filling and resin cement *Clinical Oral Investigations* **15(2)** 273-281.

8. Cecchin D, Giacomin M, Farina AP, Bhering CL, Mesquita MF, & Ferraz CC (2014) Effect of chlorhexidine and ethanol on push-out bond strength of fiber posts under cyclic loading *Journal of Adhesive Dentistry* **16(1)** 87-92.
9. Ari H, Erdemir A, & Belli S (2004) Evaluation of the effect of endodontic irrigation solutions on the microhardness and the roughness of root canal dentin *Journal of Endodontics* **30(11)** 792-795.
10. Gu XH, Mao CY, & Kern M (2009) Effect of different irrigation on smear layer removal after post space preparation *Journal of Endodontics* **35(4)** 583-586.
11. Alkhudhairy FI & Bin-Shuwaish MS (2016) The effect of sodium hypochlorite and resin cement systems on push-out bond strength of cemented fiber posts *Pakistan Journal of Medical Sciences* **32(4)** 905-910.
12. Lacerda FC, Amaral FLB, Turssi CP, Basting RT, & França FMG (2017) Endodontic irrigants effect on long-term intraradicular adhesion of resin cements *Journal of Adhesion Science and Technology* **31(22)** 2503-2514.
13. Çökük N, Kara E, Kaki D, Aydogdu M, & Saridag S (2016) Influence of the ER,CR:YSGG laser and different irrigation methods on push-out bond strength of fiber post *Journal of Adhesion Science and Technology* **30(11)** 1178-1188.
14. da Cunha LF, Furuse AY, Mondelli RFL, & Mondelli J (2010) Compromised bond strength after root dentin deproteinization reversed with ascorbic acid *Journal of Endodontics* **36(1)** 130-134.
15. Ertas H, Ok E, Uysal B, & Arslan H (2014) Effects of different irrigating solutions and disinfection methods on push-out bond strengths of fiber posts *Acta Odontologica Scandinavica* **72(8)** 783-787.
16. Seballos VG, Barreto MS, da Rosa RA, Machado E, Valandro LF, & Kaizer OB (2018) Effect of post-space irrigation with NaOCl and CaOCl at different concentrations on the bond strength of posts cemented with a self-adhesive resin cement *Brazilian Dental Journal* **29(5)** 446-451.
17. Haapasalo M, Shen Y, Qian W, & Gao Y (2010) Irrigation in endodontics *Dental Clinics of North America* **54(6)** 291-312.
18. Zhang L, Huang L, Xiong Y, Fang M, Chen JH, & Ferrari M (2008) Effect of post-space treatment on retention of fiber posts in different root regions using two self-etching systems *European Journal of Oral Sciences* **116(3)** 280-286.
19. Paiva SSM, Siqueira JF Jr, Rôças IN, Carmo FL, Leite DCA, Ferreira DC, Rachid CTC, & Rosado AS (2013) Molecular microbiological evaluation of passive ultrasonic activation as a supplementary disinfecting step: a clinical study *Journal of Endodontics* **39(2)** 190-194.
20. Cheng X, Guan S, Lu H, Zhao C, Chen X, Li N, Bai Q, Tian Y, & Yu Q (2012) Evaluation of the bactericidal effect of Nd:YAG, Er:YAG, Er, Cr:YSGG laser radiation, and antimicrobial photodynamic therapy (aPDT) in experimentally infected root canals. *Lasers in Surgery and Medicine* **44(10)** 824-831.
21. Borges AB, da Silva MA, Borges AL, Werkman C, Torres CR, & Pucci CR (2011) Microshear bond strength of self-etching bonding systems to ultrasound diamond bur-prepared dentin *Journal of Adhesive Dentistry* **13(5)** 433-438.
22. da Silva MA, Di Nicolo R, Barcellos DC, Batista GR, Pucci CR, Rocha Gomes Torres C, & Borges AB (2013) Influence of CVD diamond tips and Er:YAG laser irradiation on bonding of different adhesive systems to dentin *Journal of Contemporry Dental Practice* **14(1)** 14-20.
23. Higgins JPT & Green S (eds) (2001) Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011] The Cochrane Collaboration Available at www.cochrane-handbook.org
24. Moher D, Liberati A, Tetzlaff J, & Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PloS Medicine* **6**(7): e1000097.
25. Sarkis-Onofre R, Skupien JA, Cenci MS, Moraes RR, & Pereira-Cenci T (2014) The role of resin cement on bond strength of glass-fiber posts luted into root canals: a systematic review and meta-analysis of in vitro studies. *Operative Dentistry* **39(1)** E31-E44.
26. Bohrer TC, Fontana PE, Lenzi TL, Soares FZM, & Rocha RO (2018) Can endodontic irrigating solutions influence the bond strength of adhesives to coronal dental substrates? A systematic review and meta-analysis of in vitro studies *Journal of Adhesive Dentistry* **20(6)** 481-494.
27. Alaghemand H, Mirzae M, Ahmadi E, & Saidi A (2013) Effect of different post-space pretreatments on fiber post bonding to root dentine *Dental Research Journal* **10(4)** 545-552.
28. Alfredo E, Carvalho JR Jr, Silva-Sousa Y, Sobrinho LDC, Saquy PC, & Sousa-Neto MD (2005) Evaluation of retention of post-core system cemented with different materials on dentine surfaces treated with EDTA or Er:YAG laser irradiation *Photomedicine and Laser Surgery* **23(1)** 36-40.
29. Angeloni V, Mazzoni A, Marchesi G, Cadenaro M, Comba A, Maravi T, Scotti N, Pashley DH, Tay FR, & Breschi L (2017) Role of chlorhexidine on long-term bond strength of self-adhesive composite cements to intraradicular dentin *Journal of Adhesive Dentistry* **19(4)** 341-348.
30. Arana LA, Arana DF, & Gomes JC (2012) Efecto del grabado de la dentina radicular con ácido dietilenoaminotetra acético (EDTA) en la resistencia de unión de cementos autoadhesivos y autograbantes TT- Effect of etching diethyleneaminotetra acetic acid (EDTA) root dentin on bond strength of self-adhesive and self-etching cements *Acta Odontológica Venezolana* **50(4)**.
31. Arisu HD, Kivanç BH, Saglam BC, Simsek E, & Görgül G (2013) Effect of post-space treatments on the push-out bond strength and failure modes of glass fibre posts *Australian Endodontic Journal* **39(1)** 19-24.
32. Arslan H, Akcay M, Saygili G, Kesk A, Mese IT, Gok A, & Dalli M (2015) Bond strength of self-adhesive resin cement to root dentin. Comparison of photon-initiated photoacoustic streaming technique with needle and ultrasonic irrigation *Acta Odontologica Scandinavica* **73(5)** 348-352.
33. Baena E, Flores A, & Ceballos L (2017) Influence of root dentin treatment on the push-out bond strength of fiber posts *Odontology* **105(2)** 170-177.
34. Bitter K, Hambarayan A, Neumann K, Blunck U, & Sterzenbach

G (2013) Various irrigation protocols for final rinse to improve bond strengths of fiber posts inside the root canal. *European Journal of Oral Sciences* **121(4)** 349-354

35. Bordin D, Cavalcanti YW, Farina AP, Carlini-Júnior B, & Cecchin D (2014) Long-term effect of ethanol on the bond strength of fiber-glass posts to root dentin *Revista Odonto Ciencia* **29(2)** 35-39.

36. Carvalho CA, Cantoro A, Mazzoni A, Goracci C, Breschi L, & Ferrari M (2009) Effect of ethanol application on post-luting to intraradicular dentine *International Endodontic Journal* **42(2)** 129-135.

37. Carvalho MFFde (2018) Técnica alcoólica simplificada para a cimentação de pinos intrarradiculares pré-fabricados TT - Effect of ethanol-wet bonding on retetion of post to root dentin. Retrieved from http://hdl.handle.net/1843/ODON-B44FCQ

38. Cecchin D, Farina AP, Giacomin M, de Mattos Pimenta Vidal C, Carlini-Júnior B, & Ferraz CCR (2014) Influence of chlorhexidine application time on the bond strength between fiber posts and dentin *Journal of Endodontics* **40(12)** 2045-2048.

39. Cintra LTA, Batistella AR, Marson FC, Archangelo CM & Gomes-Filho JE (2015) Efeito de diferentes tratamentos de superfície sobre a resistência de união de pinos de fibra ao canal radicular TT - Effect of different surface treatments on the push-out bond strength of fiber posts to root canal *Dental Press Endodontics* **5(2)** 33-39.

40. Clavijo VRG, Bandéca MC, Calixto LR, Nadalin MR, Saade EG, Oliveira-Junior OB, & Andrade MF (2009) Factors affecting on bond strength of glass fiber post cemented with different resin cements to root canal *Laser Physics* **19(9)** 1920-1924.

41. Crispim da Silveira O, Bras da Silva R, Dametto FR, Machado CT, Souza Dos Santos AJ, & Cavalcanti AL (2014) Effect of endodontic irrigating solutions on the micro push-out bond strength of a fibre glass dowel *Acta Stomatologica Croatica* **48(1)** 16-24.

42. Culhaoglu AK, Özcan E, Kilicarslan MA, & Seker E (2017) Effect of boric acid versus conventional irrigation solutions on the bond strength between fiber post and root dentin *Journal of Adhesive Dentistry* **19(2)** 137-146.

43. Da Silva RS, Antunes RPDA, Ferraz CCR, & Orsi IA (2005) The effect of the use of 2% chlorhexidine gel in post-space preparation on carbon fiber post retention *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology* **99(3)** 372-377.

44. De Araújo DFG, Chaves LP, Bim O Jr, Pimentel Garcia FC, Ishikiriama SK, Honório HM, & Wang L (2014) Influence of 2% chlorhexidine digluconate on bond strength of a glass-fibre post luted with resin or glass-ionomer based cement *Journal of Dentistry* **42(6)** 735-741.

45. de Oliveira E, Cecchin D, Miyagaki DC, de Moura ALC, Disarz A, Souza MA, & Farina AP (2019) Effect of different protocols of eugenol removal on the bond strength between the fibre post and root dentin *Australian Endodontic Journal* **45(2)** 177-183.

46. Durski M, Metz M, Crim G, Hass S, Mazur R, & Vieira S (2018) Effect of chlorhexidine treatment prior to fiber post cementation on long-term resin cement bond strength *Operative Dentistry* **43(2)** E72-E80.

47. Akyuz Ekim SN & Erdemir A (2015) Effect of different irrigant activation protocols on push-out bond strength *Lasers in Medical Science* **30(8)** 2143-2149.

48. Elnaghy AM (2014) Effect of QMix irrigant on bond strength of glass fibre posts to root dentine *International Endodontic Journal* **47(3)** 280-289.

49. Fan F, Ibrahim M, Dai P, Mao Y, He B, Wu G, Ma J, & Huang S (2017) Effect of maleic acid on the bond strength of fibre posts to root dentine *European Journal of Oral Sciences* **125(5)** 396-402.

50. Faria-e-Silva AL, Menezes MS, Silva FP, dos Reis GR, & de Moraes RR (2013) Intraradiculardentin treatments and retention of fiber posts with selfadhesive resin cements *Brazilian Oral Research* **27(1)** 14-19.

51. Feng XY & Gao CZ (2016) Effects of pretreatment in post space on the bonding strength of self-adhesive resin cement to fiber posts *Chinese Journal of Tissue Engineering Research* **20(47)** 7083-7089.

52. Furuse AY, Cunha LF, Baratto SP, Leonardi DP, Haragushiku GA, & Gonzaga CC (2014) Bond strength of fiber-reinforced posts to deproteinized root canal dentin *Journal of Contemporary Dental Practice* **15(5)** 581-586.

53. Garcia LdaF, Naves LZ, Correr-Sobrinho L, Consani S, & Pires-De-Souza FdeC (2010) Bond strength of a self-adhesive resinous cement to root dentin irradiated with a 980-nm diode laser *Acta Odontologica Scandinavica* **68(3)** 171-179.

54. Garcia LdaF, Naves LZ, Farina AP, Walker CM, Consani S, & Pires-De-souza FdeC (2011) The effect of a 980 nm diode laser with different parameters of irradiation on the bond strength of fiberglass posts *General Dentistry* **59(1)** 31-37.

55. Garcia C, Ruales-Carrera E, Prates LH, & Volpato CA (2018) Effect of different irrigations on the bond strength of self-adhesive resin cement to root dentin *Journal of Clinical and Experimental Dentistry* **10(2)** e139-e145.

56. Gomes França FM, Vaneli RC, Conti CdeM, Basting RT, do Amaral FLB, & Turssi CP (2015) Effect of Chlorhexidine and ethanol application on long-term push-out bond strength of fiber posts to dentin *Journal of Contemporary Dental Practice* **16(7)** 547-553.

57. Gorus Z, Mese A, Yilmaz BD, & Adiguzel O (2018) Laser application to the root surface increases the bonding strength of surface-treated prefabricated glass-fiber posts in teeth with excessive substance loss *Medical Science Monitor* **24** 100-104.

58. Jain K, Beri L, Kunjir K, Borse N, Neekhara N, & Kadam A (2018) Comparative evaluation of the effect of 10% sodium ascorbate, 10% hesperidin, 1% riboflavin 5 phosphate, collagen cross-linkers, on the pushout bond strength of fiber postluted to radicular dentin: *In vitro* study *Journal of Conservative Dentistry* **21(1)** 95-99.

59. Kirmali O, Kustarci A, Kapdan A, & Er K (2015) Effects of dentin surface treatments including Er,Cr:YSGG laser irradiation with different intensities on the push-out bond strength of the glass fiber posts to root dentin *Acta Odontologica Scandinavica* **73(5)** 380-386.

60. Kul E, Yeter KY, Aladag LI, & Ayranci LB (2016) Effect of different post space irrigation procedures on the bond strength of

a fiber post attached with a self-adhesive resin cement *Journal of Prosthetic Dentistry* **115(5)** 601-605.

61. Lacerda AJF, Gullo MA, Xavier ACC, Pucci CR, Carvalho CAT, & Huhtala MFRL (2013) Influence of ultrasound and irrigant solutions on the bond strength of glass fiber posts to root canal dentine TT - Influência do ultrassom e de soluções irrigantes na resistência de união de pinos de fibra de vidro à dentina do canal radicular *Brazilian Dental Science* **16(1)** 53-58.

62. Leitune VCB, Collares FM, & Werner Samuel SM (2010) Influence of chlorhexidine application at longitudinal push-out bond strength of fiber posts *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology* **110(5)** e77-e81.

63. Lima LRC (2013) Avaliação da efetividade de cimentos resinosos auto-adesivos aplicados sob diferentes pré-tratamentos da dentina radicular na resistência adesiva de pinos de fibra de vidro TT - Evaluation of the effectiveness of self-adhesive resin cements applied under different pre-treatment of root dentin on the bond strength of fiber posts. Retrieved from http://repositorio.unesp.br/handle/11449/108401

64. Mao H, Chen Y, Yip KHK, & Smales RJ (2011) Effect of three radicular dentine treatments and two luting cements on the regional bond strength of quartz fibre posts *Clinical Oral Investigations* **15(6)** 869-878.

65. Martinho FC, Carvalho CAT, Oliveira LD, Farias De Lacerda AJ, Xavier ACC, Gullo Augusto M, Zanatta RF, & Pucci CR (2015). Comparison of different dentin pretreatment protocols on the bond strength of glass fiber post using self-etching adhesive. *Journal of Endodontics* **41(1)** 83-87.

66. Mathew S, Raju IR, Sreedev CP, Karthick K, Boopathi T, & Deepa NT (2017) Evaluation of push out bond strength of fiber post after treating the intra radicular post space with different post space treatment techniques: A randomized controlled in vitro trial *Journal of Pharmacy and Bioallied Sciences* **9(Supplement 1)** S197-S200.

67. Mohammadi N, Savadi Oskoee S, Abed Kahnamoui M, Bahari M, Kimyai S, & Rikhtegaran S (2013) Effect of Er,Cr: YSGG pretreatment on bond strength of fiber posts to root canal dentin using a self-adhesive resin cement *Lasers in Medical Science* **28(1)** 65-69.

68. Neelakantan P, Mohanraj R, Chua E, & Belli S (2014) Impact of conditioning regimens and time on adhesion of a fiber post to root dentin using two resin cements *Journal of Adhesion Science and Technology* **29(4)** 337-346.

69. Oral O, Kumbuloglu O, Lassila LVJ, User A, & Vallittu PK (2012) Bond strength of glass-fiber post to dentine after some treatment methods *Key Engineering Materials* **493-494** 90-95.

70. Parcina IA, Miletic I, Ionescu AC, Brambilla E, Gabric D, & Baraba A (2016) Influence of laser activated irrigation with erbium lasers on bond strength of inidividually formed fiber reinforced composite posts to root canal dentin *Acta Stomatologica Croatica* **50(4)** 321-328.

71. Ramos ATPR, Garcia Belizário L, Venção AC, Fagundes Jordão-Basso KC, de Souza Rastelli AN, de Andrade MF, & Kuga MC (2018) Effects of Photodynamic Therapy on the Adhesive Interface of Fiber Posts Cementation Protocols *Journal of Endodontics* **44(1)** 173-178.

72. Ramos ATPR, Belizário LG, Jordão-Basso KCF, Shinohara AL, & Kuga MC (2018) Effects of photodynamic therapy on the adhesive interface using two fiber posts cementation systems. *Photodiagnosis and Photodynamic Therapy* **24** 136-141.

73. dos Santos MCG, Amaral FLB, Turssi CP, Basting RT, & França FMG (2017) Long-term bond strength of a self-adhesive resin cement to intraradicular dentin pretreated with chlorhexidine and ethanol TT - Resistência de união ao longo do tempo de um cimento resinoso autoadesivo à dentina intrarradicular pré tratadas com clorexidina e etanol *Revista Odontologia da UNESP (Online)* **46(2)** 97-103.

74. Scotti N, Rota R, Scansetti M, Migliaretti G, Pasqualini D, & Berutti E (2012) Fiber post adhesion to radicular dentin: the use of acid etching prior to a one-step self-etching adhesive. *Quintessence International* **43(7)** 615-623.

75. Scotti N, Bergantin E, Tempesta R, Turco G, Breschi L, Farina E, Pasqualini D, & Berutti E (2016) Influence of dentin pretreatment with synthetic hydroxyapatite application on the bond strength of fiber posts luted with 10-methacryloyloxydecyl dihydrogen phosphate-containing luting systems *European Journal of Oral Sciences* **124(5)** 504-509.

76. Shafiei F, Yousefipour B, & Moahmmadi-Bassir M (2016) Effect of carbodiimide on bonding durability of adhesive-cemented fiber posts in root canals *Operative Dentistry* **41(4)** 432-440.

77. Shafiei F, Memarpour M, Vafamand N, & Mohammadi M (2017) Effect of antibacterial/adhesive approaches on bonding durability of fiber posts cemented with self-etch resin cement *Journal of Clinical and Experimental Dentistry* **9(9)** e1096-e1102.

78. Shafiei F, Mohammadparast P, & Jowkar Z (2018) Adhesion performance of a universal adhesive in the root canal: Effect of etch-and-rinse vs. self-etch mode. *PloS One* **13(4)** e0195367.

79. Silva LMda (2013) Influência da solução de clorexidina a 2% na resistência adesiva de pinos de fibra de vidro em raízes bovinas: acompanhamento imediato, 6 meses e 1 ano TT - 2% chlorhexidine influence on fiber posts bond strength to bovine roots: immediate, 6-month and 1-year-aging. Retrieved from http://www.teses.usp.br/teses/disponiveis/25/25148/tde-22112013-112342/pt-br.php

80. Simões TC, Luque-Martinez IV, Moraes RR, Sá ATG, Loguercio AD, & Moura SK (2016) Longevity of bonding of self-adhesive resin cement to dentin *Operative Dentistry* **41(3)** E64-E72.

81. Simões TC, Rubim MG, Carvalho RVde, Sá ATGde, Berger SB, Torres WAM, & Moura SK (2018) Effect of Polyacrylic Acid Conditioning on the Longevity of Bonding of Self - Adhesive Resin Cement to Dentin TT - Efeito do Condicionamento com Ácido Poliacrílico na Longevidade da Adesão de Cimento Resinoso Autoadesivo à Dentina *Journal of Health Sciences (Londrina)* **20(2)** 100-105.

82. Tuncdemir AR, Yildirim C, Ozcan E, & Polat S (2013) The effect of a diode laser and traditional irrigants on the bond strength of self-adhesive cement. *Journal of Advanced Prosthodontics* **5(4)** 457-463.

83. Uzun I, Keskin C, Özsu D, Güler B, & Aydemir H (2016) Push-out bond strength of oval versus circular fiber posts irradiated by erbium-doped yttrium aluminum garnet laser *Journal of Prosthetic Dentistry* **116(3)** 425-430.

84. Victorino KR, Kuga MC, Duarte MAH, Cavenago BC, Só MVR, & Pereira JR (2016) The effects of chlorhexidine and ethanol on push-out bond strength of fiber posts *Journal of Conservative Dentistry* **19(1)** 96-100.

85. Wang L, Pinto TA, Silva LM, Araújo DF, Martins LM, Hannas AR, Pedreira PA, Francisconi PA, & Honório HM (2013) Effect of 2% chlorhexidine digluconate on bond strength of a glass-fibre post to root dentine *International Endodontic Journal* **46(9)** 847-854.

86. Wu H, Hayashi M, Okamura K, Koytchev EV, Imazato S, Tanaka S, Tanka Y, Sano H, & Ebisu S (2009) Effects of light penetration and smear layer removal on adhesion of post-cores to root canal dentin by self-etching adhesives *Dental Materials* **25(12)** 1484-1492.

87. Xia Y & Cheng X (2013) Effect of different pretreatments to post-space on bonding strength of fiber posts luted with a self-adhesive resin cement *Journal Wuhan University of Technology, Materials Science Edition* **28(5)** 984-989.

88. Yaman BC, Irmak Ö, Orhan EO, Karabucak B, Ozer F, & Blatz MB (2017) The effect of canal cleansing protocols on cementation of a fiber post to saliva-contaminated root canals *Journal of Adhesion Science and Technology* **31(1)** 71-81.

89. Yu H-H, Zhang L, Xu S, Li F, Yu F, Liu Z-Y, Huang J, & Chen J-H (2017) Effects of Epigallocatechin-3-gallate (EGCG) on the bond strength of fiber posts to Sodium hypochlorite (NaOCl) treated intraradicular dentin *Scientific Reports* **7(1)** 4235.

90. Zhou J, Yang X, Chen L, Liu X, Ma L, & Tan J (2013) Pre-treatment of radicular dentin by self-etch primer containing chlorhexidine can improve fiber post bond durability *Dental Materials Journal* **32(2)** 248-255.

91. Zhu S, Liu C, Zheng Z, Yang L, & Gao X (2015) [Analysis of different endodontic sealers and strategies of root canal irrigation on the bond strength of fiber posts] *Hua Xi Kou Qiang Yi Xue Za Zhi* **33(3)** 311-314.

92. Šimundic Munitic M, Bago I, Glockner K, Kqiku L, Gabric D, & Anic I (2019) Effect of Different laser treatments on the bond strength of intracanal fiber posts cemented with a self-adhesive resin cement *Journal of Prosthodontics*. **28(1)** e290-e296.

93. Demiryürek EO, Külünk S, Yüksel G, Saraç D, & Bulucu B (2010) Effects of three canal sealers on bond strength of a fiber post *Journal of Endodontics* **36(3)** 497-501.

94. Scotti N, Scansetti M, Rota R, Breschi L, Mazzoni A, Pasqualini D, & Berutti E (2013) Active application of liquid etching agent improves adhesion of fibre posts to intrarradicular dentine *International Endodontic Journal* **46(11)** 1039-1045.

95. Tachibana A, Marques MM, Soler JMP, & Matos AB (2008) Erbium, chromium:yttrium scandium gallium garnet laser for caries removal: influence on bonding of a self-etching adhesive system *Lasers in Medical Science* **23(4)** 435-441.

96. Anic I, Segovic S, Katanec D, Prskalo K, & Najzar-Fleger D (1998) Scanning electron microscopic study of dentin lased with argon, CO2, and Nd:YAG laser.*Journal of Endodontics* **24(2)** 77-81.

97. Wang X, Sun Y, Kimura Y, Kinoshita J, Ishizaki NT, & Matsumoto K (2005) Effects of diode laser irradiation on smear layer removal from root canal walls and apical leakage after obturation *Photomedicine and Laser Surgery* **23(6)** 575-581.

98. Alfredo E, Souza-Gabriel AE, Silva SR, Sousa-Neto MD, Brugnera-Junior A, & Silva-Sousa YT (2009) Morphological alterations of radicular dentine pretreated with different irrigating solutions and irradiated with 980-nm diode laser *Microscopy Research and Technique* **72(1)** 22-27.

99. Altmann ASP, Leitune VCB, & Collares FM (2015) Influence of Eugenol-based sealers on push-out bond strength of fiber post luted with resin cement: Systematic Review and meta-analysis. *Journal of Endodontics* **41(9)** 1418-1423.

100. Caicedo R, Alongi DJ ,& Sarkar NK (2006) Treatment-dependent calcium diffusion from two sealers through radicular dentine *General Dentistry* **54(3)** 178-181.

101. Hagge MS, Wong RDM, & Lindemuth JS (2002) Effect of three root canal sealers on the retentive strength of endodontic posts luted with a resin cement *International Endodontic Journal* **35(4)** 372-378.

102. Hume WR (1988) Methods of assessment in vitro of restorative material cytotoxicity using an intact human dentine diffusion step *International Endodontic Journal* **21(2)** 85-88.

103. Bohrer TC, Fontana PE, Wandscher VF, Morari VHC, dos Santos SS, Valandro LF, & Kaizer OB (2018) Endodontic sealers affect the bond strength of fiber posts and the degree of conversion of two resin cements *Journal of Adhesive Dentistry* **20** 1-8.

104. Oliveira LV, Maia TS, Zacopé K, Menezes MS, Soares CJ, & Moura CCG (2018) Can intraradicularcleaning protocols increase the retention of fiberglass posts? A systematic review *Brazilian Oral Research* **15** 32-e16.

105. Boone KJ, Murchison DF, Schindler WG, & Walker WA (2001) Post retention: the effect of sequence of post-space preparation, cementation time, and different sealers *Journal of Endodontics* **27(12)** 768-771.

106. 106 Tsintsadze N, Garcia M, Grandini S, Goracci C, & Ferrari M (2015) Effect of Reciproc endodontic treatment with three different post space preparation instruments on fiber post retention *American Journal of Dentistry* **28(5)** 251-254.

107. Lipski M, Mrozek J, & Drozdik A (2010) Influence of water cooling on root surface temperature generated during post space preparation *Journal of Endodontics* **36(4)** 713-716.

108. Eriksson JH & Sundström F (1984) Temperature rise during root canal preparation - a possible cause of damage to tooth and periodontal tissue *Swedish Dental Journal* **8(5)** 217-223.

109. Rasimick BJ, Wan J, Musikant BL, & Deutsch AS (2010) A review of failure modes in teeth restored with adhesively luted endodontic dowels *Journal of Prosthodontics* **19(8)** 639-646.

110. Soares CJ, Pereira JC, Valdivia ADCM, Novais VR, & Meneses MS (2012) Influence of resin cement and post configuration on bond strength to root dentine *International Endodontic Journal* **45(2)** 136-145.

111. Taira Y, Sakai M, Yang L, Sawase T, & Atsuta M (2007) Bond strength between luting materials and fiber-reinforced resin composite for indirect restorations *Dental Materials* **26(5)** 628-634.

112. Carrilho MRO, Carvalho RM, Tay FR, Yiu C, & Pashley DH (2005) Durability of resin-dentin bonds related to water and oil storage *American Journal of Dentistry* **18(6)** 315-319.

113. Collares FM, Portella FF, Rodrigues SB, Celeste RK, Leitune VCB, & Samuel SMW (2016) The influence of methodological variables on the push-out resistance to dislodgement of root filling materials: A meta-regression analysis *International Endodontic Journal* **49(9)** 836-849.

114. Goracci C, Raffaelli O, Monticelli F, Balleri B, Bertelli E, & Ferrari M (2005) The adhesion between prefabricated FRC posts and composite resin cores: Microtensile bond strength with and without post-silanization *Dental Materials* **21(5)** 437-444.

115. Onay EO, Korkmaz Y, & Kiremitci A (2010) Effect of adhesive system type and root region on the push-out bond strength of glass-fibre posts to radicular dentine *International Endodontic Journal* **43(4)** 259-268.

116. Skupien JA, Sarkis-Onofre R, Cenci MS, Moraes RR, & Pereira-Cenci T (2015) A systematic review of factors associated with the retention of glass fiber posts *Brazilian Oral Research* **29**S1806-83242015000100401.