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Influence of teeth root intracanal post surface modification on its bond strength to resin-matrix cements.

Ana Filipa de Sousa Correia

Dissertação conducente ao Grau de Mestre em

Medicina Dentária (Ciclo Integrado)

Gandra, 27 de setembro de 2020

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Trabalho realizado sob a Orientação do Professor Doutor Júlio C. M. Souza e co-orientação do Mestre Valter Fernandes

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RESUMO

Motivação: Em diversos casos, a estrutura dentária remanescente de um dente endodonciado não é suficiente para promover uma correta retenção da futura restauração e torna-se necessário recorrer a meios de retenção intrarradicular. Normalmente, essa retenção é realizada sob a forma de espigões intrarradiculares associada a cimentos resinosos.

Objetivo: O objetivo deste trabalho foi realizar uma revisão sistemática integrativa sobre o efeito de diferentes tratamentos de superfície em espigões à base de fibra de vidro no que diz respeito à adesividade ao cimento resinoso.

Método: Realizou-se uma pesquisa eletrónica na base de dados PUBMED utilizando uma combinação dos seguintes termos científicos: "*intracanal post*" OR "*endodontic post*" OR "*intraradicular post*" AND "*surface*" AND "*adhesion*" OR "*bond strength*".

Resultados: A pesquisa identificou 574 artigos, dos quais 13 foram considerados relevantes para este estudo. O tratamento com jateamento de partículas abrasivas promoveu um aumento da rugosidade dos espigões endodônticos, demonstrando valores de retenção consideravelmente mais elevados comparativamente com outros tratamentos de superfície. Além do tradicional condicionamento com ácido hidrofluorídrico, outras soluções, como o condicionamento com peróxido de hidrogénio, proporcionaram modificações na superfície dos espigões à base de fibra de vidro, originando uma maior adesividade ao cimento de matriz resinosa. No entanto, foram registados valores mais elevados (ex., *push-out, pull-out, tensile bond strength*) de resistência à união entre os espigões à base de fibra de vidro e o cimento de matriz resinosa, quando se optou por uma abordagem combinada entre tratamentos de superfície físicos e químicos.

Conclusão: A combinação de tratamentos de superfície químicos e físicos promoveu uma melhoria significativa na adesão entre o espigão à base de fibra de vidro e o cimento de matriz resinosa. Consequentemente, uma maior adesão do espigão ao cimento irá promover uma melhoria na retenção intracanalar.

PALAVRAS CHAVE

Espigão intracanalar; cimento resinoso; superfície; adesão; tratamento endodôntico

ABSTRACT

Background: Endodontically treated teeth usually demonstrate an extensive loss of dental structure and require the use of intraradicular retainers to provide adequate support and retention. Retention of the post depends on the surface treatment of the endodontic post itself and root canal dentin as well as on the type of resin-matrix cement.

Purpose: The aim of this study was to conduct an integrative literature review on the influence of different teeth root intracanal post surface treatments on the bond strength to resin-matrix cements.

Method: An electronic search was conducted on the PUBMED using a combination of the following scientific terms: "intracanal post" OR "endodontic post" OR "intraradicular post" AND "surface" AND "adhesion" OR "bond strength".

Results: The research identified 574 studies, of which 13 were considered relevant to this study. Airborne particle abrasion provided significantly higher roughness of endodontic posts surfaces causing a higher bond strength to the resin-matrix cement when compared to other surface treatments. Besides the traditional use of the hydrofluoric acid etching, other solutions such as hydrogen peroxide also promoted the surface modification of glass fiber-reinforced posts leading to an enhanced bond strength to the resin-matrix cement. Thus, the highest values of bond strength (i.e., push-out, pull-out, tensile bond strength) of endodontic posts to the resin-matrix cements were recorded when a combined physico-chemical approach was assessed.

Conclusion: The combination of physical and chemical methods can enhance the surface modification of tooth root intracanal post leading to an increased adhesion to the resin-matrix cement. That also increase the retention of endodontic posts to the tooth root intracanal dentin.

KEYWORDS

Intracanal post; resin-matrix cement; surface; adhesion; bond strength, endodontic treatment

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TABLE OF CONTENTS

1. INTRODUCTION

Glass fiber-reinforced resin composite (GFRC) posts are widely used in restorative rehabilitation of endodontically treated teeth with extensive loss of coronal structure to re-establish aesthetic and mechanical outcomes (1–6). The use of GFRC posts luted with resin-matrix cement followed by composite core build-up with resin composites has become usual on restorating endodontically treated teeth (4,7–9). Such hybrid restoration has been proved to be an effective way to overcome the lack of dentin and enamel structures (1,4,8). In fact, GFRC posts provide a proper homogeneous stress distribution along the root canal due to their mechanical properties such as elastic modulus and strength (6,10–17). However, the morphological aspects of the GFRC post and intracanal dentin surfaces should be well-prepared to promote a strong retention into the teeth root canal (7,11,18,19). Thus, failures are common on the endodontically treated teeth due to the poor GFRC post retention, defects in the cementation layer, and dissimilar mechanical properties among the materials leading to stress concentration and fractures (1,12,20,21).

Debonding from the teeth root canal is dependent on the GFRC post surface conditions associated with the cementation procedure to dentin involving adhesive systems and resin-matrix cements (4,7,22,23). The modification of dentin surfaces by adhesives to establish the hybrid layer is the first step prior to cementation (2,3,20). On the other hand, several GFRC surface modification methods are currently used to improve the adhesion to the resin-matrix cements (3,7,20). Such methods include physical and chemical procedures to modify the roughness and chemical composition of the GFRC post surface leading to an increased mechanical interlocking of the resin-matrix cement (8,20,21). Additionally, the combination of physical and chemical methods are used to enhance the bond strength of GFRC posts to resin-matrix cements (12,20,23). The physical modification methods deal with the use of machining, grit-blasting (airborne particle abrasion), etching, or laser irradiation to increase and control the GFRC roughness and surface pattern (3,10,23). The modification of the roughness can be achieved at macro-, micro- and nano-scale depending on the surface modification parameters (20,21,23). The chemical modification method deals with a coating deposition mainly with silane-based solutions (21–23).

Silane is commonly applied as GFRC surface pre-treatment without change the microstructure and roughness of the GFRC post surface. Silane-based coating aims to increase the surface wettability and to establish a chemical bonding between the GFRC and resin-matrix cement via SiO_x and hydroxils groups (4,7,13,20,22). However, the use of silanes to enhance bond strength between resin composite and the fiber post still remains controversial. Several factors influence the effectiveness of silane, such as its chemical composition, pH, presence of solvent, molecular size, and the application protocol (4,13). The chemical reaction between silane and an inorganic surface may be enhanced and catalyzed by previous acid treatment of the GFRC surface or by silane heating (8,13,21). Surface etching of GFRC posts using chemical agents such as hydrofluoric acid (HF), hydrogen peroxide (H_2O_2), hydrochloric acid, and potassium permanganate changes the morphological aspects and chemistry of the GFRC surfaces (3,13,23). Hydrofluoric acid in combination with a silane-coupling agent is often utilized to enhance the bond strength between of glass-ceramic veneers to resin-matrix cements (10,20). Taking into consideration silica-based posts are comparable in chemical structure with glass-ceramic materials, hydrofluoric acid has recently been proposed for GFRC posts (10,20). Regarding the corrosive nature of HF, the partially dissolution of resin matrix and glass fibers increases the roughness at micro- and nano-scale for mechanical interlocking of the resin-matrix cement (10,13,20).

The purpose of the present study was to conduct an integrative systematic review on the influence of glass fiber-reinforced post surface modification on its bond strength to resin-matrix cements. It was hypothesized that the combination of physical and chemical methods of surface modification promotes an enhancement of the the bond strength of glass fiber-reinforced post surface to resin-matrix cements.

2. METHOD

A literature search was carried out on PUBMED (via National Library of Medicine) using the following combination of search terms: "intracanal post" OR "endodontic post" OR "intraradicular post" AND "surface" AND "adhesion" OR "bond strength". The inclusion criteria involved articles published in the English language, from January 2010 up to April 2020, reporting the push-out bond strength of glass fiber-reinforced resin composite (GFRC) post to resin-matrix cements after GFRC surface modification by different physicochemical methods. The eligibility inclusion criteria used for article searches also involved: articles written in English; *in vitro* testing; meta-analyses; randomized controlled trials; and prospective cohort studies.

Two of the authors (JCMS, AFSC) independently analyzed the titles and abstracts of potentially relevant articles. The total of articles was gathered for each combination of key terms and therefore the duplicates were deleted using Mendeley citation manager. A preliminary evaluation of the abstracts was carried out to establish whether the articles met the purpose of the study. Selected articles were individually read and evaluated concerning the purpose of this study. The following factors were retrieved for this review: authors' names, journal, publication year, purpose, GFRC chemical composition, surface modification procedures, resin-matrix cements, physicochemical characterization methods, and bond strength results.

3. RESULTS

A total of 574 articles were identified on PUBMED, as shown in Fig.1. After reading the titles and abstracts of the scientific articles, 37 studies were selected although 17 of those were duplicated. The remaining 20 studies were selected for full reading. After proper evaluation, 7 studies were excluded because they did not provide relevant information according to the purpose of the present integrative systematic review. Thus, 13 articles were included in this integrative systematic review.

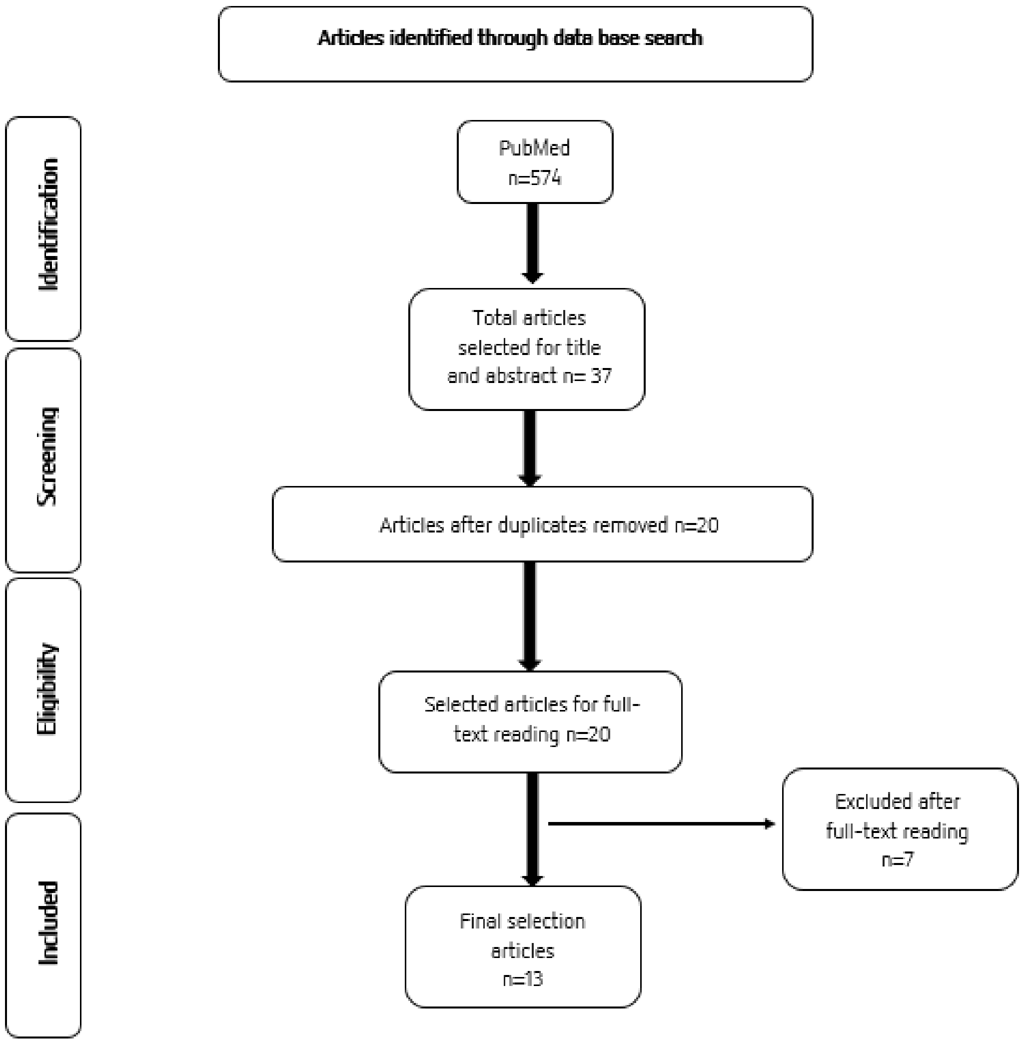

Figure 1. Flow diagram of the search strategy used in this study

Of the 13 selected *in vitro* studies, 11 (84.6%) articles evaluated the influence of different surface modification of teeth root intracanal post. Six (54.5%) articles included chemical surface modification by silanization, while 6 (54.5%) evaluated the effect of micro-scale surface modification, either by grit-blasting, etching or both surface treatment. Three (27%) articles reported the combination of micro-scale and chemical surface modification while only one included Nd:YAG laser irradiation for surface modification. One (7.6%) study evaluated the influence of the glass fiber-reinforced composite (GFRC) post surface on the bond strength to four different resin-matrix cements.

The main outcomes from the selected articles are shown in Table 1 and briefly described as follow:

- The use of silanes to enhance bond strength between composite resin and the fiber post still remains controversial. Several studies concluded that the bond strength of GFRC post to resin-matrix cements can be improved by previous silanizing (21,23). Other studies reported that the use of a silane coupling agent alone did not increase the bond strength values (4,9,11,12). A few studies showed an increase in bond strength values (from approximately 55 up to 68 MPa) after combination of acidic etching and silane (10,20). The lowest bond strength values (2.5 ±1.4MPa) were recorded for surfaces etched with 10% hydrofluoric acid for 1 min without the silane application (10,11,18).

- The bond strength of GFRC post to resin-matrix cements was significantly higher (17.5 ±2.2 MPa) after etching the GFRC surface with 24% hydrogen peroxide when compared with other surface treatments as follow: 10.5 ±1.1 MPa for ethanol treatment), 10.6 ±0.8 MPa for 37% phosphoric acid treatment and 12.1 ±1.7 MPa on 10% hydrofluoric acid treatment (20). One study reported similar bond strength results between the surfaces etched with 35% hydrogen peroxide for 1 min (5.1 ±1.3 MPa) and without pre-treatment but cleaned with 70% ethanol (4.4 ±1.8 MPa) (21). However, another study showed that 10%

hydrogen peroxide etching significantly enhanced the bond strength between fiber post and resin composite when compared to the other groups (23).

- Significantly higher bond strength values (342.8 ±70.3 N) were noticed for grit-blasted GFRC posts to resin-matrix cements when compared to GFRC posts without surface treatment or even after the phosphoric acid etching. (8) The highest bonding strength values at 5.48 ±1.36MPa were recorded for grit-blasted GFRC posts within the middle part of the teeth (18). Also, the highest bond strength results (71.8 ±16.3 MPa without silanization and 81 ±11.4 MPa with silanization) were recorded on grit-blasted GFRC surfaces with or without silane application (10).

- Regarding surface modification by laser, Nd:YAG laser irradiation for 180 and 320 µs promoted melted areas, carbonization, and deeper crevices on GFRC posts leading to surface modification. Laser irradiation for 180 µs showed similar values for bond strength (5.18 ±1.06 MPa) when compared with laser irradiation for 320 µs (5.09 ±1.43 MPa) on coronal level (18).

- Considering the teeth root anatomical effect, the highest bond strength values were recorded within the coronal region. The bond strength was lower in the middle and apical third of the teeth root canal (11,12,20). Those results were attributed to the sensitivity of the cementation procedure due to the flowing and narrow region. Consequently, regions with defects and thick resin-matrix cement layers are spots for stress concentration and fracture (11).

Table 1. Relevant data gathered from the selected studies.

Author (year)	Purpose	Study design/Methods	Tooth type	Fiber post surface treatment	Post type	Cement type
Albashaireh et al., (2010)(8)	Evaluate the influence of post surface conditioning methods and artificial aging on the retention and microleakage of adhesively luted glass fiber-reinforced composite resin posts.	In vitro	Single-rooted human teeth	Acidic treatment (36% phosphoric acid); Airborne-particle-abrasion treatment	Glass-fiber-reinforced composite posts (yellow color-coded radix fiber posts; Dentsply Maillefer)	Resin-matrix cement (Calibra; Dentsply DeTrey)

Kirmali et al.,(2017)(18)	Compare the effect of different pretreatments with the laser-activated irrigation technique on root canal dentin in terms of push-out bond strength in a fiber post.	In vitro/ Push-out bond strength test (PBS); Stereomicroscopy	Mandibular single-rooted human premolars	9.7% hydrofluoric acid; Sandblasting; Nd:YAG laser irradiation	Glass-fiber reinforced posts (Rebilda post; VOCO, Cuxhaven, Germany)	Dual-cure resin-matrix cement (Grandio Core Dual Core, VOCO)
Elnaghy et al., (2014)(11)	Evaluate the effect of different surface treatments on the flexural properties and adhesion of glass fiber post to self-adhesive luting agente and radicular dentin.	In vitro/ Micropush-out test; Stereomicroscopy; Scanning electron microscopy (SEM)	Single-rooted human teeth	Silanization; Airborne-particle abrasion; 9% hydrofluoric acid; Dichloromethane (CH_2Cl_2)	Glass-fiber post (Rebilda post; VOCO, Cuxhaven, Germany)	Dual-cure self adhesive luting agente Rely X Unicem (RXU; 3M Espe; Seefeld, Germany)
Machry et al., (2019)(10)	Evaluate the effect of surface treatment and silanization of resin composite on the bond strength of relined fiber posts cemented with self-adhesive resin-matrix cement.	In vitro/ Push-out test; Microtensile bond strength test (MTBS); Stereomicroscopy	Single-rooted bovine teeth	10% hydrofluoric acid; 35% hydrogen peroxide; air abrasion with alumina particle; silanization	Fiberglass posts, Whitepost DC N2 (FGM)	Resin Composite (Filtek Z250; 3M ESPE)

Prado et al., (2017)(7)	Evaluate the effect of different surface treatments on fiber post cemented with a self-adhesive system.	In vitro/ Push-out test; Stereomicroscopy; Fourier transform infrared spectroscopy (FTIR analysis); Scanning electron microscopy (SEM)	Post/cement specimens	Silanization; 24% hydrogen peroxide; Sandblasting with aluminum oxide particles; Hexamethyldisiloxane (HMDSO); Ammonia (NH3)	Fiber epoxy resin posts (Whitepost DC3, FGM, Joinville, SC, Brazil)	Resin-matrix cement (Rely X U200, 3M ESPE, St. Paul, MN, USA)
Mosharraf et al., (2013)(12)	Evaluate the effect of different surface conditioning on tensile bond strength of a glass fiber reinforced post to resin-matrix cement.	In vitro/ Push-out test	Human central incisors	Silanization after etching with 20% H_2O_2; Silanization after airborne-particle abrasion; Silanization	Glass reinforced fiber post (Hetco fiber post, Hakim Toos, Mashhad, Iran)	Adhesive composite resin-matrix cement (Panavia F2.0, Kuraray Medical Inc., Japan)

Samimi et al., (2014)(13)	Compare two pretreatments methods of a fiber post and to evaluate the effect of heat treatment to applied silane on the push-out bond strength for different levels of root.	In vitro/ Push-out test; Stereomicroscopy; Scanning electron microscopy (SEM)	Human canines	9.5% hydrofluoric acid (HF) etching and silane application; HF etching and heat-treated silane application and warmed post; 10% hydrogen peroxide (H_2O_2) etching and silane application; H_2O_2 etching and heat-treated silane application and warmed post	Prefabricated conical shape glass fiber posts #3 (FRC Postec Plus, Ivoclar Vivadent)	Self-etch resin-matrix cement (Panavia F2.0, Kuraray, Osaka, Japan)
Liu et al., (2014)(4)	Evaluate the influence of post surface pre-treatments on the bond strength of four different cements to glass fiber posts.	In vitro/ Micro push-out test; Stereomicroscopy	Maxillary human central incisors and canines	Group SA: Air abrasion (sandblasting with aluminum oxide particle); Group SI: Silanization; Group SS: Air abrasion plus silanization	Translucent Glassix glass fiber composite posts (size #4, diameters of 1.5mm; Harold Nordin SA, Chailly, Montreux, Switzerland)	4 dual cure resin-matrix cements

Valdivia et al., (2014)(20)	Evaluate the influence of different surface treatments of fiberglass post in their bond strength to root canal, using a push-out test.	In vitro/ Push-out test; Scanning electron microscopy	Bovine incisors	PA37% group (37% phosphoric acid); HF group (10% hydrofluoric acid gel); HP group (24% hydrogen peroxide solution)	Opaque and cylindrical/conical fiberglass posts (Exacto; Angelus, size 2, with 1.5mm in diameter and 17.0mm in length)	Self-adhesive resin-matrix cement Rely X Unicem (RXU; 3M Espe; Seefeld, Germany)
Druck et al., (2015)(22)	Evaluate the effect of fiber post surface treatments on push-out bond strength between fiber post and root dentin.	In vitro/ Push-out test; Optical microscopy; Scanning electron microscopy (SEM)	Bovine mandibular teeth	Silanization; Tribochemical silica coating	Fiber post system (White Post DC#3, FGM, Joinville, SC, Brazil)	2 resin-matrix cements: All Cem and Rely X ARC

Tian et al., (2012)(9)	Test retentive forces of different adhesive systems after cementation of glass-fiber posts with or without prior silanization of the post by using a pullout test and scanning electron microscope (SEM) observation to detect the mode of failure.	In vitro/ Scanning electron microscopy (SEM) analysis; Pull-out test	Mandibular central incisors	Silanization	Glass-fiber posts (ParaPost Taper Lux high-strength)	

Cadore-Rodrigues et al., (2019)(21)	Compare the effect of different surface treatments (pre-treatments and bonding agents) on the bond strength between glass-fiber post and composite resin, and the topographic alterations of the treated post surface.	In vitro/ Microshear test; Failure analysis (stereomicroscopy); Descriptive analysis (field emission scanning electron microscope, FE-SEM); Roughness test.	Glass-fiber blocks	35% hydrogen peroxide; Air abrasion with silica-coated aluminum oxide particles	Same manufacturing methodology of the commercially available glass-fiber posts (Whitepost DC, FGM Dental, Joinville, Brazil)	Composite resin cylinders (shade A2, Opallis, FGM)
Shori et al., (2013)(23)	Examine the interfacial strength between fiber post and composite, as core build-up material after different surface treatments of fiber posts.	In vitro/ Tensile bond strength test	Post/cement specimens	Silanization; 37% phosphoric acid etching plus silanization; 10% hydrofluoric acid etching plus silanization	Fiber posts (FIBRAPOST PLUS – Produits Dentaires SA Vevey-Switzerland)	Dual cure composite core material (Multi-core Flow – Ivoclar-Vivadent - Liechenstein)

4. DISCUSSION

4.1. Glass fiber-reinforced posts for endodontic treated teeth

Teeth with extensive coronary destruction usually require the use of intracanal retainers, which provide core retention and, consequently support for the dental prosthesis or coronary restoration, as see in Figure 2 (7,10). However, there are limitations concerning the remnant teeth tissues, restorative materials, and resin-matrix cements (10,12). Regarding the loss of teeth tissues, several studies show that a less conservative approach in the different stages of endodontic treatment (access cavity, chemical-mechanical instrumentation, filling, and groove preparation) introduce microstructural changes that jeopardize the long-term integrity of the tooth (14,23) The retention of teeth root intracanal posts luted with a resin-matrix cement may be influenced by the type of irrigation substances during the endodontic procedure, adhesive system, and surface treatment conditions (4,8). Intracanal retention issues are intensified in teeth root canal with oval shape, internal resorption, or caries (10). As a result, detachment or fracture of the endodontic posts can take place due to a poor fitting and retention to the tooth root canal surfaces. The lack of fitting also results in an excessive resin-matrix cement layer thickness which is susceptible to defects such as pores and micro-cracks from the cementation procedure and/or polymerization shrinkage (8,10). Defects are spot for stress concentration leading to a high risk of failures by fracture or detachment (10).

Teeth root intracanal posts can be manufactured from metallic, composite, and ceramic materials (1,3). Metal-based posts composed of stainless steel shows a high elastic modulus around 200 GPa while CoCr-based posts has an elastic modulus of around 240 GPa (1,14). Those values are quite high in comparison with the elastic modulus of around 20-40 GPa recorded for dentin tissues (1,14). Thus, a high mismatch in elastic modulus result in a concentration of stresses at the dentin to endodontic post interfaces (10,13). Fiber-reinforced epoxy-matrix posts were developed to overcome such mechanical issues (1,3). Fiber-reinforced composite posts consist of pre-silanized fibers held in direction and positioned by a highly cross-linked polymeric matrix (epoxy or methacrylate matrix) (3,18). The fibers can be produced from polyethylene, *Kevlar®*, glass, carbon, or quartz (5,20). Fibers usually have about 7 to 10 micrometers in diameter and are arranged in various configurations, such as braided, cross-linked, or longitudinally (15,24). The mechanical properties of the fiber-reinforced composite posts are determined by the fibers (length, orientation, and proportion) and polymeric-matrix (15). Despite the advantages of glass fiber-reinforced composite (GFRC) posts, several studies report detachment (debonding) and fracture are the major clinical complications (3,13,20,22). Debonding is dependent on the surface conditions; while the fracture behavior depends on the fiber arrangement (design, length, diameter), integrity of the adhesive system, and the resin-matrix cement layer (3,15,22).

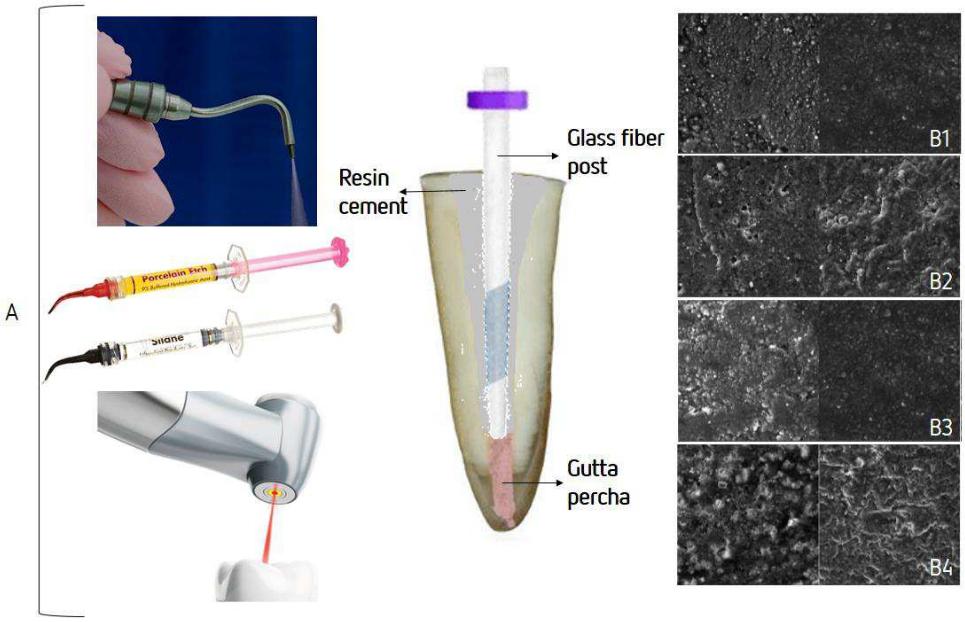

Figure 2. (A) Examples of different post surface treatments such as airborne particle abrasion (grit-blasting), hydrofluoric acid, silane coupling agent and laser irradiation. (B) Representative SEM images at x2000 magnification of (B1) non-treated surface and surfaces treated by (B2) 10% hydrofluoric acid treatment, (B3) 35% hydrogen peroxide treatment, and (B4) airborne particle abrasion treatment. Adapted from (10).

GFRC posts have a similar elastic modulus values to those recorded on dentin (6,9–11,13,17). Such a characteristic promotes favorable stress distribution and reduces the prevalence of catastrophic failures (root fracture beneath the bone level and longitudinal fractures) (11,17,23). Moreover, GFRC is an anisotropic material since it reveals different physical properties when submitted to loading from several directions (16). In contrast, the low strength and absence of radiopacity of some posts are still considered as disadvantages for teeth rehabilitation (6). Regarding GFRC posts are passively retained inside the teeth root canal, the application of adhesive resin-matrix cements has encouraged studies on adhesion and related procedures (1,11).

The choice of the resin-matrix cement, adhesive system, and the cementation procedure are important steps for the success of the GFRC post retention. Various resin-matrix cements and adhesive approaches have been proposed to bond GFRC posts to the teeth root dentin surfaces (4,17,22). Currently, the cementation procedure is based upon the previous use of an etch-and-rinse or self-etch adhesive system followed by a low viscosity resin-matrix cement composite (17,22). The cementation shows a high sensitivity since it comprises a multi-step clinical procedure, and consequently that may compromise the bonding effectiveness (2,8). Self-adhesive cement was developed with the purpose of simplifying the cementation process by assembling all the components into a single product and overcome the technique sensitivity of multi-step systems (17,22). The chemical composition of the resin-matrix cements varies according to the manufacturers although that include the following methacrylate-based monomers: UDMA, TEGDMA, Bis-GMA, and HEMA (4,17). The inorganic particles provide an increase in strength and viscosity of the resin-matrix cement. The following inorganic particles can be found in the resin-matrix cements: barium silicate, ytterbium trifluoride, colloidal silica, and zirconium silicates (4,17,25). These luting agents do not require any pretreatment of the tooth surface and their application is accomplished through a single clinical step. (2,7). That occurs due to the presence of acid monomers in its structure, which partially dissolve the smear layer and allow cement to infiltrate dentinal tubules, resulting in macro and micro-scale retention. The hybridization on the root dentin tissue that occurs after smear layer removal by etching and the adhesive polymerization are responsible for the adhesiveness of dual-polymerizing resin-matrix cements (17). However, adhesive systems are strongly dependent on the degree of residual fluids (i.e. water) in the dentin tissue (17). On the polymerization of resin-matrix cements, two modes are currently utilized for the endodontic post retention: self- and dual-polymerizing (17,22). Dual cure resin-matrix cements are the most commonly recommended, because they allow a proper control of the working time to guarantee the entire polymerization of the resin-matrix cement (17,22). Also, the resin-matrix cement has proper flowable properties, providing a thin film of resin-matrix cement into micro-scale regions. Dual-polymerizing resin-matrix cements associated with previous dentin conditioning (2- or 3-step etch-and-rinse adhesive systems) have achieved the highest bond strength values (17,22).

4.2. Retention of Teeth Root Intracanal Posts

Based on the avaible data on the bond strength of the endodontic post surfaces to resin-matrix cements, the working hypothesis was confirmed. In fact, the synergistic effect of combined physical and chemical methods of surface modification provided an enhanced adhesion of the endodontic post surfaces. Physical and chemical methods that mechanically modified the endodontic post surface increased the bond strength of the endodontic post to the resin-matrix cements, as seen in Table 1.

An *in vitro* study evaluated the effect of surface treatment and silanization of glass fiber-reinforced resin composite (GFRC) posts on the bond strength of fiber posts cemented with self-adhesive resin-matrix cement using a push-out and a microtensile bond strength test (10). For such study, 80 single-rooted bovine teeth were endodontically treated and then the GFRC posts were adjusted to the tooth root canals. The surface treatment of the GFRC posts was performed according to 4 different experimental conditions: no conditioning as control, 10% hydrofluoric acid, 35% hydrogen peroxide, or airborne particle abrasion with alumina (Al_2O_3) particles. Half of the specimens were silanized while another half was assessed without silanization. Also, groups specimens were thermocycled and stored prior to the mechanical assays. Thus, the aging promoted by thermal cycling and storing decreased bond strength of each group of endodontic posts to resin-matrix cements. Considering the aged groups, air abrasion promoted the highest values and silanization improved bond strength for all treatments except air abrasion (10). Another *in vitro* study evaluated the influence of post surface conditioning methods and aging effects on the retention and microleakage of adhesively luted GFRC posts (8). Seventy-two endodontically treated single-rooted teeth were prepared and submitted to 3 different surface treatments for post cementation, namely: non-treated; 36% phosphoric acid (36%) etching and airborne-particle abrasion. Subgroups were then allocated for 3 different experimental conditions regarding aging and adhesive conditioning. The endontic posts were luted with resin-matrix cement and post bond strength was measured at a cross head speed of 2mm/min. It was concluded that treating the surface of the posts with phosphoric acid for

15 seconds before cementation produced no significant improvement in post retention. The findings revealed the highest values of bond strength after airborne-particle abrasion of the GFRC posts even though the aging effect (8).

Another study examined the interfacial strength between GFRC posts and resin-matrix composite, as core build-up material after different surface treatments of the GFRC posts (23). Twenty GFRC posts were split into 4 groups according to different surface treatment: non-treated (control group), silanization group, 37% phosphoric acid plus silanization and 10% hydrogen peroxide plus silanization. A core of dual cured resin-matrix composite resin was built around the GFRC post and the tensile bond strength of each specimen was measured under Universal Test Machine at the cross head speed of 3mm/min. Among the four experimental groups, GFRC surfaces treated with 10% hydrogen peroxide promoted the highest bond strength values of the endodontic post to the resin-matrix cement. Also, the GRFC organic matrix provided an enhancement of the silanization procedure (23). A similar study corroborate the above-mentioned findings and therefore revealed an increase in the push-out bond strength of GFRC posts to resin-matrix cements after a previous surface treatment with 20% hydrogen peroxide etching followed by silanization of the GFRC posts (12).

Some studies showed that airborne particle abrasion on the GFRC surface of fiber posts increased the bond strength of posts adhesively luted with dual cure resin-matrix cement, especially when combined with silanization (4,21). The use of airborne partricle abrasion provides a micro-scale texturized and retentive surface leading to an increase in the roughness and in the total surface area for adhesion (4). On grit-blasting, the use of silica as abrasive particles results in the embedment of silica into the GFRC organic matrix and the surface modification for further chemical modification by hydrofluoric acid etching and/or silanization procedure (21). Significantly higher bond strength values were found for airborne-particle-abraded posts when compared to posts without treatment or etched only with phosphoric or hydrofluoric acid treatment (8). Airborne particle abrasion has provided the highest bond strength results both with or without silane application (18,21). Studies have found a large variation in the surface characteristics of GFRC posts regarding the exposure of glass fibers to the surface treatment (4). Other studies showed that the synergistic effect of hydrofuloric acid etching and silane application on the bond strength of GFRC posts to resin-matrix cement; although, the silanization showed no effect after hydrogen peroxide or airborne particle abrasion procedures (10,20). The association of surface treatment and silanization (silane coupling agent application) is able to improve the retention into root canals compared to the solely silanization deposition method.

Two *in vitro* studies evaluated the effect of different surface modification methods on the adhesion of GFRC posts to self adhesive luting agent and radicular dentin using a push-out test (11,18). Both studies divided the single-rooted human teeth into 5 groups. Control group, grit-blasting group and 9% hydrofluoric acid group were present in both studies. However, one study also assessed the effect of a Neodymium:Yttrium-Aluminum-Garnet (Nd:YAG) laser irradiation group, that was subdivided according the pulse duration of 180 or 320 µs (18). The other study focused on the functionalization of the surfaces by silanization or dichloromethane (M10) conditioning method (11). The first study concluded that the highest bond strength was recorded for the grit-blasted surfaces while the lowest values was recorded for non-treated surfaces (18). Also, groups of specimens treated with dichloromethane showed significantly higher bond strength to resin-matrix cements when compared to the other surfaces (11,18).

The bond strength of GFRC post to root canal has been reported as significantly higher on the 24% hydrogen peroxide treatment when compared with other surface modification methods such as 70% ethanol, 37% phosphoric acid, and 10% hydrofluoric acid (20). Another other study showed that with 10% hydrogen peroxide has significantly enhanced the tensile bond strength between GFRC post and resin-matrix composite core when compared to the other groups (23). The etching effect of hydrogen peroxide in different concentrations depends on its capability to partially dissolve the resin matrix, thereby breaking the epoxy resin bonds through the substrate oxidation pathway (21,23). Certain chemical compounds such as hydrogen peroxide (H_2O_2), methylene chloride, potassium permanganate, hydrofluoric acid (HF), and silane coupling agents have been used to improve the bond strength between GFRC posts and resin-matrix composite core materials. The application of HF acid did not improve shear bond strength between resin-matrix composite and GFRC posts; although a potassium permanganate treatment did increase bond strengths However, findings revealed also a detrimental effect of HF acid etching on the integrity of the glass fiber surfaces of GFRC posts (8,10,11,13,18). Hydrofluoric acid in combination with a silane-coupling agent is often applied to enhance the bond strength between resin-matrix cements and glass ceramics. Because silica and quartz present in fiber posts are comparable in chemical structure with ceramic materials, hydrofluoric acid has recently been proposed for etching GFRC posts. It is intended to promote a rough pattern on the surface, which allows the micromechanical interlocking of the resin-matrix cement and composite (11,18,20).

Although several studies have supported the use of silane coupling agents to form a strong bond between the resin-matrix composite and the GFRC post, there are also several different points of view on the efficiency of the GFRC post silanization (9,13). Silanization has the advantage of being a convenient chairside operation, but its effect on bond strength of GFRC to resin-matrix cements is controversial. Thus, silane application is susceptible to failures due to the sensivity of the technical procedure. Numerous factors influence the effectiveness of the silane layer, such as its chemical composition, pH, presence of solvent, molecular size, and the application method (13). Silane coupling agent is a hybrid organic-inorganic compound that can mediate adhesion between inorganic and organic molecules through intrinsic dual reactivity capability to increase surface wettability, surface energy of the GFRC post. That establishes a chemical bridge with OH-covered substrates, such as glass fibers, and carbon-based materials (i.e. resin-matrix composites) (4,7,13,20,22). Contrarily studies reported that the use of a silane coupling agent alone did not increase such bond strength values of GFRC to resin-matrix cements (4,11,12,21) although the specific effect of the silane coupling agent in improving bond strength of metallic and ceramic materials has been recognized. The silane coupling agent enhaces the adhesion through the chemical reaction with silica in glass fiber and the resin-matrix cement but cannot provide a good combination with the epoxy resin matrix due to the highly crosslinked nature of the epoxy-based polymeric matrix (23). In this way, a lack of adhesion can occur between the organic matrix of the GFRC post and the methacrylate-based organic matrix of the resin-matrix cement or resin composite (4,20).

Nevertheless, the bond strength of GFRC fiber posts to resin-matrix cements also depends onf the tooth root region (11,12,20). The highest bond strength values were recorded for the coronal region, while low bond strength values were recorded in the middle and apical third (11,12,20). That could be attributed to the following factors: (i) the clinical complexity in visualization and access to the apical level; (ii) limitation in the flow of the resin-matrix cement; (iii) lack of control of the resin-matrix cement layer thickness; and (iv) suscetibility to the formation of bubbles and voids in the resin-matrix cement layer prior to polymerization (11).

4. CONCLUSIONS

The outcomes from the selected studies revealed differences on the bond strength of teeth root intracanal posts to the resin-matrix cements. The following concluding remarks can be drawn as follow:

- Airborne abrasion promoted the physical modification of the glass fiber-reinforced (GFRC) posts by increasing roughness and establishing a mechanical interlocking of the resin-matrix cement. That provided the highest bond strength values of GFRC posts to resin-matrix cements when compared to other solely surface modification methods;

- Physical methods, such laser irradiation, are currently utilized to promote an increase in the roughness and surface area for adhesion. It can be an alternative method to grit-blasting once the laser approach has the advantage of controlling the surface texturizing patterns;

- Etching with hydrogen peroxide was more effective than silanization in determining surface modification and increase bond strength of GFRC posts to resin-matrix cements. Some studies revealed that silanization procedure after etching or grit-blasting promoted an increase in the bond strength of GFRC posts although other studies did not show any further beneffical effect.

- Combining chemical and physical surface modification methods can provide the most promising adhesion-enhancing mechanism of GFRC posts to resin-matrix cements. Further studies are required to evaluate different combinations surface modification methods for endodontic post surface for enhanced adhesion to resin-matrix composite cements and restorative materials. That can decrease the risk of clinical failures by fracture and detachment of endodontic posts.

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