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Thaís Camponogara Bohrer

EFEITO DOS CIMENTOS ENDODÔNTICOS E DA LIMPEZA DO ESPAÇO PARA O PINO NA RESISTÊNCIA DE UNIÃO DE DENTES TRATADOS ENDODONTICAMENTE

Santa Maria, RS
2021

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Tese apresentada ao Curso de Doutorado do Programa de Pós-Graduação em Ciências Odontológicas, Área de Concentração em Odontologia, ênfase em Prótese Dentária, da Universidade Federal de Santa Maria (UFSM, RS), como requisito parcial para obtenção do grau de **Doutora em Ciências Odontológicas**.

Orientador: Prof. Dr. Osvaldo Bazzan Kaizer

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Osvaldo Bazzan Kaizer, Dr. (UFSM)
(Presidente da Banca/Orientador)

____
Carlos Alexandre Souza Bier, Dr. (UFSM)

____
Jovito Adiel Skupien, Dr. (UFN)

Sara Fraga
____
Sara Fraga, Dra. (UFRGS)

Vinícius Felipe Wandscher
____
Vinícius Felipe Wandscher, Dr. (CNEC)

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RESUMO

EFEITO DOS CIMENTOS ENDODÔNTICOS E DA LIMPEZA DO ESPAÇO PARA O PINO NA RESISTÊNCIA DE UNIÃO DE DENTES TRATADOS ENDODONTICAMENTE

AUTORA: Thaís Camponogara Bohrer
ORIENTADOR: Osvaldo Bazzan Kaizer

No presente trabalho, dividido em três partes, foi avaliado a influência dos cimentos endodônticos e dos diferentes tratamentos para limpeza do espaço para o pino na resistência de união de pinos intrarradiculares à dentina radicular. O primeiro estudo teve o objetivo de revisar sistematicamente a literatura avaliando a influência dos cimentos endodônticos na resistência de união dos pinos à dentina. Uma busca foi realizada nas bases de dados PubMed/MEDLINE, Lilacs e Scopus sem limite de linguagem ou de ano de publicação. Um total de 65 estudos entre 891 estudos potencialmente elegíveis foram selecionados para leitura, sendo selecionado 27 estudos para inclusão na revisão. A meta-análise verificou que há influência significativa do cimento endodôntico na resistência de união do pino à dentina radicular. A segunda parte do presente trabalho teve como objetivo revisar sistematicamente a literatura para avaliar a influência do tratamento para limpeza do espaço confeccionado para o pino na resistência de união de pinos intrarradiculares à dentina radicular. Da mesma forma que na primeira parte, foi realizada uma busca nas bases de dados citadas acima, sem limites de linguagem ou de ano de publicação. De 2832 estudos potencialmente elegíveis, 453 foram selecionados para a leitura e 75 estudos foram incluídos na revisão sistemática. Na meta-análise geral, o tratamento do espaço para o pino aumentou significativamente a resistência de união do pino intrarradicular à dentina. Neste estudo, os melhores tratamentos foram, respectivamente, álcool, NaOCl + EDTA, NaOCl + EDTA+ ultrassom, laser de Er: YAG, laser de Nd: YAG e laser de diodo. A terceira parte avaliou a influência dos tratamentos de limpeza do espaço para o pino de fibra de vidro, utilizando três tipos de cimentos endodônticos para obturação do canal radicular, na resistência de união de pinos à dentina e na limpeza do espaço para o pino. Para a realização do estudo, 240 dentes bovinos foram limpos e cortados em 16 mm e o tratamento endodôntico foi realizado, obturando os canais com três cimentos endodonticos (à base de resina epóxica, à base de óxido de zinco e eugenol e cimento biocerâmico). Após, os dentes foram armazenados por 24 horas ou por 6 meses em estufa a 37°C. Feito isso, os preparos para o pino foram confeccionados e neles aplicados diferentes tratamentos de limpeza (água destilada, NaOCl + EDTA, álcool a 99% e laser de diodo). Logo, os espécimes foram cortados em *slices* com auxílio de uma máquina de corte e, após, submetidos ao teste de *push-out*. Ainda, doze dentes foram tratados endodonticamente e obturados com os diferentes cimentos endodônticos estudados, após preparado o espaço para o pino, os diferentes tratamentos de limpeza foram aplicados, os espécimes foram cortados no longo do eixo do dente e submetidos à análise no microscópio eletrônico de varredura. Com isso, verificamos que o tratamento NaOCl + EDTA obteve os melhores resultados de resistência de união do pino à dentina e foi observada uma adequada limpeza do espaço do pino após a utilização desse tratamento.

Palavras-chave: Cimentos endodônticos. Espaço do pino. Revisão. Resistência de união.

ABSTRACT

EFFECT OF ENDODONTIC SEALERS AND CLEANING THE POST-SPACE ON THE BOND STRENGTH OF ENDODONTICALLY TREATED TEETH

AUTHOR: Thaís Camponogara Bohrer
ADVISOR: Osvaldo Bazzan Kaizer

In the present study, divided into three parts, the influence of endodontic sealers and post-space treatment differents for cleaning the post-space on the post-dentin bond strength was evaluated. The first study aimed to systematically review the literature evaluating the influence of endodontic sealers on the post-dentin bond strength. A search was performed in the PubMed/MEDLINE, Lilacs, and Scopus databases without language limit or year of publication. A total of 65 studies out of 891 potentially eligible studies were selected for reading, thus 27 studies were included in the review. The meta-analysis found that there is a significant influence of the endodontic sealer on the post-dentin bond strength. Therefore, the second part of the present study aimed to systematically review the literature to evaluate the influence of the post-space treatment on the bond strength of intraradicular posts to root dentin. Just like in the first part, a search was performed in the databases mentioned above, with no limits on language or year of publication. Of 2832 potentially eligible studies, 453 were selected for reading, and 75 were included in the systematic review. In the overall meta-analysis, the post-space treatment significantly increased the bond strength of the intraradicular post to dentin. In this study, the best treatments were alcohol, NaOCl + EDTA, NaOCl + EDTA+ ultrasound, Er:YAG laser, Nd:YAG laser, and diode laser. The third part evaluated the influence of post-space cleaning treatments, using three types of endodontic sealers for root canal filling, on the bond strength of fiber posts to dentin, and cleaning the post-space. To performed the study, 240 bovine teeth were cleaned and cut in 16 mm and the endodontic treatment was carried out, filling the canals with three endodontic sealers (based on epoxy resin, based on zinc oxide and eugenol, and bioceramic cement). Afterward, the teeth were stored for 24 hours or 6 months in an oven at 37°C. After that, the preparations for the post were made and different cleaning treatments were applied (distilled water, NaOCl + EDTA, 99% alcohol, and diode laser). The specimens were cut into slices with the aid of a cutting machine and, after, submitted to the push-out test. Also, twelve teeth were endodontically treated and filled with the different endodontic sealers studied. After the post-space was prepared, the different cleanings treatments were applied and the specimens were cut along the tooth axis and analyzed under the scanning electron microscope. Thus, we verified that the NaOCl + EDTA treatment obtained higher results for post-dentin bond strength, and we observed adequate cleanliness of the post space after using this treatment.

Keywords: Bond strength. Endodontic sealer. Post-space. Review.

Sumário

1 INTRODUÇÃO

Fraturas ou lesões de cárie têm sido relatadas na literatura como as principais causas de perdas extensivas da porção coronária da estrutura dentária (DEMIRYÜREK et al., 2010; DIMITROULI et al., 2011). Nesta situação, para o restabelecimento da função, estética e adequação biológica do remanescente dentário, a necessidade da realização de tratamentos endodônticos e a utilização de pinos intrarradiculares para a retenção da restauração são fundamentais (DEMIRYÜREK et al., 2010; DIMITROULI et al., 2011; MANICARDI et al., 2011).

Vários fatores influenciam na retenção dos pinos intrarradiculares, entre eles a própria anatomia radicular, que promove um elevado fator-C e dificulta a execução correta dos passos clínicos para a cimentação de um retentor, como a lavagem e a secagem do conduto radicular (DIMITROULI et al., 2011). Há estudos laboratoriais relatando que os cimentos endodônticos utilizados na obturação do canal radicular podem influenciar na resistência de união de retentores intrarradiculares cimentados adesivamente à dentina (ALEISA et al., 2012; BOHRER et al., 2018; ÖZCAN et al., 2013).

Apesar de haver vários estudos laboratoriais analisando diferentes cimentos endodônticos na literatura, há, ainda, muitas controvérsias sobre o assunto. Além disso, existe somente uma revisão sistemática na literatura avaliando essa influência (ALTMANN et al., 2015), a qual avalia um único tipo de cimento endodôntico presente no mercado. Assim, diante da diversidade de cimentos endodônticos presente no mercado e podendo afetar a resistência de união dos pinos intrarradiculares cimentados adesivamente à dentina, mostra-se necessário uma revisão sistemática com meta-análise que aborde os diferentes tipos de cimentos endodônticos.

O cimento à base de óxido de zinco e eugenol interfere na adesão do pino à dentina devido ao fato de que o eugenol contêm radicais livres que podem interferir na polimerização do cimento resinoso utilizado na cimentação de pinos intrarradiculares, tendo, assim, um efeito negativo na resistência de união (BOHRER et al., 2018; ÖZCAN et al., 2013). Apesar disso, ainda é bastante utilizado pelos endodontistas devido ao seu longo histórico de sucesso clínico (ALEISA et al., 2012).

Além disso, o cimento biocerâmico, composto principalmente de silicato de cálcio e fosfato de cálcio, tem sido utilizado com bastante frequência na endodontia devido a vantagens como a sua biocompatibilidade e excelente estabilidade dimensional (SHOKOUHINEJAD;

HOSEINI; GORJESTANI, 2013). Porém, ainda há poucas informações a respeito de sua interferência na adesão do pino intrarradicular.

Por outro lado, os cimentos à base de resina epóxi são considerados pela literatura como padrão ouro, devido ao fato de não interferir na adesão entre o pino e a dentina (ALTMANN et al., 2015). Isso se deve à similaridade de sua composição com a do cimento resinoso utilizado para a cimentação do pino (SONMEZ; SONMEZ; ALMAZ, 2013).

Estudos prévios têm sugerido que a eficácia da adesão entre o cimento resinoso e a dentina radicular depende da remoção total da camada de *smear layer* formada após a preparação do espaço para o pino (VICHI; GRANDINI; FERRARI, 2002). Recentemente, vários tratamentos têm sido testados no espaço confeccionado para o pino para a remoção eficaz da camada de *smear layer* formada após o preparo do espaço para o retentor intrarradicular (GUERISOLI et al., 2002; KUL et al., 2016).

Dentre os tratamentos avaliados, são aplicadas soluções utilizadas separadamente ou em associação com outras, como por exemplo, o hipoclorito de sódio (NaOCl), ácido etilenodiaminotetracético (EDTA), clorexidina (CHX), etanol, entre outras (ARI; ERDEMIR; BELLI, 2004; GU; MAO; KERN, 2009; HAAPASALO et al., 2010; ZHANG et al., 2008). A utilização de ultrassom também tem sido testada com a mesma finalidade (PAIVA et al., 2013).

Recentemente, tem sido avaliada também a aplicação de lasers no interior do espaço para o pino. Vários tipos de lasers têm sido estudados, como os lasers de Nd:YAG, Er:YAG, Er,Cr:YSGG e de diodo, com diferentes protocolos de aplicações (AKYUZ EKIM; ERDEMIR, 2015).

Entretanto, diversos tratamentos e diferentes protocolos têm sido testados na literatura no espaço para pino (ARI; ERDEMIR; BELLI, 2004; AKYUZ EKIM; ERDEMIR, 2015; GU; MAO; KERN, 2009; HAAPASALO et al., 2010; KUL et al., 2016; PAIVA et al., 2013; ZHANG et al., 2008). Porém, ainda não há um consenso se o tratamento aplicado no espaço para o pino beneficia a adesão do pino intrarradicular à dentina radicular e qual o melhor tratamento a ser aplicado.

Portanto, considerando o contexto exposto acima, se justifica a realização do presente estudo. O presente trabalho foi dividido em três partes. A primeira delas, em formato de artigo, intitulada **“Cimentos endodônticos afetam a resistência de união do pino à dentina radicular: revisão sistemática e meta-análise”**, teve como objetivo avaliar o efeito de diferentes cimentos endodônticos na resistência de união do pino à dentina radicular. A partir do resultado do primeiro artigo, um segundo artigo foi realizado, intitulado: **“Tratamento do espaço para o pino influencia na resistência de união em dentes tratados**

endodonticamente: revisão sistemática e meta-análise”, o qual visou revisar sistematicamente a literatura para analisar a influência do tratamento do espaço para o pino na resistência de união dos retentores intrarradiculares. A terceira parte do estudo, que teve origem a partir dos resultados obtidos no segundo artigo, foi intitulada **“Efeito de diferentes tratamentos do espaço para o pino na resistência de união de pinos intrarradiculares à dentina”**, teve como objetivo investigar a influência de três tratamentos do espaço para o pino elencados no segundo artigo na resistência de união dos pinos de fibra e na limpeza do espaço para o pino. Ainda, avaliar a influência desses tratamentos quando diferentes cimentos endodônticos são utilizados para a obturação do canal radicular.

2 ARTIGO 1 - ENDODONTIC SEALERS AFFECT THE POST-DENTIN BOND STRENGHT: A SYSTEMATIC REVIEW AND META-ANALYSIS OF IN VITRO STUDIES

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ENDODONTIC SEALERS AFFECT THE POST-DENTIN BOND STRENGTH: A SYSTEMATIC REVIEW AND META-ANALYSIS OF IN VITRO STUDIES

T. C. Bohrer; P. E. Fontana; O. B. Kaizer.

Thaís Camponogara Bohrer
DDS, MSD, PhD student - Restorative Dentistry Department, Federal University of Santa Maria, Santa Maria, Brazil.
E-mail: thaiscbohrer@hotmail.com
Phone: +55.55.996155357

Patrícia Eliana Fontana
DDS, MSD, - Restorative Dentistry Department, Federal University of Santa Maria, Santa Maria, Brazil.
E-mail: patricia_fontana_@hotmail.com
Phone: +55.54. 92082321

Osvaldo Bazzan Kaizer
DDS, MSD, PhD - Adjunct Professor, Restorative Dentistry Department, Federal University of Santa Maria, Santa Maria, Brazil.
E-mail: obekaizer@terra.com.br
Phone: +55 55 99973003

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Corresponding author:
Thaís Camponogara Bohrer
Federal University of Santa Maria, Santa Maria, Brazil.
Department of Restorative Dentistry
Faculty of Odontology,
Floriano Peixoto Street, 1184, 97015-372, Santa Maria, Brazil.
Phone: +55-55-996155357
E-mail: thaiscbohrer@hotmail.com

ABSTRACT

ENDODONTIC SEALER AFFECT THE POST-DENTIN BOND STRENGTH: A SYSTEMATIC REVIEW AND META-ANALYSIS OF IN VITRO STUDIES

Purpose: This systematic review aimed to evaluate the effect of endodontic sealers on the post-dentin bond strength and to analyze the influence of different variables such as the type of endodontic sealer, resin cement, post-time waiting for post luting, post-time waiting for bond strength test, and different thirds of teeth on the post-dentin bond strength.
Methods: A search in the PubMed/MEDLINE, Lilacs, and Scopus databases was performed and in vitro studies up to June 2020 were included. The search had no limits on publication year or language. Two reviewers independently selected the studies based on the inclusion and exclusion criteria. Thus, the same reviewers extracted the data and evaluated the risk of bias of all studies included. A random-effect model was used for pairwise meta-analyses (control (no sealer, AH Plus sealer, or resin-based sealer) vs. endodontic sealers groups) at a significance level of $p<0.05$.
Results: A total of 65 from 891 potentially eligible studies were selected for full-text analysis, and 27 studies were included in this review. This systematic review proves that endodontic sealers negatively influence the post-dentin bond strength ($p<0.00001$). This influence persists regardless of different variables studied. Most of the included studies were considered to have a high risk of bias.
Conclusion: The endodontic sealer used for filling the root canal in the endodontic treatment negatively affects the bond strength of intrarradicular posts, independently of the type of endodontic sealer used.

Keywords: Endodontic filing material, fiber post, review, push-out, endodontics.

INTRODUCTION

The loss of the coronary portion negatively affects the dental structure functionality, which is mainly due to caries and fractures caused by trauma (1,2). It is usually necessary to perform endodontic treatment and cement an intra-radicular retainer to restore the function of this tooth structure (1,3,4).

Fiber posts are widely used among intra-radicular retainers in the dental clinic due to advantages such as an elasticity module similar of dentin, thereby favoring stress distribution inside the root compared to the other types of post, and favorable aesthetics (5-7). However, the adhesion between the post, dentin, and cement is crucial for the restoration success (8).

Several factors influence the retention of the fiber posts; for example, the anatomy of the root canal, the materials, and the restoration techniques used (2). There are several laboratory studies which indicate that the sealers used in the endodontic filling can influence the post-dentin bond strength (8-15).

One of the main types of endodontic sealers studied is a eugenol-based sealer. These sealers can negatively interfere with the polymerization degree of resin cement due to the presence of free radicals in the phenolic component of the eugenol molecule which may decrease the conversion of C = C monomeric bonds into C-C polymeric bonds by reacting with resin cement components, thereby the physical and mechanical properties of the polymer formed may be affected, which in this case is the resin cement (16,17).

Calcium hydroxide-based sealer seems to affect the post-dentin bond strength. This is due to the presence of isobutyl salicylate in its composition, which reacts with calcium forming a physical-chemical barrier, thus influencing the post adhesion (1,18). On the other hand, the epoxy resin-based sealer is considered the gold standard among endodontic sealers because it does not interfere with post adhesion to the root canal (19).

In addition, calcium silicate-based sealers are composed of bioceramic sealers and MTA (aggregated trioxide mineral) sealers. The bioceramic sealers present in its composition (mainly of calcium silicate and calcium phosphate), have been frequently used in endodontics due to advantages such as its biocompatibility and excellent dimensional stability (20). MTA-based sealers were introduced to the market due to their biological properties and for promoting an adequate seal to the root canal. [21] However, they seem to have a negative influence on post retention (15,22,23).

Through a systematic review with a meta-analysis, Altman et al. (19) demonstrated that eugenol-based sealers negatively affect the post-dentin bond strength. However, only one type of sealer was evaluated in this study, and only immediate bond strength was considered. Furthermore, few studies were included in the meta-analysis. However, there are other types of sealers which can influence the post-dentin bond strength, as previously mentioned, but there are no systematic reviews with meta-analyses in the literature which evaluate different endodontic sealers.

In addition, another aspect which has been the purpose of studies is the influence of the time elapsed between filling the root canal to the cementation of the intra-radicular post on the resistance of this retainer (3,10, 24, 25, 26). Although there are many studies on this topic, there are many controversies.

Thus, the objective of this study is to systematically review the literature and check if there is an influence of the endodontic sealers on the post-dentin bond strength and to analyze the influence of different variables (type of endodontic sealer, resin cement, post-time waiting for post luting, post-time waiting for bond strength test, and different thirds of teeth) on the post-dentin bond strength. The null hyphotesis is that no have influence of the endodontic sealers on the post-dentin bond strength.

MATERIALS AND METHODS

This systematic review was conducted according to the Cochrane Handbook and reported to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement (PRISMA) (27,28).

This study was performed by compiling all available in vitro studies to answer the following question: Is there an influence of endodontic sealers on the post-dentin bond strength in endodontically treated teeth?

Therefore, the population, intervention, comparison, and outcomes (the “PICOs”) for this review included: endodontically treated teeth (population); endodontic sealers (intervention); no sealer, or AH Plus, or resin-based sealer (comparison) and bond strength (outcome).

Literature strategy

The PubMed/MEDLINE, Lilacs, and Scopus databases were searched to identify relevant studies up to June 2020 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: ((((((((((((((((((((Nonvital Tooth) OR Tooth, Devitalized) OR Devitalized Tooth) OR Tooth, Pulpless) OR Pulpless Tooth) OR Teeth, Pulpless) OR Pulpless Teeth) OR Teeth, Devitalized) OR Devitalized Teeth) OR Teeth, Nonvital) OR Nonvital Teeth) OR Teeth, Endodontically-Treated) OR Endodontically-Treated Teeth) OR Teeth, Endodontically Treated) OR Tooth, Endodontically-Treated) OR Endodontically-Treated Tooth) OR Tooth, Endodontically Treated) OR root canal) OR endodontic) OR dentin)) AND (((((((((((((((((((((Endodontic sealer) OR sealer) OR calcium hydroxide-containing sealer) OR zinc oxide-eugenol sealer) OR Eugenol-based sealers) OR (zinc oxide and eugenol-based sealers)) OR MTA-based endodontic sealer) OR calcium silicate-based sealer) OR bioceramic endodontic sealer) OR Sealer 26) OR Bismuth) OR Calcium Hydroxide) OR N-Rickert sealer) OR Root Canal Filling Materials) OR EZ-Fill epoxy resin) OR EZ-Fill) OR Endoflas F.S.) OR Barium Sulfate) OR Drug Combinations) OR Hydrocarbons, Iodinated) OR Zinc Oxide-Eugenol Cement)) AND (((((((Strength, Tensile) OR Strengths, Tensile) OR Tensile Strengths) OR Dislocation) OR Push-out) OR Push out) OR bond strength). All studies were then imported into Mendeley software (Elsevier Inc, New York, United States) to remove duplicates.

Study selection

Two reviewers (T.B and P.F) independently assessed the titles and abstracts of studies which were included if the following inclusion criteria were fulfilled: (1) studies which evaluated the influence of endodontic sealers, include more than one sealer; (2) studies which evaluated post-dentin bond strength; (3) in vitro studies.

The final decision about the study selection was made after a full-text reading of the previously selected studies according to the following exclusion criteria: (1) studies which did not present a control group (no sealer, Ah Plus or resin-based sealer); (2) studies which did not provide bond strength values as mean and standard deviation in megapascals (MPa); (3) studies which did not present immediate bond strength data. Data was requested to the authors by e-mail (at least twice) if any were not described or were unclear in the evaluated study, and the study was excluded if they did not reply. Reference lists of all included studies were also manually checked in order to retrieve all relevant papers, but no studies were included after this analysis.

Disagreements between the reviewers were resolved by consensus or arbitration by an independent review (OBK). The inter-examiner agreement regarding the inclusion and exclusion criteria was excellent (kappa coefficient = 0.97 and 1).

Data extraction

Data extraction was independently performed by two researchers using standardized extraction sheets. The extracted information included the publication details (title, authors, year, country and language), study methodology (sample size, type of tooth, endodontic sealer used, post-time waiting for post luting, post-space treatment used, instruments used for post-space preparation, type of post used, post treatment, 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 (29,30): randomization of the teeth, sample size calculation, materials used according to the manufacturer's instructions, root canals 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 the operator of 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 which 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 (endodontic sealer) and control (no sealer, or AH Plus, or resin-based sealer). 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 endodontic sealer with the control group (no sealer, or AH Plus, or resin-based sealer). For studies which evaluated more than one the type of endodontic sealer, post-time waiting for post luting, type of cement, thirds of the root and test time, one bond strength mean of each group (experimental and control) was calculated using a formula according to the Cochrane Statistical Guidelines (27).

Subgroup analyses by type of endodontic sealer (comparing to control, no sealer, and AH Plus sealer), post-time waiting for post luting, type of resin cement and thirds of the root canal were performed to assess whether these variables modified the influence of endodontic sealers on the post-dentin bond strength.

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

RESULTS

Search and Selection

The study selection are presented in the flowchart (Figure 1). A total of 825 studies from 891 potentially eligible studies were excluded after reviewing the titles and abstracts, mainly because the studies did not evaluate post-dentin bond strength. Thus, 27 studies from 65 screened for full-text analysis were included in the systematic review (1,2,3,4,10,14,15,21,22,26,31-47). The main reason for exclusion was that studies did not present a control group.

Descriptive Analysis

All studies were published between 2006 and 2020, with the majority of studies being performed in Brazil (n=14) and Turkey (n=4) (Table 1). Among the included studies, 25 studies were published in English, 1 study in Portuguese and 1 in Chinese. Regarding type of teeth used, 22 studies used human teeth and 5 used bovine teeth.

In total, 18 brand names of endodontic sealers were used with six different compositions, including: resin-based sealers (n=6), eugenol-based sealers (n=5), calcium hydroxide-based (n=2), bioceramic sealer (n=3), MTA-based sealer (n=1), and silicone-based sealer (n=1).

There were seven different times regarding the post-time waiting for post luting in the included studies, with the time 7 days being the most used (n=17). The others times were: immediate (n=4), 24 hours (n=5), 48 hours (n=2), 2 weeks (n=3), 15 days (n=1), and 6 months (n=1). One study did not provide information about the post-time waiting for post luting (15).

Six different post-space treatments were used by the included studies. Most of the studies used water or saline solution for post-space treatment (n=14). Five studies did not present information about the post-space treatments.

A total of 16 combinations of instruments used for post space preparation were presented in the included studies. The most used was Peeso reamer + post system drill (n=6). One study did not present any information regarding the instruments (2).

Most of the included studies used fiber posts (n=25), two studies used fiber posts relined with composite resin, and one study used ceramic post. Seven different post treatments were described by the studies, with the most used being alcohol + silane (n=7) and ten studies did not present this information.

There were 15 brand names of resin cement used by the included studies, with four being self-adhesive resin cement and eleven were conventional resin cement. The most used resin cement was RelyX Unicem (3M ESPE) (n=6).

The most frequently implemented storage time before the tests was 24 hours (n=14), but three studies did not present this information. Two types of bond strength tests were used by the included studies: push-out test (n=25) and micropush-out test (n=2).

Meta-Analyses

Endodontic sealers affect the post-dentin bond strength, with a significant difference found between the control (no sealer, AH Plus, or resin-based sealer) and experimental group ($p< 0.00001$) (Figure 2).

In analyzing different types of sealers, only silicone-based sealers did not present a difference in the post-dentin bond strength compared to the control group or no sealer group (Figure 3). In comparing different types of endodontic sealers to the AH Plus sealer, only the eugenol-based sealers had lower post-dentin bond strength values (Figure 3). Other sealers did not present differences compared to the AH Plus sealer.

The resin cement, post-time waiting for post luting and for the test, and different thirds of teeth did not affect the results of this review (Figure 4). Even when separated by the factors, the endodontic sealer continued to affect the post bonding to dentin.

High heterogeneity was found in most studies in both the overall analyzes and in analyzes of different factors (I^2>50%).

Risk of Bias

Most of the included studies were scored as having a high risk of bias (n=18), eight studies scored medium risk of bias, and one study had a low risk of bias. The items which were not described by the included studies were: blinding the operator of the test machine (96.30%) and the sample size calculation (92.59%) (Table 2).

DISCUSSION

This systematic review found that endodontic sealers significantly affect the post-dentin bond strength. The overall analysis showed that endodontic sealer have negative influence on the post-dentin bond strength values compared to the control group (Figure 2). Therefore, the null hypothesis was rejected considering the meta-analysis data.

Gutta-percha and endodontic sealer are used in endodontic treatment for filling the root canal (48). The sealers aid in root canal filling, seal the canal system, and provide good adaptation to the root canal (49). Obturation forces are applied in the canal during the root canal filling, causing sealer to penetrate into the dentinal tubules, making removal of the endodontic sealer more difficult (3). The literature showed that eugenol-based sealers can penetrate up to 100 μm of dentinal tubules, and epoxy resin-based sealers can penetrate 1337 μm (50,51).

Post-space preparation is a critical step for post retention, and the literature revealed that cleaned root dentin was almost never achieved after post-space preparation of endodontically treated teeth (1,52,53). The instruments used for post-space preparation, in addition to not removing all the endodontic sealer which penetrates into the dentine tubules, creates a new smear layer with endodontic sealer and gutta-percha remnants (1,53). This new smear layer is a physiochemical barrier between the cement used for luting post and dentin, independently of the type of endodontic sealer used in filling the root canal (2). This is one of the ways that the endodontic sealer influences the post-dentin bond strength.

Regarding the endodontic sealer type, the control group (no sealer, AH Plus, or resin-based sealer) or no sealer (Figure 3) is better than any other endodontic sealer that was included in this review, except for silicone-based sealers. This reinforces the theory described above that the endodontic sealer becomes a barrier between cement and dentin, impairing retention of the dentin post. However, we must consider that there are only 3 studies which used silicone-based sealer.

Moreover, in addition to acting as a barrier, eugenol-based sealer affects the conversion degree of resin cement used in the luting post (10). The free radical of the eugenol molecule interacts with resin cement monomers, thereby inhibiting the resin polymerization to begin, or accelerating the finishing of polymerization (19,52).

The calcium hydroxide-based sealer releases calcium via the sealer dissolving, as the isobutyl salicylate present in the composition reacts with the released calcium, thereby creating a barrier which can affect the post- dentin bond strength (55). Furthermore, the removal of this sealer is difficult and sealer residues after post-space preparation can interfere in post retention (56,57).

Bioceramic sealer has good adhesion between dentin and filling material because it forms hydroxyapatite during its setting process (58). Thus, it can present more sealer residues in dentinal tubules, as demonstrated by Otra et al. (59). The bioceramic sealer has nanoparticles which can penetrate deeper into the dentinal tubules, which in turn can contribute to the presence of more sealer residues in the root canal after post-space preparation compared with other types of sealers (60). Furthermore, the bioceramic sealer can form intratubular precipitation rich in calcium and phosphate which can hinder forming a hybrid layer between cement and dentin (61).

MTA-based sealers release calcium creating an alkaline environment, which helps mineralize hard tissues and have antimicrobial properties (62). Calcium and hydroxyl ions are released in the setting reaction of MTA-based sealers, formatting residual apatite into the root canal (63). This precipitation acts like a barrier between resin cement and dentin, decreasing the post-dentin bond strength (64).

The silicone-based sealers in this review are represented by GuttaFlow. GuttaFlow is a compound made by a homogenous mixture of power gutta-percha, poly-dimethylsiloxane, silicon, nanosilver particles, and an activator (65). According to the literature, filling with this sealer presents voids and increases microleakage (66). This can be explained due to the fact that the penetration in the dentinal tubules is less than other sealers, and removing this sealer from the root canal would be easier (67,68). This can be further explained because this sealer did not present any difference from the control group or any other sealer group in this review (Figure 3). However, there are 3 studies included in this review which used GuttaFlow for filling the root canal.

Despite being compatible with dentin (41), the resin-based sealers affect the bond strength of resin cement to dentin compared to no sealer (Figure 3). Paschal et al. (69) showed that the post bond strength is lower when the root canal is filled, independent of the type of endodontic sealer used. Another explanation is that the orifices of dentinal tubules in the no sealer group provides maximum penetration of the resin cement (21).

Despite the AH Plus sealer having a similar composition to the resin cement due to the presence of epoxy resin compared to the other sealers (70), only eugenol-based sealer had lower post-dentin bond strength values (Figure 3). It seems like the characteristic of eugenol-based sealers affects the conversion degree of cement used for luting post worse than the other characteristics mentioned above in the other studied sealers. Thus, there is no difference between the use of AH Plus and other sealers for filling root canals (except for the eugenol-based sealer) in relation to the quality of intrarradicular post adhesion.

In analyzing the factors which can alter the results of this review, the endodontic sealers affected the post-dentin bond strength in all cases (Figure 4). Regardless of using conventional or self-adhesive cement for the luting post, the post-dentin bond strength is affected by the endodontic sealer.

Using resin cement is a more sensitive technique compared to other types of cement present on the market (3). Self-adhesive resin cement was recently introduced and does not require pretreatment in the root canal, making the technique easier and simpler (16, 71). The bond mechanism is based on chemical adhesion and micromechanical retention, which can be affected by endodontic sealer (22, 72, 73). In the conventional cement, the monomer is plugged to collagen dentin fibers to form the hybrid layer, which is responsible for the post bond strength (74). However, when endodontic sealer is used for filling, the sealer residues prevent the resin cement coming into contact with collagen fibers, decreasing the post retention (36, 46).

Few of the studies included in this review analyzed post retention in an aged situation for post-space preparation or for post luting. When the post-space preparation is immediate, the paper points and microbrushes may be contaminated by unset sealer, which can affect the post retention (75, 76). On the other hand, when the post-space preparation is aged, the sealer has more time to penetrate the dentinal tubules and affect the post-dentin bond strength (77, 78). There is better simulation of clinical conditions when post luting is performed late, with it always being recommended when possible. Even in these conditions, the endodontic sealer negatively affected the post retention (79), therefore, there is a need to apply post-space treatments that reduce or eliminate this influence.

There are differences between the dentinal thirds, such as high cavity configuration factor, quantity, orientation, and volume of the dentinal tubules decreasing as the apical third approaches (80). Despite this, the endodontic sealer affects the post-dentin retention in all thirds (Figure 4).

High heterogeneity was obtained in most analyzes of this systematic review, which was already expected due to the fact that it is a systematic review with meta-analysis of laboratory studies (29,30,81). This is due to the fact that there are differences between the methodologies of the studies and also to the fact that the majority of the studies obtained a high risk of bias classification, as already described above.

The limitation of this systematic review is that it is only constituted by in vitro studies. Despite the limited interpretation of the study’s findings, the results can be considered in performing clinical procedures. Also, we must consider that there are a large number of variables that can influence the results, due to this fact that subgroup analyzes were performed.

In conclusion, this systematic review of laboratory studies showed that endodontic sealers negatively affect the post-dentin bond strength. This influence persists regardless of the type of endodontic sealer used, the resin cement used for post luting, the post-time waiting time for post luting or for the test, and in the different thirds of teeth.

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FIGURES

Figure 1. Flow diagram of study selection according to PRISMA statement.

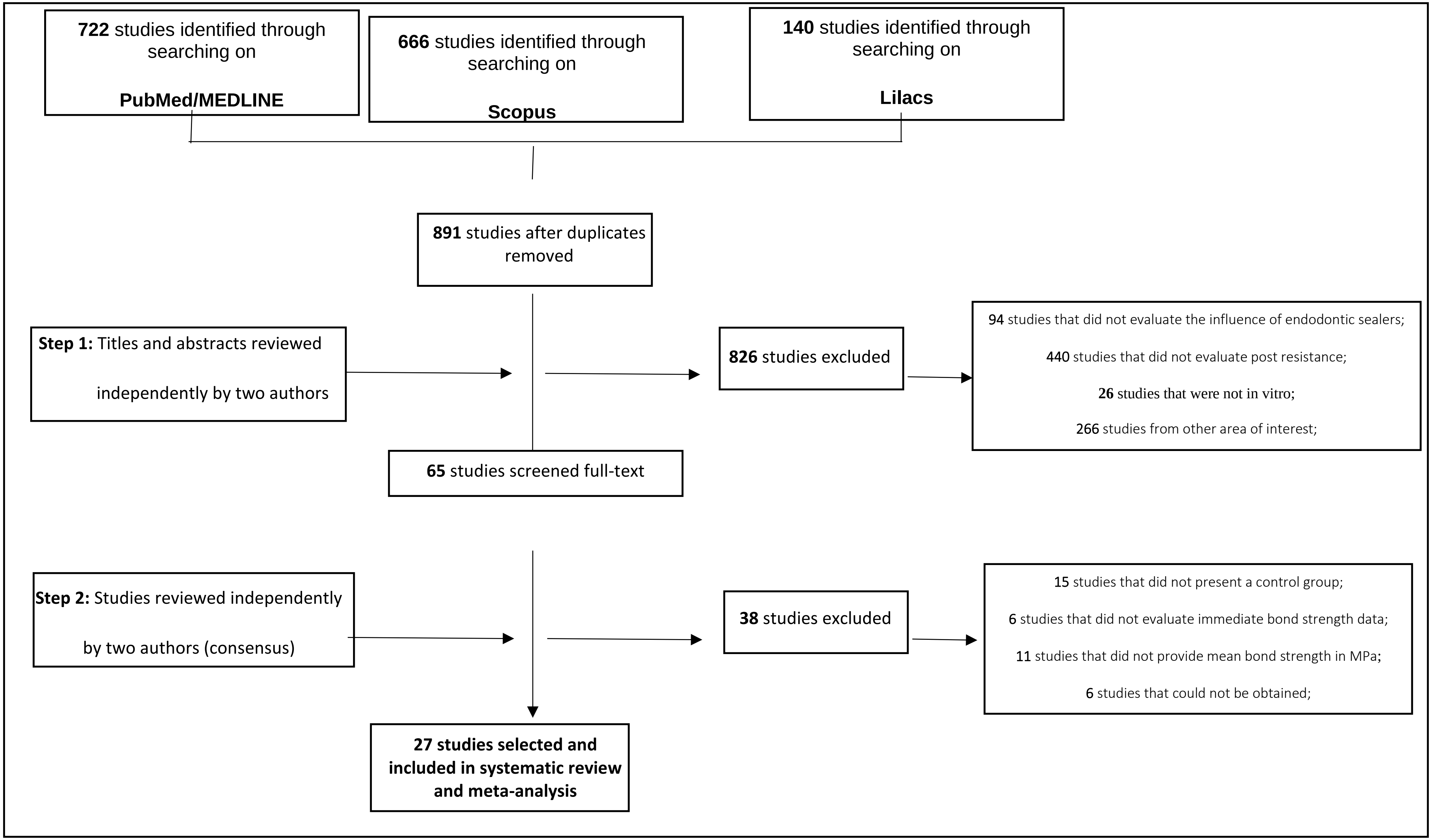
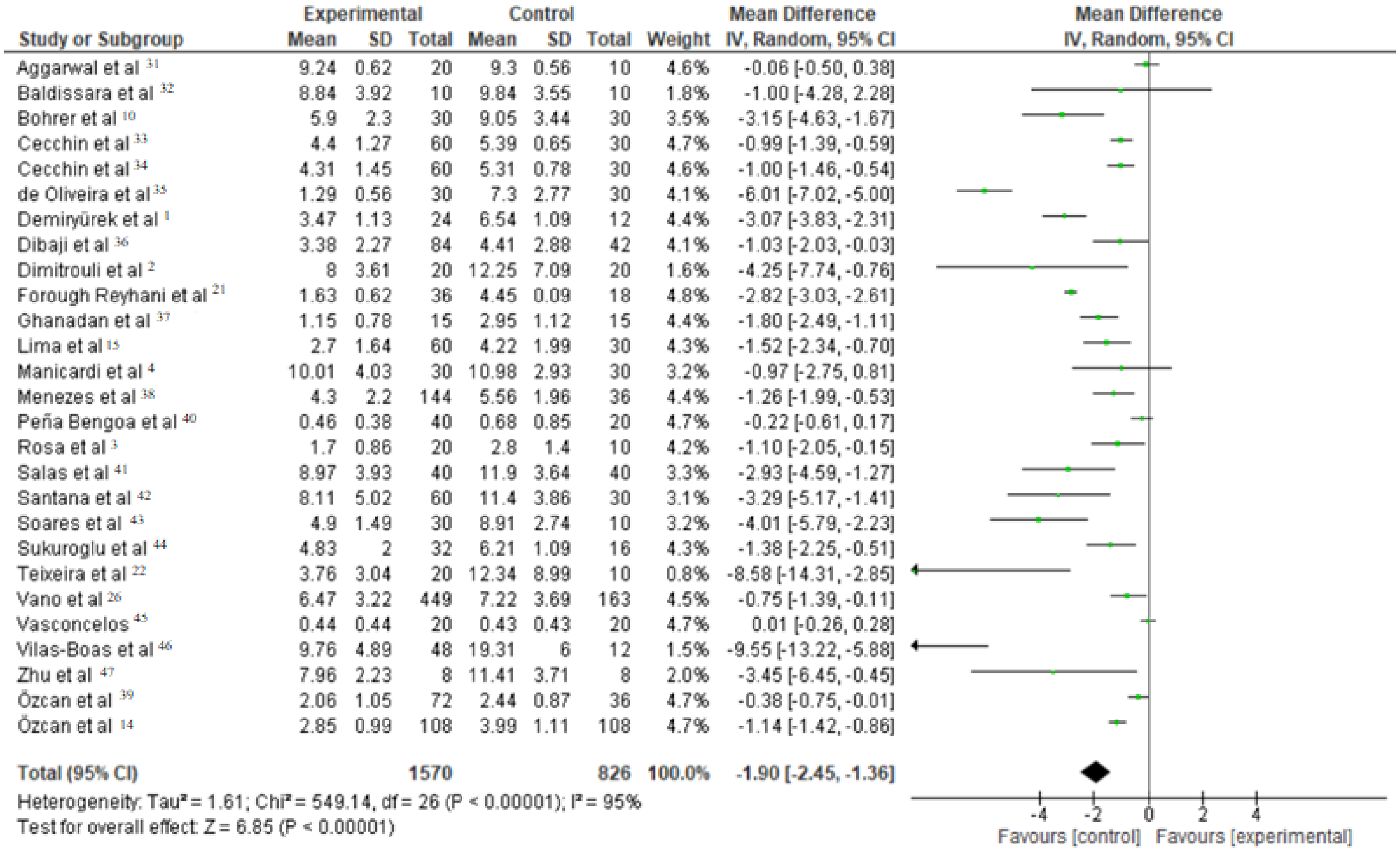


Figure 2. Forest plot of overall meta-analysis.



Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Aggarwal et al [31]	9.24	0.62	20	9.3	0.56	10	4.6%	-0.06 [-0.50, 0.38]
Baldissara et al [32]	8.84	3.92	10	9.84	3.55	10	1.8%	-1.00 [-4.28, 2.28]
Bohrer et al [10]	5.9	2.3	30	9.05	3.44	30	3.5%	-3.15 [-4.63, -1.67]
Cecchin et al [33]	4.4	1.27	60	5.39	0.65	30	4.7%	-0.99 [-1.39, -0.59]
Cecchin et al [34]	4.31	1.45	60	5.31	0.78	30	4.6%	-1.00 [-1.46, -0.54]
de Oliveira et al [35]	1.29	0.56	30	7.3	2.77	30	4.1%	-6.01 [-7.02, -5.00]
Demiryürek et al [1]	3.47	1.13	24	6.54	1.09	12	4.4%	-3.07 [-3.83, -2.31]
Dibaji et al [36]	3.38	2.27	84	4.41	2.88	42	4.1%	-1.03 [-2.03, -0.03]
Dimitrouli et al [2]	8	3.61	20	12.25	7.09	20	1.6%	-4.25 [-7.74, -0.76]
Forough Reyhani et al [21]	1.63	0.62	36	4.45	0.09	18	4.8%	-2.82 [-3.03, -2.61]
Ghanadan et al [37]	1.15	0.78	15	2.95	1.12	15	4.4%	-1.80 [-2.49, -1.11]
Lima et al [15]	2.7	1.64	60	4.22	1.99	30	4.3%	-1.52 [-2.34, -0.70]
Manicardi et al [4]	10.01	4.03	30	10.98	2.93	30	3.2%	-0.97 [-2.75, 0.81]
Menezes et al [38]	4.3	2.2	144	5.56	1.96	36	4.4%	-1.26 [-1.99, -0.53]
Peña Bengoa et al [40]	0.46	0.38	40	0.68	0.85	20	4.7%	-0.22 [-0.61, 0.17]
Rosa et al [3]	1.7	0.86	20	2.8	1.4	10	4.2%	-1.10 [-2.05, -0.15]
Salas et al [41]	8.97	3.93	40	11.9	3.64	40	3.3%	-2.93 [-4.59, -1.27]
Santana et al [42]	8.11	5.02	60	11.4	3.86	30	3.1%	-3.29 [-5.17, -1.41]
Soares et al [43]	4.9	1.49	30	8.91	2.74	10	3.2%	-4.01 [-5.79, -2.23]
Sukuroglu et al [44]	4.83	2	32	6.21	1.09	16	4.3%	-1.38 [-2.25, -0.51]
Teixeira et al [22]	3.76	3.04	20	12.34	8.99	10	0.8%	-8.58 [-14.31, -2.85]
Vano et al [26]	6.47	3.22	449	7.22	3.69	163	4.5%	-0.75 [-1.39, -0.11]
Vasconcelos [45]	0.44	0.44	20	0.43	0.43	20	4.7%	0.01 [-0.26, 0.28]
Vilas-Boas et al [46]	9.76	4.89	48	19.31	6	12	1.5%	-9.55 [-13.22, -5.88]
Zhu et al [47]	7.96	2.23	8	11.41	3.71	8	2.0%	-3.45 [-6.45, -0.45]
Özcan et al [39]	2.06	1.05	72	2.44	0.87	36	4.7%	-0.38 [-0.75, -0.01]
Özcan et al [14]	2.85	0.99	108	3.99	1.11	108	4.7%	-1.14 [-1.42, -0.86]
Total (95% CI)			**1570**			**826**	**100.0%**	**-1.90 [-2.45, -1.36]**

Heterogeneity: $Tau^2 = 1.61$; $Chi^2 = 549.14$, df = 26 (P < 0.00001); $I^2 = 95\%$
Test for overall effect: Z = 6.85 (P < 0.00001)

Figure 3. Forest plot of type of endodontic sealer x control (no sealer, AH Plus, or resin-based sealer), or no sealer, or AH Plus sealer.

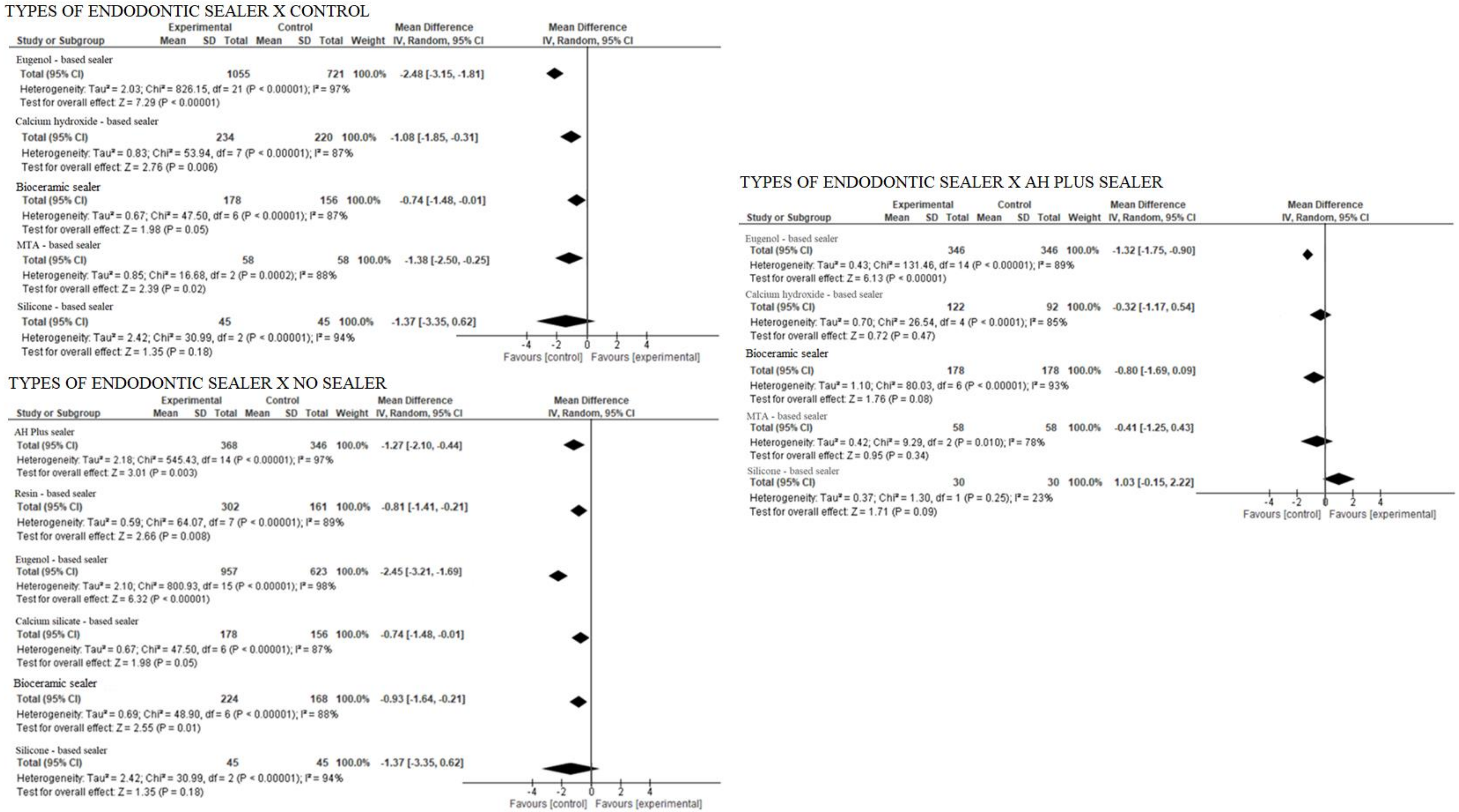
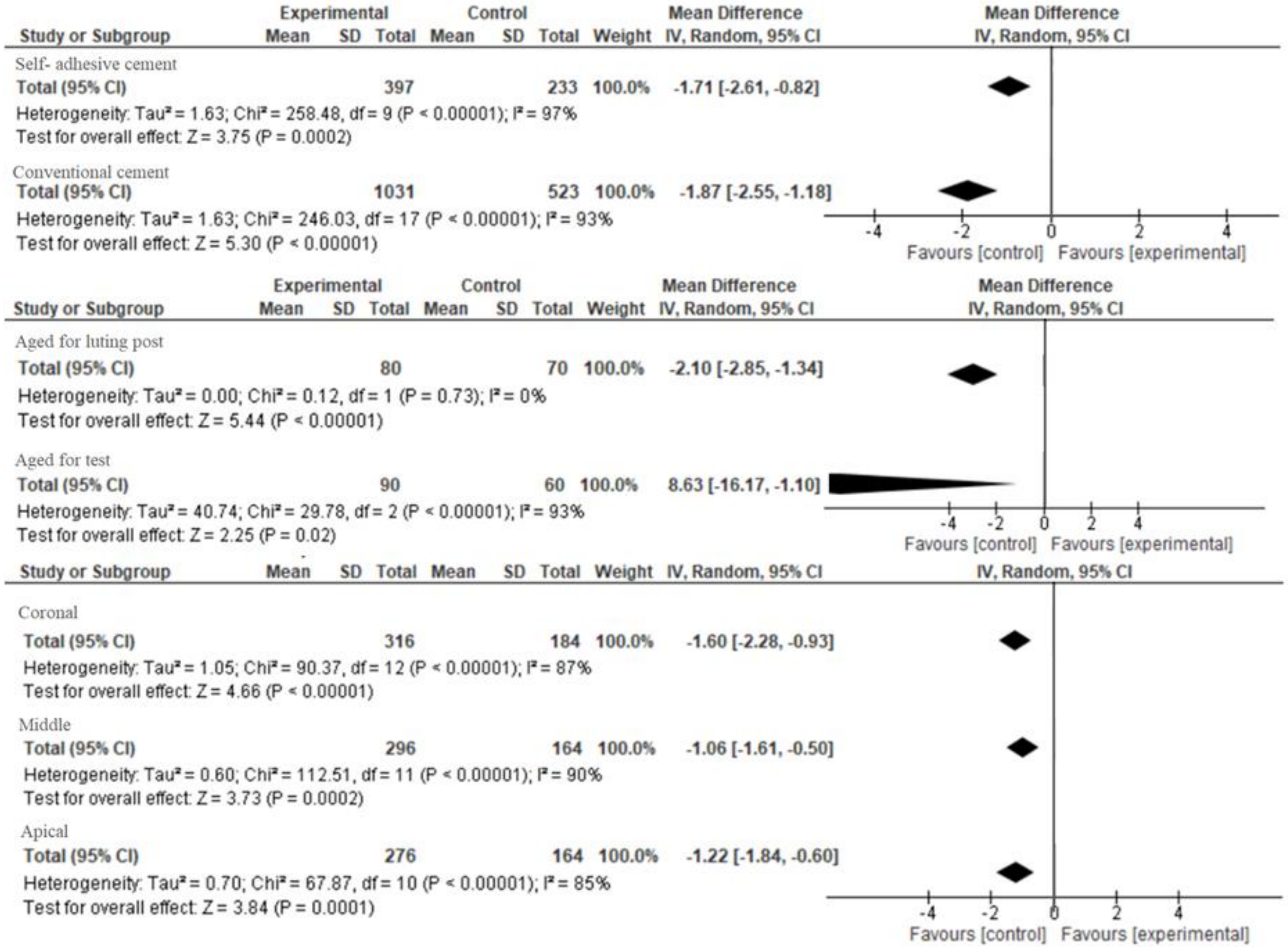


Figure 4. Forest plot of endodontic sealer x control (no sealer, AH Plus, or resin-based sealer) of factors: resin cement, post-waiting time for post luting and for test, and different thirds of teeth.



TABLES

Table 1. Description of included studies.

Article	Year	Country*	Language	Sample size	Type of tooth	Endodontic sealer	Storage time before post luting	Post-space treatment	Instruments used for post space preparantion	Type of post used	Post treatment	Resin cement used	Storage time before test	Type of test
Aggarwal et al. (31)	2012	India	english	10	human uniradicular mandibular premolar	zinc oxide eugenol sealer, AH plus, GuttaFlow, and Resilon and and Epiphany sealer. Control unfilled.	The specimens were stored at 100% humidity at 37◦C for 7 days.	The dowel spaces were rinsed with 10 ml of 17% EDTA and a final rinse of distilled water. The canals were	dowel drill (size 5.5) system	ParaPost Fiber Lux	-	ParaCore automix dual cure	The specimens were stored for at 100% humidity at 37◦C for 7 days.	Push-out test

								dried with #60 absorbent paper points.						
Baldissara et al. (32)	2006	Italy	english	5	single-rooted human teeth	Pulp Canal Sealer EWT, Topseal	At least 2 week	-	Gates Glidden burs and manual files, Forma-drills (Cabon-Denit) and DT Light-Post #2 burs	DT Light-Post #2	The fiber posts (DT Light-Post #2, RTD) were acid etched (Uni-Etch 32%) for 2 minutes before cementation	Bisfil 2B	The specimens were stored in 100% humidity at room temperature and subjected to $2x10^6$ sinusoidal fatigue cycles of 37.5 N at 8 Hz, under 37 3 °C water irrigation	Push-out test
Bohrer et al. (10)	2018	Brazil	english	15	bovine incisors	AH Plus, Endofill	24 hours or 6 months	deionized water for 15 s and dried with	hot instrument and drill of	fiber post (#3, Exacto)	cleaned with 70% alcohol and silane	Multilink Automix and RelyX U200	24 hours	Push-out test

								absorbent paper cones	fiber post system					
Cecchin et al. (33)	2011	Brazil	english	10	maxillary single-rooted canine teeth	AH Plus, Epiphany, Sealer 26, Endomethasone. Control without a sealer, just gutta-percha.	storage at 100% humidity for 1 week at 37 C,	the post space was cleaned with a 0.2% chlorhexidine digluconate solution and dried with absorbent paper points.	heated instruments, size 3 Largo burs	fibreglass posts (Angelus)	-	RelyX Unicem	The specimens were kept humid for 24 h at 37 C.	Push-out test
Cecchin et al. (34)	2011	Brazil	english	10	Single rooted human	EndoREZ, Sealapex, Endofill. Control without a	storage at 100% humidity for 1 week at 37 C	the root canals were cleaned with a 0.2%	heated instruments, size 3 Largo burs	fiberglass post; Ângelus	-	RelyX Unicem	The specimens were kept humid for 24 h at 37 C.	Push-out test

						sealer, just gutta-percha.		chlorhexidine digluconate solution and dried with absorbent paper points.						
Demiryürek et al. (1)	2010	Turkey	english	12	single-rooted human maxillary central incisors	Ah Plus, Endofill, Sealapex. Control without a sealer, just gutta-percha.	After storage at 100% humidity for 1 week at 37 C	-	#2 Peaso reamer and enlarged with a #2 drill (DT Light-Post System)	#2 DT Light-Post System	-	Panavia F 2.0	Specimens were then stored at 100% humidity and 37°C for 24 hours.	Push-out test
de Oliveira et al. (35)	2018	Brazil	english	30	bovine incisors	Endofill, control unfilled.	stored for 7 days in 100% humidity.	saline solution.according to the manufacturer’s	heated number 1 Rhein instrument followed	Glass fibre posts (Angelus) were relined	-	RelyX ARC	The specimens were stored in 100% humidity for 7 days.	Push-out test

								instructions.	by #3 Largo burs	with composite resin (Z250).				
Dibaji et al. (36)	2017	Iran	english	14	single canal human premolar teeth	AH-Plus, Dorifill, EndoSequence. Control without sealer, just gutta-percha	The teeth were incubated in 100% humidity at 37°C for one week.	The canals were then rinsed with water and dried with paper points.	#2 peeso reamer (Mani Inc., Tochigi, Japan) and a #2 drill (Innopost Premier Anatomic)	Innopost Premier Anatomic	-	Panavia F2.0	The roots were then incubated in 100% humidity at 37°C for 24 h	Push-out test
Dimitrouli et al. (2)	2011	Germany	english	10	Single rooted teeth and oral or distal roots from upper	AH Plus, Guttaflow. Control unfilled.	The root canal filling in all test groups was removed after 24 h.	Each canal was rinsed with sodium hypochlorite solution and	-	DT Light SL and RelyX Fiber Post	each post was disinfected with ethanol (99.8 vol.%) for 60 s and then thoroughly air-dried.	Variolink II/Excite DSC and RelyX Unicem	teeth were stored dry in an incubator at 37°C and 100% humidity. half of the specimens were	Push-out test

					and lower molars were used			saline solution and dried with paper points.					thermocycled (TC, 5°C/55°C, 5,000 cycles, dwell time 30 s), while the remaining specimens were stored in an incubator at 37°C for the same time period.	
Forough Reyhani et al. (21)	2016	Iran	english	18	single-rooted maxillary incisors	AH Plus, Dorfill and MTA Fillapex. Control without a sealer, just gutta-percha.	The specimens were stored at 37ºC under 100% relative humidity for 7 days	The post space was irrigated with distilled water and dried with paper cones.	#2 Peeso reamers and blue drill of the post system (Innopost Premier Anatomic)	#1.1 post Innopost Premier Anatomic Innotech	post was cleaned with alcohol	Clearfil SA Luting	24 hours	Push-out test

Ghanadan et al. (37)	2015	Iran	english	15	human anterior maxillary teeth,	AH 26, RealSeal, Guttaflow. Control with just gutta-percha.	The specimens were kept in 100% humidity for one week at 37 °C.	The root canals were washed with distilled water, then dried.	Gates-Glidden burs #2 to #4	Fiber glass posts (Angelus)	-	Panavia F2.0 system	-	Push-out test
Lima et al. (15)	2016	Brazil	english	30	Maxillary human canines	Endofill, MTA Fillapex, AH Plus		Root canals were irrigated with 10 mL deionized water and dried with absorbent paper points.	drill of the fiber post system (White Post DC) and heated pluggers.	Fiber posts (White Post DC #2) + composite resin (Z250).	A thin layer of silane coupling agent was applied on the post surfaces, gently air-dried and light-cured for 10 s.	RelyX U100	Specimens were stored in a dark container at 37°C for 24 h.	Push-out test
Manicardi et al. (4)	2011	Brazil	english	10	human maxilla	Endofill, AH Plus, Epiphany sealer, Resilon	specimens were stored for	The canals were	Gates-Glidden drills	fiber post #2 (DT	treating the post surface with a thin	Bis-Core	stored in 100% relative humidity for	Push-out test

					ry canines	and Epiphany sealer. Control unfilled.	24 hours in 100% relative humidity at 37 C	irrigated with 10 mL deionized water and dried with absorbent paper points.	sizes 3 to 6 and electric heated pluggers (System B; Sybron Dental Specialties, Orange, CA)	Light Post)	coat of primer B (All Bond 2)		24 hours at 37 C.	
Menezes et al. (38)	2008	Brazil	english	12	bovine incisor	Sealer 26, Endofill. Control unfilled.	immediate and 7 days	-	heated instrument, bur 5, 1.5 mm in diameter	Reforpost No. 3	The post was cleaned with 70% alcohol in a single application using a microbrush, and after drying a silane agent	RelyX ARC	stored in distilled water at 37 C for 24 h	Micropush-out test

										was applied (ceramic Primer).			
Özcan et al. (39)	2011	Turkey	english	12	human maxillary incisor	AH Plus, Endofill, iRoot SP. Control no sealer, just gutta-percha.	Stored at 37 C with 100% humidity for 7 days.	The post space was rinsed with distilled water and then dried with absorbent paper points.	#2 Peaso reamer and red size #14 drill (Snowpost)	Snowpost red size #14	post surface was cleaned with alcohol	Clearfil SA Cement	Specimens were then kept at 37 C with 100% humidity for 24 hours.	Push-out test
Özcan et al. (14)	2013	Turkey	english	12	maxillary single-rooted canine teeth	Endofill, control with gutta-percha	stored for 7 days at 37 C and 100 % humidity	The post space was rinsed with distilled water and dried	#2 Peeso reamer, red size #14 drill (Snowpost, Carbotech)	Snowpost red size #14	Fiberglass posts (Snowpost red size #14) were cleaned with alcohol	Panavia F or Clearfil SA Cement.	After storage at 100 % humidity for 24 h at 37 C for 1 day	Push-out test

								with absorbent paper points.						
Peña Bengoa et al. (40)	2019	Chile	english	10	upper and lower human premolars	AH Plus, Bio-C Sealer. Control without sealer, just gutta-percha.	The teeth were stored in a culture incubator for 7 days.	After post space preparation, the canals were irrigated with saline, dried with paper points	Gates-Glidden #2 drill followed by Exacto #1 drill and R2-Flatsonic ultrasonic tip cleaning. OR Gates-Glidden #2 and Exacto #1 drill. control group conforme	Exacto #1 fiber posts	-	U200 automix	7 days	Push-out test

									d only by Exacto #1 drill.					
Rosa et al. (3)	2013	Brazil	english	10	single-rooted bovine teeth	Endofill, MTA Fillapex, AH Plus	immediate fiber post cementation (0 days) or 15 days after root canal filling (15 days)	Root dentin was rinsed with distilled water and dried with paper points,	heated instrument, size 4 Largo Drill and size 3 drill from the Whitepost DC kit	size 3 Whitepost DC	the fiber posts were cleaned with ethyl alcohol 70% and coated with an MPS-based primer (Prosil)	AllCem	-	Push-out test
Salas et al. (41)	2011	Brazil	english	10	single-rooted teeth	Endofill or AH Plus. Control unfilled.	After 2 weeks storage in distilled water at 37 C	-	Gates Glidden drills sizes 1 and 2 (sizes 050 and 070, respectively) Peeso	The glass fibre posts (No. 2; Reforpost)	The glass fibre posts (No. 2; Reforpost) were cleaned with 95% ethanol for 5 min. Silane was applied with a micro-brush for 60 s	Enforce	After cementation specimens were stored in distilled water at 37 C for 24 h.	Push-out test

		reamers sizes 2 and 3 (sizes 070 and 090, respectively) were used to refine the post-space. Largo drill corresponding to the size that came with the post was used to standardize post-spaces.	(Silano, Angelusl).

Santana et al. (42)	2014	Brazil	english	10	bovine incisors	Control unfilled. Sealapex, Sealer 26, AH Plus.	samples were stored in distilled water at 37°C for 24 hours.	Root canals were irrigated, at each change of burs and at the end of the preparation, with 2 mL of 1% NaOCl and dried with absorbent paper points.	Gates-Glidden burs, sizes # 3-5 Largo burs	Reforpost # 3; Angelus	Fibreglass posts were cleaned with 70% alcohol, then in a single application using a Microbrush, and after drying, a silane agent was applied for 1 min (Silano; Angelus).	RelyX U100	In immediate groups, slices were submitted immediately (with no aging) to a push-out test, while in aged groups, slices were stored in distilled water at 37°C for 2 months (artificial accelerated aging) prior to testing.	Push-out test
Soares et al. (43)	2020	Brazil	english	10	maxillary canines roots	Endofill, Sealapex, AH Plus, Sealer Plus, EndoSequence	The samples were kept at 100% relative humidity	the dentinal walls were cleaned by	heated Paiva condensers supplemented with	White Post DC #0.5 glass fiber posts	White Post DC #0.5 glass fiber posts were disinfected with alcohol	Panavia F 2.0 luting cement	The samples were immersed in distilled water and placed at 100% relative	Push-out test

	BC. Control without sealer.	and 37 °C for 48 h.	irrigation with 2 mL sodium hypochlorite 2.5%, flooded with 1 mL EDTA 17% for 5 min, and irrigated with 5 mL of distilled water. The canal was then aspirated with microcannulas and dried with	a drill corresponding to the White Post DC #0.5 glass fiber post.		70° GL and then received a silane layer, by microbrush.		humidity and 37 °C for 24 h.

								absorbent paper points						
Sukuroglu et al. (44)	2015	Turkey	english	8	single-rooted mandibular premolar human teeth	AH Plus, Resilon + Epiphany SE sealer, Sealite sealer, iRoot SP, control unfiled.	all the specimens were stored at 37 °C and 100% humidity for 1 week	The post spaces were then cleaned using air/water spray and dried using paper points.	peeso reamer from size No. 1 through No. 4 dowel space drills of the same diameters provided in the kit from 2 respective post manufacturers; for Cytec blanco group: 1.4 mm	Cytec blanco glass fiber-reinforced posts and Cosmopost ceramic posts of 1.4 mm diameter	After 60 s of silanization (Monobond S) of each post, bonding agent Heliobond was applied simultaneously into the inner walls of the root canals and onto each post.	Variolink II;	The specimens were stored at 37 °C and 100% humidity for 1 week.	Push-out test

									Cytec blanco drill; for Cosmopost group: 1.4 mm Cosmopost drill					
Teixeira et al. (22)	2008	Brazil	english	5	uniradicular inferior premolars	EndoFill, Sealapex, EndoREZ.	48 h or 7 days	The root canals were washed with alcohol and, next, with 10 mL of deionized water.	heated instruments, # 3 Largo burs,	ReforPost Carbon fiber posts (#1, Ângelus)	-	Rely X ARC	The specimens were kept humid for 24 h at 37,8°C.	Push-out test
Vano et al. (26)	2006	Italy	english	47,48, 49, 51, 54,59	single-root human teeth	Pulp Canal Sealer. Control unfilled.	immediately, 24hours, 1 week	-	low-speed post drills provided by the	DT Light Post, FRC Postec, ENA Post	each post was cleaned with 95% ethanol. Post type: FRC Postec: Apply	Calibra Esthetic Resin Cement, MultiLink resin	-	Push-out test

									manufacturer		Monobond S (silane) to the FRC Postec post (0,85/1,45)* surface for 60 s and gently air dry for 5 s	cement, ENA Cem cement.		
Vasconcelos (46)	2016	Brazil	portuguese	10	upper incisors and lower premolars	AH Plus, Sealapex, Iroot SP e Endo Rez. Control unfilled and control with just gutta-percha.	14 days	5 ml of NaOCl 2,5%. Then the cannal was washed with 5 ml of distilled water and dried with n.50 paper cones.	gates-glidden drill, fiber post drill (Rebilda)	Rebilda Post 12 (VOCO GmbH)	they were cleaned with alcohol, dried and the futurabond DC self-etching adhesive system (VOCO GmbH) was applied for 40 s and air dried.	Rebilda DC	2 days at 37 ° C and 100% relative humidity	Push-out test

Vilas-Boas et al. (45)	2018	Brazil	english	12	single-rooted mandibular premolars	Endofill, Endosequence BC Sealer, and AH Plus. Control without a sealer.	immediately after the completion of the obturation and 7 days post obturation	Post spaces were then irrigated with 10 mL of distilled water and dried with absorbent paper points.	size 3 Largo burs and size 1 drill, provided in the White Post DC kit	Double-tapered fiberglass posts no. 1 (White Post DC)	Silano (Prosil) was applied on the post surface using a micro-brush for 1 min and, then, dried by blowing compressed air for 20 s.	RelyX™ARC	The specimens were kept humid for 7 days at 37° C.	Micropush-out test
Zhu et al. (47)	2015	China	chinese	8	single mandibular premolars with single root canal	AH Plus, Endofill	1 week	20ml of 0,9% saline solution	drill of system of post	Glassix fiberglass post	-	RelyX Unicem	1 week	Push-out test

*Country of the first author. # EDTA: ethylene diamine tetra acetic acid; NaOCl: sodium hypochlorite; CHX: chlorhexidine digluconate

Table 2. Risk bias of included studies.

Article	Randomization teeth	Sample size calculation	Use materials according to the manufacturer's instruction	Teeth with similar dimensions	Endodontic treatment performed by a single operator	Post-space treatment performed by a sinlge operator	Luting post procedures performed by the same operator	Blinding of the operator of the test machine	Failure analysis	Risk of bias
Aggarwal et al. (31)	No	No	No	Yes	No	No	No	No	Yes	High
Baldissara et al. (32)	Yes	No	No	No	No	No	No	No	Yes	High
Bohrer et al. (10)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Low
Cecchin et al. (33)	Yes	No	No	No	Yes	No	No	No	Yes	High
Cecchin et al. (34)	Yes	No	No	No	Yes	No	No	No	Yes	High
Demiryürek et al. (1)	Yes	No	Yes	No	No	No	No	No	Yes	High
De oliveira et al. (35)	Yes	No	Yes	No	No	Yes	No	No	Yes	Medium
Dibaji et al. (36)	Yes	No	Yes	No	No	No	No	No	Yes	High
Dimitrouli et al. (2)	Yes	No	No	No	No	No	No	No	Yes	High
Forough reyhani et al. (21)	Yes	No	Yes	No	Yes	No	No	No	No	High

Ghanadan et al. (37)	Yes	No	No	No	No	No	No	No	Yes	High
Lima et al. (15)	No	No	Yes	No	No	No	No	No	Yes	High
Manicardi et al. (4)	Yes	No	No	Yes	No	No	No	No	Yes	High
Menezes et al. (38)	Yes	No	No	Yes	No	No	No	No	No	High
Özcan et al. (39)	Yes	No	No	No	Yes	No	No	No	Yes	High
Özcan et al. (14)	Yes	No	Yes	No	No	No	No	No	Yes	High
Peña bengoa et al. (40)	Yes	Yes	No	Yes	No	No	No	No	Yes	Medium
Rosa et al. (3)	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Medium
Salas et al. (41)	Yes	No	No	No	Yes	Yes	Yes	Yes	No	Medium
Santana et al. (42)	Yes	No	Yes	Yes	No	No	No	No	Yes	Medium
Soares et al. (43)	Yes	No	Yes	No	Yes	Yes	Yes	No	Yes	Medium
Sukuroglu et al. (44)	Yes	No	Yes	No	No	No	Yes	No	Yes	Medium
Teixeira et al. (22)	Yes	No	No	No	No	No	No	No	Yes	High
Vano et al.(26)	No	No	No	No	Yes	No	No	No	No	High
Vasconcelos (45)	No	No	Yes	No	No	No	No	No	No	High
Vilas-boas et al. (46)	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Medium
Zhu et al. (47)	Yes	No	No	Yes	No	No	No	No	Yes	High

3 ARTIGO 2- POST-SPACE TREATMENT INFLUENCE THE BOND STRENGTH IN ENDODONTIC TREATED TEETH: A SYSTEMATIC REVIEW AND META-ANALYSIS

Este artigo foi aceito no periódico *Operative Dentistry*, ISSN:1559-2863, Fator de impacto = 1.01; Qualis A1. As normas para publicação estão descritas no Anexo B.

POST-SPACE TREATMENT INFLUENCE THE BOND STRENGTH IN ENDODONTIC TREATED TEETH: A SYSTEMATIC REVIEW AND META-ANALYSIS

TC Bohrer; PE Fontana; Rocha RO; OB Kaizer.

Thaís Camponogara Bohrer, DDS, MSD graduate student in Oral Sciences (Prosthodontics), Faculty of Odontology, Federal University of Santa Maria, Santa Maria, Brazil.

Patrícia Eliana Fontana, DDS, MSD graduate student in Oral Sciences (Prosthodontics), Faculty of Odontology, Federal University of Santa Maria, Santa Maria, Brazil.

Rachel de Oliveira Rocha, MSD, PhD, Associate Professor, MDS Graduate Program in Oral Science (Pediatric Dentistry Units), Faculty of Odontology, Federal University of Santa Maria, Santa Maria, Brazil.

Osvaldo Bazzan Kaizer MSD, PhD, Adjunct Professor, MDS Graduate Program in Oral Science (Prosthodontics Units), Faculty of Odontology, Federal University of Santa Maria, Santa Maria, Brazil.

Corresponding author:

Thaís Camponogara Bohrer

Federal University of Santa Maria, Santa Maria, Brazil.
Department of Restorative Dentistry
Faculty of Odontology,
Floriano Peixoto Street, 1184, 97015-372, Santa Maria, Brazil.

Phone: +55-55-996155357

E-mail: thaiscbohrer@hotmail.com

Authors' email addresses:

Patrícia Eliana Fontana (patricia_fontana_@hotmail.com)
Thais Camponogara Bohrer (thaiscbohrer@hotmail.com)
Rachel de Oliveira Rocha (rachelrocha@smail.ufsm.br)
Osvaldo Bazzan Kaizer (obekaizer@terra.com.br)

ABSTRACT

POST-SPACE TREATMENT INFLUENCES THE BOND STRENGTH IN ENDODONTICALLY TREATED TEETH: A SYSTEMATIC REVIEW AND META-ANALYSIS OF IN VITRO STUDIES

Short title: Post-space treatment on bond strength

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

Purpose: 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: 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-effect model was used for pairwise meta-analyses (control *vs.* post-space preparation groups) at a significance level of $p<0.05$.
Results: There 453 studies selected for full-text analysis from 2,832 potentially eligible studies, and 75 were included in this systematic review. Overall, post-space treatment significantly improves the bond strength to root canal dentin ($p < 0.00001$). Only one study was considered to have a low risk of bias.
Conclusion: Post-space treatment has a positive influence on the bond strength of post to root canal dentin. In this review, the post-space treatment which improves the resistance adhesive 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.

Keywords: Push-out, endodontics, canal irrigants, root dentine, post-space.

INTRODUCTION

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

Effective adhesion among the intra-radicular 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 intra-radicular 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 intra-radicular 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 intra-radicular 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 othersand 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, diode lasers within the post-space can contribute to disinfecting this space and eliminate the smear layer, improving the retention of the intra-radicular post[19-22].

Some studies have reported that post-space treatments improve post-resistance adhesive[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 performed 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.

MATERIALS AND METHODS

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 (T.B and P.F) independently assessed the titles and abstracts of studies which 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 which did not provide bond strength values as mean and standard deviation in megapascals (MPa); (4) studies which used experimental materials; (5) studies with contaminated specimens; (6) studies which did not present immediate bond strength data. If any data was not described or was unclear in the primary study, it was requested to authors by e-mail (at least twice), and the study was excluded if they did not reply. In case of multiple publications with the same data, only one study was considered. The group data was excluded from studies in which the aged group was stored in a solution different 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 of 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 which 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].

Pre-specified 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 2,832 potentially eligible studies, 2,379 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 which did not present a control group.

Descriptive Analysis

Descriptive analysis of the included studies is described 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, 2 studies in Chinese, 2 studies in Portuguese and 1 study in Spanish. Among the included studies, 56 studies used human teeth and 19 used bovine teeth.

Nine different endodontic sealers were used in the included studies, and among of them, epoxy resin-based sealers (n=37), calcium hydroxide-based sealers (n=17), 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 which entered in this systematic review which 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. Also, 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 1 week (n=32), while the maximum storage period was 2 weeks and the minimum was 24 hours. Moreover, 16 studies did not have any information about the storage time before post luting.

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 9 studies did not have this information. Sixty-eight studies used fiber post, 4 studies used fiber post relining, 2 studies used carbon fiber post, and 1 study used cast post.

In total, 41 commercial cements were used, and 3 of them were not resin cement: 1 zinc phosphate cement, 1 glass ionomer cement, and 1 resin-modified glass ionomer. The resin cement most used was RelyX ARC resin cement (n=19).

The maximum storage time before the bond strength test was 2 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-analyses also showed improved bond strength when post-space treatment was done using ethanol ($p<0.0001$), NaOCl + 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 (0=0.004) (Figure 3).

Moreover, subgroups analysis (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 subgroups analysis 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 sub-groups 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) [11-15,18,28,30-32,34,36,38,40-44,46-52,55-63,66-71,73-75,80-82,86,88-92], 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 intra-radicular 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 is treated.

There is the formation of debris and residues in the canal during the post-space preparation which can affect intra-radicular posts adhesion[5,6,8-10]. In addition, endodontic sealer residues might also interfere on degree of conversion of cement using 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 dentine, removing partial or total debris of the root canal and promoting the opening of dentinal tubules[95].

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 which 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[83,96]. 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[92,97]. Furthermore, the diode laser has been recommended in the literature because it is efficient in removing the smear layer and debris from root canals[98,99].

Despite not increasing the bond strength of the post to root dentin, chlorhexidine was the most used treatment among the studies that entered the meta-analysis. This is because chlorhexidine has an 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, for the post-space treatment, chlorhexidine does not seem to be effective.

Moreover, subgroup analyses were performed evaluating different factors which 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 which showed the type of canal sealer 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[100].

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 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[93,101]. 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[100]. 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 control group, except for the two days subgroup. However, it should be considered that they do not have a long storage period, and the 2 days subgroup had only 5 studies. 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[102,103]. A more extended storage period and more endodontic sealer molecules would be able to penetrate dentine 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[104].

In the sub-group 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 post; this study shows that the root canal cleaning can affect the bond strength of the fiberglass post and that NaOCl + EDTA was recommended[105]. Other types of posts should be analyzed with caution, as there are few studies included in this present review which 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 intra-radicular dentin[106-109]. 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 which used each drill: 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).

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;[110] 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[111,112]. All the included studies in this review that used resin cement for post luting, 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 fo post-treatment. Some papers[5, 51, 61, 70, 74, 82, 88, 89, 91] do not explain what was used for the post-treatment and one[67] paper used only alcohol for post-treatment.

For the post-waiting time for test analysis, the immediate (stored between 24 hours and 1 week) and delayed subgroups (stored between 4 months and 2 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 this period storage because studies in the literature suggested the integrity of cement-dentin bonds over time decreased the post bond strength[113]. 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 due to the fact of promoting shear stresses at the interface between cement-root dentine and cement-post, and the push-out test generates the best evidence available in the literature[114,115].

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[116], although others did not show any difference between thirds[44,84]. In this present review, the use of post-space treatment was better than the control group, independent of teeth thirds.

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[25,117]. 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 are usually found in a systematic review of laboratory studies[25,26,98,117].

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 which 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 simplicity of the technique and to achieve the same results as the more complicated techniques, mainly when the root canal is filled with resin-based sealer, post-waiting for luting for 2 days using fiber post and preparing the post-space with the drill provided by post system.

CONCLUSION

This systematic review of laboratory studies indicates, under the limitations of the present meta-analysis, that the 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.

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TABLES

Table 1. Description of included studies.

Authors/year	Country*	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 and others [27]	Iran	English	Human upper central incisors and canine teeth	AH Plus	24 hours	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 hours	Push-out test
Alfredo and others[28]	Brazil	English	human maxillary permanent canines	Sealer 26	2 days	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 days	tensile strength test
Alkhudhairy and others[11]	Saudi Arabia	English	Human maxillary permanent central and 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 and others[29]	Italy	English	human incisors	AH Plus	-	2% CHX	calibrated burs (3M	RelyX Fiber	RelyX Unicem or Bifix SE	24 hours, 6	Micro-push-out bond strength test

							ESPE) or calibrated burs (Voco)	Post, size: yellow or Rebilda Post, size: green		months or 1 year	
Arana and others[30]	Brazil	Spanish	Human mandibular premolar	AH Plus	1 week	24% EDTA	Gates Glidden #2 and drill #2 provided by the post system's manufacturer	Exacto, size nº 2	Rely X U100 or Para Core Automix	24 hours or Thermo cycling 5000 cycles	expulsion test
Arisu and others[31]	Turkey	English	Human mandibular premolar	AH 26	24 hours	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, 1.35 mm in diameter	Panavia F 2.0	1 week	Push-out test

							(Mirafit White Reamer)				
Arslan and others[32]	Turkey	English	Human mandibular premolar	AH Plus	1 week	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 and 1.4-mm size drill (Cytec Carbon)	Cytec Carbon, size #2 (1.4 mm diameter)	RelyX U200	24 hours	Push-out test
Baena and others[33]	Spain	English	single-rooted human teeth	AH Plus	1 week	35% H3PO4; 17% EDTA; 25% Polyacrylic acid	Gates-Glidden drills size 2, 3 and calibrated 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 week	Push-out test

Bitter and others[34]	Germany	English	human maxillary central incisors	AH Plus	24 hours	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 SmartCem 2 or CoreX Flow	-	Push-out test
Bordim and others[35]	Brazil	English	bovine incisors	-	-	100% ethanol	-	White Post DC, size 4	AllCem dual-cure	24 hours or 1 year	Push-out test
Carvalho and others[36]	Brazil	English	Human single-rooted and single-canal premolars	AH 26	24 hours	99.6% ethanol	drill recommended for RelyX Fiber Post size 2	RelyX Fiber Post, size 2	Dual Link	24 hours	Push-out test
Carvalho and others[37]	Brazil	English	bovine incisor	AH Plus	1 week	2,5% NaOCl; 100% ethanol; 2,5% NaOCl +100% ethanol	Largo burrs #3 and #4	Reforpost RX #2	RelyX ARC or	1 week	Push-out test

									RelyX U200		
Cecchin and 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 fiberglass post (Angelus) and composite resin (B0.5, Z250)	Rely X ARC	24 hours or 1 year	Push-out test
Cecchin and others[38]	Brazil	English	bovine incisors	-	-	2% CHX	-	fiberglass posts no. 3 (Angelus) relined	Rely X ARC	24 hours or 1 year	Push-out test

								with composite resin (B 0.5, Z250)			
Cecchin and 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 fiberglass post (No. 3, Angelus) and composite resin (B0.5, Z250)	Rely X ARC	24 hours or 250,000 cycles of mechanical fatigue (1 year of clinical function)	Push-out test

Cintra and others[39]	Brazil	Portuguese	human premolars	Sealapex	1 week	2,5% NaOCl; 2% CHX; 17% EDTA	drill #2 of fiber glass post system (Exacto)	Exacto #2	RelyX Unicem Aplicap	1 week	Push-out test
Clavijo and others[40]	Brazil	English	bovine incisors	Sealer 26	3 days	17% EDTA	drills designated for the quartz coated carbon fiber post Aestheti Post	Aesthet i Post	RelyX ARC or RelyX U100 or Multilink	-	Push-out test
Crispim da Silveira and others[41]	Brazil	English	bovine incisors	Sealer 26	24 hours	5.25% NaOCl + 17% EDTA; 5.25% NaOCl; 17% EDTA; 2% CHX in gel; 70% ethanol; polyacrylic acid;	#4 Gates Glidden drill and #5 Largo drill	Reforpo st	RelyX U100	24 hours	Push-out test
Culhaoglu and others[42]	Turkey	English	human incisors	-	-	2% CHX; 5,25% NaOCl+17% EDTA; 5% boric acid; 10% boric acid	-	Panavia Post (18 mm long and 1.44	Panavia F 2.0 or Panavia SA	1 week	Push-out test

								mm in diamete r)			
da Cunha and others[14]	Brazil	English	bovine incisors	Sealer 26	1 week	5.25% NaOCl; 5.25% NaOCl + 10% ascorbic acid	drills supplied by the manufacture r of the fiber posts (Exacto #3)	Exacto #3	RelyX U100 or RelyX ARC	24 hours	Push-out test
da Silva and others[43]	Brazil	English	Human maxillary canines	Sealer 26	3 days	2% CHX in gel; 20.3% EDTA +1% NaOCl; Xylene	first (#1) and second (#2) drills of the #2 C-Post carbon fiber post system	C-Post #2	Hi-X cement	24 hours	tensile-bond-strength test
de Araújo and others[44]	Brazil	English	bovine roots	Sealer 26	1 week	2% CHX; 11.5% polyacrylic acid; 11.5% polyacrylic acid + 2% CHX	#2 Gates-Glidden drill and low-speed drill provided by the post	Exacto #2	RelyX ARC or RelyX Luting 2	1 week or 6 months	Push-out test

							system's manufacturer				
de Oliveira and others[45]	Brazil	English	bovine incisors	Endofill	1 week	70% ethanol; acetone; 70% isopropyl alcohol	using a heated number 1 Rhein instrument followed by #3 Largo burs	Glass fibre posts (Angelus) were relined with composite resin (Z250)	RelyX ARC	1 week	Push-out test
Duski and others[46]	USA	English	human premolars	AH Plus	-	2% CHX	A series of sequential reamers provided for the post No. 2 (Rely-X Fiber Post	Rely-X Fiber Post, No. 2	RelyX ARC or RelyX Unicem	Imediato or Thermo cycling 20.000 cycles or 40.000 cycles	Push-out test
Ekim and Erdemir[47]	Turkey	English	human maxillary	AH Plus	1 week	2,5% NaOCl + 17%EDTA; 2,5% NaOCl + 17%EDTA + ULTRASONIC;	post drills (White Post	White Post	Panavia F 2.0	24 hours	Push-out test

			central teeth			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	DC, drill, size 1)	DC, size 1			
Elnaghy and others[48]	Egypt	English	human teeth	AH Plus	1 week	5.25% NaOCl; 2% CHX; 17% EDTA; 17% EDTA + 2% CHX; Qmix	drill provided with the post system (Rebilda post)	Rebilda post, size Ø 1.5	i Cem	1 week	Micropush-out bond strength
Ertas and others[15]	Turkey	English	single-rooted human teeth	AH Plus	24 hours	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;	post drill	UniCore, 1.5-mm	Bifix SE	-	Push-out test

						5.25% NaOCl + 17% EDTA +PAD (FotoSan Agent, photoactivated disinfection).					
Fan and others[49]	China	English	Human single-canal premolars	AH Plus	1 week	2.5% NaOCl; 17% EDTA + 2.5% NaOCl; 7% maleic acid + 2.5% NaOCl	drill provided with the post system until size 3	fibre posts (3M ESPE)	Rely X U200	1 week	Micropush-out
Faria-e-Silva and others[50]	Brazil	English	bovine incisors	Sealer 26	3 days	5% NaOCl; 17% EDTA; 11.5% polyacrylic acid	drills available in the post kit	White Post DC3	RelyX Unicem or BisCem	1 week	Push-out test
Feng and Gao[51]	China	Chinese	human mandibular canines or premolars	-	3 days	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 hours	Push-out test
Furuse and others[52]	Brazil	English	bovine incisors	Sealer 26	1 week	5.25% NaOCl; 5.25% NaOCl + 10% ascorbic acid	3 Largo and burs provided by the post manufacturer (Exacto)	Exacto 3	RelyX ARC	24 hours	Push-out test

Garcia and others[53]	Brazil	English	human maxillary canines	EndoFill	2 days	diode laser (power of 1.5 W and a frequency of 100 Hz)	low-speed post preparation bur was used (FibreKor Post System)	FibreK or Post System #2	Rely-X Unicem or Cement-Post	-	Push-out test
Garcia and others[54]	Brazil	English	human maxillary canines	Endofill	2 days	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)	No. 2 parallel fiberglass posts (Angelus)	Cement-Post	-	Push-out test
Garcia and others[55]	Brazil	English	human mandibular premolars with single canals	Sealer 26	1 week	5% NaOCl; 17% EDTA +5% NaOCl; 17% EDTA	low-speed drill provided by the post system manufacturer	White Post – DC 2	RelyX U100	24 hours	Push-out test
Gomes França and others[56]	Brazil	English	bovine roots	-	-	2% CHX; 100% ethanol	Largo Peeso Reamers at increasing	Reforpost no. 2	Rely X ARC	2 days or 6 months	Push-out test

							diameters until reaching #4				
Goruz and others[57]	Turkey	English	single-rooted and single-canaled human teeth	-	-	Er: YAG laser (15 Hz/0.6 W)+ 0.5% NaOCl	drill of the post system (Snowfiber post-drill, size 1.0)	Snowpost	Clearfil SA	24 hours	Push-out test
Jain and others[58]	India	English	single rooted human teeth	AH Plus	24 hours	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 and others[59]	Turkey	English	single-rooted human maxillary incisors	AH Plus	1 week	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, size 15	Grandio Core Dual Cure	1 week	Push-out test
Kul and others[60]	Turkey	English	mandibular premolar human teeth	AH Plus	1 week	5.25% NaOCl+17% EDTA; 2% CHX; 35% H3PO4	1 Peeso reamer, and preparation of the post was completed with a	DT Light-Post System	RelyX U200	24 hours	Push-out test

							number 1 drill (DT Light-Post System				
Lacerda and others[61]	Brazil	English	bovine teeth	Sealer 26	1 week	2% CHX; 2.5% NaOCl; ultrasound; 2% CHX + ultrasound; 2.5% NaOCl + ultrasound	burs of the system of glass fiber post (White Post DC3 and DC4)	White Post DC3 and DC4	Bifix QM	1 week	Push-out test
Lacerda and others[12]	Brazil	English	single-rooted human premolar teeth	-	-	1% NaOCl; 2% CHX gel	Largo burs 2, 3 and 4	Reforpost	RelyX ARC or RelyX U100	1 week or 6 months	Push-out test
Leitune and others[62]	Brazil	English	human upper central incisor teeth	-	-	0.2% CHX; 2% CHX	no. 2 drill from the Exacto post system	Exacto	RelyX ARC	24 hours or 6 months	Push-out test
Lima[63]	Brazil	English	bovine incisors	AH Plus	2 days	17% EDTA; 11,5% Polyacrilic acid; NaOCl	Gates-Glidden #3 and #3 post drill	White post DC #3	Variolink II or RelyX U100 or	24 hours	Push-out test

									Maxcem Elite		
Mao and others[64]	China	English	human maxillary central incisors	AH 26	1 week	10% NaOCl; 17% EDTA + 5.25% NaOCl	#3 D.T. Pre-Shaping Drills	D.T. light-post #3	Duo-Link or LuxaCore Dual	1 week	Push-out test
Martinho and others[65]	Brazil	English	bovine incisors	Sealer 26	1 week	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 week	Push-out test
Mathew and others[66]	India	English	uniradicular human teeth	AH Plus	24 hours	5% NaOCl + 17% EDTA; diode laser (3W)+5% NaOCl	number 1 (0.70 mm) peeso reamer, and preparation was completed using drill number 1	Hi Rem Over, size 1	G Cem or GC Pro	24 hours	Push-out test

							(Hi Rem Endod Drill 201)				
Mohammadi and others[67]	Iran	English	human maxillary central incisors	AH 26	24 hours	Er,Cr:YSGG laser (0.5W+ 20% water and air level) +(2.5W + 50% air and water level)	no. 4, no. 3 and no. 2 Peeso reamers and the special drills provided by the manufacturer fiber posts (Endolight Post)	Endolight Post	Maxcem Elite	24 hours	Push-out test
Neelakantan and others[68]	India	English	Human single-rooted maxillary central incisors	AH Plus	1 week	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	RelyX fiber post	Rely X Unicem or Fusion Ultra DC	24 hours or 4 months	Push-out test

							using the post-specific drill (Rely X fiber post).				
Oral and 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 and 1.75 mm from 1 mm coronal level of apices.	EverStick POST (1.5mm)	ParaCem	-	Push-out test
Parčina Amižić and others[70]	Croatia	English	single-rooted human premolars	AH Plus	1 week	Er:YAG laser with photon-induced photoacoustic streaming (PIPS) tip; Er,Cr:YSGG laser with radial-firing (RFT2) tip.	# 4 Gates Glidden burs	everStick POST, diameter 1.2 mm	G-Cem	-	Micro push-out bond strength

Ramos and others[71]	Brazil	English	human canines	AH Plus	1 week	photodynamic therapy	#2 bur (White Post DC System)	White Post DC System #2	Relyx ARC or Relyx U200	24 hours	Push-out test
Ramos and others[72]	Brazil	English	human canines	AH Plus	1 week	photodynamic therapy	#2 bur (White Post DC System)	White Post DC System #2	RelyX U200 Automix or Gold Label 1	24 hours	Push-out test
Santos and others[73]	Brazil	English	Bovine incisors	-	-	2% CHX; 100% Ethanol; 100% Ethanol+ 2% CHX	-	Reforpo st	Rely X U200	1 week. After obtain slices, the specim ens were test in time interval s of 2 days and 6	Push-out test

										months .	
Scotti and others[74]	Italy	English	human single rooted teeth	Pulp Canal Sealer EWT	24 hours	32% H3PO4	-	fiber post	Bisfill 2B	1 week	Push-out test
Scotti and others[75]	Italy	English	single-root human teeth	Pulp Canal Sealer EWT	1 week	10% EDTA; 10% EDTA + Teethmate Desensitizer; Teethmate Desensitizer	Largo drills #1 and also using dedicated drills (EasyPost n°3)	Radix #3	Panavia SA	1 week	Push-out test
Seballos and others[16]	Brazil	English	single-rooted premolars human	AH Plus	1 week	2%CHX; 1% NaOCl; 2.5% NaOCl; 5% NaOCl; 1% CaOCl; 2.5% CaOCl; 5% CaOCl	sizes 2, 3, 4 Largo drills and fiber post bur	Exacto Translúcido N2	RelyX U200	48 hours	Push-out test
Shafiei and others[76]	Iran	English	human maxillary central incisors	AH26	1 week	EDC (1-ethyl-3-(3-dimethylaminopropyl) carbodiimide pretreatment was included in the adhesive; 18%EDTA;	No.2 drills from the respective post	FRC Postec Plus No. 2	Variolink II or Panavia F2.0 or Clearfil SA	1 week or 1 year	Push-out test

						18%EDTA +EDC;	manufacturer				
Shafiei and others[77]	Iran	English	human maxillary central incisors	-	1 week	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 week or 2 years	Push-out test
Shafiei and others[78]	Iran	English	human maxillary central incisors	AH26	1 week	1% NaOCl; 17%EDTA	drills from the post manufacturer	fiber posts	Duo-link	1 week	Push-out test
Silva[79]	Brazil	Portuguese	Bovine incisors	Sealer 26	24 hours	2% CHX	Drill with 1.5mm diameter from post manufacturer	Exacto n°2	RelyX ARC	1 week or 6 months or 1 year	Push-out test
Simões and others[80]	Brazil	English	single-rooted human premolars	Sealer 26	24 hours	17% EDTA; 35% H3PO4	No. 2 Exacto drill	Exacto No. 2	RelyX ARC or RelyX U200 Automix	24 hours or 6 months	Push-out test

Simões and others[81]	Brazil	English	single-rooted human premolars	Sealer 26	24 hours	11.5% polyacrylic acid	drill number 2 was used (Angelus)	Exacto # 2	RelyX ARC or RelyX U200 Automix	24 hours or 6 months	Push-out test
Tuncdemir and others[82]	Turkey	English	Human maxillary central incisors	AH Plus	1 week	5.25% NaOCl; 17%EDTA; 37% orthophosphoric acid; Diode laser (wavelength of 660 nm, output power of 75 mW)	matching drill	Snowlight Post No. 14	Clearfil SA	-	Push-out test
Uzun and others[83]	Turkey	English	Human mandibular premolars	AH Plus	2 days	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	oval posts (Ellipson posts), circular posts (Unicore posts size 2)	RelyX Unicem	24 hours	Push-out test

							drill group: A dedicated drill (Unicore)				
Victorino and others[84]	Brazil	English	human canines	AH Plus	1 week	1% CHX diacetate; 1% CHX diacetate + 99% ethanol; 99% ethanol; 2% CHX	#2 Unicore Drill	Unicore Post	PermaFlo DC	24 hours	Push-out test
Wang and others[85]	Brazil	English	bovine roots	Sealer 26	1 week	2% CHX	size 2 Gates drill and drill provided by the manufacturer of the post-system	Exacto posts, size 2	Rely X ARC	1 week	Push-out test
Wu and others[86]	China	English	human incisors and 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 hours	Microtensile bond strength

Xia and Cheng[87]	China	English	human premolars	RealSeal SE	3 days	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 hours	Push-out test
Yaman and others[88]	Turkey	English	permanent human lower premolars	AH Plus	24 hours	Clearfil SE Primer; 37% H3PO4; ≥99.5% Ethanol; 2% CHX	Largo Peeso Reamer and drill correspondi ng to the size of the FP (ICELight reamer)	ICELig ht, 1.4 mm	Clearfil SA Cement Automix	24 hours	Microtensil e bond strength
Yu and others[89]	China	English	human premolars	AH Plus	3 days	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 of size 3	Rely X Fiber Post	Clearfil DC Core Auto-mix	24 hours or thermo cycling for 10,000 cycles	Push-out test

Zhang and others[18]	China	English	Human premolars	AH Plus	3 days	35% H3PO4; 17% EDTA+ 5.25% NaOCl; 17% EDTA+ 5.25% NaOCl + ultrasound	#2 Peeso reamer and #3 DT drill from DT Light-Post system	#3 DT Light posts	Clearfil SE Bond or Clearfil DC Bond	-	Push-out test
Zhou and 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% and 1.0%.	Gates-Glidden drills #2 and post drills provided by the post manufacturer	LuxaPost, 1.5 mm diameter	Panavia F	24 hours or 18 months	Push-out test
Zhu and others[91]	China	Chinese	Human mandibular premolars	AH 26 or AH Plus	1 week	17% EDTA + 5.25% NaOCl; 17%EDTA + 5.25% NaOCl + ultrassound	-	fiber posts	RelyX Unicem	1 week	Push-out test
Çökük and others[13]	Turkey	English	human maxillary central incisors	MMSeal	1 week	5% NaOCl; 2% CHX; 1.5W Er, Cr: YSGG laser; 1.25W Er, Cr: YSGG laser	drill #2 of fiber glass post system (Exacto)	Exacto	Panavia F2.0	1 week	Push-out test

Šimundić Munitić and others[92]	Croatia	English	anterior single-rooted permanent human teeth	AH Plus	2 weeks	Er:YAG (pulse energy 20 mJ, pulse duration 50 µs, pulse repetition rate 15 Hz, energy density 2.06 J/cm2.); 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/cm2)	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 week	Push-out test

*Country of the first author. # EDTA: ethylene diamine tetra acetic acid; NaOCl: sodium hypochlorite; CHX: chlorhexidine digluconate; H3PO4: phosphoric acid; EGCG: flavonoid produced in large amounts as a secondary metabolite by the Camellia sinensis plant, “green tea”. - : unclear information in the paper; Er:YAG: erbium-doped yttrium aluminium garnet laser; Er,Cr:YSGG: erbium, chromium-doped:yttrium, scandium, gallium, and garnet; Nd:YAG: neodymium-doped yttrium aluminium garnet; CaOCl: calcium hypochlorite

Table 2. Risk bias of the studies considering aspects reported in Materials and Methods 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 and others[27]	YES	NO	YES	NO	YES	NO	NO	NO	YES	MEDIUM
Alfredo and others[28]	YES	NO	YES	YES	NO	NO	NO	NO	NO	HIGH
Alkhudhairy and others[11]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Angeloni and others[29]	YES	NO	YES	NO	NO	NO	NO	NO	YES	MEDIUM
Arana and others[30]	NO	NO	YES	NO	NO	NO	NO	NO	NO	HIGH
Arisu and others[31]	NO	NO	YES	YES	NO	NO	NO	NO	YES	HIGH
Arslan and others[32]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Baena and others[33]	YES	NO	YES	NO	YES	NO	NO	NO	YES	MEDIUM
Bitter and others[34]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH

Bordim and others[35]	YES	NO	NO	YES	YES	NO	NO	YES	NO	MEDIUM
Carvalho and others[36]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Carvalho and others[37]	YES	NO	YES	YES	YES	NO	NO	NO	YES	MEDIUM
Cecchin and others[5]	YES	NO	NO	YES	YES	NO	NO	NO	YES	MEDIUM
Cecchin and others[38]	NO	NO	NO	YES	NO	NO	NO	NO	YES	HIGH
Cecchin and others [8]	NO	NO	YES	YES	YES	NO	NO	NO	YES	MEDIUM
Cintra and others[39]	YES	NO	YES	YES	NO	YES	NO	NO	NO	MEDIUM
Clavijo and others[40]	YES	NO	YES	NO	NO	NO	NO	NO	NO	HIGH
Crispim da Silveira and others[41]	YES	NO	YES	YES	NO	NO	NO	NO	NO	HIGH
Culhaoglu and others[42]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
da Cunha and others[14]	NO	NO	YES	YES	NO	NO	NO	NO	NO	HIGH

da Silva and others[43]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
de Araújo and others[44]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
de Oliveira and others[45]	YES	NO	YES	NO	YES	YES	NO	NO	YES	MEDIUM
Duski and others[46]	YES	NO	YES	NO	NO	NO	NO	NO	NO	HIGH
Ekim and Erdemir[47]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Elnaghy and others[48]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Ertas and others[15]	NO	NO	YES	YES	NO	NO	NO	NO	YES	HIGH
Fan and others[49]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Faria-e-Silva and others[50]	NO	NO	NO	YES	NO	NO	NO	NO	NO	HIGH
Feng and Gao[51]	YES	NO	NO	YES	NO	NO	NO	NO	YES	HIGH
Furuse and others[52]	NO	NO	YES	YES	NO	NO	NO	NO	YES	HIGH
Garcia and others[53]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM

Garcia and others[54]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM
Garcia and others[55]	YES	NO	NO	NO	YES	NO	NO	NO	NO	HIGH
Gomes França and others[56]	YES	NO	NO	YES	NO	NO	NO	NO	YES	HIGH
Goruz and others[57]	YES	NO	NO	NO	NO	NO	NO	NO	NO	HIGH
Jain and others[58]	NO	NO	NO	NO	NO	NO	NO	NO	NO	HIGH
Kirmali and others[59]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Kul and others[60]	NO	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Lacerda and others[61]	NO	NO	YES	NO	NO	NO	NO	NO	NO	HIGH
Lacerda and others[12]	YES	NO	NO	YES	NO	NO	NO	NO	NO	HIGH
Leitune and 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 and others[64]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM

Martinho and others[65]	YES	NO	YES	YES	YES	NO	NO	NO	YES	MEDIUM
Mathew and others[66]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Mohammadi and others[67]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Neelakantan and others[68]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Oral and others[69]	NO	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Parčina Amižić and others[70]	NO	NO	NO	YES	NO	NO	NO	NO	NO	HIGH
Ramos and others[71]	YES	NO	NO	YES	NO	NO	NO	NO	YES	HIGH
Ramos and others [72]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM
Santos and others[73]	NO	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Scotti and others[74]	YES	NO	NO	NO	NO	NO	NO	NO	NO	HIGH
Scotti and others[75]	YES	NO	NO	NO	NO	NO	NO	NO	NO	HIGH
Seballos and others[16]	YES	NO	YES	YES	YES	YES	YES	YES	YES	LOW

Shafiei and others[76]	YES	NO	YES	YES	NO	YES	NO	NO	YES	MEDIUM
Shafiei and others[77]	YES	NO	YES	YES	NO	NO	YES	NO	YES	MEDIUM
Shafiei and 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 and others[80]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Simões and others[81]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Tuncdemir and others[82]	YES	NO	NO	NO	YES	NO	NO	NO	YES	HIGH
Uzun and others[83]	YES	NO	YES	NO	YES	YES	YES	NO	YES	MEDIUM
Victorino and others[84]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM
Wang and others[85]	YES	NO	YES	YES	NO	NO	NO	NO	YES	MEDIUM
Wu and others[86]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Xia and Cheng[87]	YES	NO	YES	NO	YES	NO	NO	NO	YES	MEDIUM

Yaman and others[88]	YES	YES	NO	NO	NO	NO	NO	NO	YES	HIGH
Yu and others[89]	YES	YES	NO	NO	NO	NO	NO	NO	YES	HIGH
Zhang and others[18]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Zhou and others[90]	YES	NO	YES	NO	NO	NO	NO	NO	YES	HIGH
Zhu and others[91]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH
Çökük and others[13]	NO	NO	YES	NO	YES	NO	NO	NO	YES	HIGH
Šimundić Munitić and others[92]	YES	NO	NO	NO	NO	NO	NO	NO	YES	HIGH

FIGURES

Figure 1. Flow diagram of study selection according to PRISMA statement.

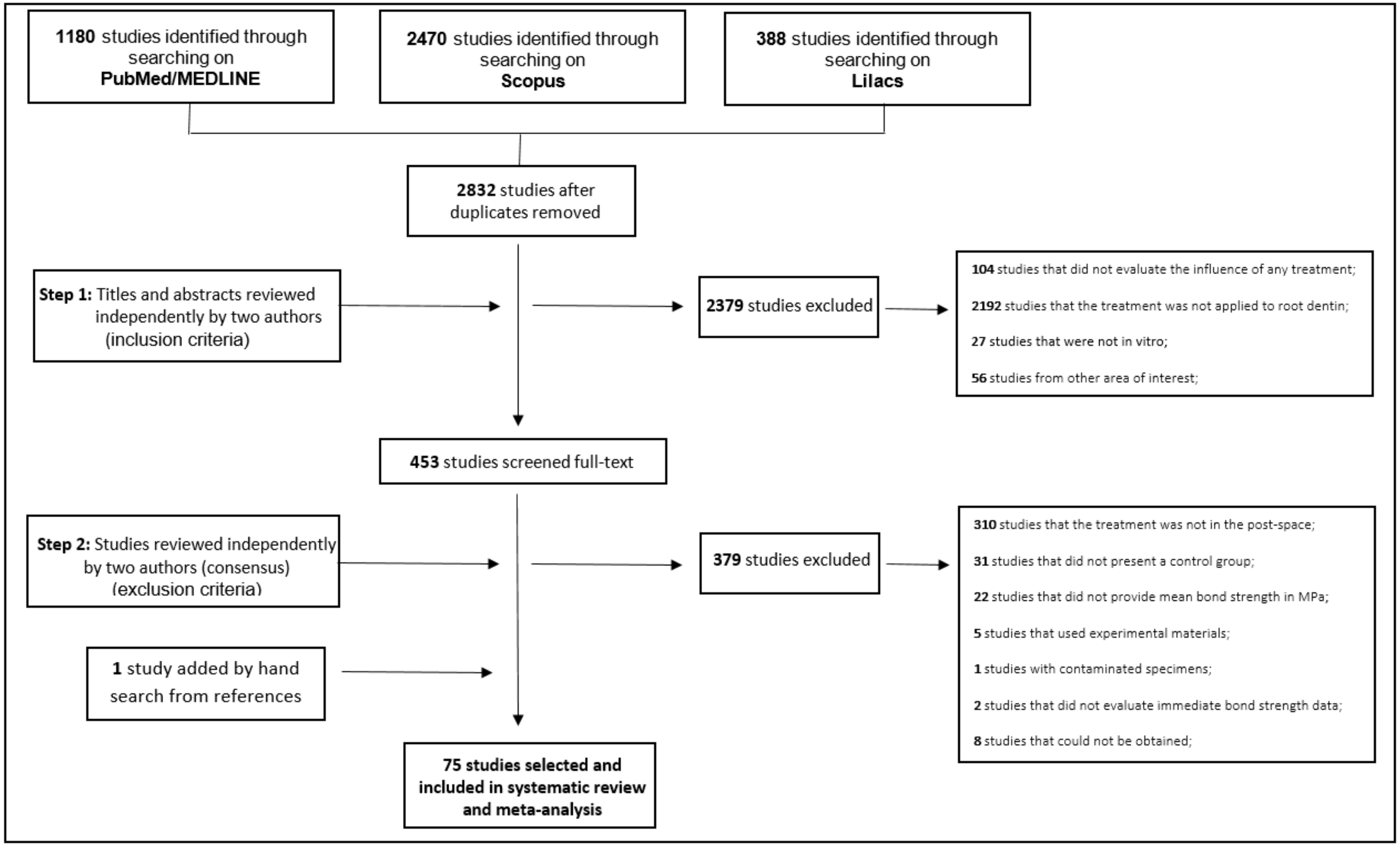


Figure 2. Forest plot of global meta-analysis.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Alaghemand and others [27]	37.69	17.64	36	35.29	20.25	12	0.1%	2.40 [-10.42, 15.22]
Alfredo and others [28]	6.8	5.9	64	4.82	1.63	32	1.3%	1.98 [0.43, 3.53]
Alkhudhairy and others [11]	17.47	5.13	80	15.02	3.26	40	1.3%	2.45 [0.94, 3.96]
Angeloni and others [29]	6.58	3.07	30	6.79	3.2	30	1.3%	-0.21 [-1.80, 1.38]
Arana and others [30]	16.74	5.92	40	18.66	5.08	40	1.0%	-1.92 [-4.34, 0.50]
Arisu and others [31]	4.25	2.03	30	3.56	1.63	10	1.5%	0.69 [-0.55, 1.93]
Arslan and others [32]	4.82	2.33	120	4.81	2.16	24	1.6%	0.01 [-0.95, 0.97]
Baena and others [33]	16.44	6.87	113	13.8	5.4	41	1.1%	2.64 [0.56, 4.72]
Bitter and others [34]	11.37	6.46	110	10.87	5.55	30	1.0%	0.50 [-1.82, 2.82]
Bordim and others [35]	8.31	3.02	20	6.89	3.74	20	1.1%	1.42 [-0.69, 3.53]
Carvalho and others [36]	6.06	2.84	10	5.08	3.43	10	0.8%	0.98 [-1.78, 3.74]
Carvalho and others [37]	8.79	5.53	27	8.87	4.93	9	0.6%	-0.08 [-3.92, 3.76]
Cecchin and others [5]	5.93	1.34	360	5.21	1.64	120	1.8%	0.72 [0.40, 1.04]
Cecchin and others [38]	5.82	1.55	180	4.34	1.62	60	1.7%	1.48 [1.01, 1.95]
Cecchin and others [8]	5.02	1.65	180	4.12	1.78	60	1.7%	0.90 [0.39, 1.41]
Cintra and others [39]	3.81	0.65	66	3.57	0.57	22	1.8%	0.24 [-0.05, 0.53]
Clavijo and others [40]	7.29	1.98	60	8.1	3.28	90	1.6%	-0.81 [-1.65, 0.03]
Crispim da Silveira and others [41]	11.93	6.73	60	12.1	5.2	10	0.6%	-0.17 [-3.82, 3.48]
Culhaoglu and others [42]	5.07	1.77	360	3.43	1.11	90	1.8%	1.64 [1.35, 1.93]
da Cunha and others [14]	5.41	3.65	90	8.04	3.32	45	1.5%	-2.63 [-3.86, -1.40]
da Silva and others [43]	20.45	10.41	30	14.49	7.72	10	0.3%	5.96 [-0.10, 12.02]
de Araújo and others [44]	2.47	2.28	180	4.99	2.71	60	1.6%	-2.52 [-3.28, -1.76]
de Oliveira and others [45]	5.36	2.76	90	7.3	2.77	30	1.5%	-1.94 [-3.08, -0.80]
Duski and others [46]	11.35	6.13	360	6.7	4.55	360	1.6%	4.65 [3.86, 5.44]
Ekim and Erdemir [47]	5.6	1.78	28	3.14	1.29	4	1.4%	2.46 [1.03, 3.89]
Elnaghy and others [48]	11.99	4.74	225	9.57	3.43	45	1.5%	2.42 [1.24, 3.60]
Ertas and others [15]	9.3	3.99	112	9.2	3.4	16	1.2%	0.10 [-1.72, 1.92]
Fan and others [49]	9.81	2.65	90	6.37	0.84	30	1.7%	3.44 [2.82, 4.06]
Faria-e-Silva and others [50]	5.18	2.51	36	5.5	1.36	12	1.5%	-0.32 [-1.44, 0.80]
Feng and Gao [51]	8.58	3.18	120	8.66	2.43	30	1.5%	-0.08 [-1.12, 0.96]
Furuse and others [52]	4.07	3.21	55	7.14	4.35	30	1.2%	-3.07 [-4.84, -1.30]
Garcia and others [53]	7.08	3.79	60	5	2.57	60	1.5%	2.08 [0.92, 3.24]
Garcia and others [54]	7.66	3.35	240	6.44	2.7	60	1.6%	1.22 [0.42, 2.02]
Garcia and others [55]	10	4.15	36	13.93	1.41	12	1.3%	-3.93 [-5.50, -2.36]
Gomes França and others [56]	24.22	18.57	216	12.86	12.02	108	0.7%	11.36 [8.00, 14.72]
Goruz and others [57]	81.39	58.48	40	102.04	10.44	40	0.0%	-20.65 [-39.06, -2.24]
Jain and others [58]	18.12	3.61	84	10.87	1.41	28	1.6%	7.25 [6.32, 8.18]
Kirmali and others [59]	4.12	1.43	180	4.11	1.49	60	1.7%	0.01 [-0.42, 0.44]
Kul and others [60]	7.77	2.33	30	7.62	1.88	10	1.4%	0.15 [-1.28, 1.58]
Lacerda and others [61]	15.6	20.96	120	11.84	13.9	60	0.4%	3.76 [-1.38, 8.90]
Lacerda and others [12]	6.43	2.16	55	7.33	2.29	11	1.4%	-0.90 [-2.37, 0.57]
Leitune and others [62]	12.82	3.51	96	12.41	3.33	48	1.5%	0.41 [-0.76, 1.58]
Lima [63]	9.3	2.51	144	9.27	2.5	72	1.7%	0.03 [-0.68, 0.74]
Mao and others [64]	7.24	3.91	216	4.45	3.56	108	1.6%	2.79 [1.94, 3.64]
Martinho and others [65]	6.55	2.59	240	7.67	3.25	30	1.5%	-1.12 [-2.33, 0.09]
Mathew and others [66]	9.03	3.13	120	9.49	2.57	60	1.6%	-0.46 [-1.32, 0.40]
Mohammadi and others [67]	12.72	6.23	15	8.5	4.93	15	0.5%	4.22 [0.20, 8.24]
Neelakantan and others [68]	11.48	6.04	160	5.64	1.88	40	1.5%	5.84 [4.74, 6.94]
Oral and others [69]	11.48	8.42	50	5.8	3.5	10	0.7%	5.68 [2.49, 8.87]
Parčina Amižić and others [70]	4.37	2.72	38	4.43	2.95	19	1.3%	-0.06 [-1.64, 1.52]
Ramos and others [71]	3.88	1.53	60	4.28	1.81	60	1.7%	-0.40 [-1.00, 0.20]
Ramos and others [72]	4.26	1.24	60	3.71	1.12	60	1.7%	0.55 [0.13, 0.97]
Santos and others [73]	0.71	0.67	360	0.67	0.73	120	1.8%	0.04 [-0.11, 0.19]
Scotti and others [74]	7.88	3.38	10	6.58	4.03	60	1.0%	1.30 [-1.03, 3.63]
Scotti and others [75]	15.52	6.94	60	13.9	5.95	20	0.7%	1.62 [-1.52, 4.76]
Seballos and others [16]	5.91	3.34	70	11.5	5.3	10	0.7%	-5.59 [-8.97, -2.21]
Shafiei and others [76]	13.89	4.13	300	12.32	3.97	60	1.5%	1.57 [0.46, 2.68]
Shafiei and others [77]	13.16	3.38	288	12.97	3.9	144	1.7%	0.19 [-0.56, 0.94]
Shafiei and others [78]	12.61	3.69	288	11.22	2.7	48	1.6%	1.39 [0.52, 2.26]
Silva [79]	4.88	3.4	270	5.84	3.77	270	1.7%	-0.96 [-1.57, -0.35]
Simões and others [80]	4.13	2.6	48	5.34	2.15	48	1.6%	-1.21 [-2.16, -0.26]
Simões and others [81]	3.31	1.5	24	5.34	2.15	48	1.6%	-2.03 [-2.88, -1.18]
Tuncdemir and others [82]	5.83	2.87	40	4.15	1.42	10	1.5%	1.68 [0.43, 2.93]
Uzun and others [83]	8.99	1.57	20	7.54	1.79	20	1.5%	1.45 [0.41, 2.49]
Victorino and others [84]	4.03	2.79	120	2.54	1.64	30	1.6%	1.49 [0.72, 2.26]
Wang and others [85]	3.1	2.67	90	5.04	2.97	90	1.6%	-1.94 [-2.77, -1.11]
Wu and others [86]	12.99	5.27	184	18.29	7.89	47	1.0%	-5.30 [-7.68, -2.92]
Xia and Cheng [87]	1.8	0.97	78	1.22	0.71	26	1.8%	0.58 [0.23, 0.93]
Yaman and others [88]	17.03	3.93	108	10.7	2.6	36	1.5%	6.33 [5.20, 7.46]
Yu and others [89]	8.38	4.37	576	7.14	3.42	192	1.7%	1.24 [0.64, 1.84]
Zhang and others [18]	9.79	4.55	90	8.42	3.99	30	1.3%	1.37 [-0.34, 3.08]
Zhou and others [90]	13.02	6.47	120	11.5	7.14	60	1.1%	1.52 [-0.63, 3.67]
Zhu and others [91]	15.5	5.09	32	9.68	3.45	16	1.0%	5.82 [3.38, 8.26]
Çökük and others [13]	6.89	1.17	120	6.79	0.27	30	1.8%	0.10 [-0.13, 0.33]
Šimundić Munitić and others [92]	1.47	1.17	70	0.74	0.13	14	1.8%	0.73 [0.45, 1.01]
Total (95% CI)			**8988**			**3822**	**100.0%**	**0.81 [0.46, 1.15]**

Heterogeneity: $Tau^2 = 1.77$; $Chi^2 = 1236.90$, $df = 74$ ($P < 0.00001$); $I^2 = 94\%$

Test for overall effect: $Z = 4.53$ ($P < 0.00001$)

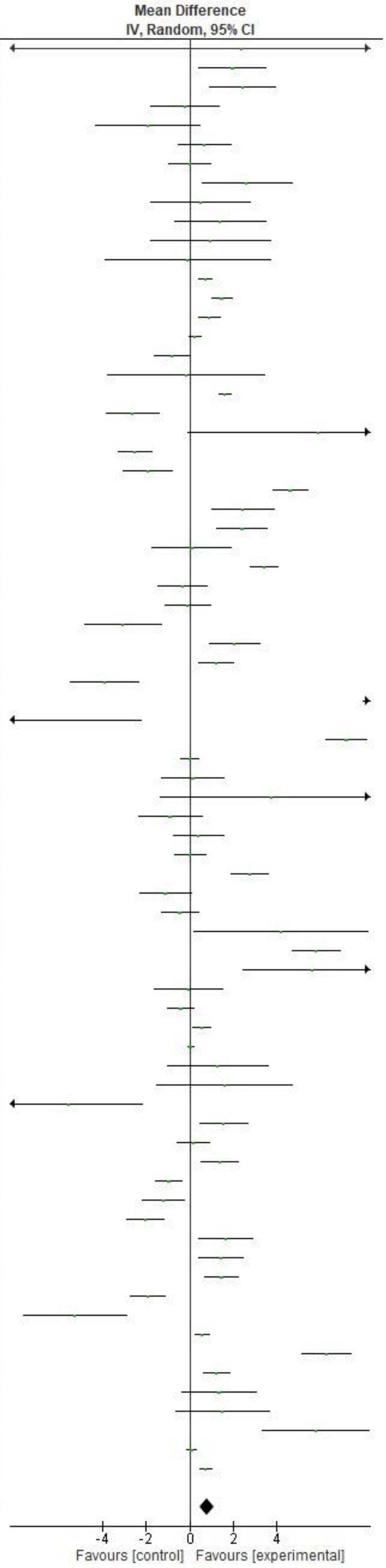


Figure 3. Forest plot of post space treatments analyzed separately.

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
NaOCl								
Subtotal (95% CI)			**1122**			**942**	**17.1%**	**-0.90 [-1.52, -0.28]**
Heterogeneity: Tau² = 1.85; Chi² = 430.24, df = 24 (P < 0.00001); I² = 94%								
Test for overall effect: Z = 2.83 (P = 0.005)								
EDTA								
Subtotal (95% CI)			**569**			**542**	**9.4%**	**-0.73 [-1.87, 0.42]**
Heterogeneity: Tau² = 4.05; Chi² = 189.61, df = 14 (P < 0.00001); I² = 93%								
Test for overall effect: Z = 1.24 (P = 0.21)								
CHX								
Subtotal (95% CI)			**2318**			**1898**	**19.2%**	**0.42 [-0.00, 0.85]**
Heterogeneity: Tau² = 0.81; Chi² = 367.29, df = 27 (P < 0.00001); I² = 93%								
Test for overall effect: Z = 1.94 (P = 0.05)								
Ethanol								
Subtotal (95% CI)			**521**			**521**	**7.0%**	**2.51 [1.32, 3.70]**
Heterogeneity: Tau² = 3.25; Chi² = 191.14, df = 12 (P < 0.00001); I² = 94%								
Test for overall effect: Z = 4.13 (P < 0.0001)								
NaOCl + EDTA								
Subtotal (95% CI)			**534**			**534**	**10.5%**	**1.68 [0.71, 2.65]**
Heterogeneity: Tau² = 3.18; Chi² = 211.56, df = 16 (P < 0.00001); I² = 92%								
Test for overall effect: Z = 3.40 (P = 0.0007)								
CHX + ethanol								
Subtotal (95% CI)			**240**			**240**	**3.0%**	**0.84 [-0.10, 1.78]**
Heterogeneity: Tau² = 0.63; Chi² = 25.93, df = 2 (P < 0.00001); I² = 92%								
Test for overall effect: Z = 1.75 (P = 0.08)								
NaOCl + ethanol								
Subtotal (95% CI)			**201**			**201**	**1.2%**	**-0.04 [-2.53, 2.45]**
Heterogeneity: Tau² = 2.13; Chi² = 2.18, df = 1 (P = 0.14); I² = 54%								
Test for overall effect: Z = 0.03 (P = 0.98)								
Phosphoric acid								
Subtotal (95% CI)			**177**			**255**	**4.2%**	**2.04 [-1.41, 5.49]**
Heterogeneity: Tau² = 20.85; Chi² = 193.65, df = 6 (P < 0.00001); I² = 97%								
Test for overall effect: Z = 1.16 (P = 0.25)								
Polyacrylic acid								
Subtotal (95% CI)			**193**			**243**	**3.8%**	**-0.28 [-1.79, 1.24]**
Heterogeneity: Tau² = 2.67; Chi² = 39.03, df = 5 (P < 0.00001); I² = 87%								
Test for overall effect: Z = 0.36 (P = 0.72)								
NaOCl + ascorbic acid								
Subtotal (95% CI)			**75**			**75**	**1.3%**	**-0.84 [-2.46, 0.78]**
Heterogeneity: Tau² = 0.70; Chi² = 1.97, df = 1 (P = 0.16); I² = 49%								
Test for overall effect: Z = 1.01 (P = 0.31)								
Ultrasound								
Subtotal (95% CI)			**41**			**41**	**1.2%**	**-1.27 [-2.50, -0.04]**
Heterogeneity: Tau² = 0.00; Chi² = 0.02, df = 1 (P = 0.89); I² = 0%								
Test for overall effect: Z = 2.02 (P = 0.04)								
NaOCl+ ultrasound								
Subtotal (95% CI)			**125**			**95**	**2.4%**	**-1.40 [-2.80, -0.01]**
Heterogeneity: Tau² = 1.26; Chi² = 8.48, df = 3 (P = 0.04); I² = 65%								
Test for overall effect: Z = 1.97 (P = 0.05)								
CHX + ultrasound								
Subtotal (95% CI)			**41**			**41**	**1.3%**	**0.53 [-0.60, 1.65]**
Heterogeneity: Tau² = 0.00; Chi² = 0.00, df = 1 (P = 0.95); I² = 0%								
Test for overall effect: Z = 0.92 (P = 0.36)								
NaOCl + EDTA + Ultrasound								
Subtotal (95% CI)			**76**			**76**	**2.4%**	**3.68 [0.43, 6.93]**
Heterogeneity: Tau² = 10.09; Chi² = 48.39, df = 3 (P < 0.00001); I² = 94%								
Test for overall effect: Z = 2.22 (P = 0.03)								
Er:YAG laser								
Subtotal (95% CI)			**110**			**109**	**4.3%**	**1.05 [0.14, 1.97]**
Heterogeneity: Tau² = 0.86; Chi² = 32.31, df = 4 (P < 0.00001); I² = 88%								
Test for overall effect: Z = 2.25 (P = 0.02)								
Nd:YAG laser								
Subtotal (95% CI)			**44**			**44**	**1.8%**	**0.13 [0.05, 0.21]**
Heterogeneity: Tau² = 0.00; Chi² = 0.46, df = 1 (P = 0.50); I² = 0%								
Test for overall effect: Z = 3.26 (P = 0.001)								
Diode laser								
Subtotal (95% CI)			**320**			**140**	**3.1%**	**2.24 [0.73, 3.75]**
Heterogeneity: Tau² = 1.98; Chi² = 19.82, df = 3 (P = 0.0002); I² = 85%								
Test for overall effect: Z = 2.91 (P = 0.004)								
Er,Cr:YSGG laser								
Subtotal (95% CI)			**288**			**138**	**3.8%**	**0.41 [-0.03, 0.85]**
Heterogeneity: Tau² = 0.11; Chi² = 9.51, df = 4 (P = 0.05); I² = 58%								
Test for overall effect: Z = 1.84 (P = 0.07)								
NaOCl + Er:YAG								
Subtotal (95% CI)			**74**			**74**	**1.1%**	**0.10 [-3.88, 4.08]**
Heterogeneity: Tau² = 6.98; Chi² = 5.72, df = 2 (P = 0.06); I² = 65%								
Test for overall effect: Z = 0.05 (P = 0.96)								
Photodynamic therapy								
Subtotal (95% CI)			**120**			**120**	**2.0%**	**0.10 [-0.83, 1.03]**
Heterogeneity: Tau² = 0.38; Chi² = 6.44, df = 1 (P = 0.01); I² = 84%								
Test for overall effect: Z = 0.21 (P = 0.83)								

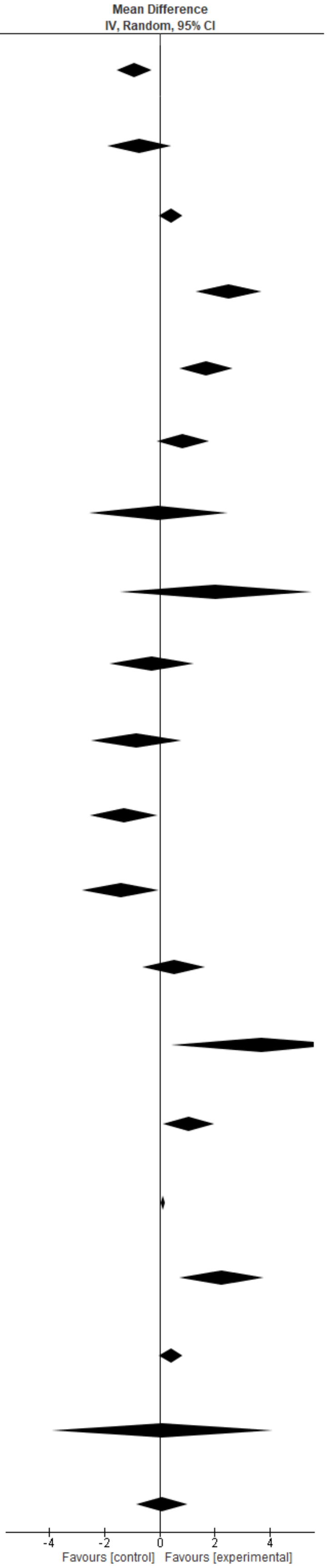
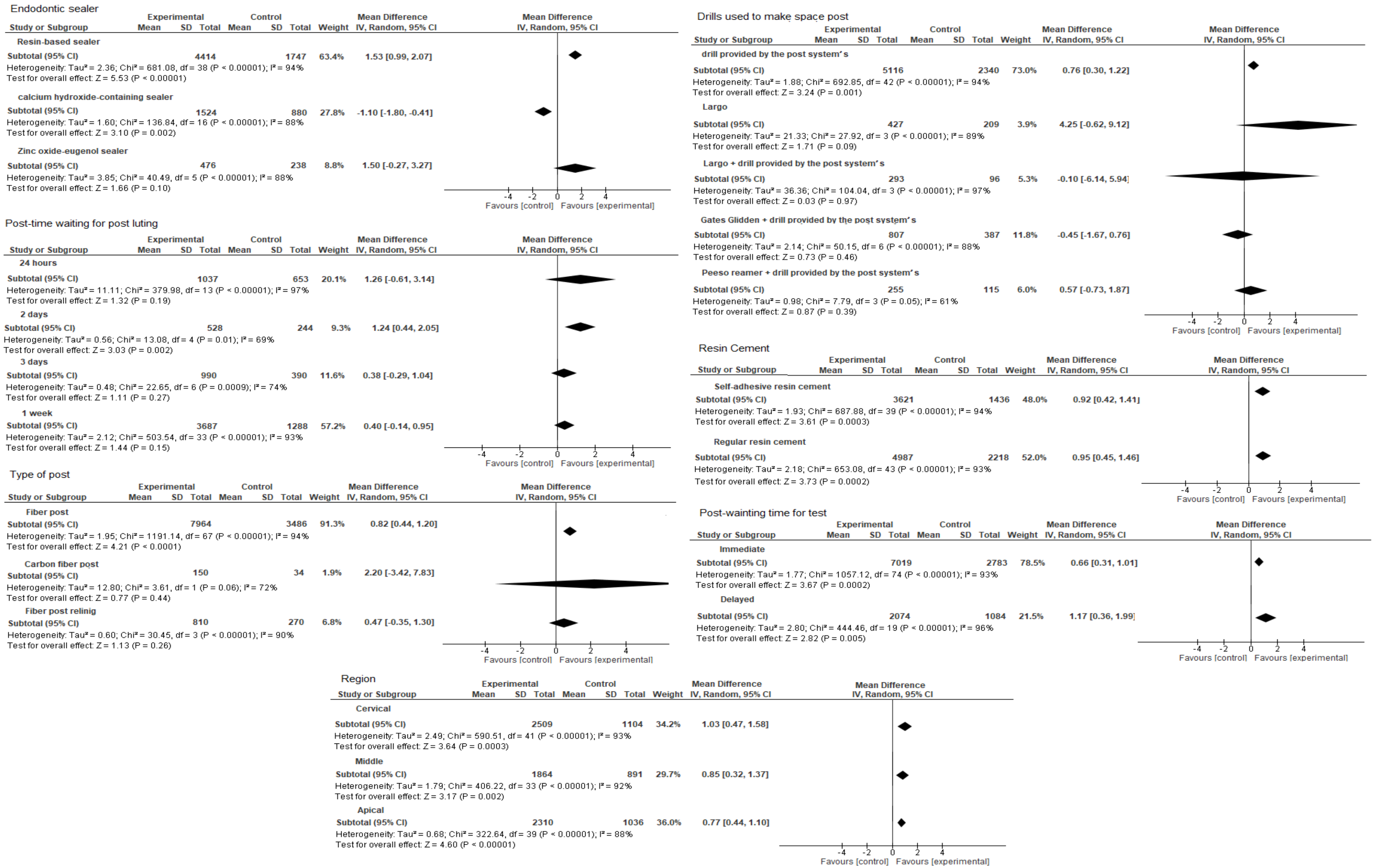


Figure 4. Forest plot of analysis subgroup of global data.



4 ARTIGO 3 - EFFECTS OF DIFFERENT POST-SPACE TREATMENTS ON THE BOND STRENGTH OF INTRARADICULAR POSTS TO DENTIN

Este artigo será submetido ao periódico *The Journal of Adhesive Dentistry*, ISSN:1461-5185, Fator de impacto =2.379; qualis A2. As normas para publicação estão descritas no anexo C.

EFFECTS OF DIFFERENT POST-SPACE TREATMENTS ON THE BOND STRENGTH OF INTRARADICULAR POSTS TO DENTIN

Purpose: This study aimed to evaluate the influence of the post-space treatments using three types of endodontic sealers on the fiber post-dentin bond strength and on the post-space cleaning.

Methods: A total of 240 bovine teeth were endodontically treated by filling the canals with three endodontic sealers: AH Plus (epoxy resin), Endofill (zinc oxide eugenol), and Bio-C Sealer (bioceramic sealer). Afterward, the teeth were stored for 24 hours or 6 months in an oven at 37 °C. Thereafter, different post-space treatments (distilled water, NaOCl + EDTA, alcohol, and diode laser) were applied onto the post-space. The luting of the post was performed using a self-adhesive cement. Then, the specimens were subjected to the push-out test. To assess the cleanliness of the post-space, twelve teeth were submitted to root canal treatment and filled with different endodontic sealers. After the post-space preparation the specimens were divided into the post-space treatments. The specimens were cut along the tooth axis and the post-space was analyzed using a field-emission scanning electron microscope.

Results: The AH Plus sealer had the highest bond strength values, but there was no difference compared to the Bio-C sealer. The NaOCl + EDTA post-space treatment obtained the highest bond strength values and the best smear layer removal in all endodontic sealers used. The storage time of 24 hours had higher bond strength values compared to6 months.

Conclusion: The endodontic sealer, post-space treatment, and storage time influence post-dentin bond strength. NaOCl + EDTA post-space treatments presented higher results than the other treatments.

Keywords: diode laser; fiber post; post space irrigation; push-out.

INTRODUCTION

Intrarradicular posts are indicated for restoring endodontically-treated teeth with large loss of the coronary portion.[19,20] Among the retainers on the market, fiber posts are widely used for presenting aesthetic characteristics, and a more favorable distribution of forces within the root canal due to the similarity of their elasticity modulus with that of dentin.[31,43]

However, the main reason of failure for this type of post is due to the post-dentin adhesion.[40] Therefore, the adhesion between the post, cement and dentin is crucial for the success of the final restoration.[3]

Many factors can influence the post adhesion to dentin, among them the type of endodontic sealer used to fill the root canal.[3,19,20] The eugenol-based sealer is one of the main sealers used among dentists, however, studies in the literature show that this type of endodontic sealer interferes with the polymerization of the resin cement used for post luting, thus affecting the post-dentin bond strength.[10,34]

Another type of sealer which has been introduced to the market is the bioceramic sealer. This sealer has presented biocompatibility with dentinal tissues and excellent dimensional stability as advantages.[42] Despite there is only a few studies, it has been verified that this type of sealer has a negative influence on the post-dentin adhesion.[22,50]

The epoxy resin-based sealer has been shown to not interfere in the adhesion between the post and dentin. For this reason, it has been considered the gold standard among endodontic sealers.[6]

In addition, the post-space preparation results in forming a smear layer within the root canal, containing dentin remains, endodontic sealer, and gutta-percha, among other components.[41] This formed smear layer causes obliteration of the dentinal tubules and affects the post adhesion to the root dentin.[14,23]

Thus, different post-space treatments have been studied in order to modify the influence of the endodontic sealer and remove the smear layer from the root canal after post-space preparation. Among the treatments which have been proposed, sodium hypochlorite (NaOCl) in combination with ethylenediaminetetraacetic acid (EDTA) has been shown to be effective,[4,7,9] as well as the use of alcohol for this cleaning.[1,13] Another proposed treatment is the use of lasers, such as the diode laser, however, there are still few studies evaluating its use.[7,8]

Another factor which can influence the bond strength of the post to dentin is the time between root canal filling and the post-space preparation.[2,10] The prolonged contact of the endodontic sealer with the dentin walls can make the cement penetrate deeper into the dentinal tubules making it more difficult to remove and thus have a greater influence on the post bond strength. [10,36] Despite this, not many studies have evaluated a period longer than 15 days between root canal filling and post-space preparation.[2,10,36]

Therefore, there is a need for studies to evaluate the new endodontic sealers which have appeared on the market, such as the bioceramic sealer, on post-dentin bond strength. Furthermore, studies are also needed to verify the influence of factors such as post-space treatment on the post-dentin bond strength and on the smear layer removal of post-space. It is also necessary to clarify the effect of time between root filling and post-space preparation on the post-dentin adhesion.

Thus, the objective of the present study is to evaluate the influence of the post-space treatments on the post-dentin adhesion using different endodontic sealers (epoxy resin, zinc oxide eugenol, and bioceramic sealer) for filling the root canals and two storage times between filling the canals and the post-space preparation. Furthermore, to evaluate the action of different post-space treatments (distilled water, NaOCl + EDTA, alcohol, or diode laser) on smear layer removal using different endodontic sealers and self-adhesive resin cement for post luting. The null hypothesis was that there would be no difference between endodontic sealers, post-space treatments and storage times evaluated on the post-dentin bond strength, and there would be no difference between post-space treatments in removing the smear layer within the post-space.

MATERIALS AND METHODS

The sample calculation was performed in the OpenEpi 3.1 program[17] to determine the sample size of the present study, with values obtained in a pilot study. The power of the study was considered to be 80% and with a significance level of 0.05. Thus, the need for nine specimens per group was demonstrated, however, considering the variability in shape between bovine teeth, 10 teeth per group were used in this study.

The coronary portions of the 240 lower bovine incisors were sectioned so that the root remnant was 16 mm long and the canals selected according to the anatomical size of a K # 80 file (Dentsply Maillefer, Ballaigues, Switzerland). The teeth that presented the largest root canal were excluded. The apical thirds of the teeth were embedded in self-curing acrylic resin (VIPI Flash, VIPI, Pirassununga, São Paulo, Brazil) with a parallelometer to ensure parallelism to the vertical plane. A trained operator performed all procedures. Afterwards, the specimens were randomly divided into groups according to Table 1. The materials used in the study are described in Table 2.

The teeth were initially submitted to endodontic treatment, with root canals instrumented and filled 1 mm below the root apex. Endodontic instrumentation was performed using the stepback technique with second and third series endodontic files (Dentsply-Maillefer, Ballaigues - Switzerland) and Gates-Glidden drills (Dentsply-Maillefer, Ballaigues - Switzerland) numbers 3, 4 and 5. The canal was irrigated with 2.5% NaOCl solution between each instrument exchange.

Then, all root canals were irrigated with 17% EDTA for 3 min, washed with distilled water and dried with absorbent paper cones (Dentsply Maillefer, Ballaigues, Switzerland). The specimens were filled with endodontic sealer according to the respective groups (Table 1), as well as with gutta-percha cones. The compaction technique was cold lateral condensation. The specimens were filled on a digital scale to standardize the condensation force, with the operator applying a maximum force of 2000g.[10]

Endodontic sealers were handled according to each manufacturer’s guidelines and inserted into the root canal with a Lentulo drill (Injecta, Diadema, São Paulo, Brazil). After filling, the specimens were sealed with composite resin (Z250, 3M-ESPE, Seelfeld, Germany) at the root canal entrance and stored at 37 °C according to the different storage times of twenty-four hours or six months (Table 1).

After the storage time had elapsed, the specimens had the root canal prepared for the post-space, first with a heated instrument compatible with the root canal diameter and later with a specific drill with the same taper of the post (Exact no. 2, Angelus, Paraná, Brazil). After post-space preparation, the specimens went through the post-space treatment corresponding to the group to which they belonged (Table 3).

At the end of the post-space treatments phase, the root canals were cleaned with distilled water for 1 minute and dried with absorbent paper cones (Tanari, Manacapuru, Amazonas, Brazil). Next, the posts were cleaned with 70% alcohol and a silane agent was applied and luting with the resin cement (RelyX U200, 3M-ESPE, Seelfeld, Germany) according to the manufacturer’s instructions.

Next, the samples were first fixed to a metal base on a cutting machine (Isomet 1000 Precision Saw, Buehler, Warwick, England) and then were perpendicularly sectioned along the long axis of the root. Thus, four slices of approximately 1.5 mm were obtained. The slices were submitted to the push-out test at a speed of 1 mm/min (DL 2000, Emic, São José dos Pinhais, Brazil).

The bond strength (σ) in MPa was obtained using the formula $\sigma = F / A$, in which F = force for specimen rupture (N) and A = adhesive area (mm^2). The formula applied for the calculation to determine the adhesive area was the lateral area of a straight circular cone with parallel bases.

The formula was defined as $A = \pi . g . (R1 + R2)$, where $\pi = 3.14$, g = adhesive surface, R1 = smaller radius, and R2 = larger radius. The following calculation was used to determine the adhesive area: $g^2 = h^2 + [R2 - R1]^2$, where h = sectioned height. R1 and R2 were obtained by measuring the internal diameters of the smaller and larger bases, respectively, which correspond to the root canal diameter. Diameters and h were measured with a digital caliper (Starrett 727; Starrett, Itu, São Paulo, Brazil).

After the test, a fractographic analysis was performed with the specimens visualized in a stereomicroscope (Stereomicroscope Discovery V20; Carl Zeiss, Germany) at 10x magnification. The failures were classified as: adhesive between cement and dentin (Adhes CD); adhesive between cement and post (Adhes CP); cement cohesive (Cohes C); post cohesive (Cohes P); dentin cohesive (Cohes D) and mixed adhesive between dentin - cement/post - cement (M Adhes DC/PC).

The data were analyzed for normality and homogeneity, and were considered normal and homogeneous. First, a general analysis of the data was performed using the 3-way ANOVA test. In addition, each studied factor was generally analyzed using the 2-way ANOVA test for the endodontic sealer and post-space treatment factors, and t-test for storage time.

The groups were subsequently analyzed separately, making comparisons between endodontic sealers, post-space treatment and storage time via Two-way ANOVA and Student's t-test.

Scanning Electron Microscope evaluation

A total of 12 bovine incisors were separately prepared for this evaluation. The incisors were sectioned in 16 mm and submitted to endodontic treatment in the same way as described above.

The root canals were randomly divided according to the endodontic sealer used to fill the root canal: AH Plus, Endofill, and Bio-C Sealer. After filling, the specimens were stored for 24 hours at 36 °C.

The post-spaces were prepared with a hot instrument compatible with the root canal and with the post drill of the post system used in the push-out test. Then, the specimens were randomly divided according to the treatment received in the post-space: distilled water, NaOCl + EDTA, alcohol, and laser diode.

After the post-space treatment, the specimens were sectioned along the root canal axis on the cutting machine (Isomet 1000 Precision Saw, Buehler, Warwick, England), and dried for 24 hours at room temperature. The specimens were gold sputtered and then examined with a field-emission scanning electron microscope (JSM 6360 Scanning Electron Microscope, Jeol, Tokyo, Japan). Each specimen was evaluated and field-emission scanning electron micrographs were taken in the one random area at 2000x magnification.

RESULTS

The Three-way ANOVA generally showed that the endodontic sealer, post-space treatment, and storage times had a statistically significant influence on the post-dentin bond strength (Table 4).

AH Plus and Bio-C Sealer obtained the highest post-dentin bond strength values among the endodontic sealers evaluated, but without a significant difference between them. The NaOCl + EDTA had the highest post-dentin bond strength values regarding the post-space treatment, despite not showing any statistically significant difference with alcohol. The storage time of 24 hoursobtained the highest post-dentin bond strength values compared with 6 months (Table 5).

In analyzing the groups separately (Table 6), the distilled water obtained the highest post-dentin bond strength values for AH Plus, both with the storage time of 24 hours or 6 months. There was no difference between distilled water and NaClO + EDTA post-space treatment for 24 hours of storage. On the other hand, there was no statistical difference between post-space treatments for 6 months of storage.

The highest post-dentin bond strength values for Endofill endodontic sealer were for alcohol in the 24-hours storage period, with no statistical difference between distilled water and NaClO + EDTA. In addition, the post-space treatment which had the highest post-dentin bond strength values for the 6-month storage period was NaOCl + EDTA, but without a statistical difference between the distilled water and alcohol post-space treatment.

The Bio-C Sealer had higher post-dentin bond strength values when alcohol was used for the post-space treatment in the storage time of 24 hours, but without a statistical difference for the NaOCl + EDTA group. There was no difference between the post-space treatments in the storage period of 6 months.

Regarding failure mode distribution, most failures were adhesive between cement and post, followed by cohesive of dentin (Table 7). In separating the studied factors, as for the post-space treatment, the distilled water and laser had the majority of adhesive failures between cement and dentin, while the majority of the failures for NaOCl + EDTA and alcohol were cohesive of the dentin. AH Plus had most of the failures for endodontic sealers, being cohesive of the dentin and the Bio-C Sealer and Endofill adhesive between the cement and dentin. Both of the storage times had the majority of adhesive failures between cement and dentin.

In analyzing the SEM photomicrographs obtained, the smear layer removal and opening of the dentinal tubules were affected by the post-space treatment used for all endodontics sealers (Figure 1). The NaClO + EDTA post-space treatment demonstrated better efficiency in relation to cleaning the post-space and opening the dentinal tubules for all endodontic sealers studied. In addition, the laser treatment apparently demonstrated adequate cleaning for the AH Plus sealer, with significant dentinal tubule opening; however, some debris and a smear layer were observed inside the dentinal tubules and covering them. The other groups showed debris and smear layers covering the dentinal tubules, with few or no open dentinal tubules.

DISCUSSION

The present study showed that there is an influence of endodontic sealer, post-space treatment, and storage time on the post-dentin bond strength. In addition, the smear layer removal seems to have been affected by post-space treatments. Therefore, the null hypothesis was rejected.

Cleaning the post-space is crucial for proper adhesion between the fiber post and the dentinal walls.[11,19,41] However, the instruments used in post-space preparation end up creating a smear layer with remnants of endodontic sealers and gutta-percha, among other products.[19,41] This smear layer created in the post-space preparation forms a physical barrier between the resin cement and the dentinal wall, thus impairing the adhesion between the post and the dentin.[20]

Moreover, the endodontic sealers used for filling the root canal can penetrate the dentinal tubules, and may not be completely removed from the canal during the post-space preparation.[29] Thus, depending on the type of endodontic sealer used, the sealer properties can also interfere with post-dentin adhesion.[3,10,34,19] Paschal et al. (1997)[35] demonstrated that the post-dentin adhesion is lower in filled canals when compared with non-filled root canals, independent of endodontic sealer type.

The resin-based sealer is considered the gold standard by literature, because the composition of this sealer shows chemical similarity to post luting resin cements, in addition to not having substances in its composition which can affect the post-dentin adhesion.[10,45] Nevertheless, this sealer remaining inside the dentinal tubules can decrease the effectiveness of bond strength between the post and the dentin.[37]

The resin-based sealer obtained the highest post-dentin adhesion values in this study, however there was no significant difference compared with the bioceramic sealer, with these findings corroborating other studies in the literature.[33,46] Moreover, in analyzing the groups separately, the BC24N and BC24S groups obtained the highest post-dentin adhesion values compared to the other groups.

Due to its composition, the bioceramic sealer in contact with the dentine forms hydroxyapatite which enables good adhesion to the root dentin, but there may be salt precipitation, and interference in the acidity of the dentine due to its alkaline pH.[15,32] In addition, the penetration into the dentinal tubules is greater compared to other endodontic sealers due to the presence of nanoparticle,.[49] According to the manufacturer, the Bio-C Sealer does not have a resinous base, as the viscosity of the sealer is acquired behind the polyethylene glycol, making the sealer more biocompatible and easy to clean.

The eugenol-based sealer obtained the lowest bond strength values, in agreement with other studies in the literature.[6,10,34] This sealer presents eugenol in its composition, which has free radicals that bind with monomers of the resin cement used for post luting, thus interfering in the polymerization of the cement and consequently in the post-dentin bond strength. [6,10,16]

The time between the endodontic treatment and post luting have an influence on the post-dentin bond strength, agreeing with other studies in the literature.[6,10] Prolonged contact of the endodontic sealer with the root canal walls can cause greater sealer penetration into the dentinal tubules, thus affecting post-dentin adhesion.[10,25,27]

Different post-space treatments were used in this study in order to clean the post-space, remove the smear layer formed during the post-space preparation and endodontic sealer present in the root dentin. The post-space treatment which obtained the greatest results on the push-out test and the greatest cleaning verified in the post-space in the scanning microscope electron evaluation was NaOCl + EDTA.

NaOCl is widely used by dentists and is capable of dissolving organic compounds.[24,52] Also, EDTA has the function of a demineralizing agent, as it has chelating action on the calcium ions, thus dissolving inorganic compounds.[24,26] Therefore, the sum of the functions of the two composites seems to be effective in cleaning the post-space and in the post-dentin adhesion.[7,8]

The second post-space treatment that obtained the highest bond strength values was alcohol, but there was no statistical difference compared with NaClO + EDTA post-space treatment, and there was also no statistical difference with distilled water post-space treatment. In analyzing the SEM photomicrographs, there was no efficacy in cleaning the post-space treatment compared with NaClO + EDTA in all endodontic sealers used in the study. Alcohol is capable of dissolving polar and non-polar molecules, and is also capable of controlling moisture within the root canal, replacing water for alcohol, which can increase the post-dentin adhesion and decrease the degradation of the adhesive layer.[18,23] BC24A obtained the highest bond strength values in this study, but with no significant difference with BC24N. In addition, the groups that used alcohol in all endodontic sealers obtained higher bond strength values when the storage time was 24 hours compared with 6 months. These results are in agreement with the literature.[1,38]

The laser diode transmits energy through thin and flexible fibers with a diameter compatible with the root canal, thus being easy to apply within the post-space.[21] The wavelength of the laser diode allows for a good interaction with water and hydroxyapatite, in addition to having the potential to reduce the microbiota of the applied region.[28,39,51] The diode laser has a pulse penetration depth of 10,000 times greater compared to the Er: YAG laser, being able to act deeper within the dentinal tubules.[12,30] Despite there only being a few studies, it has been shown to be effective in removing the smear layer, increasing post-dentin adhesion and causing changes in dentin such as cracks and melting areas.[5] These changes in the dentin can also be seen in the present study (Figure 1), which may have been the reason for the low values of post bond strength to dentin.

Laser application was not effective for removing the smear layer or increasing post-dentin adhesion in this study, agreeing with some studies in the literature.[7,48] However, when AH Plus was used to fill the root canal in which better cleaning and bond strength values were obtained, this treatment was not better than the other tested treatments.

Regarding the failure modes, most failures were generally adhesive between cement and dentine (Table 7). This result corroborates the results of other studies in the literature.[8,38] This failure occurred in all groups, except for the BC24 group, which mostly presented cohesive failure of the dentin. This demonstrates that the adhesive strength generated at the adhesive interface of this group is greater than the bond strength values generated.[47]

A limitation of this study is that bovine teeth were used, however studies have shown that the similarity between bovine and human teeth is sufficient to perform adhesion tests.[44] Just three endodontic sealers and post-space treatment were evaluated, therefore further studies are needed to evaluate other products on the market. In addition, studies evaluating a period longer than 6 months between root canal filling and post luting are necessary.

Thus, the endodontic sealer, post-space treatment, and storage time between filling root canal and post-space preparation appear to affect the post-dentin bond strength. Moreover, the post-space treatment and endodontic sealer can modify the post-space structure, changing the degree of post-space cleanliness and the number of open dentinal tubules. Therefore, further studies are needed to confirm the results.

CONCLUSION

- There is an influence of the endodontic sealer, post-space treatment, and storage time on the post-dentin bond strength.
- For the endodontic sealers studied, the NaOCl + EDTA post-space treatment proved to be a good option for clinicians for both post-dentin bond strength and for cleaning post-space.
- The 24 hours of storage time presented higher post-dentin bond strength than 6 months.
- The cleanliness of the post-space seems to be influenced by the type of post-space treatment used. The NaOCl + EDTA post-space treatment appeared to obtain adequate cleaning with all of the tested endodontic sealers.

Clinical Relevance: NaOCl + EDTA seems to be a good choice for post-space treatment when using AH Plus, Endofill, or Bio-C Sealer for filling the root canals.

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TABLES

Table 1 Division of groups and subgroups (n = 10).

Endodontic sealer	Storage times	Post-space treatment	Code
AH Plus (resin-based sealer)	24 hours	Saline solution	AH24S
		NaClO + EDTA	AH24N
		Alcohol	AH24A
		Laser	AH24L
	6 months	Saline solution	AH6S
		NaClO + EDTA	AH6N
		Alcohol	AH6A
		Laser	AH6L
Endofill (eugenol-based sealer)	24 hours	Saline solution	EN24S
		NaClO + EDTA	EN24N
		Alcohol	EN24A
		Laser	EN24L
	6 months	Saline solution	EN6S
		NaClO + EDTA	EN6N
		Alcohol	EN6A
		Laser	EN6L
Bio-C Sealer (bioceramic sealer)	24 hours	Saline solution	BC24S
		NaClO + EDTA	BC24N
		Alcohol	BC24A
		Laser	BC24L
	6 months	Saline solution	BC6S
		NaClO + EDTA	BC6N
		Alcohol	BC6A
		Laser	BC6L

Table 2 Materials used and theirs composition.

Material	Composition
Endofill (Dentsply, Maillefer, Ballaigues, Switzerland)	Zinc oxide, hydrogenated resin, barium sulfate, eugenol.
AH Plus (Dentsply, Maillefer, Ballaigues, Switzerland)	Epoxide paste: diepoxide, calcium tungstate, zirconium oxide, aerosol, pigment; Amine paste: 1-adamantane amine, N, N0-dibenzyl-5-oxa-nonandiamin-1,9, TCD-diamine, calcium tongstate, zirconium oxide, aerosil, and silicon oil
Bio-C Sealer (Angelus, Paraná, Brazil)	Calcium Silicates, calcium aluminate, calcium oxide, zirconium oxide, iron oxide, silicon dioxide and dispersing agent.
RelyX U200 (3M ESPE, Seefeld, Germany)	Glass powder treated with silane, 2-propenoic acid, 2-methyl 1, 1'-(1- [hydroxymetil]-1,2- ethanodlyl) ester dimethacrylate, TEGDMA, silica-treated silane, glass fibre, sodium persulfate and per-3,5,5-trimethyl hexanoate *t*-butyl, substitute dimethacrylate, sodium *p*-toluenesulfonate, 1- benzyl-5-phenyl-acid barium, calcium, 1,12- dodecane dimethacrylate, calcium hydroxide, and titanium dioxide (filler weight: 45%)

TEGDMA: triethyleneglycol dimethacrylate.

Table 3 Description of the application of the post-space treatment evaluated.

Post-space treatment	Application mode
Distilled water	Irrigation with distilled water for 1 minute.
NaClO + EDTA	Irrigation with 5 ml of 2.5% NaOCl for 1 minute followed by 5 ml of 17% EDTA for 1 minute.
Alcohol	Irrigation with 99% alcohol for 1 minute.
Laser	Application of a diode laser with a wavelength of 980nm (Thera Lase Surgery, DMC, São Carlos, São Paulo, Brazil) at a power of 1.5W and a frequency of 100Hz. The laser was applied to the dentin surface with helical movements along the surface for 8 seconds. Only a single movement was performed keeping the tip of the laser in contact with the dentinal wall. Afterwards, 2 mm of the laser tip was removed and a new application was performed. The root canal was kept dry during laser irradiation.

Table 4 3- way ANOVA result.

Tests of Between-Subjects Effects					
Dependent Variable: mean					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1951.648[a]	23	84.854	11.043	.000
Intercept	12145.197	1	12145.197	1580.598	.000
Endodontic sealer	278.428	2	139.214	18.118	.000
Post-space treatment	503.018	3	167.673	21.821	.000
Storage time	443.321	1	443.321	57.695	.000
Endodontic sealer * Post-space treatment	254.377	6	42.396	5.518	.000
Endodontic sealer * Storage time	290.440	2	145.220	18.899	.000
tratamento * Storage time	291.908	3	97.303	12.663	.000
Endodontic sealer * Post-space treatment * Storage time	141.274	6	23.546	3.064	.007
Error	1383.106	180	7.684		
Total	15840.360	204			
Corrected Total	3334.754	203			

a. R Squared = .585 (Adjusted R Squared = .532)

Table 5 Means and standard deviations of factors studied (MPa).

Endodontic sealer	AH Plus	Endofill	Bio-C Sealer	
	8.55 ± 3.76 A	6.73 ± 3.21B	8.53 ± 4.86 A	
Post-space endodontic treatment	Distilled water	NaClO + EDTA	Alcohol	Laser
	7.85 ± 4.34 B	9.67 ± 4.68 A	8.53 ± 3.69 AB	5.74 ± 2.49 C
Storage times	24 hours	6 months		
	9.19 ± 4.97 A	6.64 ± 2.51 B		

Table 6. Means and standard deviations of the push-out bond strength of different groups (MPa).

Endodontic sealer	Post-space treatment							
	Distilled water		NaClO + EDTA		Alcohol		Laser	
	24 hours	6 months	24 hours	6 months	24 hours	6 months	24 hours	6 months
AH Plus	16.11 ± 5.51Aa*	9.42 ± 3.93Aa*	9.91 ± 0.31ABa*°	7.16 ± 1.50Ab*	10.69 ± 2.02Ba°	6.59 ± 1.82Ab*	6.82 ± 3.42Ba*	6.79 ± 0.77Aa*
Endofill	6.64 ± 3.27ABa°	6.12 ± 2.78ABa*	7.72 ± 3.6Aa°	8.53 ± 2.41Aa*	9.51 ± 3.62Aa°	6.43 ± 2.51ABb*	3.43 ± 0.79Ba°	5.43 ± 2.37Ba*
Bio-C Sealer	9.92 ± 1.40Ba*°	5.89 ± 3.01Ab*	16.35 ± 4.6Aa*	7.02 ± 2.36Ab*	16.53 ± 2.39Aa*	6.21 ± 1.28Ab*	6.19 ± 1.85Ba*	5.78 ± 2.14Aa*

Uppers case letters compare the post-space treatment factor (lines). keeping unaltered the endodontic sealer and storage time.
Lower case letters compare the two storage times (lines). keeping unaltered the endodontic sealer and post-space treatment.
The symbols *. ° compare the endodontic sealers (column). within the same storage time and post-space treatment. same symbols indicate similarity and different symbols indicate differences.

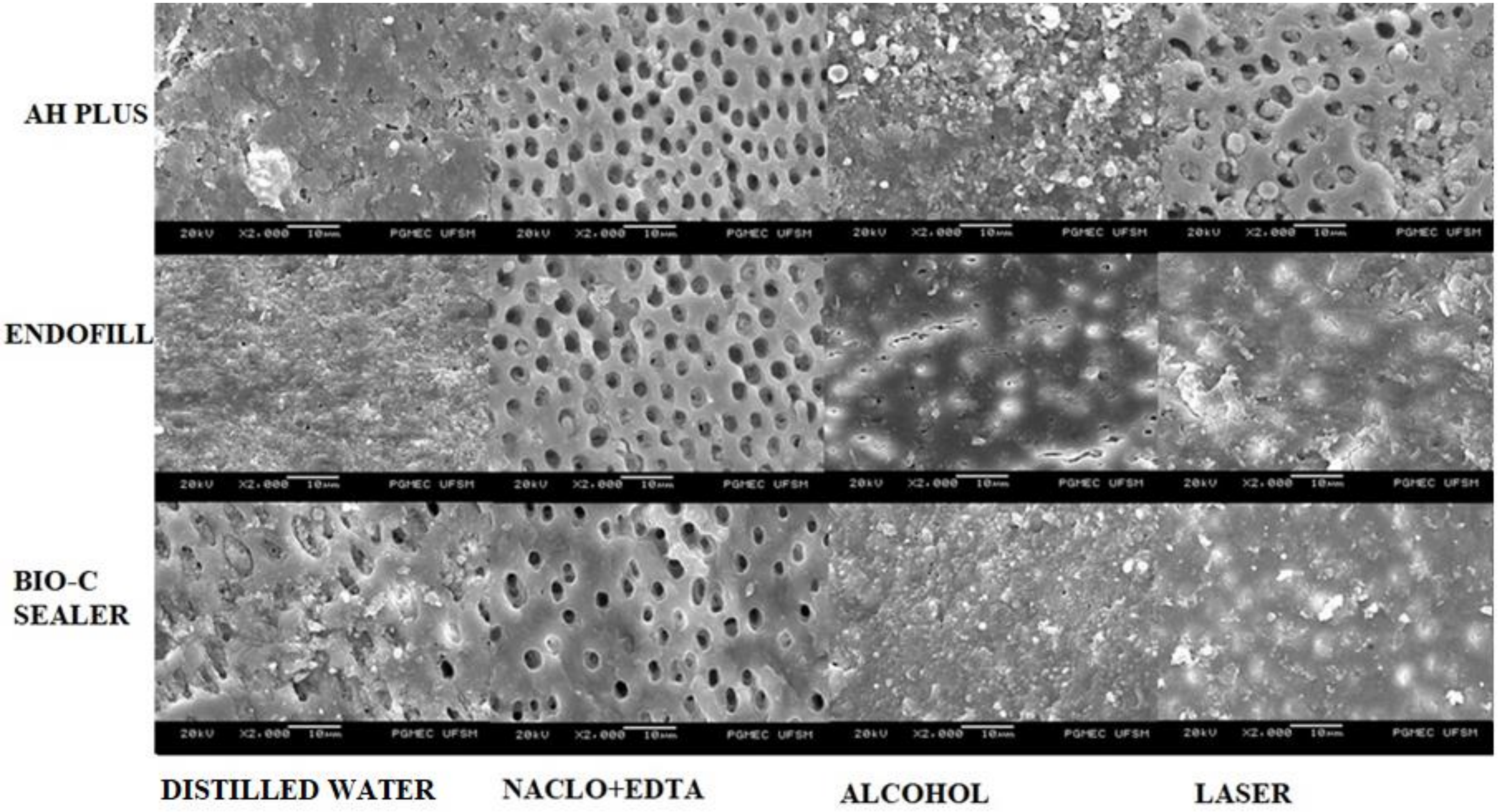
Table 7 Failure mode distribution after the push-out test.

Endodontic sealer	Storage times	Post-space treatment	Types of failures					
			Adhes c/d	Adhes c/p	Cohes c	Cohes p	Cohes d	M
AH Plus	24 hours	Distilled water	3	12	-	-	21	-
		NaClO + EDTA	3	13	-	-	20	-
		Alcohol	6	11	-	1	17	-
		Laser	33	1	-	-	2	-
	6 months	Distilled water	11	3	-	-	9	-
		NaClO + EDTA	6	5	-	-	21	-
		Alcohol	7	6	-	-	12	-
		Laser	25	3	-	-	1	-
Endofill	24 hours	Distilled water	27	5	-	-	3	-
		NaClO + EDTA	28	5	-	-	2	-
		Alcohol	29	5	-	-	-	-
		Laser	34	2	-	-	-	-
	6 months	Distilled water	28	1	-	-	5	-
		NaClO + EDTA	9	7	-	-	14	-
		Alcohol	18	4	-	-	9	-
		Laser	21	12	-	-	2	-
Bio-C Sealer	24 hours	Distilled water	7	1	-	-	27	-
		NaClO + EDTA	14	4	-	-	17	-
		Alcohol	3	3	-	-	28	-
		Laser	32	3	-	-	-	-
	6 months	Distilled water	20	4	-	-	11	-
		NaClO + EDTA	19	1	-	-	15	-
		Alcohol	12	7	-	-	10	-
		Laser	24	7	-	-	-	-
Total			419 (52,97%)	125 (15,80%)	-	1 (0,13%)	246 (31,10%)	-

Adhes c/d = adhesive failure between cement and dentine; Adhes c/p = adhesive failure between cement and post; Cohes c = cohesive failure of cement; Cohes p = cohesive failure of post; Cohes d = cohesive failure of dentine; M = mixed failure.

FIGURES

Figure 1 SEM photomicrographs showing the root canal dentin in the different groups (2000x).



5 DISCUSSÃO

O primeiro artigo apresentado demonstrou que os cimentos endodônticos afetaram negativamente a resistência do pino intrarradicular à dentina quando comparado com o grupo controle (sem cimento, AH Plus, ou cimento à base de resina) ou com o grupo sem cimento endodôntico. Ainda, apesar de haver fatores que podem modificar a união adesiva do retentor intrarradicular à dentina (tipo de cimento endodôntico, tipo de cimento utilizado na cimentação do pino, tempo entre a obturação do canal e a cimentação do pino, tempo para a realização do teste de push-out, e diferentes terços radiculares), analisando cada fator separadamente, a influência negativa do cimento endodôntico sempre persiste.

O cimento endodôntico pode afetar a resistência de união do pino à dentina radicular de duas maneiras. A primeira maneira é por formar uma barreira física entre o cimento utilizado na cimentação do pino e a dentina radicular (DIMITROULI et al., 2011). Sabemos que durante a obturação do canal radicular há o uso de forças de obturação que auxiliam a penetração do cimento endodôntico dentro dos túbulos dentinários, tornando mais difícil a remoção desse cimento durante o preparo do pino (ROSA et al., 2013). Ainda, a preparação do espaço do pino é um passo clínico crítico, pois além de não conseguir remover totalmente o cimento endodôntico do espaço do pino, acaba por criar uma nova *smear layer* contendo restos de guta-percha, cimento endodôntico, entre outros componentes (DEMIRYUREK et al., 2009; SERAFINO et al., 2004).

A segunda maneira pela qual os cimentos endodônticos podem afetar a resistência de união dos pinos intrarradiculares à dentina é pela sua composição. Os cimentos endodônticos à base de óxido de zinco e eugenol, por exemplo, apresentam em sua composição a molécula de eugenol que, ao interagir com os monômeros do cimento resinoso utilizado na cimentação do pino, acabam por inibir parcialmente a polimerização do cimento, afetando a resistência de união do pino à dentina (ALTMANN et al., 2015; BOHRER et al., 2018).

Os cimentos à base de hidróxido de cálcio são de difícil remoção do canal radicular (FONSECA et al., 2005). Além disso, contém em sua composição salicilato de isobutila, que ao reagir com o cálcio liberado pelo próprio cimento, forma uma barreira que pode afetar a resistência de união entre pino e a dentina (CAICEDO; ALONGI; SARKAR, 2006).

Os cimentos biocerâmicos apresentam uma boa adesão à dentina radicular por formar hidroxiapatita durante a reação de presa do cimento (LOUSHINE et al., 2011), além de penetrar mais facilmente dentro dos túbulos dentinários, devido à presença de nano-partículas em sua composição (UTNEJA et al., 2015). Todas essas características do cimento biocerâmico podem contribuir com a dificuldade de remoção desse cimento do espaço preparado para o pino. Além disso, esse cimento pode formar uma camada rica em cálcio e fosfato sob a dentina radicular (HAN; OKIJI, 2013).

Durante a reação de presa dos cimentos à base de MTA (mineral trióxido agregado) há liberação de íons cálcio e hidroxila formando uma precipitação de apatita dentro do canal radicular, podendo, assim, diminuir a resistência de união do pino à dentina (SARKAR et al., 2005; KUGA et al., 2011). Além disso, cimentos à base de resina epóxi também influenciam negativamente a resistência de união dos pinos à dentina comparados com o grupo sem cimento endodôntico, corroborando com os achados de outros estudos na literatura (FOROUGH REYHANI et al., 2016; PASCHAL; BURGESS; ROBBINS, 1997).

Um tipo de cimento que não teve diferença estatística comparando o seu uso ao grupo sem cimento foram o cimento à base de silicone, representado pelo GuttaFlow. A literatura demonstrou que esse tipo de cimento tem uma menor penetração dentro dos túbulos dentinários, e seu preenchimentos pode apresentar bolhas, sendo mais fácil de remover o cimento do canal radicular (ELAYOUTI et al., 2005; ORDINOLA-ZAPATA et al., 2009; SÓ et al., 2008). Porém, é preciso ter cautela ao analisar esse resultado, devido à pouca quantidade de estudos que utilizaram esse cimento incluídos na revisão sistemática.

Por conseguinte, apesar de influenciar negativamente a resistência de união do pino à dentina, sabemos que a utilização do cimento endodôntico é essencial para o sucesso da terapia endodôntica. Os cimentos selam o sistema de canais radiculares, promovendo uma adequada adaptação do material obturador ao canal radicular para que não haja um insucesso do tratamento endodôntico (SABADIN et al., 2014). Com isso, para que seja possível diminuir a influência negativa desse material, a segunda proposta de artigo foi executada.

A segunda revisão sistemática demonstrou que a limpeza do espaço do pino com diferentes substâncias aumenta a resistência de união do pino à dentina radicular, diminuindo, assim, a influência do cimento endodôntico. Essa limpeza do espaço para o pino visa remover a *smear layer* formada durante a preparação do espaço para o pino e também, provavelmente, restos de cimento endodôntico utilizado na obturação do canal radicular (ZHANG et al., 2008).

Nessa revisão, foram avaliados 43 diferentes tratamentos do espaço do pino, sendo que seis tratamentos se mostraram efetivos no aumento da resistência de união do pino à dentina: álcool, NaOCl + EDTA, laser de Er:YAG, laser de Nd:YAG e laser de diodo.

O álcool é uma molécula capaz de dissolver componentes polares e apolares, além de controlar a umidade do canal radicular, tornando a matriz de colágeno mais hidrofóbica (DE OLIVEIRA et al., 2019, GU et al., 2009). O NaOCl promove degradação de compostos orgânicos. O EDTA mostra-se efetivo como agente desmineralizante e capaz de dissolver compostos inorgânicos (HAAPASALO et al., 2010). O uso de diferentes lasers dentro do espaço do pino tem mostrado eficaz na limpeza dessa superfície (UZUN et al., 2016),mas ocorrem algumas mudanças na superfície dentinária devido ao uso dos lasers.

O laser de Er:YAG leva à ablação da dentina, evaporação de água e pode haver micro-explosões, tornando a superfície dentinária limpa e túbulos dentinários abertos (TACHIBANA et al., 2008; UZUN et al., 2016). O laser de Nd:YAG, por sua vez, pode causar fusão, resolidificação e formação de pequenos glóbulos na superfície dentinária (ALFREDO et al., 2009; WANG et al., 2005). O laser de diodo também pode haver a formação de trincas e zonas de fusão da dentina (ALFREDO et al., 2009).

Nesse estudo, foi observado que para o cimento endodôntico à base de óxido de zinco e eugenol não há influência de diferentes tratamentos do espaço do pino, porém somente 10 tratamentos foram testados com esse cimento. Além do mais, não houve estudos incluídos que utilizou o cimento biocerâmico para obturação dos canais.

Diante disso, uma terceira proposta de artigo foi realizada avaliando qual tratamento do espaço para o pino poderia ser considerado o melhor dentre os que a segunda revisão sistemática indicou. Ainda, avaliando esses tratamentos quando utilizado o cimento de óxido de zinco e eugenol, cimento biocerâmico, e o cimento à base de resina epóxi (padrão ouro) em diferentes tempos entre a obturação do canal radicular e a cimentação do pino intrarradicular.

Dentro dos tratamentos do espaço do pino avaliados, o NaOCl + EDTA obteve maiores valores de resistência de união do pino à dentina, para todos os cimentos endodônticos testados. Ainda, através da avaliação dos espécimes por microscopia eletrônica de varredura, o tratamento com NaOCl + EDTA foi o mais eficaz na remoção da *smear layer* do espaço preparado para o pino para todos os cimentos testados.

Também, o terceiro artigo executado confirmou a influência tanto do cimento endodôntico quanto dos tratamentos do espaço para o pino, corroborando com os achados das duas revisões sistemáticas executadas. Além disso, demonstrou que o tempo decorrido entre a obturação do canal e o preparo do pino tem influência na resistência de união do pino à dentina, obtendo maiores valores de resistência do pino à dentina quando decorrido 24 horas da obturação do canal até o preparo do pino comparado com 6 meses, corroborando com os achados de outros estudos na literatura (ALTMAN et al., 2015; BOHRER et al., 2018).

Por conseguinte, diante dos resultados dos estudos apresentados, podemos verificar a influência dos cimentos endodônticos na resistência de união dos retentores intrarradiculares à dentina. Ainda, podemos modificar essa influência através da limpeza adequada do espaço preparado para o pino, sendo que o melhor tratamento, diante dos produtos avaliados, é a limpeza do espaço do pino com NaOCl seguido de EDTA. Porém, novos estudos devem ser executados avaliando diferentes cimentos endodônticos que estão surgindo no mercado e novos tratamentos de limpeza a serem aplicados no espaço preparado para o pino intrarradicular.

6 CONCLUSÃO

Diante dos resultados apresentados ao longo do estudo, podemos concluir que os cimentos endodônticos afetaram negativamente a resistência de união dos retentores intrarradiculares à dentina, independente do tipo de cimento utilizado. Fatores como tipo de cimento endodôntico, tipo de cimento utilizado na cimentação do pino, tempo entre a obturação e a cimentação do pino, tempo entre a cimentação do pino e a execução do teste de *push out* e diferentes terços radiculares do espécime não alteraram essa influência.

Portanto, como é preciso utilizar os cimentos endodônticos para obturação do canal radicular, é possível diminuir a influência negativa na resistência de união do pino à dentina através de tratamentos utilizados no espaço preparado para o pino. Esses tratamentos melhoraram a adesão entre o pino e a dentina, diminuindo ou até mesmo anulando o efeito negativo dos cimentos endodônticos.

Além, disso verificamos que o melhor tratamento para se aplicar no espaço do pino seria a aplicação de NaOCl seguido de EDTA. Esse tratamento aumentou a resistência de união dos pinos à dentina e tem se mostrado eficaz na limpeza do espaço para o pino e na abertura dos túbulos dentinários quando utilizados os cimentos endodônticos estudados.

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ANEXO A – NORMAS PARA PUBLICAÇÃO NO PERIÓDICO *JOURNAL OF ENDODONTICS*

Introduction

The *Journal of Endodontics* is owned by the American Association of Endodontists. Submitted manuscripts must pertain to endodontics and may be original research (eg, clinical trails, basic science related to the biological aspects of endodontics, basic science related to endodontic techniques, case reports, or review articles related to the scientific or applied aspects of endodontics). Clinical studies using CONSORT methods (http://www.consort-statement.org/consort-statement/) or systematic reviews using meta-analyses are particularly encouraged. Authors of potential review articles are encouraged to first contact the Editor during their preliminary development via e-mail at *JEndodontics@UTHSCSA.edu*. Manuscripts submitted for publication must be submitted solely to *JOE*. They must not be submitted for consideration elsewhere or be published elsewhere.

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a. The paragraph is the ideal unit of organization. Paragraphs typically start with an introductory sentence that is followed by sentences that describe additional detail or examples. The last sentence of the paragraph provides conclusions and forms a transition to the next paragraph. Common problems include one-sentence paragraphs, sentences that do not develop the theme of the paragraph (see also section "c," below), or sentences with little to no transition within a paragraph.

b. Keep to the point. The subject of the sentence should support the subject of the paragraph For example, the introduction of authors' names in a sentence changes the subject and lengthens the text. In a paragraph on sodium hypochlorite, the sentence, "In 1983, Langeland et al, reported that sodium hypochlorite acts as a lubricating factor during instrumentation and helps to flush debris from the root canals" can be edited to: "Sodium hypochlorite acts as a lubricant during instrumentation and as a vehicle for flushing the generated debris (Langeland et al, 1983)." In this example, the paragraph's subject is sodium hypochlorite and sentences should focus on this subject.

c. Sentences are stronger when written in the active voice, that is, the subject performs the action. Passive sentences are identified by the use of passive verbs such as "was," "were," "could," etc. For example: "Dexamethasone was found in this study to be a factor that was associated with reduced inflammation," can be edited to: "Our results demonstrated that dexamethasone reduced inflammation." Sentences written in a direct and active voice are generally more powerful and shorter than sentences written in the passive voice.

d. Reduce verbiage. Short sentences are easier to understand. The inclusion of unnecessary words is often associated with the use of a passive voice, a lack of focus, or run-on sentences. This is not to imply that all sentences need be short or even the same length. Indeed, variation in sentence structure and length often helps to maintain reader interest. However, make all words count. A more formal way of stating this point is that the use of subordinate clauses adds variety and information when constructing a paragraph. (This section was written deliberately with sentences of varying length to illustrate this point.)

e. Use parallel construction to express related ideas. For example, the sentence, "Formerly, endodontics was taught by hand instrumentation, while now rotary instrumentation is the common method," can be edited to "Formerly, endodontics was taught using hand instrumentation; now it is commonly taught using rotary instrumentation." The use of parallel construction in sentences simply means that similar ideas are expressed in similar ways, and this helps the reader recognize that the ideas are related.

f. Keep modifying phrases close to the word that they modify. This is a common problem in complex sentences that may confuse the reader. For example, the statement, "Accordingly, when conclusions are drawn from the results of this study, caution must be used," can be edited to "Caution must be used when conclusions are drawn from the results of this study."

g. To summarize these points, effective sentences are clear and precise, and often are short, simple and focused on one key point that supports the paragraph's theme.

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Supplementary material such as applications, images and sound clips, can be published with your article to enhance it. Submitted supplementary items are published exactly as they are received (Excel or PowerPoint files will appear as such online). Please submit your material together with the article and supply a concise, descriptive caption for each supplementary file. If you wish to make changes to supplementary material during any stage of the process, please make sure to provide an updated file. Do not annotate any corrections on a previous version. Please switch off the 'Track Changes' option in Microsoft Office files as these will appear in the published version.

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ANEXO B - NORMAS PARA PUBLICAÇÃO NO PERIÓDICO *OPERATIVE DENTISTRY*

Operative Dentistry requires electronic submission of all manuscripts. All submissions must be sent to Operative Dentistry using the Allen Track upload site. Your manuscript will only be considered officially submitted after it has been approved through our initial quality control check, and any problems have been fixed. You will have 6 days from when you start the process to submit and approve the manuscript. After the 6 day limit, if you have not finished the submission, your submission will be removed from the server. You are still able to submit the manuscript, but you must start from the beginning. Be prepared to submit the following manuscript files in your upload:

- A Laboratory or Clinical Research Manuscript file must include:
    - a title
    - a running (short) title
    - a clinical relevance statement
    - a concise summary (abstract)
    - introduction, methods & materials, results, discussion and conclusion
    - references (see Below)
    - The manuscript **MUST NOT** include any:
        - identifying information such as:
            - Authors
            - Acknowledgements
            - Correspondence information
        - Figures
        - Graphs
        - Tables
- An acknowledgement, disclaimer and/or recognition of support (if applicable) must in a separate file and uploaded as supplemental material.
- All figures, illustrations, graphs and tables must also be provided as individual files. These should be high resolution images, which are used by the editor in the actual typesetting of your manuscript. Please refer to the instructions below for acceptable formats.
- All other manuscript types use this template, with the appropriate changes as listed below.

Complete the online form which includes complete author information and select the files you would like to send to Operative Dentistry. Manuscripts that do not meet our formatting and data requirements listed below will be sent back to the corresponding author for correction.

GENERAL INFORMATION

- All materials submitted for publication must be submitted exclusively to Operative Dentistry.
- The editor reserves the right to make literary corrections.
- Currently, color will be provided at no cost to the author if the editor deems it essential to the manuscript. However, we reserve the right to convert to gray scale if color does not contribute significantly to the quality and/or information content of the paper.

- The author(s) retain(s) the right to formally withdraw the paper from consideration and/or publication if they disagree with editorial decisions.
- International authors whose native language is not English must have their work reviewed by a native English speaker prior to submission.
- Spelling must conform to the American Heritage Dictionary of the English Language, and SI units for scientific measurement are preferred.
- While we do not currently have limitations on the length of manuscripts, we expect papers to be concise; Authors are also encouraged to be selective in their use of figures and tables, using only those that contribute significantly to the understanding of the research.
- Acknowledgement of receipt is sent automatically. If you do not receive such an acknowledgement, please contact us at editor@jopdent.org rather than resending your paper.
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REQUIREMENTS

- **FOR ALL MANUSCRIPTS**

1. **CORRESPONDING AUTHOR** must provide a WORKING / VALID e-mail address which will be used for all communication with the journal. **NOTE:** Corresponding authors MUST update their profile if their e-mail or postal address changes. If we cannot contact authors within seven days, their manuscript will be removed from our publication queue.

2. **AUTHOR INFORMATION** must include:
    - full name of all authors
    - complete mailing address for each author
    - degrees (e.g. DDS, DMD, PhD)
    - affiliation (e.g. Department of Dental Materials, School of Dentistry, University of Michigan)

3. **MENTION OF COMMERCIAL PRODUCTS/EQUIPMENT** must include:
    - full name of product
    - full name of manufacturer
    - city, state and/or country of manufacturer

4. **MANUSCRIPTS AND TABLES** must be provided as Word files. Please limit size of tables to no more than one US letter sized page. (8 ½ ” x 11”)

5. **ILLUSTRATIONS, GRAPHS AND FIGURES** must be provided as TIFF or JPEG files with the following parameters
    - line art (and tables that are submitted as a graphic) must be sized at approximately 5” x 7” and have a resolution of 1200 dpi.
    - gray scale/black & white figures must have a minimum size of 3.5” x 5”, and a maximum size of 5” x 7” and a minimum resolution of 300 dpi and a maximum of 400 dpi.

- color figures must have a minimum size of 2.5” x 3.5”, and a maximum size of 3.5” x 5” and a minimum resolution of 300 dpi and a maximum of 400 dpi.
- color photographs must be sized at approximately 3.5” x 5” and have a resolution of 300 dpi.

- **OTHER MANUSCRIPT TYPES**

1. **CLINICAL TECHNIQUE/CASE STUDY MANUSCRIPTS** must include:
   - a running (short) title
   - purpose
   - description of technique
   - list of materials used
   - potential problems
   - summary of advantages and disadvantages
   - references (see below)

2. **LITERATURE AND BOOK REVIEW MANUSCRIPTS** must include:
   - a running (short) title
   - a clinical relevance statement based on the conclusions of the review
   - conclusions based on the literature review…without this, the review is just an exercise
   - references (see below)

- **FOR REFERENCES**

REFERENCES must be numbered (superscripted numbers) consecutively as they appear in the text and, where applicable, they should appear after punctuation.

The reference list should be arranged in numeric sequence at the end of the manuscript and should include:

1. Author(s) last name(s) and initial (ALL AUTHORS must be listed) followed by the date of publication in parentheses.
2. Full article title.
3. Full journal name in italics (no abbreviations), volume and issue numbers and first and last page numbers complete (i.e. 163-168 NOT attenuated 163-68).
4. Abstracts should be avoided when possible but, if used, must include the above plus the abstract number and page number.
5. Book chapters must include chapter title, book title in italics, editors’ names (if appropriate), name of publisher and publishing address.
6. Websites may be used as references, but must include the date (day, month and year) accessed for the information.

7. Papers in the course of publication should only be entered in the references if they have been accepted for publication by a journal and then given in the standard manner with "In press" following the journal name.
8. **DO NOT** include unpublished data or personal communications in the reference list. Cite such references parenthetically in the text and include a date.

EXAMPLES OF REFERENCE STYLE

Journal article: two authors

Evans DB & Neme AM (1999) Shear bond strength of composite resin and amalgam adhesive systems to dentin *American Journal of Dentistry* **12(1)** 19-25.

Journal article: multiple authors
Eick JD, Gwinnett AJ, Pashley DH & Robinson SJ (1997) Current concepts on adhesion to dentin *Critical Review of Oral and Biological Medicine* **8(3)** 306-335.

Journal article: special issue/supplement
Van Meerbeek B, Vargas M, Inoue S, Yoshida Y, Peumans M, Lambrechts P & Vanherle G (2001) Adhesives and cements to promote preservation dentistry *Operative Dentistry* **(Supplement 6)** 119-144.

Abstract:
Yoshida Y, Van Meerbeek B, Okazaki M, Shintani H & Suzuki K (2003) Comparative study on adhesive performance of functional monomers *Journal of Dental Research* **82(Special Issue B)** Abstract #0051 p B-19.

Corporate publication:
ISO-Standards (1997) ISO 4287 Geometrical Product Specifications Surface texture: Profile method – Terms, definitions and surface texture parameters *Geneve: International Organization for Standardization* **1st edition** 1-25.

Book: single author
Mount GJ (1990) *An Atlas of Glass-ionomer Cements* Martin Duntz Ltd, London.

Book: two authors
Nakabayashi N & Pashley DH (1998) *Hybridization of Dental Hard Tissues* Quintessence Publishing, Tokyo.

Book: chapter
Hilton TJ (1996) Direct posterior composite restorations In: Schwarts RS, Summitt JB, Robbins JW (eds) *Fundamentals of Operative Dentistry* Quintessence, Chicago 207-228.

Website: single author
Carlson L (2003) Web site evolution; Retrieved online July 23, 2003 from: http://www.d.umn.edu/~lcarlson/cms/evolution.html

Website: corporate publication
National Association of Social Workers (2000) NASW Practice research survey 2000.

ANEXO C – NORMAS PARA PUBLICAÇÃO NO PERIÓDICO *THE JOURNAL OF ADHESIVE DENTISTRY*

MANUSCRIPT FORMAT AND STRUCTURE

Format

Language: The language of publication is English. It is preferred that manuscript is professionally edited. A list of independent suppliers of editing services can be found at http://authorservices.wiley.com/bauthor/english_language.asp. All services are paid for and arranged by the author, and use of one of these services does not guarantee acceptance or preference for publication

Presentation: Authors should pay special attention to the presentation of their research findings or clinical reports so that they may be communicated clearly. Technical jargon should be avoided as much as possible and clearly explained where its use is unavoidable. Abbreviations should also be kept to a minimum, particularly those that are not standard. The background and hypotheses underlying the study, as well as its main conclusions, should be clearly explained. Titles and abstracts especially should be written in language that will be readily intelligible to any scientist.

Abbreviations: International Endodontic Journal adheres to the conventions outlined in Units, Symbols and Abbreviations: A Guide for Medical and Scientific Editors and Authors. When non-standard terms appearing 3 or more times in the manuscript are to be abbreviated, they should be written out completely in the text when first used with the abbreviation in parenthesis.

Structure

All manuscripts submitted to *International Endodontic Journal* should include Title Page, Abstract, Main Text, References and Acknowledgements, Tables, Figures and Figure Legends as appropriate

Title Page: The title page should bear: (i) Title, which should be concise as well as descriptive; (ii) Initial(s) and last (family) name of each author; (iii) Name and address of department, hospital or institution to which work should be attributed; (iv) Running title (no more than 30 letters and spaces); (v) No more than six keywords (in alphabetical order); (vi) Name, full postal address, telephone, fax number and e-mail address of author responsible for correspondence.

Abstract for Original Scientific Articles should be no more than 250 words giving details of what was done using the following structure:

-Aim: Give a clear statement of the main aim of the study and the main hypothesis tested,if any.

-**Methodology**: Describe the methods adopted including, as appropriate, the design of the study, the setting, entry requirements for subjects, use of materials, outcome measures and statistical tests.

-Results: Give the main results of the study, including the outcome of any statistical analysis.

- **Conclusions**: State the primary conclusions of the study and their implications. Suggest areas for further research, if appropriate.

Main Text of Original Scientific Article should include Introduction, Materials and Methods, Results, Discussion and Conclusion

Introduction: should be focused, outlining the historical or logical origins of the study and gaps in knowledge. Exhaustive literature reviews are not appropriate. It should close with the explicit statement of the specific aims of the investigation, or hypothesis to be tested.

Material and Methods: must contain sufficient detail such that, in combination with the references cited, all clinical trials and experiments reported can be fully reproduced.

When experimental animals are used the methods section must clearly indicate that adequate measures were taken to minimize pain or discomfort. Experiments should be carried out in accordance with the Guidelines laid down by the National Institute of Health (NIH) in the USA regarding the care and use of animals for experimental procedures or with the European Communities Council Directive of 24 November 1986 (86/609/EEC) and in accordance with local laws and regulations.

All studies using human or animal subjects should include an explicit statement in the Material and Methods section identifying the review and ethics committee approval for each study, if applicable. Editors reserve the right to reject papers if there is doubt as to whether appropriate procedures have been used.

(iii) Suppliers: Suppliers of materials should be named and their location (Company, town/city, state, country) included.

Results: should present the observations with minimal reference to earlier literature or to possible interpretations. Data should not be duplicated in Tables and Figures.

Discussion: may usefully start with a brief summary of the major findings, but repetition of parts of the abstract or of the results section should be avoided. The Discussion section should progress with a review of the methodology before discussing the results in light of previous work in the field. The Discussion should end with a brief conclusion and a comment on the potential clinical relevance of the findings. Statements and interpretation of the data should be appropriately supported by original references.

Conclusion: should contain a summary of the findings.

Acknowledgements: *International Endodontic Journal* requires that all sources of institutional, private and corporate financial support for the work within the manuscript must be fully acknowledged, and any potential conflicts of interest noted. Grant or contribution numbers may be acknowledged, and principal grant holders should be listed. Acknowledgments should be brief and should not include thanks to anonymous referees and editors. See also above under Ethical Guidelines.

References

It is the policy of the Journal to encourage reference to the original papers rather than to literature reviews. Authors should therefore keep citations of reviews to the absolute minimum.and recommend the use of a tool such as EndNote or Reference Manager for reference management and formatting. The EndNote reference style can be obtained upon request to the editorial office (iejeditor@cardiff.ac.uk). Reference Manager reference styles can be searched for here: www.refman.com/support/rmstyles.asp

In the text: single or double authors should be acknowledged together with the year of publication, e.g. (Pitt Ford & Roberts 1990). If more than two authors the first author followed by *et al.* is sufficient, e.g. (Tobias *et al.* 1991). If more than 1 paper is cited the references should be in year order and separated by "," e.g. (Pitt Ford & Roberts 1990, Tobias *et al*. 1991).

Reference list: All references should be brought together at the end of the paper in alphabetical order and should be in the following form.

(i) Names and initials of up to six authors. When there are seven or more, list the first three and add *et al.*

(ii)Year of publication in parentheses

(iii) Full title of paper followed by a full stop (.)

(iv) Title of journal in full (in italics)

(v) Volume number (bold) followed by a comma (,)

(vi) First and last pages

Examples of correct forms of reference follow:

Tables, Figures and Figure LegendsTables: Tables should be double-spaced with no vertical rulings, with a single bold ruling beneath the column titles. Units of measurements must be included in the column title.

Figures: All figures should be planned to fit within either 1 column width (8.0 cm), 1.5 column widths (13.0 cm) or 2 column widths (17.0 cm), and must be suitable for photocopy reproduction from the printed version of the manuscript. Lettering on figures should be in a clear, sans serif typeface (e.g. Helvetica); if possible, the same typeface should be used for all figures in a paper. After reduction for publication, upper-case text and numbers should be at least 1.5-2.0 mm high (10 point Helvetica). After reduction, symbols should be at least 2.0-3.0 mm high (10 point). All half-tone photographs should be submitted at final reproduction size. In general, multi-part figures should be arranged as they would appear in the final version. Reduction to the scale that will be used on the page is not necessary, but any special requirements (such as the separation distance of stereo pairs) should be clearly specified.

Unnecessary figures and parts (panels) of figures should be avoided: data presented in small tables or histograms, for instance, can generally be stated briefly in the text instead. Figures should not contain more than one panel unless the parts are logically connected; each panel of a multipart figure should be sized so that the whole figure can be reduced by the same amount and reproduced on the printed page at the smallest size at which essential details are visible.

Figures should be on a white background, and should avoid excessive boxing, unnecessary colour, shading and/or decorative effects (e.g. 3-dimensional skyscraper histograms) and highly pixelated computer drawings. The vertical axis of histograms should not be truncated to exaggerate small differences. The line spacing should be wide enough to remain clear on reduction to the minimum acceptable printed size.

Figures divided into parts should be labelled with a lower-case, boldface, roman letter, a, b, and so on, in the same typesize as used elsewhere in the figure. Lettering in figures should be in lower-case type, with the first letter capitalized. Units should have a single space between the number and the unit, and follow SI nomenclature or the nomenclature common to a particular field. Thousands should be separated by a thin space (1 000). Unusual units or abbreviations should be spelled out in full or defined in the legend. Scale bars should be used rather than magnification factors, with the length of the bar defined in the legend rather than on the bar itself. In general, visual cues (on the figures themselves) are preferred to verbal explanations in the legend (e.g. broken line, open red triangles etc.)

Figure legends: Figure legends should begin with a brief title for the whole figure and continue with a short description of each panel and the symbols used; they should not contain any details of methods.

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