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O USO DE PINO DE FIBRA EM DENTES TRATADOS ENDODONTICAMENTE

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Tese apresentada ao Instituto de Ciência e Tecnologia, Universidade Estadual Paulista (Unesp), Campus de São José dos Campos, como parte dos requisitos para obtenção do título de DOUTOR, pelo Programa de Pós-Graduação em ODONTOLOGIA RESTAURADORA.
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"Seja qual for o grau a que chegamos, o que importa é prosseguir decididamente."

Filipenses 3,16

SUMÁRIO

Jurema ALB. O uso de pino de fibra em dentes tratados endodonticamente [tese]. São José dos Campos (SP): Universidade Estadual Paulista (Unesp), Instituto de Ciência e Tecnologia; 2020.

RESUMO

Este estudo envolve um estudo *in sílico*, um ensaio clínico randomizado e duas revisões sistemáticas com o objetivo de compreender a influência dos pinos de fibra (PF) na resistência à fratura de dentes tratados endodonticamente e restaurados e também, avaliar o efeito de tratamentos químicos dentinários na resistência de união da cimentação do PF na dentina intrarradicular. Estudo *in silico*: seis modelos tridimensionais de incisivos centrais superiores foram projetados em um *software* de desenho e se diferenciaram de acordo com a presença ou ausência de PF de vidro e espessura das facetas diretas de resina composta (0,5, 0,7 e 1 mm). Foram transferidos para o software *ANSYS 17.2,* no qual movimentos funcionais foram simulados com carga de 100 N a 45º nas faces linguais. Os modelos com PF apresentaram melhor distribuição de tensões e menores valores de tensão máxima na região da dentina e faceta. Ensaio clínico randomizado: selecionou-se 50 pacientes com necessidade de faceta em um incisivo central ou lateral superior tratado endodonticamente. Foram divididos em dois grupos (n=25) de acordo com o uso ou não de PF de vidro. Após 6 e 12 meses do tratamento, avaliações clínicas e radiográficas em relação à presença e tipo de fratura, apontaram taxas de sucesso de 96% para o grupo sem PF e 100% para o grupo com PF, sem diferenças estatisticamente significativas. Revisão sistemática e metanálise: as bases de dados *PubMed*, *Scopus*, *Web of Science*, *LILACS*, *BBO*, *Cochrane Library* e *Embase* foram acessadas com a estratégia de busca definida de acordo com a pergunta: ‘ O uso de PF influencia na resistência à fratura de dentes anteriores tratados endodonticamente e restaurados, quando comparados com o não uso de PF? ’ Foram incluídos 32 estudos *in vitro*. Após a metanálise, pode-se concluir que o uso de PF favoreceu a resistência à fratura dos dentes, principalmente para dentes com preparo para faceta e cavidades cervicais e os PF de vidro mostraram resultados mais satisfatórios. Revisão sistemática e metanálise em rede: as bases *PubMed*, *Scopus*, *Web of Science*, *LILACS*, *BBO* e *Cochrane Library* foram acessadas com a estratégia de busca definida de acordo com a pergunta: ‘ Tratamentos químicos da dentina intrarradicular afetam a força de união de PF em dentes tratados endodonticamente? ’ Foram incluídos 61 estudos *in vitro*. Foi realizada a avaliação do risco de viés para estudos *in vitro*. Após a metanálise em rede e análise de SUCRA para cada estratégia de cimentação (adesivo autocondicionante, adesivo de condicionamento total e cimento autoadesivo), concluiu-se que os tratamentos químicos da dentina intrarradicular que melhoram a força de união da cimentação de PF são o acetato de etila para adesivos autocondicionantes, NaOCl em baixa concentração para adesivos de condicionamento total e extrato de semente de uva para cimentos autoadesivos.

Palavras-chave: Técnica para retentor intrarradicular. Facetas dentárias. Resistência à fratura. Ensaio clínico controlado randomizado. Revisão sistemática.

Jurema ALB. Glass fiber post use in endodontically treated teeth [doctorate thesis]. São José dos Campos (SP): São Paulo State University (Unesp), Institute of Science and Technology; 2020.

ABSTRACT

This study involves an in silico study, a randomized clinical trial, and two systematic reviews to understand the influence of fiber posts (FP) on fracture strength of endodontically treated and restored teeth and also to evaluate the effect of dentin chemical treatments on bond strength of FP cementation in intraradicular dentin. In silico study: six three-dimensional models of maxillary central incisors were designed in a CAD software and differed according to the presence or absence of glass FP and thickness of composite resin direct veneer (0.5, 0.7 and 1 mm). They were transferred to the ANSYS 17.2 software, in which functional movements were simulated with a load of 100N at 45º on the lingual surfaces. The models with glass FP showed better stress distribution and lower maximum stress values in the dentin and veneer region. Randomized clinical trial: 50 patients who needed veneer treatment of an endodontically treated central or lateral maxillary incisor were selected. They were divided into two groups (n=25) according to the use or not of glass FP. Direct composite resin veneers were performed for two groups. In the FP group, they were cemented with self-adhesive resin cement. Descriptive data of the population and restored teeth were collected. After 6 and 12 months of treatment, clinical and radiographic evaluations regarding the presence and type of fracture indicated success rates of 96% for the group without FP and 100% for the group with FP, with no statistically significant differences. Systematic review and meta-analysis: PubMed, Scopus, Web of Science, LILACS, BBO, Cochrane Library and Embase databases were accessed with the search strategy defined according to the question: "Does the use of FP influence on fracture strength of endodontically treated and restored anterior teeth when compared to non-use of fiber posts?" Thirty-two in vitro studies were included. Bias risk assessment was based on existing systematic reviews of in vitro studies. After the meta-analysis, it can be concluded that the use of FP favored the fracture resistance of teeth, especially for teeth with veneer preparation and cervical cavities and the glass FP showed more satisfactory results. Systematic review and network meta-analysis: PubMed, Scopus, Web of Science, LILACS, BBO and Cochrane Library databases were accessed with the search strategy defined according to the question: 'Do intraradicular dentin chemical pretreatments affect the bond strength of fiber posts for endodontically treated teeth?' Sixty-one in vitro studies were included. Bias risk assessment for in vitro studies was performed. After network meta-analysis and SUCRA analysis for each cementation strategy (self-etching adhesive, total etching adhesive and self-adhesive cement), it was concluded that the intraradicular dentin chemical treatments that improve the bond strength of FP cementation are ethyl acetate for self-etching adhesive, low concentration NaOCl for total etching adhesives and grape seed extract for self-adhesive cements.

Keywords: Post and core technique. Dental veneers. Fracture strength. Randomized controlled trial. Systematic review.

1 INTRODUÇÃO

O restabelecimento da estética e da função dental envolve procedimentos muito procurados pelos pacientes que apresentam alterações de cor, formato, posicionamento, perda de estrutura dental, lesões cariosas extensas, fraturas dentais ou restaurações deficientes (Korkut et al., 2013). A maioria dos procedimentos restauradores promove a remoção de tecido dentário, até mesmo alguns mais conservadores. O preparo restaurador altera o comportamento biomecânico dos dentes e quanto maior a remoção de estrutura dental, mais fragilizado o dente se torna e menor é a sua resistência à fratura (Akoğlu, Gemalmaz, 2011; Layton, Clarke, 2013).

Muitos dos dentes que necessitam de procedimentos restauradores também possuem tratamento endodôntico. Os dentes tratados endodonticamente possuem algumas particularidades quando comparados aos dentes vitais. São desidratados por não possuírem quantidade semelhante de matéria orgânica dos dentes vitais, como por exemplo, o tecido pulpar e todas as suas estruturas (vascularização e inervação) e o tecido dentinário contendo fluidos e prolongamentos dos odontoblastos (Helfer et al., 1972). A desidratação e outras alterações em sua estrutura também podem ocorrer devido ao contato com substâncias utilizadas para irrigação do canal radicular durante o tratamento endodôntico (Barbosa et al., 1994; Mountouris et al., 2004; Sakae et al., 1988; Tsuda et al., 1996). Além disso, são considerados menos resistentes mecanicamente (Corsentino et al., 2018; Huang et al., 1992; Reeh et al., 1989; Santos Pantaleón et al., 2018). A abertura coronária e o preparo biomecânico dos condutos radiculares para posterior obturação endodôntica causam uma perda de estrutura dentária (Dal Piva et al., 2017). Quando analisados sob aplicações de cargas, dentes saudáveis apresentam propriedades mecânicas favoráveis quando comparados com dentes tratados endodonticamente (Ausiello et al., 2011).

O prognóstico de dentes tratados endodonticamente e restaurados depende de uma série de fatores como as condições da estrutura remanescente (Juloski et al., 2012; Naumann et al., 2018; Ng et al., 2006;

Sarkis-Onofre et al., 2014; Skupien et al., 2016), presença de restaurações (Gresnigt et al., 2012), características das guias anteriores (Kuljic, 2017), histórico de clareamento (Wei et al., 2016), histórico de trauma e hábitos parafuncionais (Signore et al., 2009). Diante dessas condições apresentadas, alguns autores têm sugerido o uso de pinos de fibra para melhorar sua resistência à fratura desses dentes (Salameh et al., 2007; Singh, Thareja, 2014)

Entre os pinos de fibra, existem o de carbono, quartzo e de vidro. O pino de fibra de carbono possui o valor do módulo de elasticidade mais próximo ao da dentina, porém apresenta limitação estética em relação à cor, é mais claro que os pinos metálicos, mas apresenta cor acinzentada que não proporciona um resultado estético ideal para dentes anteriores. Para melhorias estéticas nos sistemas de pinos intrarradiculares, os pinos de fibra de vidro e de quartzo foram introduzidos. Com características mecânicas similares às da dentina, os pinos de fibra de vidro e de quartzo tem boa resistência adesiva por conta da utilização dos sistemas de cimentação adesivos, o que confere longevidade de retenção (Al Moaleem, 2013).

Os pinos de fibra de vidro podem ser capazes de melhorar a resistência flexural dos dentes fragilizados. Os mesmos possuem módulo de elasticidade similar ao da dentina e quando submetidos a aplicações de carga, absorvem e distribuem melhor as tensões ao longo da estrutura dental, diminuindo a probabilidade de fratura (Ramírez-Sebastià et al., 2014). E mesmo diante de episódios de fratura em dentes que possuem pino de fibra de vidro, as falhas podem não ser catastróficas e há maior facilidade de reparo (Salameh et al., 2007; Singh, Thareja, 2014).

A decisão em utilizar o pino de fibra de vidro intrarradicular depende da quantidade de remanescente dental. Geralmente, quanto menor a quantidade de dentina remanescente há maior necessidade da obtenção de um suporte adicional que pode ser adquirido pelo uso do pino de fibra de vidro (Chieruzzi et al., 2017). A indicação da utilização do pino de fibra como retentor de materiais restauradores é bem consolidada da literatura, apesar disso, não há um consenso sobre o uso do pino de fibra como reforço de dentes mais fragilizados.

Em relação ao comportamento biomecânico dos pinos em dentes tratados endodonticamente, existem estudos que por meio da análise de elementos finitos avaliaram a distribuição de tensões em dentes com diferentes preparos coronários (Bergoli et al., 2014; Rajambigai et al., 2016; Santos-Filho et al., 2014; Zarone et al., 2005) em dentes tratados endodonticamente em que se utilizaram pinos de fibra (Ausiello et al., 2011; Furuya et al., 2014) em dentes com diferentes formatos e tipos de pinos de fibra (Silva et al., 2009). Entretanto, são escassas as informações sobre a influência do pino de fibra de vidro na distribuição de tensões em dentes com restaurações que não necessitam do pino como um retentor intrarradicular, como por exemplo as facetas.

A análise de elementos finitos é um teste não-destrutivo capaz de analisar em computador estruturas por meio de modelos tridimensionais numéricos (Soares et al., 2012; Versluis et al., 2004). É uma ferramenta que permite avaliar algumas situações que não são possíveis observar em testes mecânicos laboratoriais, como por exemplo, o comportamento biomecânico de dentes submetidos à determinada carga e a distribuição das tensões na estrutura dental e em materiais restauradores (Bergoli et al., 2014; Zarone et al., 2005). Entretanto, a análise de elementos finitos não apresenta dados de falhas ou fraturas, apenas indica quais as áreas dos dentes são mais suscetíveis.

Embora existam estudos laboratoriais que avaliam o uso de pinos como um reforço da estrutura dental fragilizada (Coelho-de-Souza et al., 2015; Mosharraf, Haerian, 2011; Rajambigai et al., 2016; Skupien et al., 2015), as informações desses estudos são insuficientes e não existem muitas informações obtidas por meio de estudos clínicos (Bolla et al., 2016). Diante das hipóteses geradas e da lacuna presente na literatura, surge a proposta de realizar um estudo clínico randomizado para abordar essa questão.

Com a finalidade de responder de forma mais abrangente tais questionamentos, também se fez necessário o delineamento de uma revisão sistemática e metanálise com a finalidade de avaliar a influência de pinos de fibras de diferentes tipos na resistência à fratura de dentes tratados endodonticamente e que possuem diferentes tipos de remanescentes. As revisões sistemáticas e metanálises permitem a comparação direta de dados entre estudos que apresentam similaridades em relação ao tipo de amostra e intervenções (Dias et al., 2010). Além disso, a presente revisão sistemática engloba informações atualizadas presentes na literatura que permite o melhor entendimento de questões divergentes.

Além das questões que envolvem as propriedades e comportamentos biomecânicos dos pinos de fibra e dos dentes que os recebem, outro assunto acerca da utilização dos mesmos no meio clínico e científico é quanto ao protocolo de cimentação adesiva. Agentes cimentantes com diferentes estratégias adesivas têm sido desenvolvidos para cimentação adesiva de pinos de fibra na dentina intrarradicular (Skupien et al., 2015) A integridade da interface resina-dentina tem relação direta com a força de união de pinos de fibra e com a longevidade da cimentação adesiva (Goracci, Ferrari, 2011). Alguns fatores como a propriedade hidrolítica da água, ação de enzimas endógenas proteolíticas na dentina, presença da *smear layer* com remanescente de cimento endodôntico, material obturador, microrganismos e dentina infectada podem promover a degradação da interface resina-dentina (Akman et al., 2016; Alandia-Román et al., 2017; Mayhew et al., 2000; Serafino et al., 2004; Tjäderhane et al., 2013).

Considerando tais problemas, é importante obter meios para melhorar a retenção dos pinos nos condutos radiculares e assim, aumentar a longevidade e resistência das restaurações nos dentes que o possuem. Alternativas para isso têm sido estudadas e entre elas, destacam-se os diferentes tratamentos químicos da dentina intrarradicular para efetiva desobstrução dos canalículos dentinários, limpeza do substrato dental que receberá o cimento e melhoria da superfície da dentina intrarradicular com a finalidade de aumentar a resistência de união entre cimentos e substrato dental (Kirmali et al., 2017; Toman et al., 2014; Vangala et al., 2016; Wang et al., 2013; Zare Jahromi et al., 2017).

Entre as substâncias químicas utilizadas como tratamentos da dentina intrarradicular, temos como alguns exemplos o etanol, clorexidina, hipoclorito de sódio, EDTA, ácido fosfórico e extrato de semente de uva (Cecchin et al., 2014; Demiryurek et al., 2009; Faria-e-Silva et al., 2014; Furuse et al., 2014; Khoroushi et al., 2016; Lima et al., 2015; Santana et al., 2015). Apesar de existirem numerosos estudos sobre os diferentes tratamentos químicos para a dentina, não existem informações conclusivas sobre qual deles é o mais adequado para melhorar as propriedades da dentina intrarradicular e aumentar a força de união na cimentação adesiva de pinos de fibra. Portanto, um estudo de revisão sistemática e metanálise em rede foi realizado com a finalidade de comparar o efeito de diferentes tratamentos químicos da dentina intrarradicular na força de união de diferentes estratégias de cimentação.

Desta maneira, a realização dos quatro estudos teve como objetivos compreender o desempenho clínico e o comportamento biomecânico do uso de pinos de fibra de vidro em dentes com laminados, avaliar a influência do uso de pinos de fibra na resistência à fratura de dentes tratados endodonticamente com algum tipo de restauração e analisar o efeito de tratamentos químicos da dentina intrarradicular na força de união da cimentação adesiva de pinos de fibra.

2 ARTIGOS

2.1 Artigo – Jurema ALB, Penteado MM, Tribst JPM, Caneppele TMF, Borges ALS. Efeito de pinos de fibra de vidro no comportamento biomecânico de dentes com facetas diretas / *Effect of glass fiber post on the biomechanical behavior of teeth with direct veneers**

RESUMO

Este estudo teve como objetivo avaliar o comportamento biomecânico de dentes tratados endodonticamente e que possuem faceta direta com o uso ou não do pino de fibra de vidro intrarradicular, por meio de análise de elementos finitos. Foram projetados seis modelos tridimensionais de incisivos centrais superiores, variando a presença ou ausência de pino de fibra de vidro e a espessura das facetas diretas (0,5, 0,7 e 1 mm). Os modelos foram obtidos com o software *CAD*, *Rhinoceros 4.0*, e transferidos para o software *CAE*, *ANSYS 17.2*, no qual uma carga de 100 N foi aplicada a 45 ° na superfície lingual dos dentes para simular movimentos funcionais. Os contatos da geometria foram colados e as estruturas eram isotrópicas, lineares, elásticas e homogêneas. Após análise de coerência e convergência das malhas, o critério de falha escolhido foi o de máxima tensão principal. Para o cimento e o pino de fibra de vidro, a distribuição de tensões foi semelhante independentemente da presença do pino de fibra de vidro ou da espessura da faceta. Os modelos com pino de fibra de vidro apresentaram melhor distribuição de tensão e menores valores de tensão máxima na região interna da dentina e na faceta. Facetas com 0,5 e 1mm de espessura apresentaram maiores áreas de concentração de tensão. Pode-se concluir que o de pino de fibra de vidro pode influenciar na concentração e a distribuição de tensões na dentina nas facetas diretas de resina composta.

Palavras-chave: Facetas dentárias. Análise de elementos finitos. Dente não vital. Técnica para retentor intrarradicular.

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ABSTRACT

This study aimed to evaluate the biomechanical behavior of endodontically treated teeth with direct veneer that received or not intraradicular glass fiber post by finite elements analysis. Six models were designed, varying the presence or absence of glass fiber post and the thickness of direct veneer (0.5, 0.7 and 1mm). Tridimensional models of maxillary central incisors were obtained with CAD software, Rhinoceros 4.0, and transferred to CAE software, ANSYS 17.2, which a 100N load was applied in a 45° on the lingual surface to simulate functional movements. Geometry contacts were bonded, and the structures were isotropic, linear, elastics, and homogeneous. After coherence and convergence analysis of mashes, the chosen fail criterion was the maximum principal stresses. For cement, glass fiber post, the stress distribution was similar independently of glass fiber post presence or veneer thickness. Models with glass fiber post had better stress distribution and lower values of maximum stress on inner dentin and veneer. Veneers with 0.5 and 1mm had higher stress concentration areas. It can be concluded that glass fiber post can influence stress concentration and distribution on inner dentin and veneer.

Keywords: Dental veneers. Finite element analysis. Nonvital tooth. Post and core technique.

Introduction

Esthetics re-establishment is a treatment with a high demand for patients that suffered any interference in smile harmony in tooth discoloration, change in shape and position, extensive caries, or deficient restorations [1]. Resin composite direct veneer is performed in anterior teeth that have changes involving buccal surface [2]. It is a conservative technique that has some advantages over ceramic veneer or total crowns, such as lower cost, fewer sessions and eases to repair [2, 3].

Although the direct veneers procedures are based on conservative technique and focused on the maintenance of tooth structure [4], the preparation of direct veneer can decrease the tooth resistance [5]. It is common to obtain a large preparation for discolored tooth, due to the need of many composite resin layers to cover this unfavorable condition [6].

Many of the teeth that need aesthetical restorations present endodontic treatment and its procedures can cause a decrease of the stiffness due to pulp access [7]. Also, the endodontic treatment promotes the loss of tooth structure through the access cavity and biomechanical preparation [8]. There are differences in mechanical properties between a sound and an endodontically treated anterior tooth when they are analyzed under loading [7]. Furthermore, frequently, the tooth has structure loss due to extensive caries lesions, restorations, or fractures that occurred previously [9, 10].

The higher the tooth loss by endodontic and restorative treatment, the weaker it will be, and the fracture risk increases [11]. It is believed that glass-fiber post (GFP) use can reduce coronal and radicular fracture risk, improving tooth properties. The decision to use intra-radicular fiber post depends on the amount of remaining tooth substance. Often, less amount of residual dentin requires additional reinforcement, and it can be achieved by insertion of a fiber post [12]. Despite this, there is not a consensus in the literature related the use or not of GFP for reinforcement of fragile tooth [13-16].

The finite element analysis (FEA) is a tool able to analyze the biomechanical behavior of structures by numerical models. FEA is a non-destructive test, with easy reproduction and can analyze some clinical conditions that hardly can be simulated in vitro [17, 18].

This research aimed to evaluate through FEA the influence of glass fiber post and different veneer thickness on biomechanical behavior and stress distribution of endodontically treated maxillary central incisor, restored with resin composite veneers with and without GFP.

Material and Methods

Six groups were designed for this study. For groups G0.5, G0.7, and G1, there was no GFP, just endodontic treatment and resin composite veneer with three different thickness, 0.5mm, 0.7mm, and 1.0mm, respectively. In the other groups (G0.5P, G0.7P, and G1P), GFP was used, and veneers also presented three different thickness (0.5mm, 0.7mm, and 1.0mm, respectively). The group's description is shown in Table 1.

Table 1. Division of groups

Groups	***Fiber post***	***Thickness of veneers (mm)***	***Thickness of remaining dentin (mm)***			***Mash metrics***	
			Cervical third	***Middle third***	***Incisal third***	***Nodes***	***Elements***
G0.5	*No*	*0.5*	*2.7*	*2.3*	*1.0*	*125831*	*64127*
G0.7	*No*	*0.7*	*2.6*	*2.3*	*0.9*	*131201*	*77312*
G1	*No*	*1.0*	*2.5*	*1.7*	*0.5*	*148075*	*82636*
G0.5P	*Yes*	*0.5*	*2.3*	*1.9*	*0.8*	*129312*	*65411*
G0.7P	*Yes*	*0.7*	*2.1*	*1.9*	*0.6*	*138298*	*78114*
G1P	*Yes*	*1.0*	*2.0*	*1.5*	*0.2*	*151307*	*83267*

It was modelled three maxillary central incisors with access and endodontic treatment. The models were divided according to veneer thickness, 0.5, 0.7 and 1 mm. All models were restored with the same resin composite.

Tridimensional model of maxillary central incisor was designed by CAD Rhinoceros (version 4.0SR8; McNeel North America, Seattle, WA) and a previously validated model of endodontically treated maxillary central incisor was used [8].

The model was constituted by enamel, dentin, periodontal ligament, medullary bone, cortical bone, resin cement, glass-fiber post, gutta-percha and composite resin (Figure 1).

After modelling, solids were exported in STEP format to computer-aided engineering software (ANSYS 17.2; ANSYS Inc, Houston, TX). Contacts were considered perfectly bonded, and fixture was at the medullar bone base.

Materials properties used in this Ansys software were collected from literature (Table 2) and considered isotropic, linearly elastic and homogeneous.

Table 2. Material properties: Elastic modulus (E) and Poisson coefficient (v)

Material	***E (GPa)***	***v***
Enamel	*84.00[19]*	*0.30[19]*
Dentin	*18.00[19]*	*0.23[19]*
Gutta Percha	*0.14[20]*	*0.49[20]*
Composite Resin	*14.9[21]*	*0.30*
Glass Fiber Post	*37.00[22]*	*0.34[22]*
Cement	*10.10[23]*	*0.30*
Periodontal Ligament	*0.00118[24]*	*0.45[24]*
Cortical Bone	*13.70[25]*	*0.30[25]*
Medular Bone	*0.00186[26]*	*0.34[26]*

The models were loaded with 100N/45º to the longitudinal axis of the tooth, simulating functional movements (Figure 2) [8]. The results in MPa are presented in graphics. The stress distribution at the interfaces between each structure was analysed by maximum principal stresses or the Von Mises criterion.

Results

Figure 3 shows the peak of the maximum principal stress of each structure and table 3 shows these values. It is observed that maximum stress obtained on veneer is indirectly proportional to its thickness and groups of teeth without GFP (G0.5, G0.7, and G1) had the higher values *peek of stress. In contrast, groups G0.5P, G0.7P, and G1P presented better stress distribution and lower maximum stress values. In inner dentin, structure can be observed that the higher dentin loss, the higher peak of MPS. In another hand, in enamel, glass fiber post, and cement, the peak of MPS was inversely proportional to veneer thickness. GFP groups presented lower stress loads than groups that did not have GFP. Despite differences among peak of MPS, qualitatively the stress distribution was similar for enamel, glass fiber post and cement.*

Table 3. Peek of Maximum principal stress (by Mpa) obtained after FEA

Groups	**Veneer**	**Dentin**	**Enamel**	**Glass fiber post**	**Cement**
G0.5	4.51	28.50	6.17	-	-
G0.7	3.76	30.70	4.86	-	-
G1	2.83	31.00	4.30	-	-
G0.5P	4.02	28.40	6.00	6.10	7.31
G0.7P	3.62	30.80	4.90	5.50	7.30
G1P	2.65	31.30	4.40	5.30	7.30

Discussion

After analysis of results and answering the objectives of this study, it was observed that despite GFP did not provide changes on the biomechanical behavior of tooth remaining external surface (qualitatively and quantitatively), this modification was found on dentin inner portion. Regarding veneer thickness, different preparation depth presented changes in stress distribution.

The FEA is a methodology that enables to analyze the biomechanical behavior of complex structures submitted to determined load. The analyzed models in this study were designed under tridimensional structures. It leads a better understanding of teeth and restorative materials mechanical properties as they are presented on the oral environment [17, 18]. This fact can help to improve tooth preparation design and to choose appropriate restorative materials [27]. Besides that, different of mechanical *analysis in bench studies, the structures can be standardized, reducing risk of bias that interferes with final results [11].*

However, only FEA cannot be an indicator of fractures or restoration fails; it can show which restoration or tooth areas are more susceptible to failure. Stress concentration areas and their propagation can be identified on models, where fails and fractures are originated [28]. This methodology is ideally used for static analysis and to obtain some data that cannot be obtained by other laboratory methods and it is used to design better following clinical and laboratory researchers [29].

Few studies evaluated intra-radicular posts to reinforce tooth structure; their use is related to tooth damage and the restoration to be done [30, 31, 32]. The fracture risk of endodontically treated teeth depends on tooth structure loss, cavity access, instrumentation and canal irrigation [31]. Restoration success depends on ferule conditions and extension and GFP use [9, 11]. Some studies show anterior teeth are more susceptible to fracture [10].

GFP use has done more often because it shows better performance than conventional metallic post. GFP presents better aesthetical properties and better adhesion to resin cement [1]. A study evaluated stress distribution on endodontically treated tooth with GFP or with a dentin post. Results showed that dentin post was advantageous absorbing stress and distributing to tooth structure [15]. If the restorative material modulus of elasticity is similar to tooth's modulus of elasticity, there is less stress concentration in other areas of the tooth. This information can be found in previous studies [13, 16].

Comparing GFP with other post materials, GFP presents better mechanical performance. The stress distribution decreases in middle and cervical thirds in GFP about zirconia and titanium posts [14]. Tooth roots are more vulnerable to fracture as the higher the post stiffness is, and the higher the load is transferred to them.[11] Metallic posts do not properly distribute the stress received by teeth [10].

The present study showed that stress decreased in direct veneer in the group with GFP, compared to the group without GFP. GFP was able to *absorb and distributes stress to teeth, protecting it from fails. It can absorb better the stress load and decrease the flexural force that enamel and dentin are submitted. This force that is not well absorbed and it is transferred to dentin and enamel, can be also transferred to veneer. Then, the veneer was weakened when GFP was not present.*

Enamel has a modulus of elasticity higher than dentin, making it resisting better to deformations, absorbing stress, and do not transmit to veneer. Dentin has a lower modulus of elasticity and transmits more stress to adjacent structures, such as composite resin. The insufficient tooth reduction can be injurious to restoration resistance. However, higher tooth reduction is injurious because the veneers are bonded mostly in dentin, while lower thickness can damage mechanic behavior of composite resin [7]. To obtain better adhesion conditions, 50-70% of tooth substrate should be enamel. The restoration longevity decreases if adhered in its most part in dentin [3]. Adhesion has an essential role in direct veneers performance because they do not have macromechanical retention due to preparation design [6]. Models with 1.0mm thickness veneers did not show good biomechanical behavior on stress distribution. It can be worse with the fact that veneer is bonded in their most extension to dentin substrate. The 0.5mm thickness veneer had the worst results on stress distribution because they do not have a material thickness enough to absorb applied forces, making its inner structure less resistance [7].

Conclusion

Within limitations of this study, it can be concluded that GFP use is biomechanically favorable for restored teeth with direct veneers. Regarding veneer thickness, very thin or very thick preparations can damage the biomechanical behavior of restorations.

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Figures

Figure 1. Schematic illustration of the modeling sequence in Rhinoceros 4.0 CAD Software.

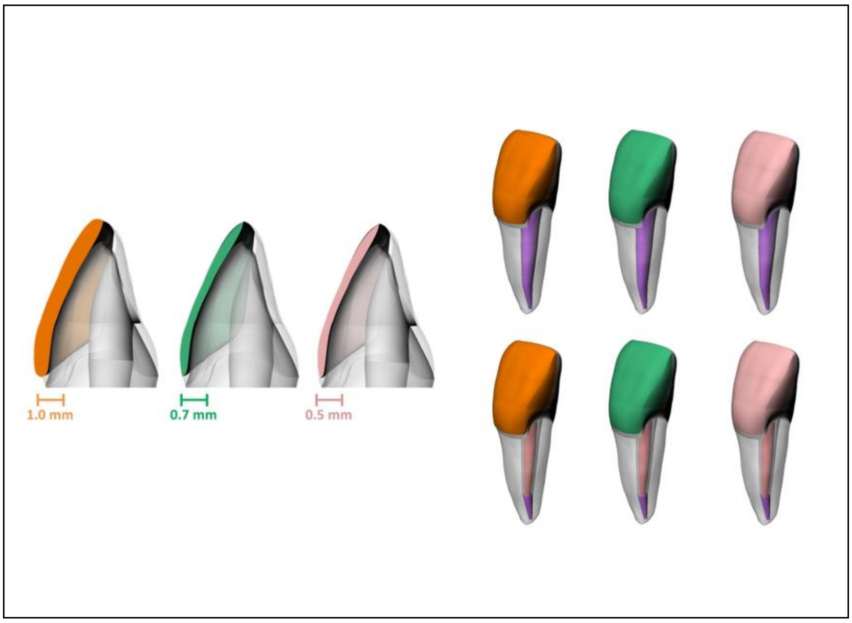


Figure 2. (A) Image composed by arrangement of tetrahedral elements and meshes. (B) Force vector applied in the static analysis test. (C) Fixing system.

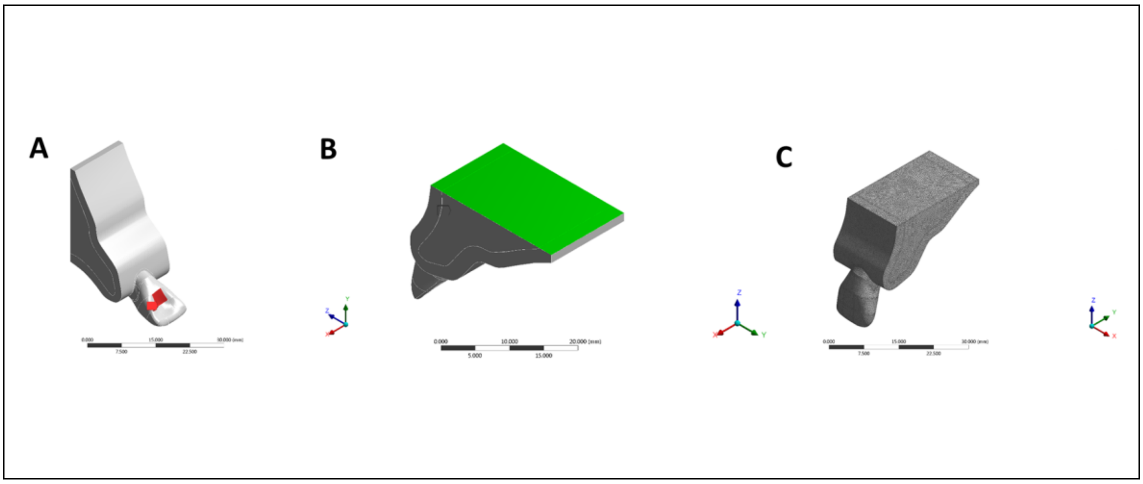
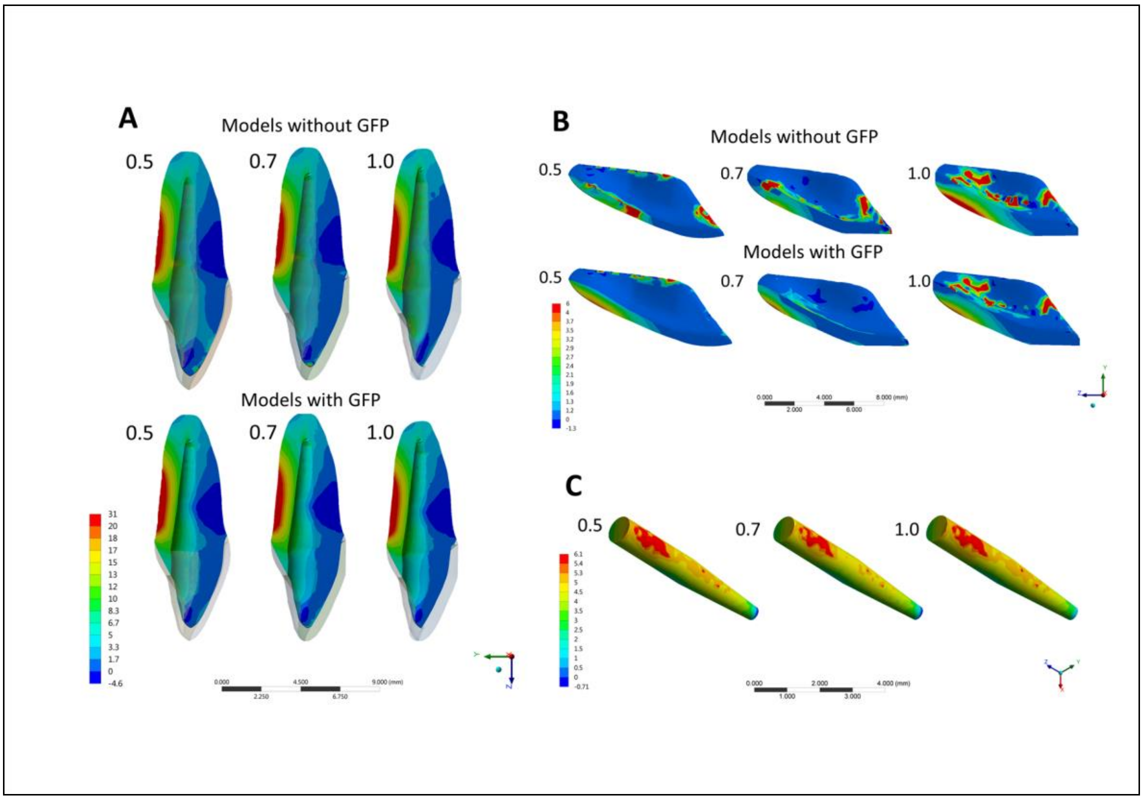


Figure 3. Maximum principle stresses results at models with different veneer thickness (0.5, 0.7 and 1.0) and with or without GFP. (A) Stress distribution at dentin. (B) Stress distributions at veneer (sectioned). (C) Stress distribution at fiber post.



2.2 Artigo – Jurema ALB, Bresciani E, Caneppele TMF. Influência dos pinos de fibra de vidro na resistência à fratura de dentes anteriores superiores tratados endodonticamente com facetas diretas: Resultados preliminares de um estudo clínico ramdomizado / *Influence of glass fiber posts on the fracture susceptibility of endodontically treated maxillary anterior teeth with direct veneers: Preliminary results of a randomized clinical trial* *

RESUMO

Objetivo: avaliar a influência do pino de fibra de vidro na resistência à fratura de dentes anteriores superiores tratados endodonticamente com facetas diretas.
Materiais e Métodos: 50 participantes tiveram um dente anterior superior tratado endodonticamente restaurado por um operador com faceta direta de resina composta. Eles foram divididos em dois grupos (n = 25), de acordo com o uso ou não do pino de fibra de vidro intrarradicular. Todos os materiais foram aplicados seguindo as instruções dos fabricantes em todos os procedimentos restauradores. A avaliação clínica foi realizada, 6 e 12 meses após o tratamento por dois examinadores calibrados. O sucesso do tratamento foi avaliado e determinado pela presença ou ausência de fratura dentária. Se houve fratura, foi classificada de acordo com sua extensão. O teste exato de Fischer foi realizado para análise entre os grupos em cada período de avaliação. A análise de variância de Friedman avaliou a diferença no desempenho de cada grupo entre os períodos tempos de avaliação. Um nível de significância de 5% foi adotado em todos os testes.
Resultados: Para o grupo controle, aos 6 meses de seguimento, houve um dente que sofreu uma falha catastrófica, que foi uma fratura com extensão radicular que resultou na extração do dente. A análise estatística de Fisher não mostrou diferença significativa entre a taxa de sucesso acumulada dos grupos por um período de 6 meses ($P>.999$) e 12 meses ($P>.999$). O teste de Friedman não mostrou diferença significativa entre os períodos avaliados ($P>.999$).
Conclusões: Ambos os grupos, com ou sem pino de fibra de vidro, apresentaram taxa de sucesso semelhante para dentes anteriores superiores tratados endodontia e que possuem facetas diretas em 12 meses. O uso do pino de fibra de vidro não influencia na resistência à fratura de dentes superiores anteriores tratados endodonticamente com facetas diretas em curto prazo.

Palavras-chave: Técnica para retentor intrarradicular. Facetas dentárias. Dente não vital. Fratura dental. Resistência à fratura.

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ABSTRACT

Objective: The purpose of this randomized clinical trial was to evaluate the influence of glass fiber posts on fracture susceptibility of endodontically treated maxillary anterior teeth with direct veneers.

Materials and Methods. Fifty participants had 1 maxillary anterior tooth restored with a direct veneer. They were divided into 2 groups (n=25) according to the use of intraradicular glass fiber posts. Clinical evaluation was performed at baseline, 6 and 12 months. The treatment success was determined by the absence of tooth fracture. If there was fracture, it was classified according to its extent. Fischer exact test was performed to analyze the criteria among the groups at each evaluation time. Friedman repeated analysis of variance assessed the difference in the performance of each group at 3 recall times (α=0.5).

Results: For control group, at the 6-month follow-up, 1 tooth had suffered a catastrophic failure, which resulted in tooth extraction. Fisher statistical analysis showed no significant difference between the cumulative success rate of the groups for the 6 (P>.999) and the 12-month (P>.999) period. Friedman test showed no significant difference among the periods of evaluation (P>.999).

Conclusions: Both groups had a similar success rate for maxillary anterior endodontically treated teeth with direct veneers after 12 months.

Keywords: Post and core technique. Dental veneers. Nonvital tooth. Tooth fractures. Flexural Susceptibility.

INTRODUCTION

Patients with poor smile harmony may be treated with an esthetics rehabilitation,[1] including with direct composite resin veneers. They are a conservative option that have advantages over ceramic veneers or full crowns, including lower cost, fewer treatment sessions, and ease of repair.[2]

Esthetic restorations are often needed for endodontically treated teeth that may be weakened after endodontic treatment.[3] These teeth may also be prepared for direct veneers, although the preparation should be designed to conserve maximum tooth structure.[4] Nevertheless tooth preparation can decrease strength.[5] In addition, the endodontic treatment leads to loss of tooth structure through the access cavity and biomechanical preparation.[6] The mechanical properties of a sound and an endodontically treated anterior tooth under loading are different.[3] Additionally, the tooth often has lost structure from caries, restorations, or fractures.[7,8] The prognosis for endodontically treated and restored teeth has been related to the ferrule structure,[9–13] presence of existing restorations,[14] type of post, anterior guidance,[15] nonvital bleaching history,[16] trauma history, and parafunctional habits.[17]

The mechanical resistance of endodontically treated teeth has been studied,[18–20] and it has been suggested that posts with characteristics similar to those of dentin could improve fracture strength.[21,22] Placement of glass fiber posts with an elastic modulus similar to that of dentin may improve flexural resistance and prevent some failures. Under load, they improve stress absorption, thus decreasing the probability of fracture.[23] The use of fiber posts for weakened teeth has been evaluated with in vitro studies.[24–28]

Even teeth which do not have large structural destruction as those that need a full crown, for example, not using the glass fiber post can cause a catastrophic failure in less time. However, if the fiber posts do not provide a reinforcement structure, its use can generate injuries such as the greater removal of dental structure due to the intraradicular preparation and the longer session time that is not comfortable for the patients. Although, it is important to raise this empirical question, which does not have a consensus in the literature,[29–32] and clinical studies are scarce. Therefore, randomized clinical trials are needed to determine the influence of glass fiber posts on weakened *teeth and to clarify the influence of the remaining tooth structure on the success of the restorative treatment.[33] Therefore, the purpose of this randomized clinical trial was to evaluate the influence of glass fiber posts on the fracture susceptibility of endodontically treated maxillary anterior teeth with direct composite resin veneers. The null hypothesis was that no differences would be found between participants that received or did not receive a glass fiber post.*

MATERIALS AND METHODS

The treatment protocol was approved by the local ethics committee for investigations involving human participants. A consent form was issued for this study (protocol 1.963.431/2017), and all participants signed it before the treatment.

Registration in the Brazilian Clinical Trials Registry system (REBEC) was obtained under protocol RBR-9rpv92. The nature and objectives of this study were explained to all participants. This clinical investigation followed the Consolidated Standards of Reporting Trials statement (CONSORT).[34]

The randomized, controlled, blinded (examiners) clinical trial was conducted between June 2017 and December 2019 at the clinic of the School of Dentistry. Participants were recruited in the order in which they attended the screening session in the Restorative Dentistry Department of the local university. A total of 50 participants were considered eligible for this study after clinical examination. The participants were to be at least 18 years old and in good general and oral health. In addition, they had to have 1 central or lateral maxillary incisors with antagonist and adjacent teeth that needed esthetic treatment with direct veneers (tooth which presented coronal darkness, large or deficient restorations, or anatomic form alterations) and to have received successful endodontic treatment. Participants with poor oral hygiene, severe or chronic periodontal disease, orthodontic appliances, severe parafunctional habits, and removable prostheses contacting the study tooth were excluded.

The sample size calculation was based on the clinical success rate of ceramic veneers observed in a previous study (98%).[35] Using a significance level of .05, power of 90%, and equivalence limit of 15%, the sample size *required was 19 per group. Considering possible dropouts, a total of 25 teeth were selected for each group (N=50).*

The process of randomization was generated by creating a randomization list with a website (www.random.org/lists/) and with an equal allocation ratio for 2 treatment options. For allocation, opaque and sealed envelopes were used and numbered by a person not involved in the study. The envelope was opened just before the restorative procedure began to ensure allocation concealment.

Before the restorative procedure, the participants were informed of the risks and benefits of treatment and signed the informed consent form. Each participant received a direct composite resin veneer on a maxillary anterior endodontically treated tooth. The teeth were divided into 2 groups (n=25): one received an intraradicular glass fiber post, and the other group (control group) did not.

The restorative procedures were performed by 1 single trained operator (A.L.B.J). First, a clinical form was filled out with the initial data of the participant and of the tooth. This form collected data about sex, age, endodontic treatment conditions, trauma history, tooth discoloration, previous restorations, position or anatomic form alterations, tooth bleaching history, symptomatology, coronal height and width, occlusion type, anterior guidance, and vertical and horizontal overlap. An initial periapical radiograph was obtained to evaluate the periapical conditions and to collect data about the length and width of the root canal.

Cotton roll isolation was used for all procedures. Gingival displacement cord (Ultrapak #000; Ultradent Products, Inc), cotton rolls, a mouth prop, and a saliva ejector were used. The lingual surface was accessed in a standardized way and prepared to a depth of 1 mm beyond the clinical crown. Then, the tooth was prepared for the veneer with diamond rotary instruments according to the tooth size and thickness. The preparation thickness was determined according to esthetic necessity. Darker teeth needed a thicker preparation, in order to obtain satisfactory esthetic results with composite resin veneer. Teeth that presented caries or unsatisfactory restorations had the damaged structure removed and involved to veneer preparation. The thickness of the remaining dental structure was measured with a thickness gauge (Wilcos do Brasil

Indústria e Comércio Ltda) which was centered in the most cervical portion of the clinical crown. This measurement was made before veneer preparation, after veneer preparation, and after composite resin placement.

All materials were used according to the manufacturer's instructions and their compositions and manufacturer are presented in Table 2. A universal adhesive system was used (Futurabond U; VOCO), and the tooth surface was conditioned with 37% phosphoric acid for 30 seconds on enamel and 15 seconds on dentin. Then, it was washed and dried with cotton and a gentle air stream. The adhesive was actively applied and light polymerized for 20 seconds at 800 mW/cm^2 (Radii cal; SDI). A conventional composite resin (Amaris; VOCO) was used for the veneer with an incremental technique, and each increment was light polymerized for 10 seconds (translucent resin) or for 40 seconds (opaque resin).

For the control group, the pulp chamber was restored with conventional composite resin. For the group that received the intraradicular glass fiber post, gutta percha was partially removed from the root canal. The minimum post space was equivalent to the crown height, and the maximum was two thirds of the height from the alveolar crest to the apex of the tooth. At least 4 mm of apical gutta percha remained.

The intraradicular preparation was performed with largo burs #1, #2, and #3 (according to the diameter of the root canal) following the inclination of the tooth long axis. A glass fiber post (Rebilda Post; VOCO) was selected according to the root preparation diameter. It was evaluated in the root canal and sectioned before the cementation procedure. The root canal was irrigated with copious water, irrigated with 1% sodium hypochlorite, and dried with absorbent paper points. The fiber post was disinfected with 70% ethanol, the self-adhesive cement (Bifix SE; VOCO) was applied to the root canal with its applicator tip, the post was placed, the excess cement was removed, and the cement was light polymerized for 40 seconds. The lingual surface was restored with conventional composite resin.

Excess restorative material was removed with 12-fluted tungsten carbide burs (FG Bur; KG Sorensen) immediately after the restorative *procedure. The restoration was polished with disks (Sof-Lex; 3M ESPE) 7 days after placement.*

The primary outcome was tooth fracture susceptibility, as evaluated by whether there was a fracture or not. The secondary outcome was whether the tooth had symptoms or a recurrent radiographic periapical lesion.

Two examiners T.M.F.C. and E.B.), besides the operator, were blinded to the presence of the glass fiber post in the teeth for the primary outcome evaluation. A third, not blinded, examiner (R.S.R.) assessed the secondary outcome from a periapical radiograph. The operator was not blinded, since each technique required a different clinical procedure. Participants were not blinded to the intervention and were aware that they would or would not receive a glass fiber post.

The examiners evaluated all teeth independently with disagreements resolved by discussion. The restorations were evaluated at baseline and at 6- and 12-months after restoration placement. Restoration success was determined by the presence or absence of tooth fracture, classified according to fracture type (Table 1). The preservation of the tooth in the oral cavity was considered treatment success, including the presence of cracks, partial or complete veneer fracture, simple, medium, or extensive tooth fracture, or extensive root fracture with the possibility of repair and tooth preservation. Catastrophic failures that resulted in tooth loss were considered treatment failure.

Statistical software (R Studio, version 3.4.4; R Studio Team) was used for the statistical analysis. The inferential statistical analyses followed the intention-to-treat protocol suggested by CONSORT, which involved all teeth being initially randomized, including those that were not evaluated at the specified time. In this situation, the missing data were included with the score of the last evaluation.

The Fischer exact test was performed to analyze all evaluated criteria between the groups at each evaluation time. The Friedman repeated analysis of variance assessed the difference in the performance of each group at the 3 recall times (baseline, 6 months, and 12 months) (α=.05 for all tests).

RESULTS

Sixty-three individuals were examined. Two did not have endodontic treatment, 2 chose another treatment, 2 declined to participate, 3 had unsatisfactory endodontic treatment that was not adequately addressed before the end of the recruitment step, 3 had extensive structural damage, and 1 did not return to initiate the treatment. Therefore, 50 participants were included in the clinical trial (Fig. 1). Details about the participants and characteristics of the restored tooth are presented in Tables 3 and 4.

All the participants were evaluated at baseline and after 6 months. After 12 months, the recall rate was 98% (49 restorations of 50). One participant in the group without a glass fiber post did not attend the follow-up. One participant in the group that received the glass fiber post had a partial veneer fracture at the 12-month follow-up that was restored with a composite resin restoration (Fig. 2A). Two participants had extensive root fractures (Fig. 2B and Fig. 2C). They received orthodontic extrusion and then a new glass fiber post and full crown.

One tooth in the control group had an extensive dental fracture at the 6-month follow-up (Fig. 3C). It was prepared for a full crown. Another tooth had a catastrophic failure (Fig. 4) that could not be addressed with orthodontic extrusion, and it was extracted. The participant received an implant-supported restoration. At the 12-month follow-up, 2 teeth had partial veneer fractures (Fig. 3A and Fig. 3B) that were restored with composite resin.

The Fisher statistical analysis showed no significant difference between the groups for the 6-month period ($P>.999$) or at 12 months ($P>.999$). The Friedman test did not show significant difference between the periods evaluated ($P>.999$). The percentage of failure and the cumulative success rate of each group at the 2 recall times are presented in Table 5.

DISCUSSION

In response to a lack of randomized clinical trials that evaluated the use of fiber posts and the influence of the remaining tooth structure on the treatment of endodontically treated teeth,[33] the purpose of this randomized clinical trial was to evaluate the influence of glass fiber posts on the fracture susceptibility of *endodontically treated maxillary anterior teeth with direct composite resin veneers. Based on the findings, the null hypothesis that no differences would be found between participants that received or did not receive a glass fiber post was not rejected. Correcting esthetic problems in endodontically treated teeth can result in significant coronal destruction that increases the risk of tooth fracture during function.*[23] *The use of fiber posts has been recommended under these conditions and in vitro studies have been developed to predict clinical outcomes.*[24-28,32]

The present randomized clinical trial indicated that the success of the tooth restoration with or without a glass fiber post was similar (100% and 96%, respectively), a not unexpected result for a preliminary 1-year study. The survival rate for endodontically treated maxillary anterior teeth restored with ceramic crowns and glass fiber posts was reported to be 98.48% at 8 years.[17] *Another study that evaluated direct composite resin veneers for more than 3 years reported an overall survival rate of 87.5%.*[14] *However, in these studies, failure rates were related to other criteria besides fractures, including restoration adaptation, color match, discoloration, surface roughness, secondary caries, and postoperative sensitivity, For the primary outcome of the present study (fracture susceptibility), a longer follow-up time will be needed to identify any significant differences.*

The prognosis for endodontically treated teeth requiring restorative procedures depends on a wide range of factors which can be evaluated independently or in association.[17] *These included the remaining tooth structure (ferrule effect), presence of existing restorations,*[14] *type of post, anterior guidance,*[15] *nonvital bleaching history,*[16] *trauma history, and parafunctional habits.*[17]

The importance of the ferrule for restored endodontically treated teeth has been emphasized, in previous studies.[9-11,20] *Teeth with sufficient coronal tooth structure can sustain higher loads to failure compared with teeth lacking coronal tooth structure.*[12] *The preservation of at least 1 coronal wall has been reported to be one of the most critical factors.*[13] *The more residual coronal dentin, the better the survival rate.*[17] *In addition, the ferrule decreases the impact of the post and core system, luting agents, and the definitive restoration* *on the outcome of endodontically treated teeth.[23] Then, the fracture strength of teeth depends also on the ferrule. Therefore, it can be considered that for increase tooth strength, the coronal remaining structure should be sufficient, even for teeth as those selected in this study (which still presented a considerable coronary structure after the veneer preparation). For these teeth, important regions, as the cervical structure and reinforcement structures, as the marginal ridges influence fracture resistance. Previous studies showed that for teeth with veneer preparation and class III or cervical cavities, the use of fiber post were favorable for fracture strength.* [36,37]

In the present study, the tooth which had a catastrophic failure in the group that did not receive a glass fiber post had less remaining thickness (1.8 mm) when compared with the group average (2.18 mm), which may explain the fracture. Additionally, the participant did not have balanced anterior guidance, with an edge-to-edge incisal contact, which could have generated load concentrations that fractured the tooth during function.

A previous study evaluated the survival rate of veneered nonvital teeth, reporting that the presence of existing composite resin restorations did not lead to statistically significant differences. The survival rates were 100%, 90.6%, and 82.7% for intact teeth, presence of small existing composite resin restorations, and extensive restorations, respectively.[14] The teeth that had noncatastrophic failures had existing proximal composite resin restorations, as well as poor anterior occlusion and a history of nonvital tooth bleaching or trauma.

This study included teeth treated many years before the proposed treatments and other which had root canal treatment done just before the procedures. These data were collected by filling a clinical form before the restorative procedures. For the preliminary results, this did not seem to be a determining factor for failures. The average time that had passed from root canal treatment to entrance into the study was 7 year for group with fiber post and 5 years for group which did not use fiber post. And all root canal of teeth that presented failures had been treated for 3 years or less.

The non-use of glass fiber posts was associated with more unfavorable complications that resulted in a catastrophic failure, with a fractured root that could not be repaired, requiring tooth extraction. Although, it should be *considered that this failure occurred in only one tooth with an unfavorable occlusal loading given the edge-to-edge relationship. Other type of fractures occurred in both experimental groups, but in some failures (partial veneer fractures, extensive tooth fracture, and extensive root fractures with repair possibility), the tooth could be restored and remained in service.*

The preliminary findings of the present study indicate that veneer restorations may be possible for maxillary anterior endodontic treated teeth without the use of a fiber post. This is an advantage because more tooth structure is preserved, and the clinical procedure is less invasive.[23,38]

Limitations of this randomized clinical trial include its short-term (1 year) and single-center design. Longer follow-up evaluations may show complete responses regarding the long-term behavior of the teeth and materials. In addition, multicenter studies are recommended to allow more participants to be enrolled.

CONCLUSIONS

Based on the findings of this short-term randomized clinical trial, it could be concluded that both groups with and without glass fiber posts presented a similar success rate for maxillary anterior endodontically treated teeth with direct veneers.

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TABLES

Table 1 *Description of fracture types*

Fracture type	**Description:**
Cracks	*Presence of cracks in veneer or dental structure.*
Partial veneer fracture	*Fracture of composite resin portion, with restorative material still bonded on tooth.*
Total veneer fracture	*Fracture of composite resin veneer, without restorative material remaining on tooth.*
Simple dental fracture	*Dental fracture extending to incisal third of crown involving restorative material and tooth structure.*
Medium dental fracture	*Dental fracture extending to middle third of crown involving restorative material and tooth structure.*
Extensive dental fracture	*Dental fracture extending to cervical third of crown involving restorative material and tooth structure.*
Extensive root fracture *(possibility of repair and preserving tooth)*	*Coronary fracture with extension to root with possibility of providing new restoration and root preservation.*
Extensive root fracture *(no possibility of preserving tooth)*	*Coronary fracture with extension to root with no possibility of providing new restoration. Tooth extraction necessary.*

Table 2 *Composition and manufacturers of the materials used in the study*

Material	***Composition***	***Manufacturer***
Amaris (composite resin)	*Bis-GMA UDMA, TEGDMA, glass ceramic fillers, pre-polymerized ISO filler and silica nano particles*	*Voco, Cuxhaven, Germany*
Futurabond U (universal adhesive system)	*HEMA, Bis-GMA, HEDMA, acidic adhesive monomer, urethane dimethacrylate, catalyst, silica nanoparticles and ethanol*	
Rebilda Post	*Glass fibers, inorganic fillers and PDMA*	
Bifix SE (self-adhesive cement)	*Bis-GMA UDMA, Gly-DMA, phosphate-monomers, initiators and stabilizer*	

Table 3 *Study participants*

Participant characteristics	***With fiber post***	***Without fiber post***
Sex		
Female	*42%*	*42%*
Male	*8%*	*8%*
Age mean ± standard deviation (years)	*44.08 ±11.43*	*45.6 ±9.28*

Table 4 *Characteristics of restored teeth*

Characteristics of restored tooth	***With fiber post***		***Without fiber post***	
	Yes	***No***	***Yes***	***No***
Trauma history	*22%*	*28%*	*18%*	*32%*
Coronal staining	*48%*	*2%*	*44%*	*6%*
Nonvital tooth bleaching history	*36%*	*14%*	*28%*	*22%*
Presence of restorations	*36%*	*14%*	*42%*	*8%*
Anterior guidance	*2%*	*48%*	*6%*	*44%*
Central incisor	*42%*		*44%*	
Lateral incisor	*8%*		*6%*	
Mean ±standard deviation crown height (mm)	*9.14 ±0.77*		*9.7 ±0.95*	
Mean ±standard deviation crown width (mm)	*8.02 ±1.05*		*7.92 ±1.66*	
Mean ±standard deviation remaining cervical thickness (mm)	*2.07 ±0.51*		*2.13 ±0.43*	
Mean ±standard deviation vertical overlap (mm)	*2.2 ±1.42*		*2.6 ±1.83*	
Mean ±standard deviation horizontal overlap (mm)	*3.4 ±2.37*		*3.1 ±2.14*	

Table 5 *Number (percentage) of evaluated restorations for each recall time according to group and cumulative success rate*

	With fiber post			***Without fiber post***		
Fracture type	***6 months***	***12 months***	***Total of failure***	***6 months***	***12 months***	***Total of failure***
Cracks	*0*	*0*	*0*	*0*	*0*	*0*
Partial veneer fracture	*0*	*1 (4%)*	*1 (4%)*	*0*	*2 (8%)*	*2 (8%)*
Total veneer fracture	*0*	*0*	*0*	*0*	*0*	*0*
Simple dental fracture	*0*	*0*	*0*	*0*	*0*	*0*
Medium dental fracture	*0*	*0*	*0*	*0*	*0*	*0*
Extensive dental fracture	*0*	*0*	*0*	*1 (4%)*	*0*	*1 (4%)*
Extensive root fracture *(possibility of repair and tooth preservation)*	*0*	*2 (8%)*	*2 (8%)*	*0*	*0*	*0*
Extensive root fracture *(no possibility of tooth preservation)*	*0*	*0*	*0*	*1 (4%)*	*0*	*1 (4%)*
Cumulative success rate			***100%***			***96%***

Figures

Figure 1 *Flow diagram with details of recruitment and allocation*

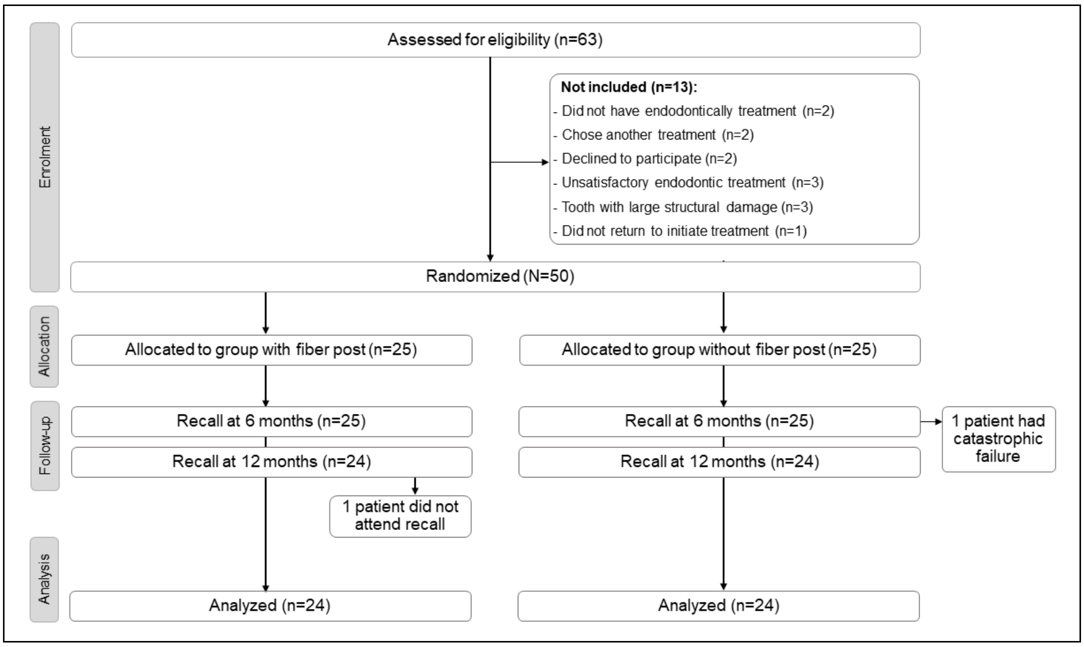

***Figure 2A** Noncatastrophic failures of group with glass fiber post in 12-month follow-up. Partial veneer fracture.*

***Figure 2B** Noncatastrophic failures of group with glass fiber post in 12-month follow-up. Extensive root fracture.*

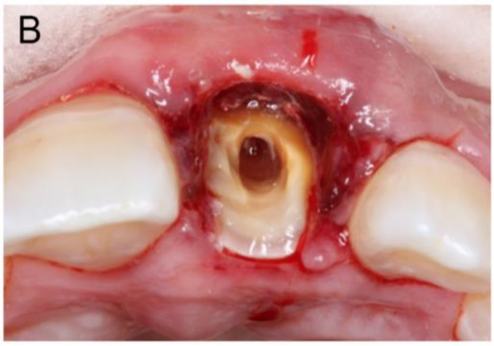

***Figure 2C** Noncatastrophic failures of group with glass fiber post in 12-month follow-up. Extensive root fracture.*

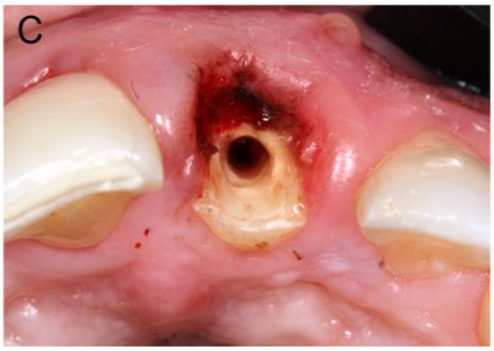

Figure 3A. *Noncatastrophic failures of group without glass fiber post. Partial veneer fracture (12-month follow-up).*

Figure 3B. *Noncatastrophic failures of group without glass fiber post. Partial veneer fracture (12-month follow-up).*

Figure 3C. *Noncatastrophic failures of group without glass fiber post. Extensive dental fracture (6-month follow-up).*

Figure 4A. *Catastrophic failure of group without glass fiber post (extensive root fracture without possibility of repair).*

Figure 4B. *Catastrophic failure of group without glass fiber post (extensive root fracture without possibility of repair). Vestibular view of tooth fragment.*

Figure 4C. *Catastrophic failure of group without glass fiber post (extensive root fracture without possibility of repair). Palatine view of tooth fragment.*

2.3 Artigo – Jurema ALB, Santos KA, Filgueiras AT, Bresciani E, Caneppele TMF. Efeito do pino de fibra intrarradicular na resistência à fratura de dentes anteriores tratados endodonticamente e restaurados – Revisão sistemática e metanálise / *Effect of intraradicular fiber post on the fracture strength of endodontically treated and restored anterior teeth: A systematic review and meta-analysis***

RESUMO
O objetivo desta revisão sistemática e metanálise foi avaliar a resistência à fratura de dentes anteriores tratados endodonticamente e que possuem restaurações e responder à pergunta de pesquisa "O uso de pino de fibra influencia a resistência à fratura de dentes anteriores tratados endodonticamente e restaurados quando comparados com a não utilização de pinos de fibra?" Foi realizada uma busca no *PubMed, Scopus, Web of Science, LILACS, BBO, Cochrane Library* e *Embase* sem restrições de data ou de idiomas em 27 de novembro de 2018 (atualizado em julho de 2019). Foram incluídos estudos *in vitro* que possuem grupos que utilizaram pinos de fibra intrarradicular em dentes anteriores tratados endodonticamente e restaurados e grupos controle, que não foi utilizado o pino de fibra, comparando a resistência à fratura. O risco de viés (RV) foi avaliado baseado em análises de estudos que realizaram revisões sistemáticas de estudos *in vitro*. Os resultados foram apresentados como diferença média padronizada, com intervalo de confiança de 95%. A heterogeneidade estatística dos efeitos do tratamento entre os estudos foi avaliada utilizando o teste *Cochran Q* e o teste de inconsistência I^2, e valores superiores a 50% foram considerados indicativos de heterogeneidade substancial. Após a remoção de duplicatas e triagem de títulos e resumos, restaram 32 estudos. Dezessete foram considerados de RV baixo, 13 com RV médio e 2 com RV alto. A metanálise, comparando os grupos controle e experimental, favoreceu o uso de pino de fibra em dentes tratados endodonticamente melhorando a resistência à fratura (I^2 = 90%; p <0,01), o uso de pinos de fibra de vidro também mostrou resultados favoráveis (I^2 = 79%; p <0,01). Para dentes com preparo para faceta e com cavidades cervicais, o pino de fibra aumenta a resistência à fratura (I^2 = 74%; p <0,01 e I2 = 0%; p = 0,73, respectivamente). O uso de pinos de fibra de vidro aumenta a resistência à fratura dos dentes tratados endodonticamente com algum tipo de restauração. No entanto, são necessários ensaios clínicos para avaliar o uso de pinos de fibra para reforçar os dentes com perda de estrutura. A utilização de pino de fibra de vidro é um método apropriado para melhorar a resistência à fratura de dentes anteriores tratados endodonticamente e que possuem algum tipo de restauração, especificamente dentes com preparos para facetas ou cavidades cervicais.

Palavras-chave: Técnica para retentor intrarradicular. Resistência à fratura. Revisão Sistemática.

*Artigo elaborado de acordo com as normas do Periódico *The Journal of Prosthetic Dentistry*. (Print version ISSN 0022-3913). Submetido em: 23/07/2020.

ABSTRACT
Statement of problem: A fiber post is indicated when there is a significant loss of tooth structure and additional support for the restoration is needed. However, whether the use of a glass fiber post affects the fracture susceptibility of the restored anterior teeth is unknown.
Purpose: The purpose of this systematic review and meta-analysis was to evaluate the fracture strength of endodontically treated and restored anterior teeth and to answer the research question "Does the use of a fiber post influence the fracture strength of endodontically treated and restored anterior teeth when compared with the non-use of fiber posts?"
Material and Methods: A search was performed in PubMed, Scopus, Web of Science, LILACS, BBO, Cochrane Library and Embase without date and/or language restrictions in November 27, 2018 (updated on July, 2020). In vitro studies that included groups which used intraradicular fiber posts in endodontically treated and restored anterior teeth and control groups, which did not used fiber posts, comparing fracture bond strength, were included. The risk of bias (RoB) was evaluated using the description of studies that performed a meta-analysis of in vitro studies. The results were presented as standardized mean difference, with a 95% confidence interval. Statistical heterogeneity of treatment effects between studies was assessed using the Cochran Q test and the I2 inconsistency test, and values greater than 50% were considered indicative of substantial heterogeneity.
Results: After the removal of duplicates and title and abstract screening, 31 studies remained. Seventeen were considered low RoB, 10 were medium RoB, and 4 were a high RoB. Meta-analysis comparing control and experimental groups favored the use of a fiber post in endodontically treated teeth with some types of restoration to improve fracture strength(SMD= 0.5[0.08;0.92]); a glass fiber post was also favored (SMD=0.92[0.43;1.42]); For veneer preparations and teeth with cervical cavities, a fiber post increases the fracture strength (SMD= 0.74[0.01;1.47]; 1.18[0.35;2.02], respectively).
Conclusions: The use of glass fiber posts increases the fracture strength of endodontically treated and restored teeth. However, clinical trials are needed to evaluate the use of fiber posts to reinforce teeth with structure loss.

Keywords: Post and core technique. Fracture strength. Systematic review.

INTRODUCTION

Restoration of esthetics and function is a desired outcome for patients with a smile damaged by tooth discoloration, change in shape or position, extensive caries, or deficient restorations.[1] Some teeth requiring restoration have had endodontic treatment, and this condition might negatively affect their fracture resistance.[2]

An endodontically treated tooth is weakened by the endodontic access, as well as the damage that led to pulpal involvement.[3] The cementation of an intraradicular fiber post has been suggested for increasing the biomechanical properties and improving the fracture strength of endodontically treated teeth that require restoration. Fiber posts are resistant to fatigue, have high tensile strength, and an elastic modulus similar to that of dentin, and, although a consensus in the literature is lacking, their use may decrease the risk of coronal or radicular fracture.[4-8]

The decision to use an intraradicular fiber post depends on the amount of remaining tooth structure. Typically, a post is indicated when there is a significant loss of tooth structure and additional support for the restoration is needed.[9] However, a consensus on the use of fiber posts to reinforce weakened teeth that still have considerable remaining structure is lacking. Fiber posts have been reported to perform well when compared with metal posts because of their lower elastic modulus (similar to dentin) and may be associated with fewer root fractures in the long-term.[10,11] Besides that, it is important to evaluate the behavior of different types of fiber posts.

Therefore, the aim of this systematic review and meta-analysis was to evaluate the fracture strength of endodontically treated and restored anterior teeth and to answer the following research question: “Does the use of a fiber post influence the fracture strength of endodontically treated and restored anterior teeth when compared with the non-use of fiber posts?”

METHODS

Protocol and registration

The review was registered in the PROSPERO (International Prospective Register of Systematic Reviews) database (November 27th, 2018;

www.crd.york.ac.uk/PROSPERO) and reported in accordance with the recommendations of the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) statement (www.prisma-statement.org).

Eligibility criteria

The question of this systematic review and meta-analysis was "Does the use of a fiber post influence the fracture strength of endodontically treated and restored anterior teeth when compared with the non-use of fiber posts?"

In vitro studies that included groups in which intraradicular fiber posts were used in endodontically treated and restored anterior teeth and control groups which did not use fiber posts to compare fracture bond strength were included according to the PICO strategy described below:

Population (P) - endodontically treated and restored anterior teeth;

Intervention (I) - intraradicular fiber post cementation;

Comparison (C) - non-use of intraradicular fiber post;

Outcome (O) - fracture strength.

It was not found randomized clinical trials through the searches and non-randomized clinical trials, observational studies, case reports, and reviews were excluded. Publication date and language restrictions were not applied.

Information sources and search strategy

The search strategy was conducted using combinations of controlled vocabulary (MeSH terms) and free keywords related to the PICO question.

The search was performed first in the electronic database MEDLINE by PubMed. Then, the search terms were adapted for use in the following electronic databases: citation databases (Scopus and Web of Science), Embase, Cochrane Library, Latin American and Caribbean Health Sciences Literature database (LILACS), Brazilian Library in Dentistry (BBO), dissertations and theses (Periódicos Capes Theses database), and System for Information on Grey Literature in Europe (OpenSIGLE). In order to identify possible relevant studies, the reference lists of the eligible studies were manually checked. (Table 1)

A "Search Alert" with the search strategy has been created for PubMed, citation databases (Scopus and Web of Science), Embase, and the Cochrane Library. The search was updated from inception through July, 2020.

Study selection and data collection process

Titles and abstracts were reviewed for study selection in accordance with the search strategy. Duplicate studies were removed. Full-text articles were retrieved where the title and abstract did not provide sufficient information to make a clear decision. Two reviewers (A.F.T. and K.A.S.) identified the studies that met the eligibility criteria. Subsequently, a code combining the first author name and year of publication was given to each eligible study.

Custom extraction forms were used by two reviewers to independently extract the relevant data from the included studies, including type of tooth (bovine or human), type of restoration, type of fiber post, type of remaining structure, mechanical test information, failure mode analysis and outcomes. In case of any doubt, a third reviewer (T.M.F.C) was consulted. A qualitative evaluation of studies characteristics was performed considering the extracted information.

When data from multiple root slices were provided, they were collected and grouped to calculate an average for each tooth. When more than one type of fiber post was included in the study, their values were collected separately for each fiber post (glass, quartz, and carbon). When more than one type of remaining tooth structure was included in the study, their values were also collected separately for each type of remaining tooth structure (no ferule, 1-mm, 2-mm or 3-mm ferule, class III cavities, cervical cavities, endodontic access, veneer preparation, and crown preparation on natural tooth).

Risk of bias in individual studies

Two reviewers (A.F.T. and K.A.S.) independently performed quality assessments of the studies using the description in the studies of the following criteria: teeth randomization, use of materials according to the manufacturer's instructions, use of teeth with similar dimensions, endodontic treatment performed by a single operator, and blinding of the operator of the testing machine. Yes (Y) or No (N) were assigned to the criteria in each study. When the criteria were reported by a study, a "Y" was assigned; if the criteria were not reported, the study received an "N." The study was considered at low risk of bias if four or five criteria were reported. If three criteria were reported, the study was judged as having medium risk of bias. Those reporting one or two criteria *were considered at high risk of bias. Disagreements between the reviewers during this process were discussed until an agreement was reached. A third reviewer (T.M.F.C) was consulted when necessary.*

Data synthesis and statistical analysis

The data were analyzed using the R statistical language R Studio (version 3.4.4, Studio Team, Boston, MA, USA). The meta-analysis was performed, including the low, medium, and high risk of bias studies.

A general meta-analysis was performed considering only the presence or absence of an intraradicular fiber post. Because of high heterogeneity, another 2 meta-analyses by subgroup were performed considering the type of fiber post (glass, quartz, and carbon) and the type of remaining tooth structure (no ferule, 1-mm, 2-mm or 3-mm ferule, class III cavities, cervical cavities, endodontic access, veneer preparation, and crown preparation on natural tooth).

The results were presented as the standardized mean difference (SMD), with a 95% confidence interval. SMD analysis is used when the studies evaluate the same outcome, but the measurement is done with different methods and it is necessary to standardize the results. The SMD analysis was performed for this meta-analysis because of the variety of fracture strength evaluation, there were different load values and load angle of application for the mechanical tests. Statistical heterogeneity of treatment effects between studies was assessed using the Cochran Q test and the I^2 inconsistency test; values greater than 50% were considered indicative of substantial heterogeneity.

RESULTS

Study selection

The process of study selection is presented in Figure 1. The search strategy resulted in 10242 potentially relevant studies, and after removing duplicates 5257 studies remained. The title and abstract screenings were conducted, and a total of 124 studies remained to verify the eligibility. Of those, 92 studies were excluded after reading the full text for the following reasons: no assigned control group, different study designs, posterior teeth evaluation, type of post not reported, only fiber post fracture evaluated, only groups with metal *posts tested, only groups with composite resin posts tested, different tests performed, specimens fractured before restorative procedure, teeth had open root apex, and deciduous teeth tested.*

Finally, 31 in vitro studies met the eligibility criteria and were included in the systematic review. Of those, 2 studies were not selected for quantitative analysis because one of them did not present a strength measure unit with the possibility of conversion to Newtons (measure unit chosen for meta-analysis).[11] The other study did not report standard deviations, and it was not possible to obtain this information until the end of the meta-analysis.[12] Therefore, a meta-analysis was performed with 29 studies.

Study characteristics

The main characteristics of the 31 selected in vitro studies are presented in Table 3. Human teeth were used in most of the studies (n=27). There were 24 studies using glass fiber posts, 8 studies using carbon fiber posts, and 3 studies using quartz fiber posts. Different types of remaining tooth structure were considered. Eight studies had groups of teeth without ferule, 5 with a 1-mm ferule, 10 with a 2-mm ferule, 2 with a 3-mm ferule, 2 with class III cavities, 1 with cervical cavities, 5 with only endodontic access, 2 with veneer preparations, and 2 with crown preparations. Fifteen studies performed the failure mode analysis of the specimens and different classifications of failures were used to describe it. Some studies classified the fracture mode according to repair possibility (repairable or unrepairable, favorable or unfavorable, restorable or not restorable), according to fracture extension (above or below the cement-enamel junction) and fracture localization (root, coronal or restoration fracture). Between these fracture description, there was nine studies which groups with fiber post use presented better results related to fracture mode, two groups that groups without fiber posts presented better results, three groups that all groups presented similar results and one study that only the group with veneer preparation presented better fracture mode when fiber post was used (Table 2).[11-41]

Assessment of the risk of bias

The assessment of the risk of bias for the 31 included in vitro studies is presented in table 3, and the summary of finding is presented in the Figure 2.

According to the criteria considered in the analyses, 17 studies were classified as low risk of bias, 10 studies presented medium risk of bias, and 4 presented high risk of bias.

Meta-analysis

The meta-analysis of the included studies was performed, and the collected data were extracted and presented in Figures 3, 4, and 5. The use or not of a fiber post was considered for a general meta-analysis, and the type of intraradicular fiber post and remaining tooth structure for subgroup analysis. The meta-analysis to compare the control groups (non-use of intraradicular fiber posts) and the experimental groups (use of intraradicular fiber posts) favored the use of fiber posts in endodontically treated teeth with some type of restoration to improve their fracture strength (SMD=0.5[0.08;0.92]) with I2 = 90% (Figure 4).

Figure 5 shows the subgroup analysis considering the type of fiber posts, and the use of glass fiber posts improved fracture strength values (SMD= 0.92[0.43;1.42]), I2 = 89 %). Carbon and quartz posts had no statistically significant differences in fracture strength.

Figure 6 presents the subgroup analysis considering the different types of remaining tooth structure. Favorable fracture strength results were found when using intraradicular fiber posts in teeth with cervical restorations or veneer preparations. For other remaining types (complete crown preparations, absence of ferule, 1-mm, 2-mm or 3-mm ferule, class III cavities, and endodontic cavity access) the use of the fiber posts did not influence the fracture strength.

DISCUSSION

The purpose of the present study was to answer the question: "Does the use of fiber posts influence the fracture strength of endodontically treated and restored anterior teeth when compared with the non-use of fiber posts?" In the studies selection step, 124 papers were eligible because they presented information in their titles and abstracts that would enable the qualitative analysis or extraction of data for meta-analysis. However, after reading the full texts, some studies were excluded because, when they were analyzed in detail, they did not conform to the selection criteria. The reasons the studies were not eligible for qualitative analysis or meta-analysis were as follows: not having a control group (non-use of fiber post); being another type of study (such as literature reviews, systematic reviews, clinical reports); used posterior teeth; did not perform the fracture strength test; evaluated only fiber post fracture; did not specify the type of post used in the study; evaluated failure mode by radiographic examination; evaluated metal or composite resin posts; used specimens of fractured teeth prior to the restorative procedure, used open-apex or deciduous teeth. This fact demonstrated that it was not possible to identify important information from the titles and abstracts of some studies. Authors should, therefore, improve titles and abstracts to facilitate systematic reviewing.

For some study designs it is possible to standardize the methodology and reporting by following a guideline, for example the CONSORT (Consolidated Standards of Reporting Trials) for clinical trials and the PRISM for systemic reviews. However, for in vitro studies, there is not an official guideline, consequently, there is no standardization when authors design the studies and report them. This characteristic was observed in the present study by the analysis of risk of bias, which the blinding of the operator of the testing machine was not done or reported by any study. Many studies did not present some important items which may compromise the quality of in vitro studies, and it results in absence of important evidence. The lack of items as teeth randomization, materials according to the manufacturer's instructions, teeth with similar dimensions, endodontic treatment performed by a single operator, blinding of the operator of the testing machine may be because they were not considered in the study design or it is probable that they were performed at some moment of the study, but were not reported correctly. The adequate report of these studies would promote better methodological quality and transparency.[42]

High heterogeneity was found, even considering SMD analysis and performing meta-analyses by subgroup. This result is also founded in other meta-analyses of in vitro studies. It can be explained considering the methodological variability among the studies and the unclear reporting of them.[43,44] In the present study, these variables were the method of fracture strength evaluation (different load values and load angle of application for *mechanical tests), the different restorative materials and manufacturers, variability in the remaining tooth characteristics and sample size among the studies. It is observed that the heterogeneity was 0% for some subgroup analysis, which were performed between a few studies or the groups were from the same article, therefore, there were not considerable variability.*

Although it was not possible to include data from clinical studies, and the characteristics of in vitro studies resulted in high heterogeneity, this study presented relevant questions about the necessity of the fiber post for weakened tooth. Besides that, the finds reinforce the need of well-designed and well-reported randomized clinical trials to provide clinical evidence about these questions. The present systematic review could be used to better guide such clinical studies.

The general meta-analysis, which considered the use or non-use of intraradicular fiber post, regardless of the post material and the remaining tooth structure (Figure 4), revealed that fracture strength was improved with the use of a fiber post, explained by the better stress distribution in tooth structure. When teeth have lost structure from endodontic treatment or crown preparation, stresses are concentrated in the cervical region; thus, the placement of a fiber post is important to distribute stress.[14-16]

Besides increased fracture strength, some studies reported that the fracture pattern of teeth with fiber posts could contribute to a better prognosis after a fracture. According to the qualitative analysis of studies that evaluated the fracture modes, most of groups that used fiber posts showed better results: favorable, restorable or repairable fractures, fractures above cement-enamel junction or coronal fractures without root extension.[11,24,25,28,30,31,37,39,40] *It avoids the loss of tooth structure and allows the tooth to be retreated.*[23,39]

Different types of fiber post (glass,[13-24,27,29-31,33,35,36-41] *carbon,*[14,15,17,19,24-26,34] *and quartz* [27,28,32]*) were considered for subgroup analysis, of which the glass fiber post was the only one associated with increased fracture strength. This improvement was presumably because the elastic modulus of a glass fiber post is similar to that of dentin, which improves stress distribution during load application.*[46]

For subgroup analysis that considered different remaining tooth structure, the following were identified in the studies: no ferule,[13,23,25,28,29,30,33] 1-mm,[16,25,32,34,38] 2-mm,[23-25,27-29,31,35,37,39] or 3-mm ferule,[25,36] class III cavities,[14,41] cervical cavities,[15] endodontic access,[17-20,40] veneer preparation,[21,22,41] and crown preparation on natural tooth.[26,41] The use of a fiber post improved fracture strength for teeth that had cervical cavities and preparation for veneers. This is probably because of the stress concentration in the cervical region and because the loss of cervical dentin weakens the tooth. The presence of the fiber post might avoid the stress concentration and distribute the stress better to other areas of the tooth.[6,22,23,45] For other groups, there were no differences in the use or not of a fiber post, probably because there was no structure loss in the cervical region (for class III cavity and endodontic access) and because the loss of structure after complete crown preparations weakened the tooth to a point where, even with the use of fiber post, its fracture strength could not be modified.

Systematic reviews and meta-analyses were initially designed to analyze clinical trials, providing the highest level of evidence.[46] However, because few clinical studies have studied this question, a systematic review and meta-analysis of in vitro studies was used to reach a consensus among laboratory studies that reached different conclusions. Additional clinical studies are needed to address the deficit.

CONCLUSIONS

Despite the heterogeneity found in this systematic review and meta-analysis and according to the obtained results, in vitro literature indicates that glass fiber posts are favorable for the fracture strength of endodontically treated and restored teeth. Additionally, clinical trials evaluating fiber post use as an additional reinforcement for teeth with structure loss are needed.

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FIGURES

Fig. 1 *Flowchart of study selection*

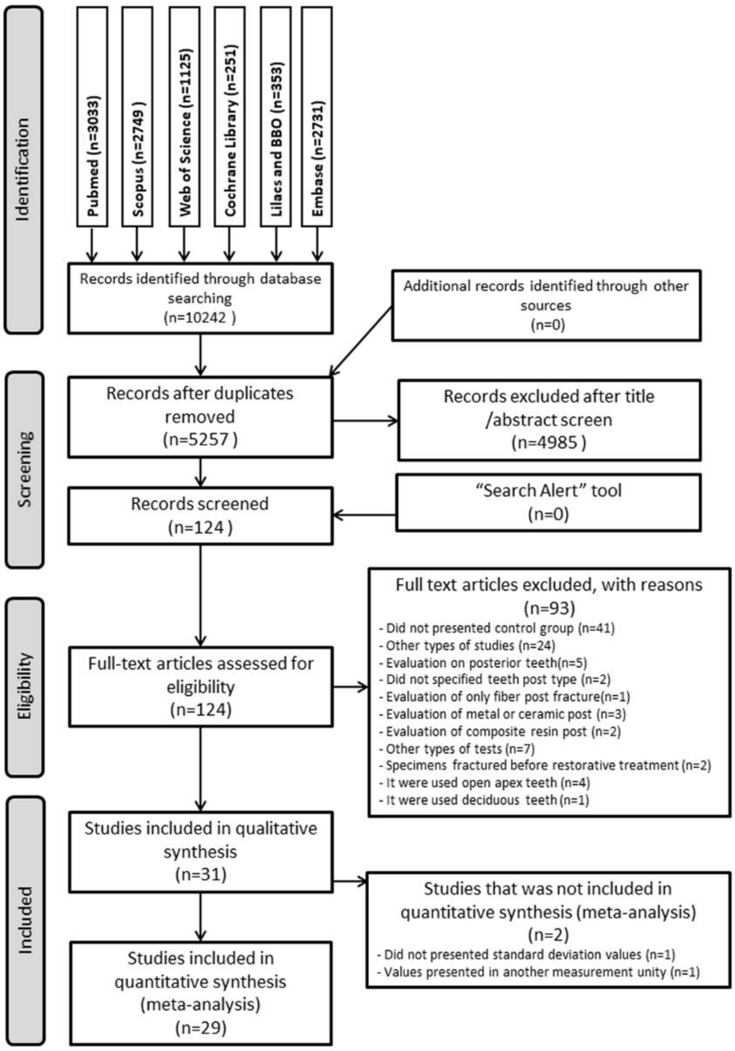


Fig. 2 *Summary of the risk of bias assessment*

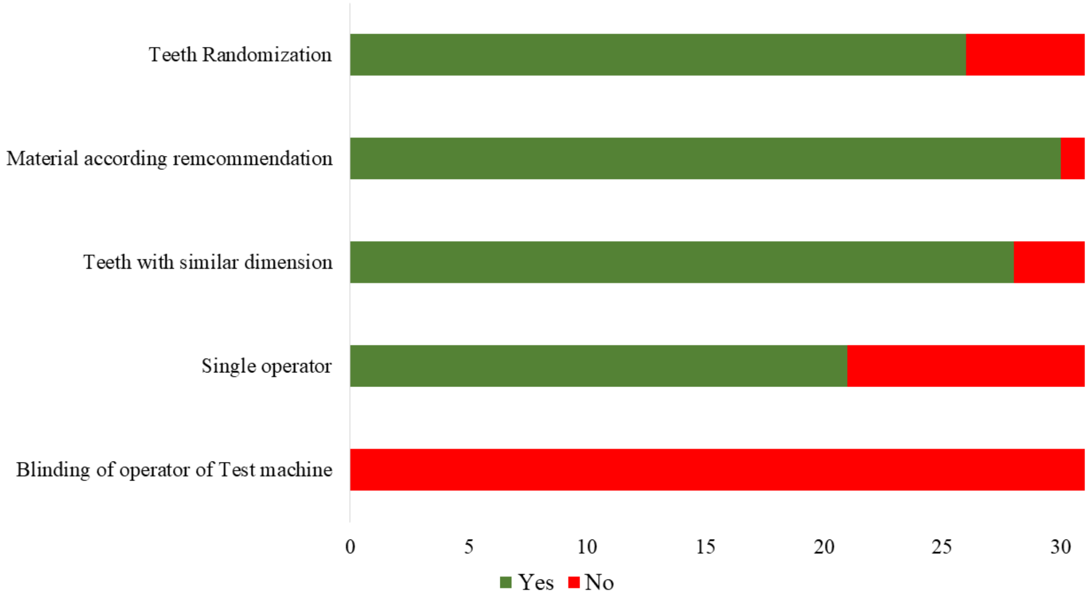


Fig. 3 *Meta-analysis to compare the control groups and the experimental groups*

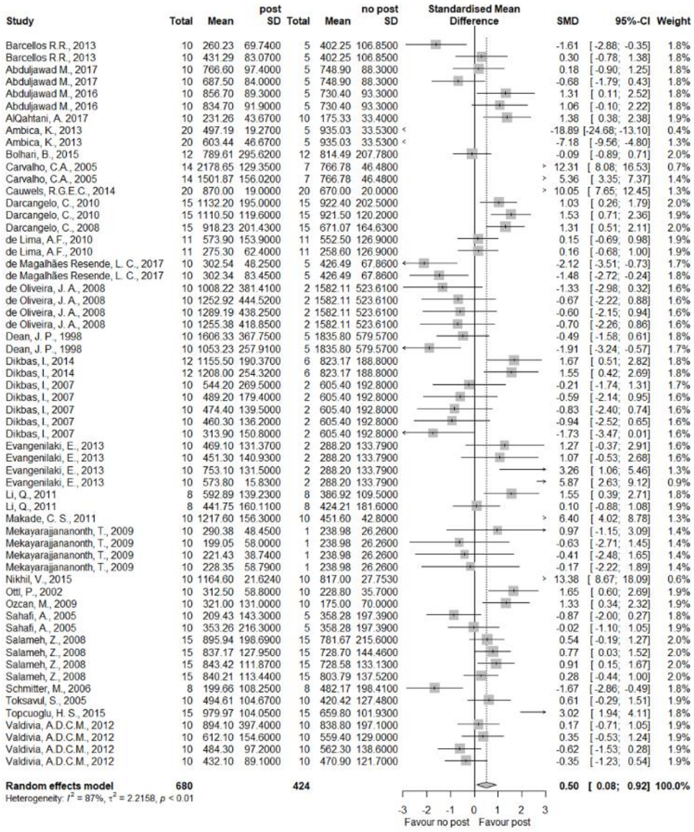


Fig. 4 *Subgroup analysis considering the type of fiber posts*

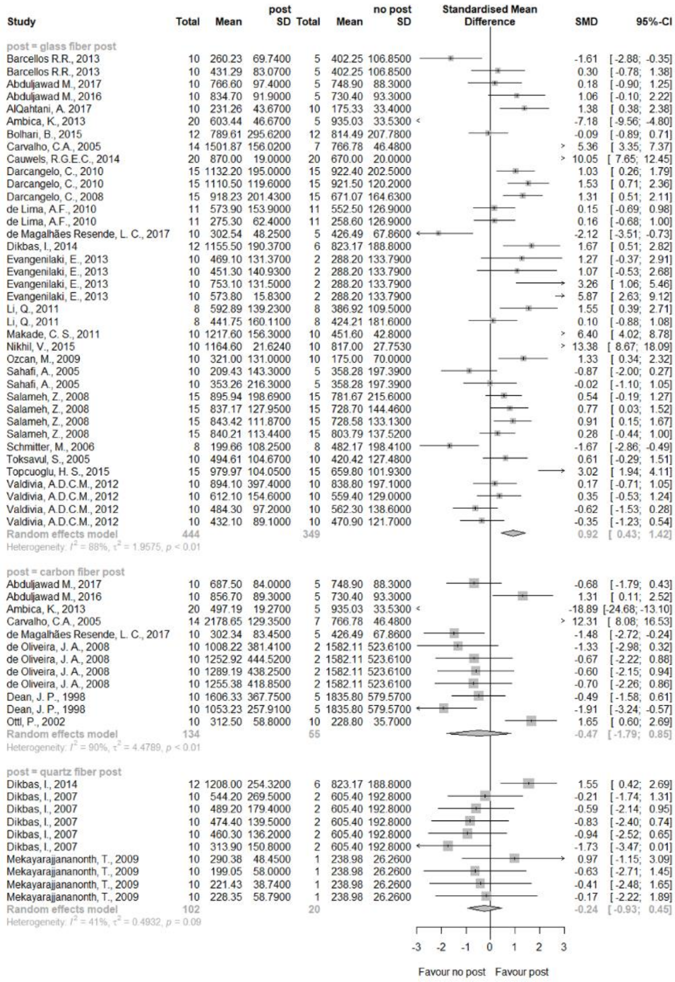
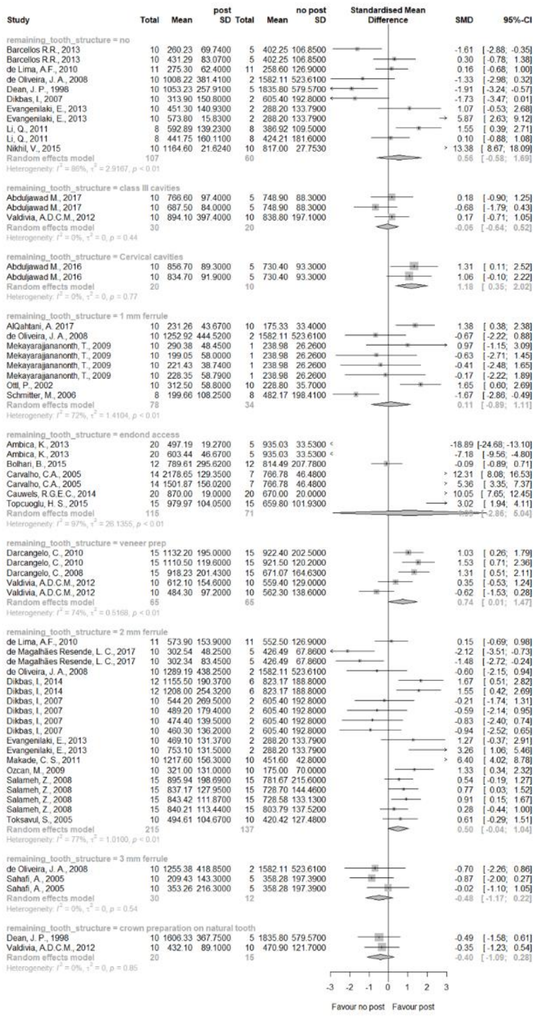


***Fig. 5** Subgroup analysis considering the types of remaining tooth structure*



TABLES

Table 1. *Electronic database and search strategy (27/Nov/2018 updated in July/2020)*

(continue)

Pubmed

((("Tooth, Nonvital"[MeSH Terms]) OR "Nonvital Tooth"[Title/Abstract]) OR "Devitalized Tooth"[Title/Abstract]) OR "Pulpless Tooth"[Title/Abstract]) OR "Pulpless Teeth"[Title/Abstract]) OR "Devitalized Teeth"[Title/Abstract]) OR "Nonvital Teeth"[Title/Abstract]) OR "Endodontically-Treated Teeth"[Title/Abstract]) OR "Endodontically-Treated Tooth"[Title/Abstract]) OR "Root Canal Therapy"[MeSH Terms]) OR "Root Canal Therapy"[Title/Abstract]) OR Apexification[Title/Abstract]) OR "Root Canal Obturation"[Title/Abstract]) OR "Root Canal Preparation"[Title/Abstract]) OR "Root canal treatment"[Title/Abstract]) OR "Endodontic treatment"[Title/Abstract]) OR "Endodontic therapy"[Title/Abstract]) OR "Dental Pulp Devitalization"[MeSH Terms]) OR "Dental Restoration, Permanent"[MeSH Terms]) OR Restoration[Title/Abstract]) OR "Dental Filling*"[Title/Abstract]) OR "Composite Resins"[MeSH Terms]) OR "Composite Resin*"[Title/Abstract]) OR "Resin composite*"[Title/Abstract]) OR Ceramics[MeSH Terms]) OR Ceramic*[Title/Abstract]) OR "Dental Porcelain"[MeSH Terms]) OR Porcelain*[Title/Abstract]) OR "Dental Veneers"[MeSH Terms]) OR Veneer*[Title/Abstract]) OR Tooth Crown[MeSH Terms]) OR "Tooth Crown*"[Title/Abstract]) OR "Crown Tooth"[Title/Abstract]) OR "Dentition, Permanent"[MeSH Terms]) OR "Permanent Dentition"[Title/Abstract]) OR "Secondary Dentition"[Title/Abstract]) OR "Adult Dentition"[Title/Abstract]) OR "Permanent tooth"[Title/Abstract]) OR "Permanent teeth"[Title/Abstract]) OR Incisor[MeSH Terms] OR Incisor*[Title/Abstract]) OR Cuspid[MeSH Terms] OR Cuspid*[Title/Abstract]) OR "Canine tooth"[Title/Abstract]) OR "Canine teeth"[Title/Abstract]))) AND ((((((((("Post and Core Technique"[MeSH Terms]) OR "Post Technique*"[Title/Abstract]) OR "Fiber post*"[Title/Abstract]) OR "Fibre post*"[Title/Abstract]) OR "Fiber dowel*"[Title/Abstract]) OR "Canal post*"[Title/Abstract]) OR "Post System*"[Title/Abstract])))*

Table 1. *Electronic database and search strategy (27/Nov/2018 updated in July/2020)*

(continuation)

Scopus

(TITLE-ABS-KEY-AUTH ("Nonvital Tooth" OR "Devitalized Tooth" OR "Pulpless Tooth" OR "Pulpless Teeth" OR "Devitalized Teeth" OR "Nonvital Teeth" OR "Endodontically-Treated Tooth" OR "Endodontically-Treated Teeth" OR "Root Canal Therapy" OR apexification OR "Root Canal Obturation" OR "Root Canal Preparation" OR "Root canal treatment" OR "Endodontic treatment" OR "Endodontic therapy" OR "Dental Pulp Devitalization" OR "Restoration" OR "Restorations" OR "Dental Filling" OR "Dental Fillings" OR "Composite Resins" OR "Composite Resin" OR "Resin composite" OR "Resin composites" OR "Ceramics" OR "Ceramic" OR porcelain OR porcelains OR veneers OR veneer OR "Tooth Crown" OR "Tooth Crowns" OR "Crown Tooth" OR "Permanent Dentition" OR "Secondary Dentition" OR "Adult Dentition" OR "Permanent tooth" OR "Permanent teeth" OR incisor OR incisors OR cuspid OR cuspids OR "Canine tooth" OR "Canine teeth")) AND (TITLE-ABS-KEY ("Post and Core Technique" OR "Post Technique" OR "Post Techniques" OR "Fiber post" OR "Fiber posts" OR "Fibre post" OR "Fibre posts" OR "Fiber dowel" OR "Fiber dowels" OR "Canal posts" OR "Canal post" OR "Post System" OR "Post Systems")) AND (LIMIT-TO (SUBJAREA , "DENT"))

Web of Science

#1: TS=("Nonvital Tooth" OR "Devitalized Tooth" OR "Pulpless Tooth" OR "Pulpless Teeth" OR "Devitalized Teeth" OR "Nonvital Teeth" OR "Endodontically-Treated Tooth" OR "Endodontically-Treated Teeth" OR "Root Canal Therapy" OR apexification OR "Root Canal Obturation" OR "Root Canal Preparation" OR "Root canal treatment" OR "Endodontic treatment" OR "Endodontic therapy" OR "Dental Pulp Devitalization" OR "Restoration" OR "Restorations" OR "Dental Filling" OR "Dental Fillings" OR "Composite Resins" OR "Composite Resin" OR "Resin composite" OR "Resin composites" OR "Ceramics" OR "Ceramic" OR porcelain OR porcelains OR veneers OR veneer OR "Tooth Crown" OR "Tooth Crowns" OR "Crown Tooth" OR "Permanent Dentition" OR "Secondary Dentition" OR "Adult Dentition" OR "Permanent tooth" OR "Permanent teeth" OR incisor OR incisors OR cuspid OR cuspids OR "Canine tooth" OR "Canine teeth")

#2: TS=("Post and Core Technique" OR "Post Technique" OR "Post Techniques" OR "Fiber post" OR "Fiber posts" OR "Fibre post" OR "Fibre posts" OR "Fiber dowel" OR "Fiber dowels" OR "Canal posts" OR "Canal post" OR "Post System" OR "Post Systems")

#1 and #2

Table 1. *Electronic database and search strategy (27/Nov/2018 updated in July/2020)*

(continuation)

Lilacs and BBO

((mh:(“dente N vital”)) OR (tw:(“dente N vital”)) OR (tw:(“diente no vital”)) OR (tw:(“dente desvitalizado”)) OR (tw:(“dente tratado endodonticamente”)) OR (tw:(“dente sem polpa”)) OR (mh:(“Tratamento do Canal Radicular”)) OR (tw:(“Tratamento do Canal Radicular”)) OR (tw:(“Tratamiento del Conducto Radicular”)) OR (mh:(“Desvitalização da Polpa Dentária”)) OR (tw:(“Desvitalização da Polpa Dentária”)) OR (tw:(“Desvitalización de la Pulpa Dental”)) OR (mh:(“Restauração Dentária Permanente”)) OR (tw:(“Restauração Dentária Permanente”)) OR (tw:(“Restauración Dental Permanente”)) OR (mh:(“resinas compostas”)) OR (tw:(“resinas compostas”)) OR (tw:(“Resinas Compuestas”)) OR (tw:(Compósitos)) OR (mh:(Cerâmica)) OR (tw:(Cerâmica)) OR (tw:(Cerámica)) OR (tw:(Cerâmicas)) OR (mh:(“porcelana dentária”)) OR (tw:(Porcelana)) OR (mh:(“facetas dentárias”)) OR (tw:(“facetas dentárias”)) OR (tw:(“coronas con frente estético”)) OR (tw:(“Facetas acrílicas”)) OR (tw:(“Laminados dentários”)) OR (mh:(“coroa dentária”)) OR (tw:(“coroa dentária”)) OR (tw:(“corona del diente”)) OR (mh:(“Dentição Permanente”)) OR (tw:(“Dentição Permanente”)) OR (tw:(“Dentición Permanente”)) OR (tw:(“Dente Permanente”)) OR (tw:(“dentes permanentes”)) OR (tw:(“dentição de adulto”)) OR (tw:(“dentição secundária”)) OR (mh:(incisivo)) OR (tw:(incisivo)) OR (tw:(incisivos)) OR (mh:(“Dente canino”)) OR (tw:(“Dente canino”)) OR (tw:(canino)) OR (tw:(caninos)) OR (tw:(“dientes caninos”))) AND ((mh:(“Técnica para Retentor Intrarradicular”)) OR (tw:(“Técnica para Retentor Intrarradicular”)) OR (tw:(“Técnica de Perno Muñón”)) OR (tw:(“tarugos”)) OR (tw:(“pinos de retenção dentária”)))

Table 1. *Electronic database and search strategy (27/Nov/2018 updated in July/2020)*

(continuation)

Cochrane Library

#1 MeSH descriptor: [Tooth, Nonvital] explode all trees
#2 "Nonvital Tooth"
#3 "Devitalized Tooth"
#4 "Pulpless Tooth"
#5 "Pulpless Teeth"
#6 "Devitalized Teeth"
#7 "Nonvital Teeth"
#8 "Endodontically-Treated Teeth"
#9 "Endodontically-Treated Tooth"
#10: #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9
#11 MeSH descriptor: [Root Canal Therapy] explode all trees
#12 "Root Canal Therapy"
#13 "Apexification"
#14 "Root Canal Obturation"
#15 "Root Canal Preparation"
#16 "Root canal treatment"
#17 "Endodontic treatment"
#18 "Endodontic therapy"
#19: #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18
#20 MeSH descriptor: [Dental Pulp Devitalization] explode all trees
#21 MeSH descriptor: [Dental Restoration, Permanent] explode all trees
#22 "Restoration"*
#23" Dental Filling"*
#24: #21 OR #22 OR #23
#25 MeSH descriptor: [Composite Resins] explode all trees 1932
#26 "Composite Resin"*
#27 "Resin composite"*
#28: #25 OR #26 OR #27
#29 MeSH descriptor: [Ceramics] explode all trees
#30 "Ceramic"*
#31: #29 OR #30
#32 MeSH descriptor: [Dental Porcelain] explode all trees
#33 "Porcelain"*
#34: #32 OR #33
#35 MeSH descriptor: [Dental Veneers] explode all trees
#36 "Veneer"*
#37: #35 OR #36
#38 MeSH descriptor: [Tooth Crown] explode all trees
#39 "Tooth Crown"*
#40 "Crown Tooth"
#41: #38 OR #39 OR #40
#42 MeSH descriptor: [Dentition, Permanent] explode all trees
#43 "Permanent Dentition"

Table 1. *Electronic database and search strategy (27/Nov/2018 updated in July/2020)*

(conclusion)

#44 "Secondary Dentition"
#45 "Adult Dentition"
#46 "Permanent tooth"
#47 "Permanent teeth"
#48: #42 OR #43 OR #44 OR #45 OR #46 OR #47
*#49 MeSH descriptor: [Incisor] explode all trees Incisor**
#50 MeSH descriptor: [Cuspid] explode all trees
#51 "Cuspid"*
#52 "Canine Teeth"
#53 "Canine Tooth"
#54: #50 OR #51 OR #52 OR #53
#55: #10 OR #19 OR #20 OR #24 OR #28 OR #31 OR #34 OR #37 OR #41 OR #48 OR #49 OR #54
#56 MeSH descriptor: [Post and Core Technique] explode all tree
#57 "Post Technique"*
#58 "Fiber post"*
#59 "Fibre post"*
#60 "Fiber dowel"*
#61 "Canal post"*
#62 "Post System"*
#63: #56 OR #57 OR #58 OR #59 OR #60 OR #61 OR #62
#64 #55 AND #63

Embase

('tooth pulp desease'/exp OR 'nonvital tooth':ab,ti OR 'devitalized tooth':ab,ti OR 'pulpless tooth':ab,ti OR 'pulpless teeth':ab,ti OR 'devitalized teeth':ab,ti OR 'nonvital teeth':ab,ti OR 'endodontically-treated teeth':ab,ti OR 'endodontically-treated tooth':ab,ti OR 'endodontic procedure'/exp OR 'root canal therapy':ab,ti OR 'apexification':ab,ti OR 'root canal obturation':ab,ti OR 'root canal preparation':ab,ti OR 'root canal treatment':ab,ti OR 'endodontic treatment':ab,ti OR 'endodontic therapy':ab,ti OR 'dental pulp devitalization'/exp OR 'dental restoration'/exp OR 'restoration':ab,ti OR 'restorations':ab,ti OR 'dental filling':ab,ti OR 'resin'/exp OR ‘composite resin':ab,ti OR 'composite resins':ab,ti OR 'resin composite':ab,ti OR 'resin composites':ab,ti OR 'ceramics'/exp OR 'ceramic':ab,ti OR 'ceramics':ab,ti OR 'dental porcelain'/exp OR 'porcelain':ab,ti OR 'porcelains':ab,ti OR 'dental veneer'/exp OR 'veneer':ab,ti OR ‘tooth crown’/exp OR ‘tooth crown’:ab,ti OR ‘tooth crowns’:ab,ti OR ‘crown tooth’:ab,ti OR 'secondary dentition'/exp OR ‘permanent dentition’:ab,ti OR 'secondary dentition':ab,ti OR 'adult dentition':ab,ti OR 'permanent teeth':ab,ti OR ‘permanent tooth’:ab,ti OR 'incisor'/exp OR 'incisor':ab,ti OR ‘incisors’:ab,ti OR 'canine tooth'/exp OR 'cuspid':ab,ti OR 'cuspids':ab,ti OR 'canine teeth':ab,ti OR 'canine tooth':ab,ti) AND ('carbon fiber'/exp OR 'glass fiber'/exp OR 'post technique':ab,ti OR 'post techniques':ab,ti OR 'fiber post':ab,ti OR 'fiber posts':ab,ti OR 'fibre post':ab,ti OR 'fibre posts':ab,ti OR 'fiber dowel':ab,ti OR 'fiber dowels':ab,ti OR 'canal post':ab,ti OR 'canal posts':ab,ti OR 'post system':ab,ti)

Table 2. *Main characteristics extracted from selected studies. (CEJ=Cement-enamel junction; NR=Not reported)*

(continue)

Study ID	***Type of specimen***	***Remaining tooth structure***	***Type of fiber post***	***Angle of load application***	***Fracture mode***
Barcellos R.R., 2013 [13]	*Human*	*Crown preparation (no remaining tooth structure)*	*Glass*	*135º*	*100% of repairable fractures*
			Glass (realigned with composite resin)		*70% of repairable fractures*
			No post		*100% of repairable fractures*
Abduljawad M., 2017 [14]	*Human*	*Class III restoration*	*Glass* *Carbon* *No post*	*45º*	*NR*
Abduljawad M., 2016 [15]	*Human*	*Cervical cavity*	*Glass* *Carbon* *No post*	*45º*	*NR*
AlQahtani, A. 2017 [16]	*Human*	*Crown preparation (1 mm of ferrule)*	*Glass*	*135º*	*80% above CEJ*
			No post		*100% above CEJ*
Ambica, K., 2013 [17]	*Human*	*Endodontic access*	*Carbon* *Glass* *No post*	*135º*	*NR*
Bolhari, B., 2015 [18]	*Human*	*Endodontic access*	*Glass*	*135º*	*From 3 mm coronal to the lingual CEJ, up to approximately 2 mm apical to facial CEJ without fracturing the post*
			No post		*From 3 mm coronal to the lingual CEJ, up to approximately 2 mm apical to facial CEJ*
Carvalho, C.A., 2005 [19]	*Bovine*	*Endodontic access*	*Glass* *Carbon* *No post*	*130º*	*NR*
Cauwels, R.G.E.C., 2014 [20]	*Bovine*	*Endodontic access*	*Glass*	*30°*	*90% of favorable fractures*
			No post		*95% of favorable fractures*
Clavijo, V.G., 2009 [12]	*Bovine*	*Crown preparation*	*Glass* *No post*	*135º*	*NR*
Darcangelo, C., 2010 [21]	*Human*	*Veneer preparation (composite resin)*	*Glass*	*45º*	*NR*
			No post		
		Veneer preparation (porcelain)	*Glass*		
			No post		
Darcangelo, C., 2008 [22]	*Human*	*Veneer preparation*	*Glass*	*45º*	*NR*
		Veneer preparation	*No post*		

Table 2. *Main characteristics extracted from selected studies. (CEJ=Cement-enamel junction; NR=Not reported)*

(continuation)

Study ID	Type of specimen	Remaining tooth structure	Type of fiber post	Angle of load application	Fracture mode
de Lima, A.F., 2010 [23]	*Bovine*	*Crown preparation (no remaining tooth structure)*	*Glass*		*45º*
		Crown preparation (no remaining tooth structure)	*No post*		
		Crown preparation (2 mm of ferrule)	*Glass*		
		Crown preparation (2 mm of ferrule)	*No post*		
de Magalhães Resende, L. C., 2017 [24]	*Human*	*Crown preparation (2 mm of ferrule)*	*Glass*	*45º*	*100% supra-crestal*
			Carbon		*100% supra-crestal*
			No post		*60% supra-crestal*
de Oliveira, J. A., 2008 [25]	*Human*	*1 mm of ferule*	*Carbon*	*45º*	*50% of composite resin core fracture and 50% of coronal structure and composite resin core fracture*
		2 mm of ferule			*40% of composite resin core fracture and 60% of coronal structure and composite resin core fracture*
		3 mm of ferule			*100% of coronal structure and composite resin core fracture*
		No ferule (no remaining tooth structure)			*100% of composite resin core fracture*
		No ferule	*No post*		*100% of root fractures*
Dean, J. P., 1998 [26]	*Human*	*Crown preparation on natural tooth)*	*Carbon*	*45º*	*NR*
			No post		
Dikbas, I., 2014 [27]	*Human*	*2 mm of ferule*	*Glass* *Quartz* *No post*	*45º*	*NR*
Dikbas, I., 2007 [28]	*Human*	*2 mm of ferule (circumferential)*	*Quartz*	*135º*	*Horizontal and oblique fractures*
		2 mm of ferule (buccal surface)			
		2 mm of ferule (palatal surface)			
		2 mm of ferule and interproximal concavities)			
		No ferule			
		No preparation	*No post*		*Horizontal and oblique fractures and catastrophic fracture*

Table 2. *Main characteristics extracted from selected studies. (CEJ=Cement-enamel junction; NR=Not reported)*

(continuation)

Study ID	***Type of specimen***	***Remaining tooth structure***	***Type of fiber post***	***Angle of load application***	***Fracture mode***
Evangenilaki, E 2013 [29]	*Human*	*2 mm of ferule No ferule (no remaining tooth structure)*	*Glass*	*135 º*	*NR*
		No preparation	*No post*		
Li, Q., 2011 [30]	*Human*	*Crown preparation (minor diameter canal)*	*Glass*	*45 º*	*62.5% of favorable fractures*
		Crown preparation (minor diameter canal)	*No post*		*37.5% of favorable fractures*
		Crown preparation (major diameter canal)	*Glass*		*50% of favorable fractures*
		Crown preparation (major diameter canal)	*No post*		*36.5% of favorable fractures*
Makade, C. S., 2011 [31]	*Human*	*Crown preparation (2 mm of ferule)*	*Glass*	*130 º*	*100% of restorable fractures*
			No post		*70% of restorable fractures*
Mekayarajjananonth, T., 2009 [32]	*Human*	*Crown preparation (1 mm of ferule)*	*Quartz*	*130 º*	*NR*
			No post		
Nikhil, V., 2015 [33]	*Human*	*Crown preparation (no remaining tooth structure)*	*Glass*	*135 º*	*NR*
		No preparation	*No post*		
Ottl, P., 2002 [34]	*Human*	*1 mm of ferule*	*Carbon*	*135 º*	*NR*
			No post		
Ozcan, M., 2009 [35]	*Human*	*Crown preparation (2 mm of ferule)*	*Glass*	*135 º*	*100% of favorable failures*
			No post		
Sahafi, A., 2005 [36]	*Human*	*Crown preparation (3 mm of ferule)*	*Glass*	*45 º*	*NR*
			No post		
Salameh, Z., 2008 [37]	*Human*	*2 mm of ferule*	*Glass*	*45 º*	*60% of restorable*
			No post		*10% of restorable*
			Glass		*60% of restorable*
			No post		*20% of restorable*
			Glass		*70% of restorable*
			No post		*50% of restorable*
			Glass		*80% of restorable*
			No post		*60% of restorable*
Schmitter, M., 2006 [38]	*Human*	*1 mm of ferule*	*Glass*	*45 º*	*NR*
			No post		
Sidoli, G. E., 1997 [11]	*Human*	*Crown preparation*	*Carbon*	*45 º*	*60% of favorable*
			No post		*20% of favorable*
Toksavul, S., 2005 [39]	*Human*	*2 mm of ferule*	*Glass*	*135 º*	*50% of repairable*
		2 mm of ferule	*No post*		*100% of repairable*

Table 2. *Main characteristics extracted from selected studies. (CEJ=Cement-enamel junction; NR=Not reported)*

(conclusion)

Study ID	Type of specimen	Remaining tooth structure	Type of fiber post	Angle of load application	Fracture mode
Topcuoglu, H. S., 2015 [40]	Human	Endodontic access	Glass	45º	Fractures above CEJ
			No post		Fractures at CEJ or mid-root fracture
		Class III restoration	Glass		80% of cohesive fracture of tooth or restoration less than half of crown
			No post		80% of cohesive fracture of tooth or restoration less than half of crown
Valdivia, Adcm, 2012 [41]	Human	Veneer preparation (composite)	Glass	135º	80% of cohesive fracture of tooth or restoration less than half of crown
			No post		60 % of root fracture in the cervical third
		Veneer preparation (ceramic)	Glass		90% of cohesive fracture of restoration
			No post		90% of cohesive fracture of restoration
		Crown preparation	Glass		90% of cohesive fracture of restoration
			No post		90% of cohesive fracture of restoration

Table 3. *Summary of the risk of bias assessment, according to the review authors' judgments about each risk of bias item for each included in vitro study. (Abbreviations: N-no; Y-yes)*

Study ID	***Teeth Randomization***	***Materials According to the Manufacturer's Instructions***	***Teeth with similar Dimensions***	***Endodontic Treatment Performed by a Single Operator***	***Blinding of the Operator of the Testing Machine***	***Risk of Bias***
Barcellos R.R., 2013 [13]	*N*	*Y*	*Y*	*Y*	*N*	*Medium*
Abduljawad M., 2017 [14]	*N*	*N*	*Y*	*N*	*N*	*High*
Abduljawad M., 2016 [15]	*N*	*Y*	*Y*	*N*	*N*	*High*
AlQahtani, A. 2017 [16]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Ambica, K., 2013 [17]	*N*	*Y*	*Y*	*N*	*N*	*High*
Bolhari, B., 2015 [18]	*N*	*Y*	*Y*	*N*	*N*	*High*
Carvalho, C.A., 2005 [19]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Cauwels, R.G.E.C., 2014 [20]	*Y*	*Y*	*Y*	*N*	*N*	*Medium*
Clavijo, V.G., 2009 [12]	*Y*	*Y*	*Y*	*N*	*N*	*Medium*
Darcangelo, C., 2010 [21]	*Y*	*Y*	*Y*	*N*	*N*	*Medium*
Darcangelo, C., 2008 [22]	*Y*	*Y*	*Y*	*N*	*N*	*Medium*
de Lima, A.F., 2010 [23]	*Y*	*Y*	*Y*	*N*	*N*	*Medium*
de Magalhães Resende, L. C., 2017 [24]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
de Oliveira, J. A., 2008 [25]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Dean, J. P., 1998 [26]	*Y*	*Y*	*Y*	*N*	*N*	*Medium*
Dikbas, I., 2014 [27]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Dikbas, I., 2007 [28]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Evangenilaki, E., 2013 [29]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Li, Q., 2011 [30]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Makade, C. S., 2011 [31]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Mekayarajjananonth, T., 2009 [32]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Nikhil, V., 2015 [33]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Ottl, P., 2002 [34]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Ozcan, M., 2009 [35]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Sahafi, A., 2005 [36]	*Y*	*Y*	*N*	*Y*	*N*	*Medium*
Salameh, Z., 2008 [37]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Schmitter, M., 2006 [38]	*Y*	*Y*	*N*	*Y*	*N*	*Medium*
Sidoli, G. E., 1997 [11]	*Y*	*Y*	*N*	*Y*	*N*	*Medium*
Toksavul, S., 2005 [39]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Topcuoglu, H. S., 2015 [40]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*
Valdivia, Adcm, 2012 [41]	*Y*	*Y*	*Y*	*Y*	*N*	*Low*

2.4 Artigo – Jurema ALB, Correia AMO, Bresciani E, Caneppele TMF. Influência de diferentes tratamentos químicos intrarradiculares na resistência de união de pinos de fibra em dentes tratados endodonticamente: Revisão sistemática e metanálise em rede / *Influence of different intraradicular dentin chemical pretreatments on fiber post bond strength in endodontically treated teeth: A systematic review and network meta-analysis* *

RESUMO

Objetivos: Uma revisão sistemática e meta-análise em rede foram realizadas para responder à seguinte pergunta: Os tratamentos químicos para dentina intrarradicular afetam a força de união dos pinos de fibra em dentes tratados endodonticamente?”.
Materiais e Métodos: Uma busca foi realizada no *PubMed*, *Scopus*, *Web of Science*, *LILACS, BBO* e *Cochrane Library*, sem restrições de data/idioma, em 24 de outubro de 2018 (atualizado em junho de 2019). Foram incluídos estudos *in vitro* que comparavam a força de união entre pelo menos dois tratamentos químicos de dentina intrarradicular prévios à cimentação adesiva de pinos de fibra. O risco de viés (RV) foi avaliado. Um modelo bayesiano com efeito randômico de comparação mista de tratamentos foi utilizado para comparar a força de união (por meio de testes de *push-out*) de diferentes tratamentos químicos em dentina intrarradicular que recebem pinos de fibra. A análise SUCRA foi realizada para classificar o melhor tratamento para cada estratégia de cimentação adesiva.
Resultados: 61 estudos foram selecionados. Considerando comparações diretas e indiretas, os melhores valores de força de união para cimentos autocondicionantes, de condicionamento total e cimentos autoadesivos foram para os tratamentos: acetato de etila, NaOCl em baixa concentração e extrato de semente de uva, respectivamente, e os baixos valores de resistência adesiva foram com NaOCl em alta concentração, ácido poliacrílico e peróxido de hidrogênio.
Conclusões: O uso de tratamentos químicos na dentina intrarradicular de dentes tratados endodonticamente depende da estratégia adesão e cimentação, na estratégia de adesivo autocondicionante, o acetato de etila apresentou maiores valores de resistência de união. Nos adesivos e condicionamento total, o NaOCl em baixa concentração apresentou melhores resultados. O extrato de semente de uva foi indicado como um bom tratamento de dentina intrarradicular previamente à cimentação de pinos de fibra com cimentos autocondicionantes.

Palavras-chave: Técnica para retentor intrarradicular. Irrigantes do canal radicular. Dente não vital. Força de união.

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ABSTRACT

Objectives: A systematic review and network meta-analysis were performed to answer the question: Do intraradicular dentin chemical pretreatments affect the bond strength of fiber posts for endodontically treated teeth?"

Materials and Methods: A search was performed in PubMed, Scopus, Web of Science, LILACS, BBO, and Cochrane Library, in October 24, 2018 (updated on June, 2019). In vitro studies that included at least two dentin treatments prior to fiber post cementation, comparing push-out bond strength test between pretreatments, were included. Risk of bias was evaluated. A random-effects Bayesian-mixed treatment comparison model was used to compare push-out bond strength of different chemical pretreatments in radicular dentin that receive fiber posts. SUCRA analysis was performed to rank the best pretreatments.

Results: Sixty-one studies were selected. The best bond strength values for self-etch, etch-and-rinse, and self-adhesive cements were of ethyl acetate, low concentration NaOCl, and grape seed extract, respectively, and low bond strength values were with high concentration NaOCl, polyacrylic acid, and hydrogen peroxide.

Conclusions: The use of chemical pretreatments in intraradicular dentin of endodontically treated teeth depends on the adhesive and cementation strategy. For self-etch adhesive, ethyl acetate presented increased bond strength values. For etch-and-rinse adhesives, low concentration NaOCl showed better results. Grape seed extract was indicated as a good intraradicular dentin treatment for self-adhesive cements.

Clinical Relevance: When associated to self-etch adhesive, etch-and-rinse adhesives and self-adhesives cements, respectively, the use of ethyl acetate, low concentration NaOCl and grape seed extract as radicular dentin pretreatment improve the bond strength of intraradicular fiber posts.

Keywords: Post and core technique. Root canal irrigants. Nonvital tooth. Bond strength.

1. Introduction

Endodontically treated teeth typically present with loss of coronal structure caused by caries or trauma in addition to the endodontic access cavity and root canal preparation. Fiber posts and cores have been widely used to treat teeth with loss of structure [1, 2]. The use of fiber posts is a suitable treatment because of the biomechanical properties of the material, the elastic modulus of fiber posts being similar to that of the remaining dentin [3].

Luting agents with different adhesive strategies have been developed for the adhesive cementation of fiber posts to root canal dentin [4]. The etch-and-rinse adhesive technique with resin cements consists of a phosphoric acid application for conditioning the dentin substrate and removing the smear layer, followed by the application of primer and/or bond [5, 6]. Self-etch adhesive systems can also be used with a simplified application without the acid etching step [5, 7]. Self-adhesive cements have also been developed with bonding based on the presence of an acid monomer (methacrylate phosphoric acid ester)[8], eliminating the adhesive application step. The use of self-adhesive cements has been reported to decrease the influence of water or excessive drying [9].

Debonding of fiber posts has been reported to be a common cause of restoration failure and the integrity of the resin-dentin interface is directly related to the bond strength of the fiber post and, consequently, longevity of the adhesive cementation [1]. Resin components of cements are susceptible to the hydrolytic properties of water and the action of endogenous proteolytic enzymes in the dentin [10]. Furthermore, a smear layer is created during the post space preparation that might contain gutta percha and endodontic sealer remnants, microorganisms, and infected dentin [11–13]. These factors promote interface degradation, decreasing fiber post retention and negatively influencing the adhesive systems or adhesive cement penetration into the dentinal tubules [13].

Considering the issues related to fiber post bond strength in post space preparation, it is important to investigate strategies to improve adhesion between adhesive systems and intraradicular dentin. Among these strategies, the use of different pretreatments has been suggested, including ethanol, chlorhexidine, sodium hypochlorite (NaOCl), EDTA (ethylenediaminetetracetic *acid), phosphoric acid, and grape seed extract [14–20]. These pretreatments might increase the patency of the dentinal tubules, clean the dentin substrate, or inhibit proteolytic enzymes, increasing the bond strength of fiber posts [10, 21–26].*

Although the effect of various pretreatments has been studied [14, 16–20, 27], a consensus about the optimal treatment that improves dentin properties and increases the retention rate of fiber posts is lacking. Therefore, the aim of this systematic review and mixed treatment comparison meta-analysis was to compare the effect of different intraradicular dentin pretreatments on fiber post bond strength using different cementation systems.

2. Materials and methods

2.1 Protocol and registration

The review was registered in the PROSPERO (International Prospective Register of Systematic Reviews) database (May 23rd, 2017; www.crd.york.ac.uk/PROSPERO) and developed in accordance with the recommendations of the PRISMA-NMA (Preferred Reporting Items for Systematic Review and Meta-Analysis - for Network Meta-Analyses) statement (www.prisma-statement.org) [28].

2.2 Eligibility criteria

The question of this systematic review and network meta-analysis was: Do intraradicular dentin chemical pretreatments affect the bond strength of fiber posts for endodontically treated teeth? In vitro studies that included at least two dentin pretreatments before fiber post cementation, comparing the push-out bond strength test between pretreatments, were included according to this PICO strategy:

Population (P) - endodontically treated teeth with need of intraradicular fiber posts;

Intervention (I)/Comparison (C) - use of dentin chemical pretreatments;

Outcome (O) - push-out bond strength.

It was expected to include randomized clinical trials, but they were not found in searches for studies that would have the necessary characteristics to *answer the PICO strategy. Nonrandomized clinical trials, observational studies, case reports, and reviews were excluded. Publication date and language restrictions were not applied.*

2.3 Information sources and search strategy

The search strategy was conducted using combinations of controlled vocabulary (MeSH terms) and free keywords related to the PICO question described in the previous item.

The search was performed first on the electronic database MEDLINE by PubMed. Then, the search terms were adapted for use in the following electronic databases: citation databases (Scopus and Web of Science), Cochrane Library, Latin American and Caribbean Health Sciences Literature database (LILACS), Brazilian Library in Dentistry (BBO), dissertations and theses (Periódicos Capes Theses database), and System for Information on Grey Literature in Europe (OpenSIGLE). In order to identify possible relevant studies, the reference lists of the eligible studies were manually checked.

A "Search Alert" with the search strategy has been created for the PubMed, citation databases (Scopus and Web of Science), and Cochrane Library. The search was updated from inception through to June 2019.

2.4 Study selection and data collection process

The titles and abstracts were reviewed for study selection in accordance with the search strategy (appendix Table S1). Duplicate studies were removed. Full-text articles were retrieved where the title and abstract did not provide sufficient information to make a clear decision. Two reviewers (A.L.B.J. and A.M.O.C.) verified the studies that met the eligibility criteria. Subsequently, an identification number was given to each eligible study, combining the first author's name and year of publication.

Customized extraction forms were used by the two reviewers to independently extract relevant data from the included studies, including type of tooth (bovine or human; anterior or posterior), type of dentin pretreatment, type of adhesive, type of fiber post, cementation agents, and outcomes. In case of doubt, a third reviewer was consulted to make a decision (T.M.F.C.).

When data from multiple root slices were provided, we collected and grouped them to calculate an average for each tooth. When more than one type of fiber post was included in the study, their values were combined to make a single entry according to the dentin pretreatment. It was not included groups which associated two or more substances as pretreatment. In the studies where more than one dentin pretreatment was assessed with different cementation strategies, the data were collected separately for each strategy. Some studies presented bond strength data after aging or cycling, but for this meta-analysis, it was collected the immediate bond strength data.

2.5 Risk of bias in individual studies

Two reviewers (A.L.B.J. and A.M.O.C.) independently performed quality assessments of the studies using the description in the studies of the following criteria: tooth randomization, use of teeth free of caries or restoration, endodontic treatment performed by a single operator, use of materials according to the manufacturer's instructions, use of teeth with similar dimensions, and blinding of the operator of the testing machine. Yes (Y) or No (N) were assigned to the criteria in each study. When the criteria were reported by a study, a "Y" was assigned; if the criteria were not reported, the study received an "N." The study was at low risk of bias if five or six criteria were reported. If three or four criteria were reported, the study was judged as having a medium risk of bias. Those reporting one or two criteria were considered at high risk of bias. Disagreements between the reviewers during this process were discussed until an agreement was reached. A third reviewer (T.M.F.C.) was consulted when necessary.

2.6 Data synthesis and statistical analysis

The data were analyzed using the R statistical language R Studio (version 3.4.4, Studio Team, Boston, MA, USA). The meta-analysis was performed including low, medium, and high risk of bias studies. Substances with similar concentrations were grouped and in some cases were considered as low or high concentration products. Dentin pretreatments such as saline solution, distilled water, or no substance were considered as a control group (no *treatment). Table 1 shows the substances grouped according to each dentin pretreatment.*

The meta-analyses were divided according to the cementation procedures: self-etch adhesive + resin cement, etch-and-rinse adhesive + resin cement, and self-adhesive cement, because it would not be reasonable to merge these data. For each of these types of cementation, the results of every possible comparison of push-out bond strength among groups within the study was carried out.

The three network meta-analyses were performed using the mixed treatment comparison (MTC) methodology, which allows the incorporation of studies with three or more arms and simultaneous comparison of all dentin pretreatments, combining direct evidence, indirect evidence, or both direct and indirect evidence. First, a traditional meta-analysis with random effect model was used for each pairwise comparison from different studies. The Cochran Q test and the inconsistency I2 test were used to test heterogeneity among studies. Then, one network meta-analysis was performed using the fixed and random effect to define the one with the better Deviance Information Criterion (DIC). The random effect model showed the best value of DIC for every type of cementation. Convergence was assessed by trace plots and inconsistency by split node method [29]. The results were displayed in point estimates and the surface under the cumulative ranking curve (SUCRA) probabilities (the probability of being the best dentin pretreatment on the bond strength of intraradicular fiber posts) was also calculated. Credibility intervals were obtained and a p value of 0.05 was set for statistical significance.

3. Results

3.1 Study selection

The process of study selection is presented in Figure 1. The search strategy resulted in 2303 potentially relevant studies, and, after the removal of duplicates, 1754 studies remained. After title and abstract screening had been conducted, a total of 107 studies remained for verification of eligibility, and 2 studies were eligible by 'search alert' tool. Of those, 48 studies were excluded after reading the full text for the following reasons: they presented only *qualitative evaluation (n = 8); all groups designed were association of pretreatments (n = 10); all groups designed were association of chemical and mechanical treatment (n = 17); the mechanical test to evaluate bond strength was not the push-out test (n = 19). Finally, 61 in vitro studies met the eligibility criteria and were included in this systematic review and meta-analysis.*

3.2 Study characteristics

The main characteristics of the 61 selected in vitro studies are presented in the appendix (appendix Table S2). Human teeth were used in most of the studies (n = 40), of which 6 studies used posterior teeth, 31 used anterior teeth, and 24 reported using only single-rooted teeth. The self-etch adhesive + resin cement was tested in 25 studies. The etch-and-rinse adhesive + resin cement was used in 17 studies, and, in 39 studies, experimental groups used the self-adhesive cement. There were 57 studies using glass fiber posts, 3 studies using carbon fiber posts in most groups, and 1 study using quartz fiber posts for all groups. Different types of dentin pretreatment were used. Fifty-seven studies used a control group (saline solution, distilled water, or no treatment), 32 used chlorhexidine, 30 used NaOCl, 16 used EDTA, 11 used ethanol, 8 used phosphoric acid, 4 used polyacrylic acid, 2 used grape seed extract, 2 used citric acid, 1 used carbodiimide, 1 used hydrogen peroxide, 1 used boric acid, 1 used hydrofluoric acid, 1 used ethyl acetate, and 1 used xylene.

3.3 Assessment of the risk of bias

The assessment of the risk of bias for the 61 included in vitro studies is presented in the appendix (appendix Table S3). According to the criteria considered in the analyses, six studies were classified as at low risk of bias. Forty-seven studies presented medium risk of bias, and eight presented high risk of bias.

3.4 Evidence network

The results, based on data derived from 61 in vitro studies, include direct comparisons and indirect comparisons of dentin pretreatment on the bond strength of fiber posts for endodontically treated teeth.

The self-etch adhesive + resin cement meta-analysis included 25 studies, with 15 of these having 2 arms, 7 having 3 arms, 2 having 4 arms, and 1 study having 5 arms. The network meta-analysis plot of dentin pretreatment comparisons for the self-etch adhesive + resin cement is presented in Figure 2. In brief, 13 pretreatments were compared, totaling 26 pairs of comparisons and 765 specimens.

For etch-and-rinse adhesive + resin cement meta-analysis, 17 studies were included, 9 studies having 2 arms, 5 having 3 arms, and 3 having 4 arms. The network meta-analysis plot of dentin pretreatment comparisons is displayed in Figure 3. In this meta-analysis, 9 pretreatments were compared, totaling 15 pairs of comparisons and 619 specimens.

Thirty-nine studies were included in the self-adhesive cement meta-analysis, with 15 of these having 2 arms, 14 having 3 arms, 9 having 4 arms, and 1 having 5 arms. Figure 4 shows the network meta-analysis plot of dentin pretreatment comparisons for the self-adhesive cement. Thirteen pretreatments were compared in this meta-analysis, totaling 32 pairs of comparisons and 1459 specimens.

3.5 Network meta-evidence

The results, based on data derived from 61 in vitro studies, include direct comparisons and indirect comparisons of dentin pretreatment on the bond strength of fiber posts for endodontically treated teeth.

For the three network meta-analyses some of the pairwise comparisons had no direct evidence, but an indirect comparison of the pretreatment that had not been compared head-to-head previously (for example, EDTA and CTRL pretreatments). Each node represents a dentin pretreatment, and the line thickness represents the number of studies included in this comparison. The node size and distances are for plot clarity and do not reflect other information. Tables 2, 3, and 4 summarize the results of the network meta-analyses conducted with pairwise comparisons between pretreatments for self-etch *adhesive + resin cement, etch-and-rinse adhesive + resin cement, and self-adhesive cement, respectively. The ranking of the various pretreatment solutions was based on their bond strength by using SUCRA (surface area under the cumulative ranking) curves. This ranking presents the probability of each treatment of being the best one. With higher SUCRA probability nearing one (range 0–1) demonstrating higher efficacy. This ranking is presented in Table 5.*

4 Discussion

After the evaluation of studies appropriate to the research question of this study, different protocols were found regarding the use of chemical dentin treatments, before cementation, in the intraradicular region of endodontically treated teeth to receive glass fiber posts. Many studies aimed to compare the bond strength that these treatments might offer with different cementation strategies, but no consensus was reached as to the best.

Data from clinical and in vitro studies were to be included for data extraction, but the delineated search did not reveal an in vivo study. The analysis of in vitro studies presented relevant questions as to the adhesive strategies of fiber posts in intraradicular dentin, although, well-designed and well-reported randomized clinical trials are needed to provide clinical evidence about these questions. The present systematic review could be used to better guide such clinical studies.

The traditional meta-analysis obtains conclusions from direct comparisons among studies with similarities regarding the number and the type of interventions [29]. However, the present systematic review identified 61 studies with various study designs. There was considerable variability in the number of dentin pretreatments of each study and in the type of pretreatments used. For such a situation, a mixed treatment comparison, also called network meta-analysis, has been recommended [77]. In this case, this analysis was adequate because it considered indirect relationships between treatments performed in different studies with a common comparator. Indirect comparisons improve the evidence of comparisons obtained directly and, in the absence of direct comparative data, may provide valuable information [77, 78].

Pretreatments that are evaluated against a common comparator in different studies could be compared with each other indirectly. Considering that several dentin pretreatments were identified in this search, the indirect comparisons provided an estimation of the relationship between treatments that were not tested by direct comparisons.

Each of the pretreatments tested in the studies depends on a mechanism that should improve the bond strength. Citric acid, EDTA, hydrofluoric acid, phosphoric acid, and polyacrylic are used to remove the smear layer, opening the dentin tubules, and may etch the intertubular dentin, which increases the micromechanical retention of the adhesives and the luting agent [11, 13, 35, 44, 51]. NaOCl in various concentrations, besides the removal of smear layer, has antimicrobial activity and the capability to dissolve organic tissue remnants [26]. Chlorhexidine has antimicrobial activity, substantivity, and does not affect the bond strength of composite resin restorations by inhibiting the proteolytic activity of MMPs in the hybrid layer [42]. Ethanol could displace residual water from the demineralized dentin [79]. Grape seed extract can induce cross-links in collagen fibers as a natural cross-linking agent and thus is capable of increasing the mechanical properties of dentin [10]. Ethyl acetate is a cleaning agent that is used for the removal of temporary or endodontic cement remnants from dentin surfaces [27]. Boric acid removes the smear layer, exposes the collagen fibrils and opens the dentin tubules, in addition to acting as a disinfectant [24]. Carbodiimide has been shown capable of inactivating the catalytic sites of MMPs and cathepsins [69]. Xylene dissolves gutta percha and sealer and eliminates the secondary smear layer [30].

In the data extraction stage, a considerable variation was observed in the adhesive and cementation strategy of the intraradicular fiber posts. Thus, three network meta-analysis were performed, one for each cementation strategy (self-etch adhesive + resin cement, etch-and-rinse adhesive + resin cement, and self-adhesive cement). The network meta-analysis allowed the ranking of treatments according to the probability of being the best treatment regarding bond strength.

In Table 5, for groups that used the self-etch adhesive + resin cement, ethyl acetate was identified as the best pretreatment (SUCRA probability:

99.8%), showing better results than control groups (SUCRA probability: 39.6%). Ethyl acetate provides a chemical dentin surface treatment that shows good push-out bond strength values because it is not able to remove the smear layer effectively on radicular dentin surfaces. Removal of the smear layer and opening of the dentinal tubules are not recommended when a self- etching adhesive system is used [15]. However, in this systematic review, only one selected study used it as dentin pretreatment. Therefore, more studies evaluating ethyl acetate are needed for more consistent conclusions. According to the ranking, phosphoric acid and ethanol as dentin pretreatments (SUCRA probabilities: 86.1% and 78.6%, respectively) provided good bond strength results. Although self-etching adhesive systems require the presence of a smear layer, phosphoric acid showed good bond strength results as a dentin pretreatment. The acid dissolves residual canal sealer and opens dentinal tubules by demineralizing intertubular and peritubular dentin [15]. Ethanol has the ability to replace water in dentin, avoiding collagen matrix collapse, and promotes the shrinking of collagen fibrils diameter, it could improve the infiltration of hydrophobic monomers, providing higher shear bond strength values [37, 72, 79].

For groups that used etch-and-rinse adhesives + resin cement, the better dentin pretreatment for the increased bond strength of intraradicular posts was low concentration NaOCl (SUCRA probability: 83.4%). It presented higher scores when compared with control groups (SUCRA probability: 43.8%). It has antimicrobial activity and the capability to dissolve remnants of endodontic sealers or organic tissue and in lower concentrations does not interfere with the bonding of resin materials [23]. Groups that used self-adhesive resin cements had an increase in fiber post bond strength with the use of grape seed extract, ethanol, and phosphoric acid (SUCRA probabilities: 97.6%, 76.2% and 74.9%, respectively), all percentages were higher than control groups (SUCRA: 39.6%). Grape seed extract is a natural product rich in pro-anthocyanidins; this irrigant has antimicrobial properties and the potential for improving the mechanical properties of dentin. It is a cross-linking agent that modify the biochemistry of collagen and interacts with proteoglycans, reinforcing the collagen of the dentin matrix. Additionally, it provides resistance against *enzymatic degradation [10, 14]. This product was placed second among those used as a pretreatment associated with etch-and-rinse adhesive strategies. However, only two studies evaluated grape seed extract, which has only recently been proposed for dentin treatment and for coronal dentin and enamel; the extract requires further investigation [80, 81].*

It should be noted that ethanol is a highlighted pretreatment in the SUCRA ranking of the three adhesive strategies. It presented high probabilities of being a good treatment to improve the bond strength, in all strategies, with scores higher than the control groups. In addition, there is a greater number of selected studies which evaluated ethanol, thus, there are more direct comparisons of ethanol with other pretreatments and, consequently, more indirect comparisons. Thus, the favorable results of ethanol to improve bond strength are based on higher quality evidence. Therefore, it is proposed to design clinical studies that evaluate the effect of ethanol on the bond strength of fiber posts to consider the conditions and factors of oral environment and its functionality.

The performance of high concentration NaOCl was poor in improving the bond strength between fiber posts and intraradicular dentin for all adhesive strategies (SUCRA probability: 6.5% for self-etch adhesives, 21.48% for etch-and-rinse adhesives and 12.4% for self-adhesive cements). High concentration NaOCl is an oxidizing agent, leaves residual oxygen on the dentin substrate, and could degrade the dentin organic matrix. In addition, high concentration NaOCl residue may diffuse into dentin and interfere with monomer polymerization, possibly reducing the bond strength between dentin and resin cement [23, 26, 66, 82]. Therefore, the most appropriate approach would be to irrigate alternatively with an endodontic solution, use NaOCl at low concentrations, or even use a solution capable of neutralizing or minimizing the action of high concentration NaOCl.

Neither polyacrylic acid irrigation before etch-and-rinse (SUCRA probability: 14.03%) adhesives or hydrogen peroxide irrigation before self-adhesive resin cements (SUCRA probability: 1.6%) improved the bond strength. Although acidic, polyacrylic acid is not able to significantly remove the smear layer, which is essential for total etch adhesive techniques [82]. The application *of hydrogen peroxide to tooth structures could decrease the microhardness and modulus of elasticity, producing morphological alterations, affecting the intertubular and peritubular dentin, and causing structural alterations to the hydroxyapatite because of ionic bonds that weaken its structure and consequently decrease the bond strength values of self-adhesive resin cements [11].*

Limitations of this systematic review included that the analyses did not consider the differences in the protocols of each pretreatment application, but in most of the studies, the authors followed the manufacturer's instructions. It was not possible to include any clinical research for the systematic review or meta-analysis. Few studies matched the main question; therefore, clinical investigations related to this research question are needed. Most of the studies included presented a medium bias and few studies presented a low risk of bias; therefore, future studies should be well designed and reported to provide firm evidence.

5 Conclusions

The use of dentin pretreatments in the intraradicular dentin of endodontically treated teeth depends on the adhesive and cementation strategy. In association with the self-etch adhesive strategy, intraradicular pretreatment with ethyl acetate yielded increased bond strength values between the fiber posts and endodontically treated teeth. For etch-and-rinse adhesives, low concentration NaOCl showed the best results. Grape seed extract was indicated as a good intraradicular dentin treatment before fiber post cementation with self-adhesive cements. Despite smear layer removal with phosphoric acid, it was an appropriate dentin pretreatment before using the self-adhesive cement and self-etch adhesive system. Irrigation with NaOCl in high concentrations appears to adversely affect intraradicular dentin and is contraindicated with any adhesive strategy.

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Tables

Table 1 *Electronic database and search strategy (05/Dec/2016 updated in July/2018).*

(continue)

PUBMED
((((((((((Post and Core Technique[MeSH Terms])) OR Fiber post[Title/Abstract]) OR Fibre post*[Title/Abstract]) OR Post System*[Title/Abstract])))))) AND (((((((((((((((((Root Canal Irrigants[MeSH Terms]) OR Root Canal Irrigant*[Title/Abstract]) OR Surface treatment*[Title/Abstract])) OR (((Chlorhexidine[MeSH Terms]) OR Chlorhexidine[Title/Abstract]) OR CHX[Title/Abstract])) OR Plasma Gases[MeSH Terms]) OR Plasma[Title/Abstract]) OR (((Ethanol[MeSH Terms]) OR Ethanol[Title/Abstract]) OR Absolute Alcohol[Title/Abstract])) OR ((((Sodium Hypochlorite[MeSH Terms]) OR Sodium Hypochlorite[Title/Abstract]) OR NaOCl[Title/Abstract])) OR ((((Edetic Acid[MeSH Terms]) OR Edetic Acid[Title/Abstract]) OR EDTA[Title/Abstract]) OR Ethylenediaminetetraacetic Acid[Title/Abstract])) OR ((((Hydrogen Peroxide[MeSH Terms]) OR Hydrogen Peroxide[Title/Abstract]) OR Hydroperoxide[Title/Abstract]) OR H2O2[Title/Abstract])) OR (((Ascorbic Acid[MeSH Terms]) OR Ascorbic Acid[Title/Abstract]) OR Vitamin C[Title/Abstract])) OR ((Phosphoric Acids[MeSH Terms]) OR Phosphoric Acid*[Title/Abstract])) OR ((((Sodium Chloride[MeSH Terms]) OR Sodium Chloride[Title/Abstract]) OR Saline Solution[Title/Abstract]) OR NaCl[Title/Abstract])) OR Acid Etching, Dental[MeSH Terms]) OR ((((Dentin-Bonding Agents[MeSH Terms]) OR Dentin-Bonding Agent*[Title/Abstract]) OR Hybrid layer[Title/Abstract]) OR Hybridization[Title/Abstract])) OR ((((((((((Dental Cements[MeSH Terms]) OR Dental Cement*[Title/Abstract]) OR Dental Adhesives[Title/Abstract]) OR Dental Adhesive[Title/Abstract]) OR Luting Agent*[Title/Abstract]) OR Dentin adhesive*[Title/Abstract])))))))*
Scopus
(TITLE-ABS-KEY ("Post and Core Technique" OR "Fiber post" OR "Post System")) AND (TITLE-ABS-KEY ("Root Canal Irrigants" OR "Surface treatment" OR chlorhexidine OR CHX OR plasma OR ethanol OR "Absolute Alcohol" OR "Sodium Hypochlorite" OR NaOCl OR "Edetic Acid" OR edta OR "Ethylenediaminetetraacetic Acid" OR "Hydrogen Peroxide" OR hydroperoxide OR h2o2 OR "Ascorbic Acid" OR "Vitamin C" OR "Phosphoric Acid" OR "Sodium Chloride" OR "Saline Solution" OR nacl OR "Acid Etching, Dental" OR "Dentin-Bonding Agents" OR "Hybrid layer" OR hybridization OR "Dental Adhesive" OR "Luting Agents" OR "Dental Cement" OR "Dentin adhesive"))

Table 1 *Electronic database and search strategy (05/Dec/2016 updated in July/2018).*

(continuation)

Web of Science
#2 AND #1 P:# 1: TS=("Post and Core Technique" OR "Fiber post" OR "Post System") I:# 2: TS=("Root Canal Irrigants" OR "Surface treatment" OR chlorhexidine OR CHX OR plasma OR ethanol OR "Absolute Alcohol" OR "Sodium Hypochlorite" OR NaOCl OR "Edetic Acid" OR edta OR "Ethylenediaminetetraacetic Acid" OR "Hydrogen Peroxide" OR hydroperoxide OR h2o2 OR "Ascorbic Acid" OR "Vitamin C" OR "Phosphoric Acid" OR "Sodium Chloride" OR "Saline Solution" OR nacl OR "Acid Etching, Dental" OR "Dentin-Bonding Agents" OR "Hybrid layer" OR hybridization OR "Dental Adhesive" OR "Luting Agents" OR "Dental Cement" OR "Dentin adhesive")
Lilacs and BBO
(tw:((tw:(MH: “post and core technique”)) OR (tw:(“técnica para retentor intrarradicular”)) OR (tw:(“técnica de perno muñón”)) OR (tw:(“fiber post$”)) OR (tw:(“pino de fibra”)) OR (tw:(“fibre post$”)) OR (tw:(“post system$”)) OR (tw:(“sistema de pino”)) OR (tw:(“sistemas de pino”)) OR (tw:(“sistema de clavijas”)) OR (tw:(“sistemas de clavijas”)))) AND (tw:((tw:((tw:(MH: “root canal irrigants”)) OR (tw:(“root canal irrigants”)) OR (tw:(“irrigantes del conducto radicular”)) OR (tw:(“irrigantes do canal radicular”)) OR (tw:(“surface treatment$”)) OR (tw:(“tratamiento de superficies”)) OR (tw:(“tratamento de superfície”)))) OR (tw:((tw:(MH: “chlorhexidine”)) OR (tw:(“chlorhexidine”)) OR (tw:(“chx”)) OR (tw:(“clorhexidina”)) OR (tw:(“clorexidina”)))) OR (tw:((tw:(MH: “plasma gases”)) OR (tw:(“gases em plasma”)) OR (tw:(“plasma”)))) OR (tw:((tw:(MH: “ethanol”)) OR (tw:(“ethanol”)) OR (tw:(“etanol”)) OR (tw:(“absolute alcohol”)) OR (tw:(“alcohol absolute”)) OR (tw:(“álcool absoluto”)))) OR (tw:((tw:(MH: “sodium hypochlorite”)) OR (tw:(“sodium hypochlorite”)) OR (tw:(“hipoclorito de sodio”)) OR (tw:(“hipoclorito de sódio”)) OR (tw:(“naocl”)))) OR (tw:((tw:(MH: “edetic acid”)) OR (tw:(“edetic acid”)) OR (tw:(“ácido edético”)) OR (tw:(“edta”)) OR (tw:(“ethylenediaminetetraacetic acid”)) OR (tw:(“ácido etilenodiaminotetracético”)))) OR (tw:((tw:(MH: “hydrogen peroxide”)) OR (tw:(“hydrogen peroxide”)) OR (tw:(“peróxido de hidrógeno”)) OR (tw:(“peróxido de hidrogênio”)) OR (tw:(“hydroperoxide”)) OR (tw:(“hidroperóxido”)) OR (tw:(“h2o2”)))) OR (tw:((tw:(MH: “ascorbic acid”)) OR (tw:(“ascorbic acid”)) OR (tw:(“ácido ascórbico”)) OR (tw:(“vitamin c”)) OR (tw:(“vitamina c”)))) OR (tw:((tw:(MH: “phosphoric acids”)) OR (tw:(“phosphoric acid$”)) OR (tw:(“ácidos fosfóricos”)))) OR (tw:((tw:(MH: “sodium chloride”)) OR (tw:(“sodium chloride”)) OR (tw:(“cloruro de sodio”)) OR (tw:(“cloreto de sódio”)) OR (tw:(“saline solution”)) OR (tw:(“solución salina”)) OR (tw:(“solução salina”)) OR (tw:(“nacl”)))) OR (tw:((tw:(MH: “acid etching, dental”)) OR (tw:(“grabado ácido dental”)) OR (tw:(“ataque ácido dentário”)))) OR (tw:((tw:(MH: “dentin-bonding agents”))

Table 1 *Electronic database and search strategy (05/Dec/2016 updated in July/2018).*

(continuation)

Lilacs and BBO
OR (tw:(“dentin-bonding agents”)) OR (tw:(“recubrimientos dentinarios”)) OR (tw:(“adesivos dentinários”)) OR (tw:(“hybrid layer”)) OR (tw:(“capa híbrida”)) OR (tw:(“camada híbrida”)) OR (tw:(“hybridization”)) OR (tw:(“hibridación”)) OR (tw:(“hibridização”)))) OR (tw:((tw:(MH: “dental cements”)) OR (tw:(“dental cements”)) OR (tw:(“cementos dentales”)) OR (tw:(“cimentos dentários”)) OR (tw:(“dental adhesive$”)) OR (tw:(“adhesivo dental”)) OR (tw:(“adhesivos dental”)) OR (tw:(“adesivo dental”)) OR (tw:(“adesivos dental”)) OR (tw:(“luting agent$”)) OR (tw:(“agentes de cementación”)) OR (tw:(“agentes de cimentação”)) OR (tw:(“dental cement”)) OR (tw:(“cemento dental”)) OR (tw:(“cimento dental”)) OR (tw:(“dentin adhesive$”)) OR (tw:(“adhesivos dentinarios”)) OR (tw:(“adesivos dentinários”))))))
Cochrane Library
#1 MeSH descriptor: [Post and Core Technique] explode all trees #2 "Fiber post" #3 "Fibre post*" #4 "Post System*" #5 #1 or #2 or #3 or #4 #6 MeSH descriptor: [Root Canal Irrigants] explode all trees #7 "Root Canal Irrigant*" #8 "Surface treatment*" #9 #6 or #7 or #8 #10 MeSH descriptor: [Chlorhexidine] explode all trees #11 Chlorhexidine #12 CHX #13 #10 or #11 or #12 #14 MeSH descriptor: [Plasma Gases] explode all trees #15 Plasma #16 #14 or #15 #17 MeSH descriptor: [Ethanol] explode all trees #18 Ethanol #19 "Absolute Alcohol" #20 #17 or #18 or #19 #21 MeSH descriptor: [Sodium Hypochlorite] explode all trees #22 "Sodium Hypochlorite" #23 NaOCl #24 #21 or #22 or #23 #25 MeSH descriptor: [Edetic Acid] explode all trees #26 "Edetic Acid" #27 EDTA #28 "Ethylenediaminetetraacetic Acid" #29 #25 or #26 or #27 or #28*

Table 1 *Electronic database and search strategy (05/Dec/2016 updated in July/2018).*

(conclusion)

Cochrane Library
#30 MeSH descriptor: [Hydrogen Peroxide] explode all trees
#31 "Hydrogen Peroxide"
#32 Hydroperoxide
#33 H2O2
#34 #30 or #31 or #32 or #33
#35 MeSH descriptor: [Ascorbic Acid] explode all trees
#36 "Ascorbic Acid"
#37 "Vitamin C"
#38 #35 or #36 or #37
#39 MeSH descriptor: [Phosphoric Acids] explode all trees
#40 "Phosphoric Acid"*
#41 #39 or #40
#42 MeSH descriptor: [Sodium Chloride] explode all trees
#43 "Sodium Chloride"
#44 "Saline Solution"
#45 NaCl
#46 #42 or #43 or #44 or #45
#47 MeSH descriptor: [Acid Etching, Dental] explode all trees
#48 MeSH descriptor: [Dentin-Bonding Agents] explode all trees
#49 "Dentin-Bonding Agent"*
#50 "Hybrid layer"
#51 Hybridization
#52 #48 or #49 or #50 or #51
#53 MeSH descriptor: [Dental Cements] explode all trees
#54 "Dental Cement"*
#55 "Dental Adhesives"
#56 "Dental Adhesive"
#57 "Luting Agent"*
#58 "Luting Agent"
#59 "Dental Cement"
#60 "Dentin adhesive"*
#61 #53 or #54 or #55 or #56 or #57 or #58 or #59 or #60
#62 #9 or #13 or #16 or #20 or #24 or #29 or #34 or #38 or #41 or #46 or #47 or #52 or #61
#63 #5 and #62

Table 2 *Groups of pretreatments with similar characteristics*

Group	***Range***
Boric Acid	*5% and 10% boric acid*
Chlorhexidine	*0.2%, 1%, and 2% chlorhexidine*
Control	*Saline solution, distilled water, or no substance*
Ethanol	*70% and 100% ethanol*
Grape Seed Extract	*6.5% and 10% grape seed extract*
High Concentration NaOCl	*5% and 10% NaOCl*
Low Concentration NaOCl	*1%, 2%, and 2.5% NaOCl*
Phosphoric Acid	*32%, 35%, and 37% phosphoric acid*

***Table 3** Data extraction from selected studies. ID: intervention comparison; type of post: type of adhesive and cementation system, type of specimens, and number of teeth.*

(continue)

Study ID	***Interventions***	***Type of fiber post***	***Adhesive system / Cement***	***Specimens***	***Number of teeth***
Abasi M 2016 [30]	*Chlorhexidine X Phosphoric acid X Saline solution X Xylene*	*Glass*	*Self-adhesive cement*	*Human / posterior*	*80*
Akman M 2016 [11]	*Citric acid X EDTA X Saline solution*	*Glass*	*Self-etch adhesive*	*Human / single rooted*	*36*
Aktermur Turker S 2013 [31]	*Ethanol X No treatment*	*Glass*	*Self-adhesive cement*	*Human / posterior*	*96*
Alaghemand H 2013 [32]	*EDTA X Ethanol X No treatment*	*Quartz*	*Self-adhesive cement*	*Human / anterior*	*36*
Alandia-Román CC 2017 [10]	*Chlorhexidine X Grape seed extract X Saline solution*	*Glass*	*Self-adhesive cement*	*Human / anterior*	*60*
Alkhudhairy FI 2016 [26]	*NaOCl X Saline solution*	*Glass*	*Self-adhesive cement*	*Human / anterior*	*60*
Arisu HD 2013 [33]	*Distilled water X EDTA X NaOCl*	*Carbon*	*Self-adhesive cement*	*Human / single rooted*	*60*
Arslan H 2015 [34]	*EDTA X NaOCl*	*Carbon*	*Self-adhesive cement*	*Human / posterior*	*72*
Baena E 2016 [35]	*EDTA X No treatment X Phosphoric acid X Polyacrylic acid*	*Glass*	*Self-adhesive cement*	*Human / single rooted*	*20*
Barreto MS 2016 [21]	*EDTA X NaOCl X Saline solution*	*Glass*	*Self-adhesive cement*	*Human / single rooted*	*36*
Bitter K 2013 [22]	*Chlorhexidine X Distilled water X NaOCl*	*Glass*	*Etch and rinse adhesive, self-adhesive cement and self-etch adhesive*	*Human / anterior*	*120*

Table 3 *Data extraction from selected studies. ID: intervention comparison; type of post: type of adhesive and cementation system, type of specimens, and number of teeth.*

(continuation)

Study ID	**Interventions**	**Type of fiber post**	**Adhesive system / Cement**	**Specimens**	**Number of teeth**
Bitter K 2014 [36]	*Chlorhexidine X Distilled water X Ethanol*	*Glass*	*Etch and rinse adhesive and self-adhesive cement*	*Human / anterior*	*60*
Bitter K 2017 [37]	*Chlorhexidine X Distilled water X Ethanol*	*Glass*	*Etch and rinse adhesive, self-adhesive cement and self-etch adhesive*	*Human / anterior*	*48*
Bueno CE 2016 [23]	*Chlorhexidine X Saline solution X NaOCl*	*Glass*	*Etch and rinse adhesive, self-adhesive cement and self-etch adhesive*	*Bovine / anterior*	*96*
Carvalho CA 2009 [38]	*Ethanol X No treatment*	*Glass*	*Self-etch adhesive*	*Human / Single rooted*	*10*
Cecchin D 2011.a [39]	*Chlorhexidine X Ethanol X Saline solution*	*Glass*	*Etch and rinse adhesive*	*Bovine / anterior*	*15*
Cecchin D 2011.b [40]	*Chlorhexidine X Ethanol X Saline solution*	*Glass*	*Etch and rinse adhesive*	*Bovine / anterior*	*30*
Cecchin D 2014.a [41]	*Chlorhexidine X Saline solution*	*Glass*	*Etch and rinse adhesive and self-etch adhesive*	*Bovine / anterior*	*60*
Cecchin D 2014.b [42]	*Chlorhexidine X Ethanol X Saline solution*	*Glass*	*Etch and rinse adhesive*	*Bovine / anterior*	*30*
Cecchin D 2015 [14]	*Grape seed extract X Saline solution*	*Glass*	*Etch and rinse adhesive and self-etch adhesive*	*Bovine / anterior*	*216*
Cintra LTA 2015 [43]	*Chlorhexidine X EDTA X NaOCl X Saline Solution*	*Glass*	*Self-adhesive cement*	*Human / Single rooted*	*44*
Clavijo VRG 2009 [44]	*EDTA X No treatment*	*Carbon*	*Self-adhesive cement*	*Bovine / anterior*	*40*
Cokuk N 2016 [45]	*Chlorhexidine X Distilled water X NaOCl*	*Glass*	*Self-etch adhesive*	*Human / anterior*	*30*
Culhaoglu AK 2017 [24]	*Boric acid X Chlorhexidine X NaOCl X No treatment*	*Glass*	*Self-adhesive cement and self-etch adhesive*	*Human / anterior*	*60*
da Cunha LF 2010 [46]	*NaOCl X Saline solution*	*Glass*	*Self-adhesive cement and self-etch adhesive*	*Bovine / anterior*	*30*
da Silveira OC 2014 [25]	*Chlorhexidine X EDTA X NaOCl X Polyacrylic acid X Saline Solution*	*Glass*	*Self-adhesive cement*	*Bovine / anterior*	*50*
de Araujo DF 2014 [47]	*Chlorhexidine X No treatment X Polyacrylic acid*	*Glass*	*Etch and rinse adhesive*	*Bovine/ Single-rooted*	*20*
Demiryurek EO 2009 [15]	*Citric acid X EDTA X Ethyl acetate X NaOCl X Orthophosphoric acid*	*Glass*	*Self-etch adhesive*	*Human / anterior*	*60*
Ekambaram M 2014 [48]	*Chlorhexidine X Distilled water X Ethanol*	*Glass*	*Self-adhesive cement*	*Human / Single rooted*	*24*

Table 3 *Data extraction from selected studies. ID: intervention comparison; type of post: type of adhesive and cementation system, type of specimens, and number of teeth.*

(continuation)

Study ID	Interventions	Type of fiber post	Adhesive system / Cement	Specimens	Number of teeth
Elnaghy AM 2011 [49]	*Chlorhexidine X Distilled water X EDTA X NaOCl*	*Glass*	*Self-adhesive cement*	*Human / Single rooted*	*40*
Ertas H 2014 [50]	*Chlorhexidine X EDTA X NaOCl X Saline solution*	*Glass*	*Self-adhesive cement*	*Human / Single rooted*	*64*
Fan F 2017 [51]	*EDTA X NaOCl X Saline Solution*	*Glass*	*Self-adhesive cement*	*Human / Single rooted*	*45*
Faria-e-Silva AL 2014 [16]	*EDTA X NaOCL X No treatment X Polyacrylic acid*	*Glass*	*Etch and rinse adhesive and self-adhesive cement*	*Bovine / Anterior*	*48*
Furuse AY 2014 [17]	*NaOCl X Saline solution*	*Glass*	*Etch and rinse adhesive and self-etch cement*	*Bovine/ Single-rooted*	*20*
Gomes Franca FM 2015 [52]	*Chlorhexidine X Ethanol X Saline solution*	*Glass*	*Etch and rinse adhesive*	*Bovine / Anterior*	*54*
Jardim OS 2014 [53]	*Chlorhexidine X Ethanol X No treatment*	*Glass*	*Self-adhesive cement*	*Human / Single rooted*	*65*
Khamverdi Z 2014 [54]	*No treatment X Phosphoric acid*	*Glass*	*Self-etch adhesive*	*Human / Single rooted*	*45*
Khoroushi M 2016 [18]	*NaOCl X Saline solution*	*Glass*	*Self-adhesive cement and self-etch adhesive*	*Human / Single rooted*	*24*
Kirmali O 2017 [55]	*Hydrofluoric acid X No treatment*	*Glass*	*Self-etch adhesive*	*Human / Single rooted*	*20*
Kul E 2016 [56]	*Chlorhexidine X Distilled water X Phosphoric acid*	*Glass*	*Self-adhesive cement*	*Human / Single rooted*	*30*
Lacerda AJF 2013 [57]	*Chlorhexidine X NaOCl X Saline solution*	*Glass*	*Self-etch adhesive*	*Bovine / Anterior*	*33*
Lacerda FC 2017 [58]	*Chlorhexidine X NaOCl X Distilled water*	*Glass*	*Self-adhesive cement*	*Human / Single rooted*	*45*
Lima SF 2015 [59]	*Chlorhexidine X NaOCl X Saline solution*	*Glass*	*Self-adhesive cement*	*Bovine / Anterior*	*30*
Lindblad RM 2010 [60]	*Chlorhexidine X Saline solution*	*Glass*	*Self-adhesive cement and self-etch adhesive*	*Human / Posterior*	*40*
Liu C 2011 [61]	*EDTA X NaOCl X Phosphoric acid*	*Glass*	*Self-adhesive cement*	*Human / Anterior*	*24*
Marques J 2016 [62]	*NaOCl X Phosphoric acid*	*Glass*	*Etch and rinse adhesive*	*Bovine/ Single-rooted*	*20*
Martinho FC 2015 [63]	*Chlorhexidine X Saline solution*	*Glass*	*Self-etch adhesive*	*Bovine / Anterior*	*30*
Moreira PEO 2015 [64]	*Hydrogen peroxide X No treatment*	*Glass*	*Self-etch adhesive*	*Human / Single rooted*	*20*
Motta CAVB 2015 [65]	*Distilled water X NaOCl*	*Glass*	*Self-adhesive cement*	*Human / Single rooted*	*60*
Neelakantan P 2015 [66]	*NaOCl X Water*	*Glass*	*Etch and rinse adhesive and self-adhesive cement*	*Human / Anterior*	*80*

Table 3 *Data extraction from selected studies. ID: intervention comparison; type of post: type of adhesive and cementation system, type of specimens, and number of teeth.*

(conclusion)

Study ID	Interventions	Type of fiber post	Adhesive system / Cement	Specimens	Number of teeth
Renovato SR 2013 [67]	*NaOCl X No treatment*	*Glass*	*Self-adhesive cement*	*Bovine / Anterior*	*20*
Santana FR 2015 [20]	*Chlorhexidine X NaOCl X Saline solution*	*Glass*	*Self-adhesive cement*	*Bovine / Anterior*	*40*
Santos MCG 2017 [68]	*Chlorhexidine X No treatment*	*Glass*	*Self-adhesive cement*	*Bovine / Anterior*	*20*
Shafiei F 2016 [69]	*Carbodiimide X No treatment*	*Glass*	*Etch and rinse adhesive, self-adhesive cement and self-etch adhesive*	*Human / Anterior*	*60*
Toman M 2014 [70]	*Chlorhexidine X No treatment*	*Glass*	*Self-etch adhesive*	*Human / Single rooted*	*40*
Tuncdemir AR 2013 [71]	*EDTA X NaOCl X Orthophosphoric acid X Saline solution*	*Glass*	*Self-adhesive cement*	*Human / Anterior*	*44*
Victorino K 2016 [72]	*Chlorhexidine X Distilled water X Ethanol*	*Glass*	*Self-etch adhesive*	*Human / Single rooted*	*30*
Wang L 2013 [73]	*Chlorhexidine X No treatment*	*Glass*	*Etch and rinse adhesive and self-etch adhesive*	*Bovine/ Single-rooted*	*80*
Xia Y 2013 [74]	*Distilled water X NaOCl*	*Glass*	*Self-adhesive cement*	*Human / Posterior*	*10*
Zhang L 2008 [75]	*Distilled water X Phosphoric acid*	*Glass*	*Self-etch adhesive*	*Human / Posterior*	*10*
Zhou J 2013 [76]	*Chlorhexidine X No treatment*	*Glass*	*Self-etch adhesive*	*Human / Anterior*	*10*

***Table 4** Summary of the risk of bias assessment according to the review authors' judgments about each risk of bias item for each included in vitro study.*

(continue)

Study ID	***Tooth Randomization***	***Endodontic Treatment Performed by a Single Operator***	***Materials According to the Manufacturer's Instructions***	***Teeth with Similar Dimensions***	***Sample Size Calculation***	***Blinding of the Operator of the Testing Machine***	***Teeth Free of Caries or Restoration***	***Risk of Bias***
Abasi M 2016 [30]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Akman M 2016 [11]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*N*	*High*
Aktermur Turker S 2013 [31]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Alaghemand H 2013 [32]	*Y*	*Y*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Alandia-Román CC 2017 [10]	*N*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*High*
Alkhudhairy FI 2016 [26]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*N*	*High*
Arisu HD 2013 [33]	*N*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*High*
Arslan H 2015 [34]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Baena E 2016 [35]	*Y*	*N*	*N*	*Y*	*N*	*N*	*Y*	*High*
Barreto MS 2016 [21]	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Low*
Bitter K 2013 [22]	*Y*	*Y*	*Y*	*Y*	*N*	*N*	*N*	*Medium*
Bitter K 2014 [36]	*Y*	*Y*	*Y*	*Y*	*N*	*N*	*N*	*Medium*
Bitter K 2017 [37]	*Y*	*N*	*N*	*Y*	*N*	*N*	*N*	*High*
Bueno CE 2016 [23]	*Y*	*Y*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Carvalho CA 2009 [38]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*N*	*High*
Cecchin D 2011.a [39]	*Y*	*Y*	*Y*	*Y*	*N*	*N*	*N*	*Medium*
Cecchin D 2011.b [40]	*Y*	*Y*	*Y*	*Y*	*N*	*N*	*N*	*Medium*
Cecchin D 2014.a [41]	*N*	*Y*	*Y*	*Y*	*N*	*N*	*N*	*High*
Cecchin D 2014.b [42]	*N*	*Y*	*Y*	*Y*	*N*	*N*	*N*	*High*
Cecchin D 2015 [14]	*N*	*N*	*N*	*Y*	*N*	*N*	*N*	*High*
Cintra LTA 2015 [43]	*N*	*Y*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Clavijo VRG 2009 [44]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*N*	*High*

Table 4 *Summary of the risk of bias assessment according to the review authors' judgments about each risk of bias item for each included in vitro study.*

(continuation)

Study ID	***Tooth Randomization***	***Endodontic Treatment Performed by a Single Operator***	***Materials According to the Manufacturer's Instructions***	***Teeth with Similar Dimensions***	***Sample Size Calculation***	***Blinding of the Operator of the Testing Machine***	***Teeth Free of Caries or Restoration***	***Risk of Bias***
Cokuk N 2016 [45]	*N*	*Y*	*N*	*Y*	*N*	*N*	*N*	*High*
Culhaoglu AK 2017 [24]	*Y*	*N*	*N*	*Y*	*N*	*N*	*N*	*High*
da Cunha LF 2010 [46]	*N*	*Y*	*Y*	*Y*	*N*	*N*	*N*	*High*
da Silveira OC 2014 [25]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
de Araujo DF 2014 [47]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Demiryurek EO 2009 [15]	*Y*	*Y*	*N*	*Y*	*N*	*N*	*Y*	*Medium*
Ekambaram M 2014 [48]	*Y*	*Y*	*N*	*Y*	*N*	*Y*	*Y*	*Medium*
Elnaghy AM 2011 [49]	*N*	*N*	*N*	*Y*	*N*	*N*	*N*	*High*
Ertas H 2014 [50]	*N*	*N*	*Y*	*Y*	*N*	*N*	*N*	*High*
Fan F 2017 [51]	*Y*	*N*	*N*	*Y*	*N*	*N*	*Y*	*High*
Faria-e-Silva AL 2014 [16]	*N*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*High*
Furuse AY 2014 [17]	*N*	*N*	*Y*	*Y*	*N*	*N*	*N*	*High*
Gomes Franca FM 2015 [52]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*N*	*High*
Jardim OS 2014 [53]	*Y*	*N*	*Y*	*N*	*N*	*N*	*Y*	*High*
Khamverdi Z 2014 [54]	*N*	*N*	*Y*	*Y*	*N*	*N*	*N*	*High*
Khoroushi M 2016 [18]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Kirmali O 2017 [55]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Kul E 2016 [56]	*N*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*High*
Lacerda AJF 2013 [57]	*N*	*N*	*Y*	*N*	*N*	*N*	*N*	*High*
Lacerda FC 2017 [58]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*N*	*High*
Lima SF 2015 [59]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Lindblad RM 2010 [60]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Liu C 2011 [61]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*

***Table 4** Summary of the risk of bias assessment according to the review authors' judgments about each risk of bias item for each included in vitro study.*

(conclusion)

Study ID	Tooth Randomization	Endodontic Treatment Performed by a Single Operator	Materials According to the Manufacturer's Instructions	Teeth with Similar Dimensions	Sample Size Calculation	Blinding of the Operator of the Testing Machine	Teeth Free of Caries or Restoration	Risk of Bias
Marques J 2016 [62]	*N*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*High*
Martinho FC 2015 [63]	*Y*	*Y*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Moreira PEO 2015 [64]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Motta CAVB 2015 [65]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Neelakantan P 2015 [66]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Renovato SR 2013 [67]	*N*	*Y*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Santana FR 2015 [20]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Santos MCG 2017 [68]	*N*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Shafiei F 2016 [69]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Toman M 2014 [70]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Tuncdemir AR 2013 [71]	*Y*	*Y*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Victorino K 2016 [72]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Wang L 2013 [73]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Xia Y 2013 [74]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Zhang L 2008 [75]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*
Zhou J 2013 [76]	*Y*	*N*	*Y*	*Y*	*N*	*N*	*Y*	*Medium*

Table 5: *Pairwise comparisons between pretreatments for the bond strength of fiber post cementation in intraradicular dentin with self-etch adhesive system.*

Pairwise comparison	Citric acid	EDTA	Low Concentration NaOCl	High Concentration NaOCl	Chlorhexidine	Ethanol	Grape Seed Extract	Ethyl acetate	Phosphoric acid	Boric acid	Hydrofluoric acid	Carbodiimide
Control	2.2 (-0.8, 5.2)	-1.6 (-4.4, 1.5)	-0.3 (-2.2, 1.9)	-3.3 (-4.9, -1.6)	0.6 (-0.8, 1.8)	3.1 (0.4, 6)	0.7 (-3.2, 4.7)	8.8 (5.1, 12.6)	4.2 (1.3, 6.9)	1.5 (-2.2, 4.9)	-0.2 (-4.1, 3.8)	-3.4 (-8.1, 1.1)
Citric acid		-3.8 (-6.6, -0.5)	-2.4 (-6, 1.2)	-5.4 (-8.7, -2.3)	-1.6 (-4.9, 1.6)	1 (-3.1, 4.9)	-1.5 (-6.4, 3.4)	6.7 (2.9, 10.6)	2 (-1.4, 5.3)	-0.6 (-5.5, 3.8)	-2.4 (-7.3, 2.5)	-5.6 (-11.3, 0)
EDTA			1.3 (-2.3, 4.7)	-1.7 (-4.9, 1.2)	2.1 (-1.2, 5.1)	4.7 (0.6, 8.5)	2.2 (-2.7, 6.9)	10.4 (6.7, 14.1)	5.7 (2.3, 8.8)	3.1 (-1.8, 7.4)	1.4 (-3.5, 6.3)	-1.9 (-7.5, 3.5)
Low Concentration NaOCl				-3 (-5.5, -0.7)	0.8 (-1.5, 2.8)	3.4 (0, 6.8)	1 (-3.6, 5.3)	9.1 (4.9, 13.3)	4.4 (0.7, 7.9)	1.7 (-2.3, 5.7)	0.1 (-4.6, 4.4)	-3.2 (-8.4, 1.8)
High Concentration NaOCl					3.8 (1.8, 5.7)	6.4 (3.2, 9.6)	4 (-0.1, 8.2)	12.2 (8.3, 15.9)	7.4 (4.3, 10.4)	4.8 (0.7, 8.4)	3.1 (-1.2, 7.4)	-0.1 (-5.1, 4.7)
Chlorhexidine						2.6 (-0.3, 5.5)	0.1 (-3.9, 4.3)	8.3 (4.5, 12.3)	3.6 (0.5, 6.6)	0.9 (-2.7, 4.5)	-0.8 (-4.9, 3.5)	-4 (-8.8, 0.7)
Ethanol							-2.4 (-7.3, 2.5)	5.7 (1.3, 10.3)	1.1 (-3, 4.9)	-1.6 (-6.2, 2.6)	-3.3 (-8.2, 1.6)	-6.6 (-11.9, -1.3)
Grape seed extract								8.2 (2.8, 13.4)	3.5 (-1.4, 8.3)	0.8 (-4.4, 6)	-0.9 (-6.4, 4.8)	-4.1 (-10.2, 1.9)
Ethyl acetate									-4.7 (-8.6, -0.9)	-7.3 (-12.8, -2.4)	-9 (-14.5, -3.5)	-12.3 (-18.1, -6.4)
Phosphoric acid										-2.7 (-7.3, 1.7)	-4.3 (-9.4, 0.6)	-7.7 (-13.1, -2.3)
Boric acid											-1.7 (-7, 3.7)	-4.9 (-10.8, 1)
Hydrofluoric acid												-3.3 (-9.5, 2.8)

Table 6: Pairwise comparisons between pretreatments for the bond strength of fiber post cementation in intraradicular dentin with an etch and rinse adhesive system.

Pairwise comparison	***EDTA***	***Low Concentration NaOCl***	***High Concentration NaOCl***	***Chlorhexidine***	***Ethanol***	***Grape Seed Extract***	***Carbodiimide***	***Polyacrylic Acid***
Control	*0.6 (-3.4, 5.6)*	*2.3 (-1.3, 5.9)*	*-1 (-2.5, 0.8)*	*0.1 (-1.1, 1.3)*	*0.4 (-1.1, 2.4)*	*1 (-2.3, 4.6)*	*0.6 (-3.3, 4.9)*	*-1.7 (-4.5, 1.8)*
EDTA		*1.8 (-4.6, 6.6)*	*-1.5 (-6.1, 2.7)*	*-0.5 (-5.4, 4)*	*-0.2 (-5.4, 4.1)*	*0.4 (-5.7, 5.9)*	*-0.1 (-6.6, 5.3)*	*-2.3 (-7.1, 2.2)*
Low Concentration NaOCl			*-3.3 (-6.6, 0.8)*	*-2.2 (-5.6, 1.7)*	*-1.9 (-5.4, 2.2)*	*-1.5 (-6.2, 4)*	*-1.7 (-7, 3.6)*	*-3.9 (-8.7, 0.8)*
High Concentration NaOCl				*1 (-1.2, 3)*	*1.4 (-0.8, 3.7)*	*1.9 (-2.4, 5.5)*	*1.4 (-3, 6)*	*-0.7 (-4.2, 2.8)*
Chlorhexidine					*0.3 (-1.2, 2.4)*	*0.8 (-3.1, 4.4)*	*0.5 (-3.8, 4.8)*	*-1.7 (-5.3, 2.1)*
Ethanol						*0.6 (-3.6, 4)*	*0.2 (-4.3, 4.7)*	*-2.1 (-5.8, 1.6)*
Grape Seed Extract							*-0.3 (-6.3, 5.3)*	*-2.5 (-7.5, 2.2)*
Carbodiimide								*-2.2 (-7.1, 3.3)*

Table 7: Pairwise comparisons between pretreatments for the bond strength of fiber post cementation in intraradicular dentin with self-etch adhesive system.

Pairwise comparison	EDTA	Low Concentration NaOCl	High Concentration NaOCl	Chlorhexidine	Ethanol	Grape Seed Extract	Phosphoric acid	Boric acid	Carbodiimide	Polyacrylic acid	Hydrogen Peroxide	Xylene
Control	0 (-1.3, 1.3)	0.4 (-0.9, 1.8)	-1.4 (-2.7, 0)	-0.4 (-1.6, 0.9)	2.7 (0.5, 4.9)	9.5 (1.7, 17.1)	2.5 (0.5, 4.7)	2.7 (-1.2, 6.5)	1.8 (-2.9, 6.8)	1.6 (-1.8, 4.9)	-6 (-11.2, -0.6)	0.7 (-3.2, 4.7)
EDTA		0.4 (-1.2, 2.1)	-1.4 (-2.9, 0.2)	-0.4 (-1.9, 1.3)	2.7 (0.2, 5.1)	9.5 (1.7, 17.1)	2.5 (0.3, 4.9)	2.7 (-1.4, 6.9)	1.8 (-3.2, 6.9)	1.6 (-1.8, 4.9)	-6.1 (-11.3, -0.4)	0.7 (-3.3, 4.8)
Low Concentration NaOCl			-1.8 (-3.6, -0.1)	-0.8 (-2.4, 0.9)	2.2 (-0.3, 4.7)	9 (1.3, 16.6)	2.1 (-0.2, 4.6)	2.3 (-1.8, 6.2)	1.4 (-3.6, 6.6)	1.1 (-2.4, 4.6)	-6.4 (-11.8, -0.9)	0.3 (-3.8, 4.3)
High Concentration NaOCl				1 (-0.5, 2.6)	4 (1.6, 6.5)	10.9 (3, 18.5)	3.9 (1.6, 6.3)	4 (-0.1, 8.1)	3.2 (-1.8, 8.3)	2.9 (-0.6, 6.4)	-4.7 (-10, 0.8)	2 (-2, 6.1)
Chlorhexidine					3 (0.7, 5.4)	9.9 (2.2, 17.4)	2.9 (0.7, 5.2)	3.1 (-0.9, 6.8)	2.2 (-2.9, 7.2)	1.9 (-1.6, 5.3)	-5.7 (-10.9, -0.2)	1.1 (-2.9, 5)
Ethanol						6.8 (-1.2, 14.8)	-0.2 (-3.1, 2.9)	0 (-4.4, 4.3)	-0.8 (-6.2, 4.7)	-1.1 (-5.1, 2.7)	-8.7 (-14.2, -2.9)	-1.9 (-6.3, 2.4)
Grape Seed Extract							-7 (-14.7, 1.1)	-6.7 (-15.3, 2)	-7.6 (-16.6, 1.6)	-7.9 (-16.2, 0.4)	-15.5 (-24.8, -5.9)	-8.7 (-17.2, -0.1)
Phosphoric acid								0.2 (-4.2, 4.4)	-0.7 (-5.9, 4.5)	-1 (-4.9, 2.9)	-8.6 (-14, -2.9)	-1.8 (-6, 2.2)
Boric acid									-0.8 (-7.4, 5.4)	-1.2 (-6.1, 3.9)	-8.7 (-15.4, -2)	-2 (-7.5, 3.4)
Carbodiimide										-0.3 (-6.2, 5.6)	-7.9 (-15, -0.4)	-1.2 (-7.3, 5.1)
Polyacrylic acid											-7.6 (-13.9, -1.1)	-0.9 (-6, 4.1)
Hydrogen Peroxide												6.8 (-0.1, 13.2)

Table 8 *SUCRAs for bond strength of intraradicular pretreatment. Surface under the cumulative rankings (SUCRA) between 0 and 1 represent the probability of being ranked highest and, in parentheses, its percentage of being the best treatment for each adhesive strategy.*

Pretreatments	***Self-etch adhesive + resin cement***	***Etch and rinse adhesive + resin cement***	***Self -adhesive cement***
Control	*0.40 (39.6%)*	*0.44 (43.8%)*	*0.36 (36.2%)*
Citric acid	*0.69 (68.8%)*	–	–
EDTA	*0.22 (22.5%)*	*0.58 (57.9%)*	*0.36 (36.2%)*
Low Concentration NaOCl	*0.38 (39.6%)*	*0.83 (83.43%)*	*0.45 (45.1%)*
High Concentration NaOCl	*0.06 (6.5%)*	*0.21 (21.48%)*	*0.12 (12.4%)*
Chlorhexidine	*0.50 (50.3%)*	*0.47 (46.73%)*	*0.28 (27.7%)*
Ethanol	*0.79 (78.6%)*	*0.57 (56.95%)*	*0.76 (76.2%)*
Grape Seed Extract	*0.50 (50.1%)*	*0.67 (66.65%)*	*0.98 (97.6%)*
Ethyl Acetate	*0.99 (99.8%)*	–	–
Phosphoric Acid	*0.86 (86.1%)*	–	*0.75 (74.9%)*
Boric Acid	*0.61 (60.9%)*	–	*0.73 (73.2%)*
Hydrofluoric Acid	*0.40 (39.8%)*	–	–
Carbodiimide	*0.10 (10.3%)*	*0.59 (58.92%)*	*0.61 (60.9%)*
Polyacrylic Acid	–	*0.14 (14.03%)*	–
Hydrogen Peroxide	–	–	*0.02 (1.6%)*
Xylene	–	–	*0.48 (47.6%)*

Figures

Fig. 1. *Flow diagram of the study identification.*

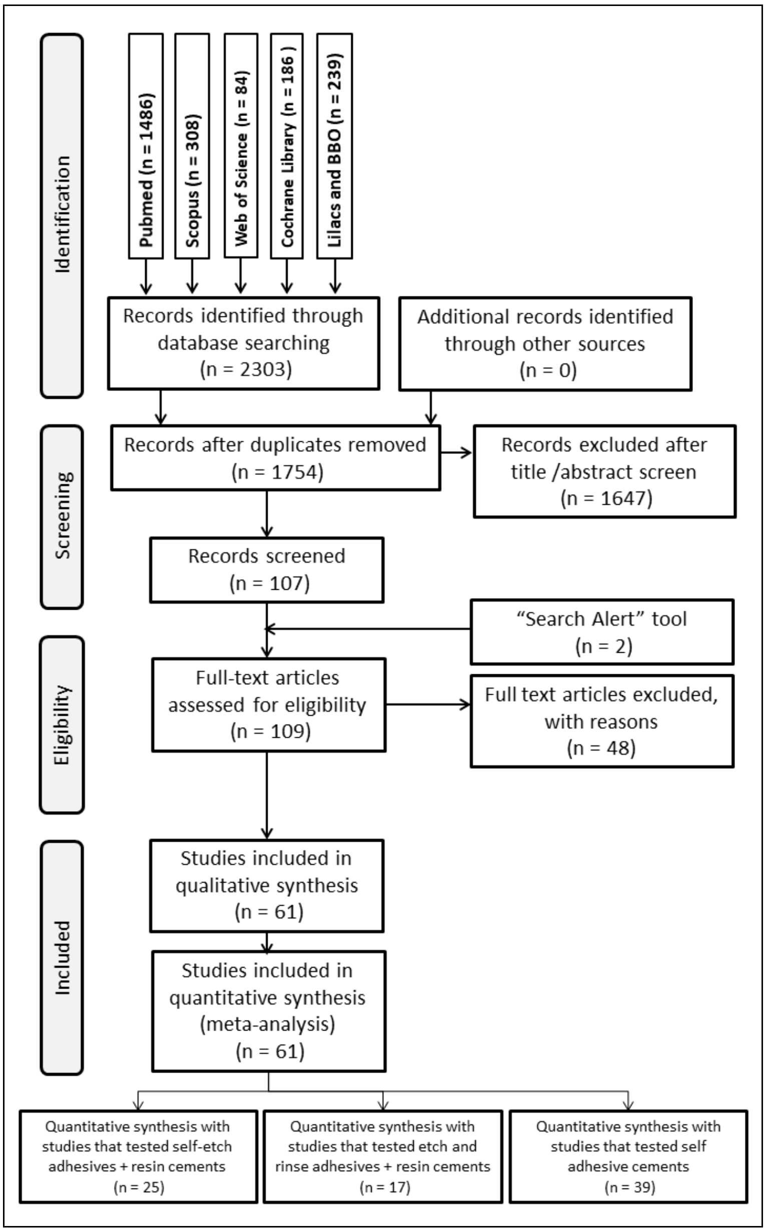


Fig. 2. *The network meta-analysis plot with all the direct and indirect comparisons of dentin pretreatment for self-etch adhesive + resin cement.*

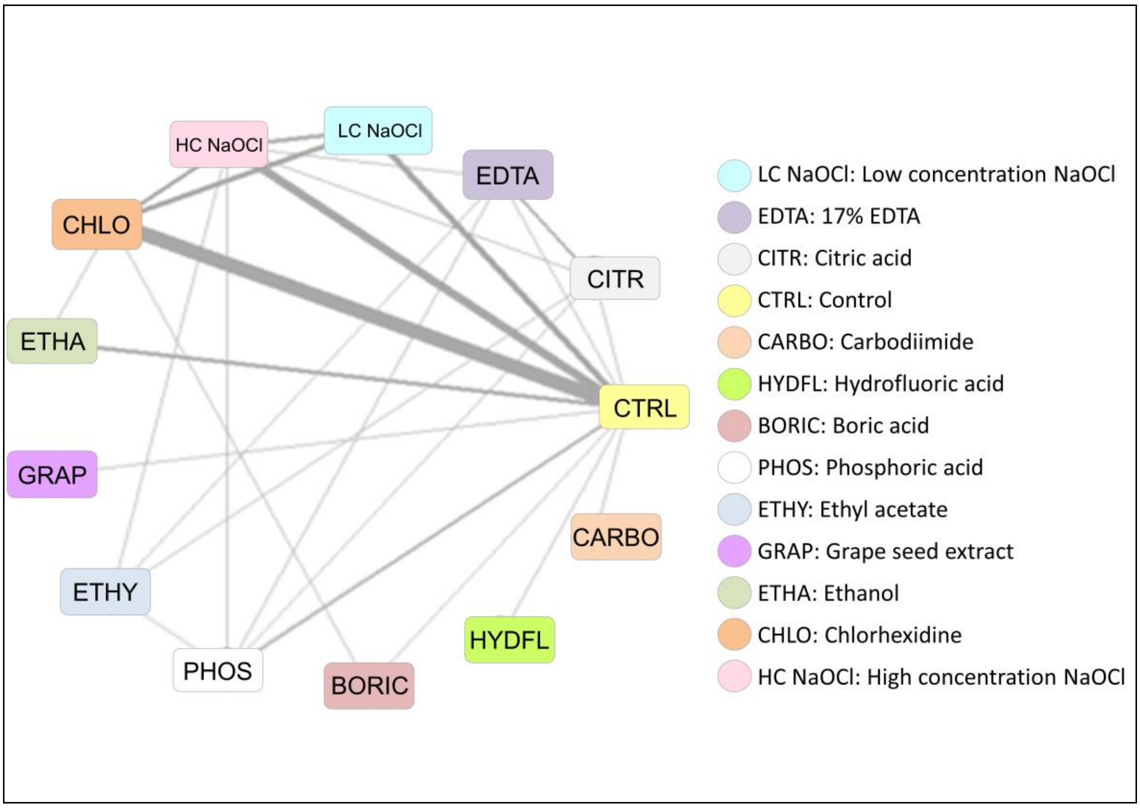


Fig. 3. *The network meta-analysis plot with all the direct and indirect comparisons of dentin pretreatment for etch-and-rinse adhesive + resin cement.*

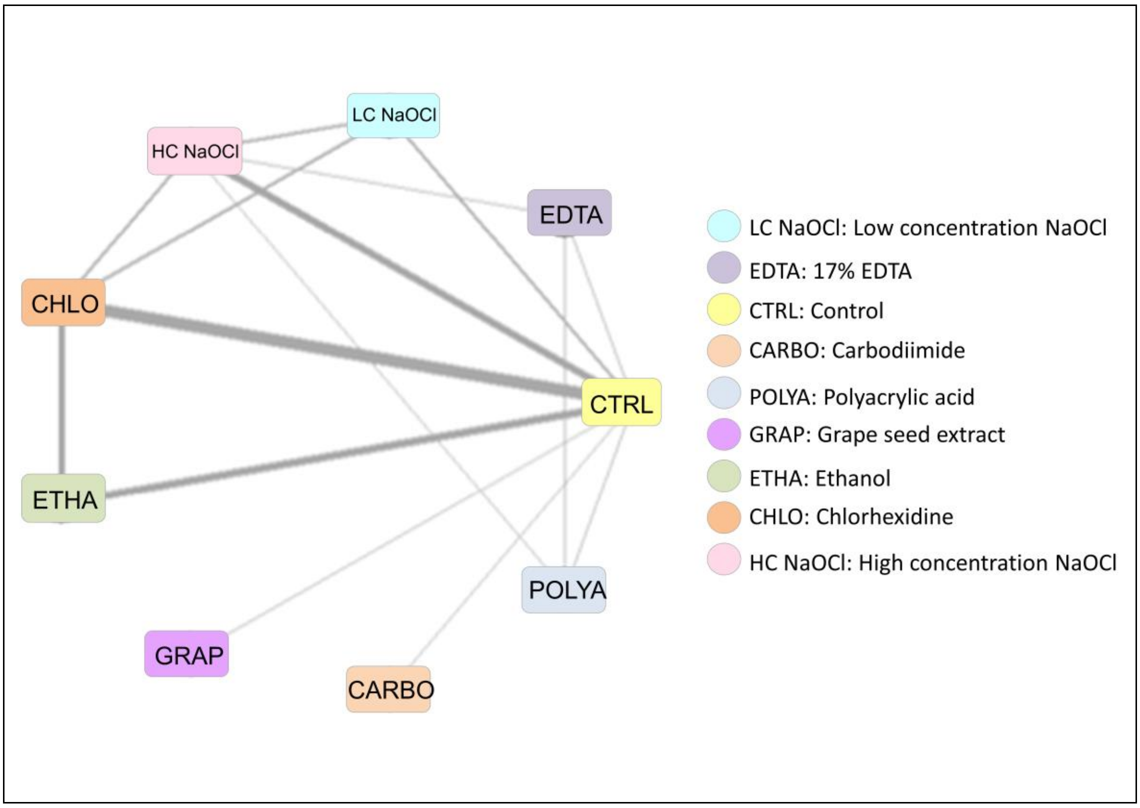
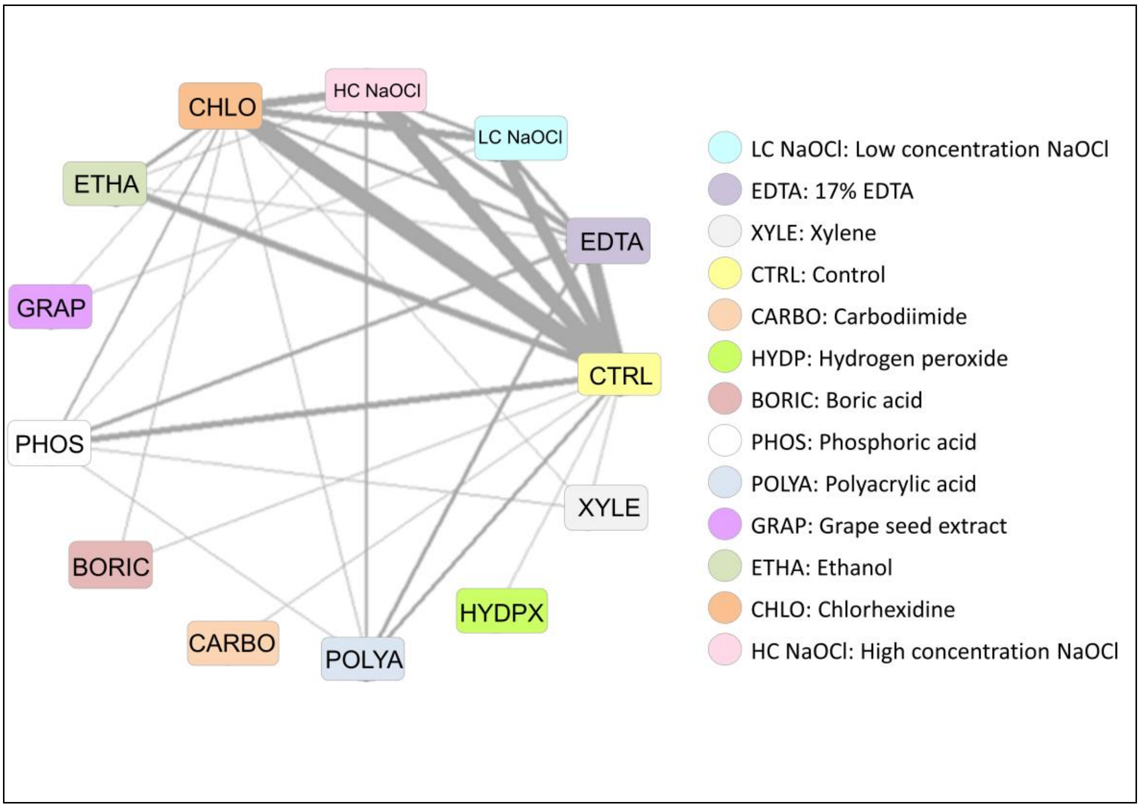


Fig. 4. *The network meta-analysis plot with all the direct and indirect comparisons of dentin pretreatment for self-adhesive cement.*



3 CONSIDERAÇÕES GERAIS

O prognóstico dos dentes desvitalizados está relacionado com uma série de fatores, entre eles, as condições do remanescente dental, o tipo de restauração que ele necessita, os materiais utilizados e seus protocolos de uso. Muitos dentes tratados endodonticamente necessitam de restaurações extensas e da utilização de pinos de fibra intrarradiculares. Diversos estudos têm sido desenvolvidos com a finalidade de investigar a longevidade dos tratamentos restauradores de dentes com essa condição. Agregando à vasta literatura existente, o presente estudo buscou elucidar questões relacionadas à biomecânica, longevidade e características clínicas dos dentes tratados endodonticamente com necessidade da utilização de pinos intrarradiculares e o esclarecimento acerca do uso de tratamentos químicos da dentina intrarradicular nos protocolos de cimentação adesiva dos pinos de fibra.

Para avaliar o comportamento biomecânico de estruturas complexas submetidas a determinada carga, a análise de elementos finitos é uma metodologia apropriada. Os modelos tridimensionais analisados neste estudo levaram à melhor compreensão das propriedades mecânicas dos dentes e dos materiais restauradores. A utilização do *software* de desenho permitiu a determinação dos preparos dentais e seleção dos materiais restauradores de uma forma controlada e padronizada, o que reduz o risco de viés relacionado à variabilidade de dimensões e condições de amostras dentais utilizada em outros testes laboratoriais. (Bergoli et al., 2014; Zarone et al., 2005).

Os gráficos de distribuição de tensão gerados no presente estudo mostraram que, nos modelos com pino de fibra de vidro, a concentração de tensão nas facetas diretas de resina composta e na estrutura da dentina foi menor quando comparados aos dentes sem pino de fibra. O pino de fibra de vidro foi capaz de absorver e distribuir melhor as tensões nos dentes. Isso diminui a tensão de flexão à qual o esmalte e a dentina são submetidos. Essa tensão quando não é bem absorvida nem distribuída pode ser transferida também para a região da faceta. Por meio dessa análise estática foi possível identificar áreas de concentração de tensões e sua propagação nas estruturas, ou seja, áreas dos dentes ou do material restaurador que podem ser mais suscetíveis a falhas (Furuya et al., 2014). Essa metodologia é idealmente utilizada para obter dados como os valores de tensão máxima encontrados nas estruturas e a visualização nos gráficos da distribuição e concentração de tensões. Por vezes, tais características não são obtidas em metodologias convencionais de laboratório. Apesar da análise de elementos finitos não ser o único indicador de possíveis falhas e danos em dentes ou restaurações, o embasamento em seus resultados, permite o melhor delineamento de futuros estudos laboratoriais e clínicos (Silva et al., 2009).

Quando comparados com outros tipos de materiais, os pinos de fibra de vidro apresentam maior vantagem de uso. Eles possuem propriedades estéticas e boas taxas retenção por conta da cimentação adesiva com cimentos resinosos quando comparados com os metálicos (Korkut et al., 2013). Além disso, o módulo de elasticidade do material é similar ao módulo de elasticidade da dentina, sendo assim, há melhor distribuição de forças ao longo da estrutura dental (Coelho-de-Souza et al., 2015; Rajambigai et al., 2016; Skupien et al., 2015). Em outros materiais, como a zircônia, titânio ou metal há maior concentração de tesão nas regiões de terço médio e cervical (Dietschi et al., 2008; Mosharraf, Haerian, 2011; Korkut et al., 2013). Desta maneira, as raízes dentárias se tornam mais vulneráveis à fratura, pois quanto maior a rigidez dos pinos, maior a carga transferida para a estrutura dental (Bergoli et al., 2014).

Relacionando e complementando as características biomecânicas encontradas, o presente ensaio clínico randomizado foi desenvolvido para obtenção de informações com maior evidência clínica, em resposta à escassez de ensaios clínicos relacionados ao efeito do uso de pinos de fibra na estrutura dentária remanescente em dentes tratados endodonticamente (Bolla et al., 2016).

Os resultados indicaram que o sucesso da restauração do dente com ou sem pino de fibra de vidro foi semelhante (as taxas de sucesso foram de 100% e 96% para os dentes com pino e sem pino de fibra de vidro, respectivamente). Esse resultado é esperado para um estudo preliminar de um ano de acompanhamento. Um estudo prévio com *follow-up* de oito anos mostrou uma taxa de sobrevivência de 98,48% para os dentes anteriores superiores tratados endodonticamente restaurados com coroas totais de cerâmica e pinos de fibra de vidro (Signore et al., 2009). Outro estudo que avaliou facetas diretas de resina composta por mais de três anos de acompanhamento, mostrou uma taxa de sobrevivência de 87,5% (Gresnigt et al., 2012). Nesses estudos, as taxas de falha também foram relacionadas a outros critérios, além da resistência à fratura, como por exemplo, a adaptação de restauração, combinação de cor, descoloração, rugosidade da superfície, cárie secundária e sensibilidade pós-operatória. Portanto, os resultados para o desfecho primário deste estudo (resistência à fratura) são esperados, considerando o período de avaliação de um ano, e mostram que é necessário um tempo de acompanhamento maior para eventualmente identificar alguma diferença significativa.

Outro ponto a respeito dos fatores que podem determinar a longevidade de um dente tratado endodonticamente é a importância das condições do remanescente dental, o efeito da presença da férula e as condições e extensões das restaurações pré-existentes nesses dentes (Juloski et al., 2012; Naumann et al., 2018; Skupien et al., 2016; Zhi-Yue, Yu-Xing, 2003). Dentes que possuem estrutura dental coronária em boas condições suportam maior quantidade de carga (em relação à intensidade e à frequência) até sofrer algum tipo de falha quando comparados com dentes sem remanescente coronário (Ng et al., 2006) A preservação de pelo menos uma parede na região coronária é importante para a manutenção do elemento dental em condições adequadas (Ng et al., 2006; Sarkis-Onofre et al., 2014;). Quanto maior o remanescente dentinário, maior a taxa de sobrevida dos dentes (Signore et al., 2009). Além disso, presença da férula diminui o impacto dos preparos dentais para confecção de pinos e restaurações (Ramírez-Sebastià et al., 2014). Em relação às restaurações pré-existentes nos dentes, um estudo avaliou a taxa de sobrevivência de dentes não vitais que possuíam facetas por cerca de 41,3 meses. Sem diferenças estatísticas, as taxas de sobrevida foram de 100%, 90,6%, 82,7% para os dentes intactos, para dentes que possuíam pequenas restaurações de resina compostas e restaurações extensas, respectivamente (Gresnigt et al., 2012), mostrando assim, que a presença ou extensão das restaurações não influencia na taxa de sobrevivência dos dentes.

Neste estudo, o dente do grupo que não recebeu pino de fibra de vidro e que sofreu falha catastrófica, tinha o remanescente cervical menos espesso (1,8 mm) quando comparado à média do grupo (2,18 mm). A fratura extensa pode estar relacionada a essa perda de estrutura. Além disso, o paciente não possuía guias anteriores em equilíbrio e a posição das incisais era “topo a topo”, o que poderia gerar concentração de forças no dente que fraturou por movimentos funcionais.

Os dentes que sofreram falhas não catastróficas tinham restaurações de resina composta nas superfícies proximais, além de desordens oclusais nas guias anteriores, histórico de clareamento interno e histórico de trauma no dente que recebeu o tratamento. Embora não tenham perdido o elemento dental, esses fatores podem ter alguma associação com as falhas. Embora não existam diferenças significativas, complicações mais desfavoráveis que resultaram na falha catastrófica (fratura radicular sem possibilidade de reparo e preservação do elemento) ocorreram no grupo sem pino. Houve episódios de fratura em ambos os grupos experimentais, mas em outras situações de falhas, o dente pôde ser restaurado e permaneceu em função.

Os achados preliminares deste estudo indicam que restaurações como facetas podem ser uma alternativa de tratamento para dentes superiores anteriores tratados endodonticamente sem o uso de pino de fibra. Isso é uma vantagem, pois é possível preservar maior quantidade de estrutura dentária, o procedimento clínico é menos invasivo e mais confortável para o paciente (Magne et al., 2017; Ramírez-Sebastià et al., 2014) Porém, avaliações de acompanhamento mais longas podem apresentar respostas mais esclarecedoras em relação ao comportamento a longo prazo dos dentes e dos materiais. Além disso, estudos multicêntricos são recomendados, o que permitiria envolver maior quantidade de participantes, aumentando a significância clínica dos resultados observados. Contudo, os achados e discussões deste estudo podem elucidar questões clínicas frequentes e gerar novas hipóteses de estudo sobre os fatores associados ao prognóstico dos dentes tratados endodonticamente.

Apesar da escassez de informações de estudos clínicos relacionados à utilização de pinos de fibra em dentes tratados endodonticamente, existem numerosos estudos laboratoriais que permeiam o assunto. Por esse motivo, foi delineada uma revisão sistemática e metanálise com o objetivo de responder à seguinte pergunta: “O uso de pino de fibra influencia na resistência à fratura de dentes anteriores tratados endodonticamente e restaurados, quando comparados com o não uso de pino de fibra?” As buscas resultaram em 32 estudos laboratoriais que foram utilizados para análise qualitativa e destes, 30 foram selecionados para extração dos dados a metanálise.

Nas etapas de seleção e triagem dos estudos, alguns deles foram excluídos das análises por não corresponderem aos objetivos da busca e também, por outros motivos mais específicos: não ter um grupo controle (não uso de pino de fibra); ser outro tipo de estudo (como revisões de literatura, revisões sistemáticas e relatórios clínicos), utilizaram dentes posteriores, não realizaram testes de resistência à fratura, avaliaram apenas a fratura de pinos de fibra, não especificam o tipo de pino utilizado no estudo, avaliaram somente o modo de falha por exame radiográfico, utilizaram pinos de metal ou de resina composta, utilizaram espécimes de dentes fraturados antes do procedimento restaurador, utilizaram dentes com ápice aberto ou decíduos. Isso demonstrou que algumas informações importantes não são facilmente identificadas partir dos títulos e resumos de alguns estudos. Os autores devem, portanto, aprimorar títulos e resumos para facilitar os trabalhos revisão sistemática e permitir que os pesquisadores em geral encontrem as corretas informações nas bases de dados.

A metanálise geral, que considerou o uso ou não do pino de fibra intrarradicular, independentemente do tipo de pino e da estrutura dentária remanescente, revelou que a resistência dos dentes à fratura melhorou com o uso do pino de fibra. Isso pode estar relacionado com os achados da análise de elementos finitos do presente estudo e de outros estudos anteriores que mostraram a melhor distribuição de tensões na estrutura dentária. Quando os dentes perdem estrutura no preparo do tratamento endodôntico ou restaurador, as tensões são concentradas na região cervical, assim, a utilização do pino de fibra é importante para distribuir essas tensões (Abduljawad et al., 2017, 2016). Ainda em relação à importância da similaridade do módulo de elasticidade do pino de fibra com a dentina, na metanálise que considerou a diferença do tipo de pino (vidro, carbono, quartzo ou zircônia) o pino de fibra de vidro foi o único associado a favorecer a resistência dos dentes à fratura. Os pinos de fibra de vidro têm características mecânicas mais próximas às da dentina (Al Moaleem, 2013). Além disso, alguns autores relataram que o padrão de fratura de dentes com pino de fibra confere melhor prognóstico para o dente, evita fraturas mais extensas e permite o reparo do dente, sem necessidade de extração do elemento (D’Arcangelo et al., 2010; Salameh et al., 2007).

Para análises de subgrupos que consideraram diferentes estruturas remanescentes dos dentes. O uso de pino de fibra de vidro foi favorável à resistência à fratura de dentes com cavidades cervicais e preparo para facetas. Isso provavelmente ocorre, pois, independente das condições do dente, as tensões de origem mastigatórias se concentram na região cervical. A presença do pino de fibra pode evitar essa concentração de forças e distribui melhor para outras áreas do dente (D'Arcangelo et al., 2010, 2007; Rajambigai et al., 2016; Valdivia et al., 2012). Para outros tipos de remanescentes, não houve diferenças no uso de um pino de fibra, provavelmente porque em alguns tipos de remanescentes não houve perda de estrutura na região cervical e para remanescente de dentes que receberam preparos para coroas totais, a perda de estrutura já é capaz de fragilizar o dente a um ponto em que, nem mesmo o uso de pinos de fibra pode influenciar na resistência à fratura.

Além da biomecânica, longevidade e desempenho clínico dos dentes tratados endodonticamente com pinos de fibra intrarradiculares existem muitas informações na literatura a respeito dos procedimentos de cimentação adesiva com diferentes sistemas adesivos e cimentos resinosos e ainda em relação uso de tratamentos químicos da dentina intrarradicular previamente à cimentação dos pinos intrarradiculares. A revisão sistemática e metanálise em rede foram desenvolvidas para abordar essa questão. Muitos estudos têm como objetivo comparar a resistência de união que esses tratamentos podem oferecer em diferentes estratégias de cimentação, mas nenhum consenso foi alcançado quanto à qual produto é o mais favorável para as diferentes estratégica de cimentação.

A metanálise tradicional obtém conclusões de comparações diretas entre estudos com similaridades em relação ao número e ao tipo de intervenções (Dias et al., 2010). No entanto, a presente revisão sistemática identificou 61 estudos com vários modelos de estudo. Houve uma variabilidade considerável no número de tratamentos químicos de dentina de cada estudo e nas estratégias de cimentação utilizadas. Para tal situação, uma comparação mista de tratamento, também chamada de meta-análise em rede, foi recomendada (Maran et al., 2019). Nesse caso, essa análise foi adequada porque considerou relações indiretas entre tratamentos realizados em diferentes estudos com um comparador comum. As comparações indiretas melhoram a evidência das comparações diretas e, na ausência de dados comparativos diretos, podem fornecer informações valiosas

(Maran et al., 2019; Sekine et al., 2015). Considerando que vários tratamentos químicos dentinários foram identificados em diferentes trabalhos, as comparações indiretas forneceram uma estimativa da relação de tratamentos que não foram testados no mesmo estudo.

Na etapa de extração de dados, foi observada uma variação considerável na estratégia de adesivo e cimentação dos pinos de fibra intrarradicular. Assim, foram realizadas três metanálises em rede, uma para cada estratégia de cimentação (adesivo autocondicionante e cimento resinoso, adesivo de condicionamento total e cimento resinoso e cimento resinoso autoadesivo). A metanálise em rede permitiu a classificação dos tratamentos de acordo com a probabilidade de ser o melhor tratamento em relação à força de união.

Para os grupos que utilizaram o adesivo autocondicionante e cimento resinoso, o acetato de etila foi identificado como o melhor pré-tratamento. O acetato de etila mostra bons valores de resistência à adesão, porque não é capaz de remover a *smear layer* na dentina. A remoção da *smear layer* e a abertura dos túbulos dentinários não são recomendadas para os sistemas adesivos autocondicionante (Demiryurek et al., 2009). No entanto, nesta revisão sistemática, apenas um estudo utilizou o acetato de etila como tratamento dentinário. Portanto, são necessários mais estudos avaliando tal tratamento para conclusões mais consistentes. Segundo o *ranking*, o ácido fosfórico e etanol também proporcionaram bons resultados de resistência de união. Embora o ácido fosfórico seja capaz de remover a *smear layer,* ele também dissolve resíduos do cimento endodôntico e abre os túbulos dentinários desmineralizando a dentina intertubular e peritubular (Demiryurek et al., 2009). O etanol tem a capacidade de substituir a água na dentina, evitando o colapso da matriz de colágeno e promovendo a diminuição do diâmetro das fibrilas de colágeno, isso possivelmente melhora a infiltração de monômeros hidrofóbicos, fornecendo valores mais altos de resistência ao cisalhamento. (Aktemur Turker et al., 2013; Carvalho et al., 2009; Victorino et al., 2016)

Para os grupos que usaram adesivos de condicionamento total e cimento resinoso, o melhor tratamento químico da dentina intrarradicular para o aumento da resistência de união dos pinos de fibra foi o NaOCl em baixa concentração. O mesmo, possui atividade antimicrobiana e a capacidade de dissolver resíduos de cimento endodôntico ou tecido orgânico e em concentrações mais baixas não interfere na adesão de materiais resinosos (Rezende et al., 2016). Os grupos que utilizaram cimento resinoso autoadesivo tiveram um aumento na resistência de união de pinos de fibra com o uso de extrato de semente de uva, etanol e ácido fosfórico. O extrato de semente de uva é um produto natural rico em pró-antocianinas; esse irrigante possui propriedades antimicrobianas e potencial para melhorar as propriedades mecânicas da dentina. É um agente de *cross-linking* que modifica a bioquímica do colágeno e interage com os proteoglicanos, reforçando o colágeno da matriz dentinária. Além disso, fornece resistência contra a degradação enzimática do substrato dentinário (Alandia-Román et al., 2017; Cecchin et al., 2015). Apesar de, na literatura, o extrato de semente de uva apresentar bons resultados de adesão, quando proposto como tratamento de esmalte e dentina coronários (Gajjela et al., 2017; Sharafeddin, Farshad, 2015)., no levantamento da presente revisão sistemática, apenas dois estudos avaliaram o extrato de semente de uva em dentina intrarradicular (Alandia-Román et al., 2017; Cecchin et al., 2015).

O desempenho do NaOCl em alta concentração foi insatisfatório na resistência de união entre os pinos de fibra e a dentina intrarradicular. O NaOCl em alta concentração é um agente oxidante, deixa oxigênio residual no substrato dentinário e pode degradar a matriz orgânica da dentina. Além disso, o resíduo de NaOCl em alta concentração pode se difundir na dentina e interferir na polimerização dos monômeros de cimentos resinosos e sistemas adesivos, possivelmente reduzindo a resistência da união entre a dentina e o cimento resinoso (Alkhudhairy, Bin-Shuwaish, 2016; Faria-e-Silva et al., 2013; Neelakantan et al., 2015; Rezende et al., 2016). Portanto, a abordagem mais apropriada no momento do tratamento endodôntico ou limpeza da região intrarradicular, seria irrigar com uma solução endodôntica alternativa, ou com NaOCl em baixas concentrações, ou mesmo utilizar uma solução capaz de neutralizar ou minimizar a ação do NaOCl em alta concentração.

O tratamento da dentina intrarradicular com ácido poliacrílico ou peróxido de hidrogênio, em associação com os adesivos de condicionamento total, não melhoraram a resistência da união dos pinos de fibra. Embora tenha pH ácido, o ácido poliacrílico não é capaz de remover significativamente a *smear layer*, o que é essencial para as técnicas de adesivo de condicionamento total (Faria-e-Silva et al., 2013). A aplicação de peróxido de hidrogênio nas estruturas dentárias pode diminuir a microdureza e o módulo de elasticidade, produzindo alterações morfológicas, afetando a dentina intertubular e peritubular e causando alterações estruturais na hidroxiapatita devido a ligações iônicas que enfraquecem sua estrutura e, consequentemente, diminuem os valores de resistência de união dos cimentos resinosos autoadesivos (Akman et al., 2016).

A partir do levantamento de estudos nesta revisão sistemática, o intuito inicial seria encontrar estudos clínicos e *in vitro* para análise qualitativa e quantitativa, mas as buscas e triagem dos estudos não trouxeram estudos *in vivo*. Poucos estudos clínicos correspondem à questão principal; portanto, são necessárias investigações clínicas relacionadas a esta questão de pesquisa. Embora sejam necessários ensaios clínicos randomizados para fornecer evidências clínicas sobre essas questões, a análise dos estudos *in vitro* apresentou questões relevantes sobre as estratégias adesivas dos pinos de fibra na dentina intrarradicular e poderia servir como base para formular novas hipóteses de estudo. Além disso, outras limitações desta revisão sistemática foram que, apesar de na maioria dos estudos os autores seguirem as orientações de uso dos fabricantes, as análises não consideraram as diferenças nos protocolos de aplicação de cada tratamento químico dentinários. A maioria dos estudos incluídos apresentou risco médio ou alto de viés, portanto, estudos futuros devem ser melhor delineados e relatados para providenciar evidências mais consistentes.

Desta maneira, por meio dos estudos realizados e dos resultados obtidos, conclui-se então, que os pinos de fibra de vidro absorvem e distribuem melhor as tensões recebidas pelos dentes tratados endodonticamente e restaurados com facetas diretas de resina composta. Em estudos laboratoriais, o pino de fibra apresenta melhores valores de resistência à fratura, principalmente os pinos de fibra de vidro e em dentes que possuem preparos passa facetas e cavidades cervicais, porém para evidências científicas de maior validade é necessária a realização de estudos clínicos bem delineados, bem reportados e com acompanhamento a longo prazo. Em relação ao protocolo de uso de agentes irrigantes da dentina intrarradicular, os tratamentos químicos da dentina intrarradicular que melhoram a força de união da cimentação de pinos de fibra são o acetato de etila para adesivos autocondicionantes, NaOCl em baixa concentração para adesivos de condicionamento total e extrato de semente de uva para cimentos autoadesivos.

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ANEXO – Certificado do Comitê de Ética em Pesquisa

UNESP - INSTITUTO DE CIÊNCIA E TECNOLOGIA - CAMPUS DE SÃO JOSÉ DOS

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: EFEITO DA UTILIZAÇÃO DE PINO DE FIBRA DE VIDRO INTRACANAL NA RESISTÊNCIA À FRATURA EM DENTES COM LAMINADOS: ESTUDO CLÍNICO RANDOMIZADO

Pesquisador: Ana Luiza Barbosa Jurema

Área Temática:

Versão: 2

CAAE: 64187517.2.0000.0077

Instituição Proponente: Instituto de Ciência e Tecnologia de São José dos Campos - UNESP

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 1.963.431

Apresentação do Projeto:

Este estudo clínico randomizado, controlado avaliará a resistência à fratura de incisivos centrais e laterais superiores tratados endodonticamente que receberão restaurações do tipo facetas laminadas, associadas ou não ao uso de pinos de fibra de vidro (PFV) intracanal. Para isto, pacientes com necessidade delaminados para reabilitação estética anterior serão selecionados de acordo com critérios de inclusão. Serão realizadas 50 facetas dentárias, que serão aleatoriamente alocadas em dois grupos (n=25) de acordo com o

uso ou não de PFV. Será realizado o acesso lingual da câmara pulpar, preparo para a faceta, mensuração da espessura da estrutura dental remanescente e a inserção de resina composta pela técnica incremental sobre o preparo. No grupo em que se utilizará o PFV, será feito o preparo e a cimentação do mesmo, com posterior selamento da facelingual do dente com resina composta. Para o grupo controle (não uso do PFV),será feito o preenchimento da câmara pulpar com resina composta. Serão utilizados cimento resinoso (Grupo que receberá o PFV) , sistema adesivo universal e resina composta convencional. Os tratamentosserão avaliados por dois examinadores, devidamente calibrados, no início do estudo e após 6, 12, 18 e 24 meses, utilizando os critérios de avaliação de fraturas e condições periapicais. Os dados serão avaliados por testes não paramétricos e testes de sobrevida, ambos com nível de significância de 5%.

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Objetivo da Pesquisa:

Avaliar o desempenho clínico da utilização de pinos de fibra de vidro na resistência à fratura em dentes anteriores com laminados

Avaliação dos Riscos e Benefícios:

Riscos:

Possibilidade de dano radicular durante o preparo endodôntico e trauma na gengiva

Benefícios:

Os pacientes receberão facetas que contribuem para sua estética, saúde e reabilitação estrutural do dente em questão.

Comentários e Considerações sobre a Pesquisa:

Projeto de pesquisa muito bem apresentado. Proposta importante dentro da área específica da pesquisa.

Considerações sobre os Termos de apresentação obrigatória:

Todos os termos obrigatórios foram apresentados.

Recomendações:

Manter o CEPh atualizado sobre a pesquisa.

A pesquisadora deverá enviar ao CEP, via notificação relatório científico, conforme cronograma de execução apresentado, sob pena de não ter analisados por este CEPh, novos protocolos que possam ser enviados, até o atendimento da pendência.

Conclusões ou Pendências e Lista de Inadequações:

Não há pendências.

Considerações Finais a critério do CEP:

O Colegiado acata o parecer da relatora.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_858095.pdf	14/02/2017 15:34:37		Aceito
Outros	Resposta_as_pendencias.pdf	14/02/2017 15:34:05	Ana Luiza Barbosa Jurema	Aceito
Projeto Detalhado / Brochura Investigador	PROJETO_Reformulado.pdf	14/02/2017 15:32:25	Ana Luiza Barbosa Jurema	Aceito

TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE_Reformulado.pdf	14/02/2017 15:32:04	Ana Luiza Barbosa Jurema	Aceito
Folha de Rosto	FolhaDeRostoOK.pdf	27/01/2017 14:33:34	Ana Luiza Barbosa Jurema	Aceito
Projeto Detalhado / Brochura Investigador	PROJETO.pdf	27/01/2017 11:59:17	Taciana Marco Ferraz Caneppele	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE.pdf	27/01/2017 11:59:04	Taciana Marco Ferraz Caneppele	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

SAO JOSE DOS CAMPOS, 14 de Março de 2017

Assinado por:
Denise Nicodemo
(Coordenador)