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Surface modification of intracanal post by using hydrogen peroxide for endodontically treated teeth: an integrative review

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Camilia Marie Dominique Tuttle

Dissertação conducente ao Grau de Mestre em Medicina Dentária (Ciclo Integrado)

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Trabalho realizado sob a Orientação de Professor Valter Raul da Cunha Fernandes e Co-Orientador Professor Doutor Júlio C. M. Souza

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Resumo

Na reabilitação de dentes com tratamento endodôntico com recurso a meios de retenção intracanalar, existem várias lacunas relativas à adesão. A adesão dos cimentos/adesivos à dentina está amplamente estudada e atinge valores clinicamente aceitáveis, sendo que, muitas vezes as falhas adesivas, ocorrem entre o espigão e o cimento. O objetivo principal deste estudo foi realizar uma revisão integrativa sobre a modificação da superfície do espigão intracanalar com o uso de peróxido de hidrogênio na reabilitação radicular de dentes. Uma pesquisa eletrónica foi realizada na base de dados PubMed, utilizando combinações das palavras-chave e abrangendo artigos entre 2010 e 2020 de idioma Inglês.

Dos 13 estudos selecionados, 12 investigaram a resistência de união entre o espigão de fibra e o cimento resinoso após o tratamento de superfície do espigão, 5 artigos analisaram falhas usando um estereomicroscópio, 7 estudos analisaram a topografia de superfície usando SEM. O condicionamento com H_2O_2 alterou a morfologia da superfície dos espigões de fibra ao dissolver seletivamente a matriz sem danificar as fibras, originando uma área de superfície maior de fibras expostas disponível para reagir com as moléculas de silano. Valores mais elevados foram registados de resistência à união entre os espigões pré-tratado com H_2O_2 aos materiais do núcleo de resina.

Os pré-tratamentos na cadeira ainda são considerados uma etapa sensível à técnica. No entanto, os tratamentos com peróxido de hidrogênio parecem promissores devido à sua aplicação simples e económica, resultando na melhoria da resistência de união aos espigões de fibra.

PALAVRAS CHAVE - Peróxido de hidrogênio, Espigão endodôntico, Espigão intraradicular, Espigão de fibra, Espigão reforçado com fibra, superfície.

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Abstract

In the rehabilitation of teeth with endodontic treatment using intracanal retention means, there are several gaps regarding adherence. The adhesion of cements/adhesives to dentin has been widely studied and reaches clinically acceptable values, and adhesive failures often occur between the post and the cement. The main aim of this study was to conduct an integrative review on the surface modification of intracanal post by using hydrogen peroxide for teeth root rehabilitation. An electronic search was performed in the PubMed database, using combinations of keywords and covering articles between 2010 and 2020 in English.

Of the 13 selected studies, 12 investigated the bond strength between the fiber post and the resin cement after the surface treatment of the post, 5 articles analyzed failures using a stereomicroscope, 7 studies analyzed the surface topography using SEM. Etching with H_2O_2 altered the surface morphology of the FRC post by selectively dissolving the matrix without damaging the fibers, resulting in a larger surface area of exposed fibers available to react with silane molecules. Higher bond strength values were recorded between the H_2O_2 pretreated posts to the resin core materials.

Chairside post pretreatments are still considered a technique-sensitive step. However, treatments with hydrogen peroxide seem promising because of their simple, not expensive application resulting in the improvement of bond strength to fiber posts.

KEYWORDS - Hydrogen peroxide, endodontic post, Intraradicular post, Fiber post, Fiber-reinforced post, Surface.

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List of acronyms and abbreviations

FRC – Fiber-reinforced composite

GPa – Gigapascal

MPa – Megapascal

SEM – Scanning electron microscope

BS – Bond strength

TBS – Tensile bond strength

SBS – Shear bond strength

POBS – Push-out bond strength

H_2O_2 – Hydrogen peroxide

H_3PO_4 – Phosphoric acid

NH3 – Ammonia

HDMSO – Hexamethyldisoloxane

HF – Hydrofluoric acid

CH_2Cl_2 – Methylene chloride, dichloromethane

$KMnO_4$ – Potassium permanganate

C_3H_6O – Acetone

C_2H_6O – Ethanol

C_3H_8O – Isopropanol

C_4H_8O – Tetrahydrofuran

UDMA – Urethane Di-Methacrylate

G – Group

1. Introduction

Endodontically treated teeth that lack coronal tooth structure due to severe damage by decay, previous restorations or excessive wear are exposed to shearing chewing forces and commonly need the placement of a post to ensure adequate retention of a core foundation.[1,2] Cast metal posts and cores have been traditionally used in these situations to provide the necessary retention for the subsequent prosthodontic restoration. The main disadvantage of these structures was the concentrated stresses in zones that are vital to the tooth root. Many authors believe that the use of a dental post with a Young modulus higher than the dentin can create stresses at cement interfaces and can cause the separation of the post or a root fracture [3]. Recently, the use of FRC posts in the restoration of endodontically treated teeth has increased in popularity. First introduced in 1990, they were rapidly accepted by clinicians, and are currently perceived as promising alternatives to cast metal posts, as their elastic moduli are similar to that of dentin, producing a favorable stress distribution closer to that produced in an intact tooth, reducing the risk of root's catastrophic fractures. [2,4,5]. Moreover, using FRC posts provides superior aesthetics for endodontically treated anterior teeth, easier removal, and less treatment visits. [2,6]

The clinical success of a post-and-core restoration depends on the post, the composite resin selected and the quality of the post and- core interface, where materials of different compositions are in intimate retentive contact [2]. It has been shown that the establishments of reliable bonds at the root-post-core interfaces are important because it would effectively transfer stress under functional loading [1,7]. In vitro and in vivo research indicates that failure of fiber post-and-core restorations often occurs because of debonding between the fiber post-resin and/or resin-root canal dentin interfaces as a result of inadequate bond strength [2]. The problem of adhesion between the FRC posts and the reconstitution composites would result from the absence of chemical bond between the epoxy resin matrix of the posts and the composite resins based on methacrylate.

In an attempt to maximize resin bonding to FRC posts, several surface treatments have been recently suggested[5]. These are common methods for improving the general adhesion properties of a material, by facilitating chemical and micromechanical retention between different constituents. [8] The application of a silane coupling agent is used as adhesion promoter in fiber post/core units. The most common used in dentistry is 3-methacryloxypropyltrimethoxysilane. Its working mechanism is based on enhanced surface wettability with chemical bridge formation between the resin matrix of the adhesive resin or composite core and the glass phase of the post. [1] But for silane applications, related articles have reported conflicting results. Since silane (chemical surface treatments) alone cannot create a strong bond between fiber posts and resin cements, a combination protocol, which consists of micromechanical surface roughening and subsequent silane application, is commonly used in clinical practice. [9,10] Although, sandblasting and hydrofluoric acid etching are used to improve the bonding of fiber posts to resin cement, these techniques can damage the fibers and affect the post integrity. [10] Other chemical treatments, more conservative, have been proposed to improve bonding between fiber posts and composite resin core materials like hydrogen peroxide, potassium permanganate, and sodium ethoxide. Hydrogen peroxide is commonly used in dental practice, mostly for dental bleaching, and is easy and safe to utilize. [1] He is considered an acceptable mild etchant for clinical use. A reliable theory proposes that hydrogen peroxide shows an etching effect by breaking epoxy resin bond by hydrogen peroxide oxidation through a mechanism of substrate oxidation. [9]

2. Objectives and hypotheses

The main aim of this study was to perform an integrative review on the influence of the hydrogen peroxide conditioning on tooth intracanal posts and on the bond strength between resin composite and FRC post. The null hypothesis was the etching with hydrogen peroxide didn't modified the surface of the fiber post and didn't affect the surface strength between fiber posts and composite resins core build-up.

3. Method

3-1 Information sources and search strategy

A literature search was performed on PubMed (via National Library of Medicine) considering such database includes the major articles in the field of dentistry and biomaterials. The following combination of search terms were applied in this study: "*hydrogen peroxide*" AND "*surface*" AND "*endodontic post*" OR "*intracanal post*" OR "*intraradicular post*" OR "*fiber-reinforced*" OR "*fiber post*". The inclusion criteria involved articles published in the English language, from 2010 to 2020, reporting the effects of the hydrogen peroxide conditioning on the surface modification of tooth intracanal posts and on the bond strength between post and resin cement. The eligibility inclusion criteria used for article searches also involved: in vitro studies; meta-analyses; randomized controlled trials; prospective cohort studies and studies based on glass, quartz or carbon fibers endodontics posts. The exclusion criteria were the following: papers without abstract, systematic reviews, bibliography review, theses and dissertations; articles whose title and / or abstract do not fit the theme; all papers in a foreign language (not in the English language), where the full text was not available; studies testing endodontic posts other than fiber, i.e., metal posts and studies with no control group. Also, a hand-search was performed on the reference lists of all primary sources and eligible studies of this systematic review for additional relevant publications. Studies based on publication date were not restricted during the search process.

3-2 Study selection and data collection process

The articles retrieved by the search process were evaluated in three steps. Studies were primarily scanned for relevance by title, and the abstracts of those that were not excluded at this stage were assessed. Three of the authors (JCMS, VF, CT) independently analyzed the titles and abstracts of the retrieved, potentially relevant articles meeting the inclusion criteria. The total of articles was compiled for each combination of key terms and therefore the duplicates were removed using Mendeley citation manager (Ed. Elsevier). The second step comprised the evaluation of the abstracts and non-excluded articles, according to the eligibility criteria on the abstract review. 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 analyzed concerning the purpose of this study. At last, the eligible articles received a study nomenclature label, combining first author names and year of publication. The following variables were collected for this review: authors' names, publication year, aims, type of study, study design, post type, composite core material, type of analysis and main outcomes. PICO question was adjusted to the issue where "P" was related to the specimens, while "I" referred to the methods of analyses.

4. Results

The literature search identified a total of 147 articles in PubMed, as shown in Fig. 1. Duplicates were removed, and then titles and abstracts of 83 articles were independently evaluated by three authors. A total of 67 articles was excluded because they did not meet the inclusion criteria. The remaining 16 potentially relevant studies were then evaluated. Of those studies, 3 were excluded because they did not provide comprehensive data considering the purpose of the present study. Thus, 13 studies were included in this review.

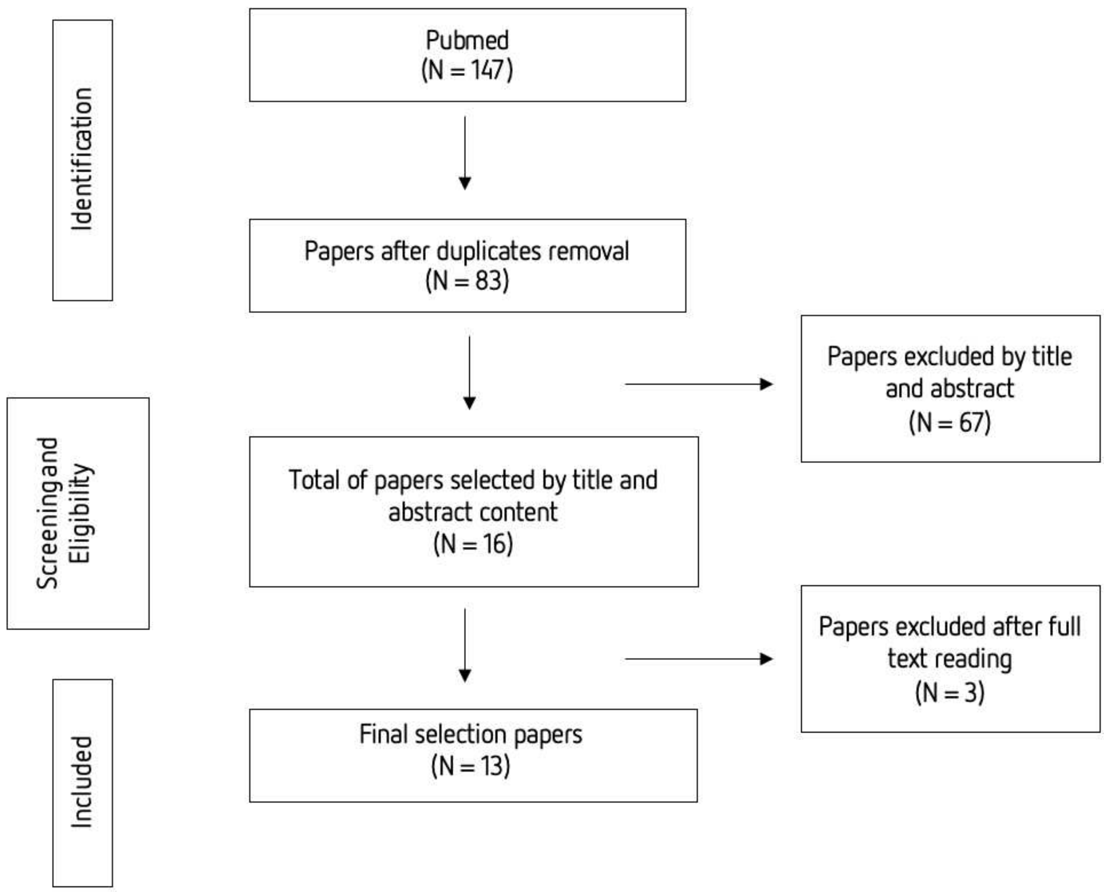

Figure 1 – Prisma flow diagram of the search strategy

Regarding the publication period, the year 2013 registered the largest number of articles on the subject in question, with 4 articles (30.7%), the year 2017, 2014, 2012 and 2011 with 2 articles each (15.4%) and, finally the year 2016 with one article (7.7%).

As for the type of studies of the articles evaluated, all studies are in vitro studies.

Of the 13 selected studies, 12 investigated the interfacial strength between fiber post and composite after different surface treatment using different tests with universal testing machine (Fig. 2), 5 analyzed types of failures using a stereomicroscope and 7 studies analyzed surface topographical using SEM. The retrieved data on the resin-matrix cement, intracanal post and surface modification are given in Table 1. The most relevant results were found in each study were subsequently extracted and organized in a table in order to provide a more dynamic, interactive and structured analysis.

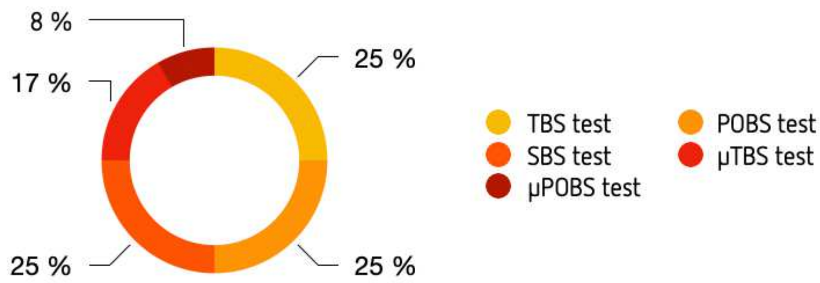

Figure 2 - Distribution by type of BS tests

In the included studies, hydrogen peroxide was used for the pre-treatment of posts at concentrations varying from 6% to 50%; 10% and 24% being the most cited; in application time of 5 to 20 min. The concentrations and times of applications used were identified in Fig. 3.

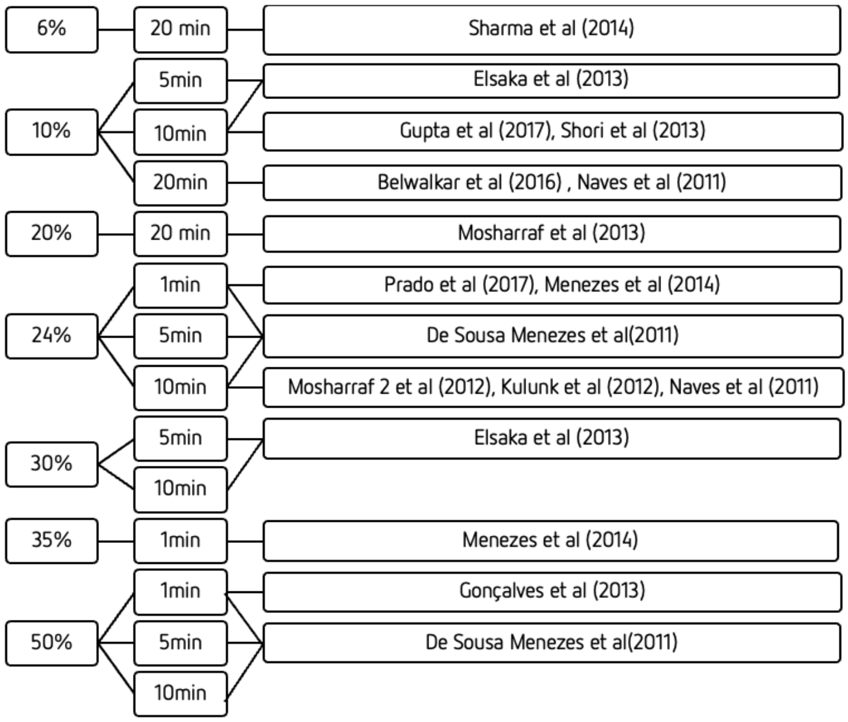

Figure 3- H_2O_2's Concentration and times applications

The major findings are drawn as follow:

- The use of silanes to enhance bond strength between composite resin and the fiber post still remains controversial. Two studies [12,14] reported an increasing significantly effect of silanization on the bond strength between the post and resin cement compared to untreated controls, whereas other studies [1,10,13] did not detect any significantly difference between silanated and untreated control posts.
- SEM examination showed that application of surface pretreatment affected the surface morphology of fiber posts. Non-etched post presents a relatively smooth surface without fiber exposure. Hydrogen peroxide may induce effectively a dissolution of the resin matrix, exposing the fiber content which are then available to be silanated. [1, 5, 14, 16, 17, 18,]. The exposed fibers were not damaged or fractured by H_2O_2 unlike treatment of fiber post with silica coating with 30 mm SiOx and air abrasion with 50 mm Al_2O_3 particles. [18]

- Surface treatment of FRC post affect the bonding strength. Seven studies concluded that the pre-treatment of FRC posts using H_2O_2 followed by silanization resulted in increased bond strengths to resin core materials. [10,11, 12, 15, 16, 18, 20] Two other studies [13,14] were inconsistent with the evidence found in these studies. They reported that the use of H_2O_2 alone did not increase the bond strength. Stereomicroscope showed that the predominant fracture pattern was adhesive failure between post and core material. [1, 13,18, 20]
- The concentration and time of application of H_2O_2 as influencing factors in increasing the bonding strength are controversial. [1, 17] Sharma et al [1] indicate that use of 10% H_2O_2 for 5 or 10 min did not have a significant effect on the post/core bond strength unlike 30% H_2O_2 for 5 or 10 min as compared with the control and silanization groups. However, De Sousa Menezes et al [17], them, reported that 24% of H_2O_2 applied to the glass fiber posts for 1 min generated bond strength to resin cores similar to that obtained with a higher concentration, 50% of H_2O_2, applied for longer times (5 and 10 min).
- Menezes et al [19] demonstrated that for immersion of the post into 24% and 35% H_2O_2 solutions, there was no difference between concentrations. The two effectively improves the bond strength of resin composite to the post although using 35% H_2O_2 resulted in higher bond strength (18.7±3.7; 21.1±4.1 MPa). When the solutions were applied over the post surface, the application of 24% H_2O_2 failed to effectively expose the glass fibers and effectively improve bond strength (13.4±3.0 MPa), which showed similar values to the control (without treatment) (11.0±4.1 MPa) unlike application of 35% (21.0 2.8 MPa).

Author (year)	Purpose	Surface modification	Intracanal post	Resin matrix cement	Methods	Main Outcomes
Gupta et al (2017) (11)	Evaluate the effect of various post-surface treatments on the interfacial strength between the posts and composite materials that are used for building up the core portion.	G1: 37% H_3PO_4 for 5min + silane coupling agent G2: $KMnO_4$ for 10min + silane coupling agent G3: 10% H_2O_2 for 10min + silane coupling agent G4 (control group): silane coupling agent	Clear post-tapers (Dentmark Co.)	--	TBS Test (--)	Mean bond strength (MPa) G1: 15.02 G2: 20.46 → Highest bond strength G3: 17.22 G4: 10.82 → Lowest bond strength Chemical treatment protocol significantly affected the mean bond strength of the post and core restoration.
Mosharraf et al (2013) (10)	Evaluate the effect of different surface conditioning on tensile bond strength (TBS) of a glass fiber reinforced post to resin cement.	G1: 20% H_2O_2 for 20min + silane coupling agent for 60s G2: air bone particle abrasion + silane coupling agent for 60s G3: silane coupling agent for 60s G4 (control group): No conditioning	Glass reinforced fiber post (Hetco fiber post; Silicon dioxide 55%, calcium oxide 20%, baron oxide 12%, aluminium oxide 14%, sodium oxide 1%, potassium oxide 1%, magnesium oxide 4%; Hakim Toos, Mashhad, Iran)	Adhesive composite resin cement (10-MDP, DMA, Bis-MPEPP (22wt%); silanized barium glass fillers (78wt% fillers) - Panavia F 2.0, Kuraray Medical Inc., Japan)	POBS test (Walt + Bai AG Testing Machines Industriestrass 4, Löhningen, Switzeréland)	Mean bond strength (MPa) G1: Coronal: 21.5365 → Highest bond strength Middle: 19.0880 Apical: 9.1230 G2: Coronal: 18.4550 Middle: 10.1700 Apical: 6.5450 G3: Coronal: 20.5310 Middle: 14.5660 Apical: 6.3020 G4: Coronal: 9.7650 Middle: 9.0770 Apical: 5.5850 →Lowest bond strength Different surface treatments and root dentin regions had significant effects on TBS. The interaction between surface treatments and root canal regions had no significant effect on TBS.

						Significant difference among H2O2 + Silane Group and other three groups.
Shori et al (2013) (12)	Examine the interfacial strength between fiber post and composite, as core build-up material after different surface treatments of fiber posts.	G1 (negative control group): No conditioning G2 (positive control group): silane coupling agent for 60s G3: 37% H_3PO_4 for 15s + silane coupling agent for 60s G4: 10% H_2O_2 for 10 min + silane coupling agent for 60s	Glass reinforced fiber post (65%reinforced, UDMA resin 20%. (FIBRAPOST PLUS- Produits Dentaires SA Vevey Switzerland)	Dual cure composite core material (Bis-GMA, urethane dimethacrylate, and triethylene glycol dimethacrylate. (28wt%), Barium glass, ytterbium trifluoride, Ba-Al-fluorosilicate glass, and silica fillers (72wt% fillers), Multi-core Flow – Ivoclar-Vivadent-Liechenstein)	TBS test (--)	Mean bond strength (MPa) G1: 3.99 → Lowest bond strength G2: 7.68 G3: 10.28 G4: 12.38 → Highest bond strength 10% Hydrogen peroxide had a marked effect on micro tensile bond strength values between the tested materials.
Mosharraf 2 et al (2012)(13)	Evaluate the effects of some surface treatment methods on the tensile bond strength (TBS) between fiber post and composite core.	G1: silane coupling agent for 60s G2: sand- blasted with 50 µm aluminum oxide particles for 10s G3: 24% H_2O_2 for 10min G4 (control group): No conditioning	Glass reinforced fiber post (Exacto Fiber Post; Epoxy 20%; Glass 80%; Angelus, Londrina, PR, Brazil) Hetco fiber post (Silicon dioxide 55%, calcium oxide 20%, baron oxide 12%, aluminium oxide 14%, sodium oxide 1%, potassium oxide 1%, magnesium oxide 4%; Hakim	Clearfil Photo core Composite (Bis-GMA, TEG-DMA (30wt%), silanated barium glass filler (70wt% fillers), (Clearfil esthetic cement, Kuraray Medical Inc., Tokyo, Japan)	TBS test (Electromechanical low-capacity testing Machines, walter + bai, AG, Switzerland)	Mean bond strength (MPa) Exacto Fiber G1: 14.1550 → Highest bond strength G2: 12.9400 G3: 9.8800 → Lowest bond strength G4: 12.4450 Hetco Fiber G1: 14.3875 → Highest bond strength G2: 12.8762 G3: 9.8150 → Lowest bond strength G4: 11.5138 Different surface treatments had a significant effect on TBS. Different brands of post and interaction between the brand of post and surface treatment had no significant effect on TBS.

			Toos, Mashhad, Iran)		Failure analysis: Stereomicroscope (MBC, 10 Number: n 9116734 SF- 100B, LOMO, Russia)	Significant difference between H2O2 and Silane groups and between H2O2 and Sandblast groups but other groups had no significant differences. Two types of fracture mode: Adhesive between post and core and cohesive in the core material. None of the test groups demonstrated cohesive failure within the post material. Silane and Sandblast groups: most of the fractures were cohesive H2O2 and control groups: predominant fracture pattern was adhesive failure
Prado et al (2017)(14)	Evaluate the effect of different surface treatments on fiber post cemented with a self-adhesive system.	G1 (control group): No conditioning G2: silane coupling agent 60s G3: 24% H_2O_2 for 1 min G4: sandblasting with aluminum oxide for 30s G5: NH3 plasma for 3min G6: HMDSO plasma for 15min	Glass reinforced fiber post (White Post DC3; 80% glass fiber and 20% epoxy resin; FGM, Joinville, SC, Brazil)	Resin cement (Methacrylate monomers containing phosphoric acid groups, methacrylate monomers (28wt%), silanated fillers, alkaline fillers (72wt% fillers), RelyX U200, 3M ESPE, St. Paul, MN, USA)	POBS test (DL 1000, Emic, São José dos Pinhais, PR, Brazil) Failure analysis: Stereomicroscope (SMZ800, Nikon Instruments, São Paulo, SP, Brazil)	Mean bond strength (MPa) G1: 9.648415 G2: 15.935862 → Highest bond strength G3: 9.400132 → Lowest bond strength G4: 13.133998 G5: 14.441980 G6: 14.441980 Silane, blasting, NH3 plasma and HMDSO plasma showed higher POBS when compared to control and similar among them. H2O2 treatment showed POBS values statistically similar to control. Failure were predominantly cohesive post and cement in all groups.

					Surface topographical analysis: SEM evaluation (JSM 6460 LV (JEOL, Tokyo, Japan).	Control, silane and HMDSO groups evidenced similar topography, with slightly removal of epoxy resin after treatment. Blasting and H2O2 showed the degradation of the epoxy resin matrix and exposed fibers with no apparent fiber damage. NH3 group presented smoother surfaces without remarkable change in the fiber exposition.
Belwalkar et al (2016)(15)	Compare the effect of four chemical surface treatments of a GFP on adhesion with a resin-based luting agent.	G1: (control group) silane coupling agent for 60s G2: 20% $KMnO_4$ + silane coupling agent for 60s G3: 4% HF for 60s + silane coupling agent for 60s G4: 10% H_2O_2 for 20 min + silane coupling agent for 60s	Glass reinforced fiber post (D. T. Light-Post; Quartz 60%, Resin epoxy 40%; Bisco, Inc., Schaumburg, IL, USA)	Calibra light shade base and regular viscosity catalyst (Dentsply, Caulk, Milford, U.S.A)	SBS test (Instron 4467; Instron Corp, Norwood, Mass)	Mean bond strength (MPa) G1: 16.421 → Lowest bond strength G2: 27.233 → Highest bond strength G3: 21.781 G4: 19.037 The control group values were low which showed a less influence of silane as a surface treatment. Highly significant difference between the tested groups. Combination of chemical pre-surface treatments followed by silanization significantly enhanced the bond strength at the post/adhesive interface.
Sharma et al (2014)(16)	Evaluate effect of newer chemical solvents, i.e., 6% hydrogen peroxide and 37% phosphoric acid on shear bond strength of glass fiber posts to core material.	G1: (control group) silane coupling agent for 60s G2: 6% H_2O_2 for 20 min + silane coupling agent for 60s G3: 37% H_3PO_4 for 20s + silane coupling agent for 60s	Glass fiber post (--)	--	SBS test (--) Surface topographical analysis: SEM evaluation	Mean bond strength (MPa) G1: 19.41 → Lowest bond strength G2: 25.52 → Highest bond strength G3: 21.14 Surface treatment with hydrogen peroxide had greatest impact on the post surface followed by 37% phosphoric acid and silane. The post surface morphology was modified, and surface treatments dissolved the epoxy resin matrix and exposing the quartz and glass fibers in the posts.

					(LEO 430, LEO Electron Microscopy Ltd, Cambridge, UK)	G1: Less exposed fibers after treatment G2: More exposed fibers after treatment G3: More exposed fibers compared to G1(control group) but less exposed fibers in comparison to G2.
De Sousa Menezes et al (2011) (17)	Evaluate the effect of concentration and application time of hydrogen peroxide on the surface topography and bond strength of glass fiber posts to resin cores.	G1: (control group): No conditioning G2: 24 % H_2O_2 for 1min + silane coupling agent for 60s G3: 24 % H_2O_2 for 5min + silane coupling agent for 60s G4: 24 % H_2O_2 for 10min + silane coupling agent for 60s G5: 50 % H_2O_2 for 1min + silane coupling agent for 60s G6: 50 % H_2O_2 for 5 min + silane coupling agent for 60s G7: 50 % H_2O_2 for10 min + silane coupling agent for 60s	Quartz reinforced fiber post (Aestheti-Plus; Quartz fibers 60% embedded in an epoxy resin matrix 40%; Bisco, Schaumburg, IL, USA)	Core-Flo DC, composite resin, dual-cured (Ethoxylated Bis A Dimethacrylate, Bis-GMA, silica, glass fillers (50-75wt%) Bisco Inc, Schaumburg, IL, USA)	μTBS Test (DL 2000; EMIC, Sao Jose dos Pinhais, PR, Brazil) Surface topographical analysis: SEM evaluation (JSM-5600LV; JEOL, Tokyo, Japan).	The control group presented the lowest means. Significant difference among the groups treated with hydrogen peroxide (G2-G3-G4-G5-G6-G7) and the control group (G1). No significant differences for the factor ''concentration of H2O2'', ''application time'', or the interaction between the factors (no significant difference among the groups treated with hydrogen peroxide.) Both 24% and 50% hydrogen peroxide exposure increased the bond strength of resin to the posts, irrespective of the application time. Non-etched post presents a relatively smooth surface without fiber exposure. Application of hydrogen peroxide increased the surface roughness and exposed the fibers for all concentrations and application times The exposed glass fibers were not damaged or fractured by any etching protocol.
Kulunk et al (2012) (18)	Evaluate the effect of mechanical and chemical surface treatment methods on the bond strength of resin cement to fiber post	G1: (control group) silane coupling agent for 60s G2: CH_2Cl_2 for 5s + silane coupling agent for 60s G3: 24% H_2O_2 for 10 min + silane coupling agent for 60s G4: air abrasion with 30 mm aluminum oxide particles modified by silica (SiOx) + silane coupling agent for 60s	Quartz reinforced fiber post (Light-Post; 2-stage, translucent fiber post 62% Quartz Fiber, 38% Epoxy Resin; Bisco, Schaumburg, USA)	Adhesive composite resin cement (Panavia F 2.0; ED Primer 2: adhesive phosphate monomer (MDP), HEMA and water Dual-cure resin cement: MDP, comonomers, fillers,	Push out test (Lloyd LRX; Lloyd Instruments PIC, Fareham, Hampshire, UK)	Mean bond strength (MPa) G1: 6.49 → Lowest bond strength G2: 7.22 G3: 9.13 G4: 10.78 G5: 11.73 G6: 13.66 → Highest bond strength Surface pre-treatment methods affected the bond strength.

		G5: air abrasion with 50 mm alumina oxide particles (Al2O3) + silane coupling agent for 60s G6: air abrasion with 1–3 mm synthetic diamond particles (Micron+MDA) + silane coupling agent for 60s		initiators and functional sodium fluoride; Kuraray, Okayama, Japan)	 Failure analysis: Stereomicroscope (Leica, MZ125, Milton Keynes, UK) Surface topographical analysis: SEM evaluation (JSM_6335F; JEOL, Tokyo, Japan)	Application of hydrogen peroxide resulted in higher push-out bond strength values than the other chemical surface pre-treatment methods. The majority of failures were adhesive failure. Application of surface pre-treatment affected the surface morphology of quartz fiber posts. Silane treatment has no significant effect on the surface of quartz fiber post when compared with other surface pretreatment methods. Chemical surface treatment with hydrogen peroxide and methylene chloride affected the superficial layer of epoxy resin matrix of quartz fiber post and exposed quartz fibers. Silica coating with 30 mm SiOx and air abrasion with 50 mm Al2O3 particles removed and abraded the epoxy resin matrix and fractured quartz fiber in some areas.
Menezes et al (2014) (19)	Evaluate the effect of the concentration and application mode of hydrogen peroxide on the surface topography and bond strength of resin composite to glass- fiber posts.	G1 (control group): No conditioning G2: Immersion of 24 % H_2O_2 for 1min + silane coupling agent for 60s G3: Application of 24 % H_2O_2 for 1min + silane coupling agent for 60s G4: Immersion of 35 % H_2O_2 for 1min + silane coupling agent for 60s G5: Application of 35 % H_2O_2 for 1min + silane coupling agent for 60s	Glass reinforced fiber post (WhitePost DC3, 80% glass fiber; 20% epoxy resin. FGM, Joinvile, SC, Brazil)	Microhybrid resin composite, Opallis, (Matrix : Bis-GMA, Bis-EMA, TEGDMA Filler: 40nm-3.0 µm with a mean particle siez of 0.5µm (57vol%); FGM Dental Products,Joinville, SC, Brazil)	µTBS Test (EMIC DL 2000, Sao Jose dos Pinhais, PR, Brazil)	Mean bond strength (MPa) G1: 11.0 → Lowest bond strength G2: 18.7 G3: 13.4 G4: 21.1 G5: 21.0 Immersion of the post into H2O2 solutions: no difference between concentrations, although using 35% H2O2 resulted in higher bond strength.

						Application of H2O2: Except for the application of 24% H2O2, the other experimental conditions resulted in higher bond strength than the control. Although immersion resulted in higher values for the 24% H2O2 application, the mode of application did not alter bond strength when 35% H2O2 was used.
					Surface topographical analysis: SEM evaluation (LEO 435 VP, Nano Technology Systems Division of Carl Zeiss SMT, Cambridge, UK)	Without treatment, epoxy resin covering the glass fibers of the post and some areas with exposed fibers and flaws. More exposed fibers were observed when the post was etched by immersion in H2O2 (both concentrations) and when 35% H2O2 was applied. The application of 24% H2O2 on the post surface did not effectively expose the glass fibers.
Gonçalves et al (2013) (20)	Influence of chemical cleaning agents on the bond strength between resin cement and glass-fiber posts	G1(control group): silane coupling agent for 60s G2: 10% HF for 60s + silane coupling agent for 60s G3: 35% H_3PO_4 for 60s + silane coupling agent for 60s G4: 50% H_2O_2 for 60s+ silane coupling agent for 60s G5: C_3H_6O for 60s + silane coupling agent for 60s G6: CH_2Cl_2 for 60s + silane coupling agent for 60s G7: C_2H_6O for 60s + silane coupling agent for 60s G8: C_3H_8O for 60s + silane coupling agent for 60s G9: C_4H_8O for 60s + silane coupling agent for 60s	Glass-fiber epoxy specimens (Glass fiber 80%, epoxy resin 20%; Angelus (Londrina, PR, Brazil)	Dual-cure resin cement base and catalyst paste (Methacrylate monomers containing phosphoric acid groups, methacrylate monomers (28wt%), silanated fillers (72wt% fillers), RelyX ARC; 3M ESPE, St. Paul, USA)	SBS Test (DL500; EMIC, São José dos Pinhais, Brazil) Failure analysis: stereomicroscope (--)	All chemical agents provided significantly increased bond strength compared with the control group. The bond failures were exclusively adhesive (interfacial) in all groups, with no residual resin cement left on the post surface after debonding.

Naves et al (2011) (5)	Evaluate the effect of different chemical etching procedures on the surface characteristics of carbon and glass/epoxy fiber-reinforced resin posts.	G1: (control group): No conditioning G2: 24% H_2O_2 for 10min G3: 10% H_2O_2 for 20min G4: 4% HF gel for 60s G5: 37% H_3PO_4 gel for 30s	Glass fiber post, Gfp (85% quartz fiber, 15% epoxy resin. Reforpost Glass, Angelus, Londrina, Parana, Brazil) Carbon fiber post, Cfp (62% carbon fiber, 38% epoxy resin; Reforpost Carbon; Angelus)	--	Surface topographical analysis: SEM evaluation (LEO 435 VP; LEO Electron Microscopy Ltd., Cambridge, UK)	The post surface morphology was modified following all treatment when compared with a control group, for both type of reinforced posts. G1/Gfp and Cfp: rough surface with fibers covered by epoxy resin. G2-G3/Gfp and Cfp: dissolution of epoxy resin and exposure of the superficial fiber G4/Gfp: HF seems to penetrate around the fibers and promoted surface alterations with the presence of by-product precipitate along the resin matrix-glass fiber interface. G4/Cfp: The surface of post seems to be inert to treatment with HF 4%. The epoxy polymer matrix also seems unmodified after the same treatment. G5/ Gfp and Cfp: Relative smooth surface area was produced, but with similar features to untreated group.
Elsaka et al (2013) (1)	Evaluate the effect of fiber post surface treatment with CH2Cl2 and H2O2 on the morphological aspects of the post surface, and the influence of different surface treatments on the micropushout bond strength of fiber posts to different composite resins for core-build up.	G1(control group): No conditioning G2: silane coupling agent for 60s G3: 10% H_2O_2 for5min G4: 10% H_2O_2 for10min G5: 30% H_2O_2 for5min G6: 30% H_2O_2 for10min G7: CH_2Cl_2 for10min G8: CH_2Cl_2 for 5min	RP: Reblida post (70% glass fiber, 10% filler, 20% UDMA) VOCO, Cuxhaven, Germany RX: RelyX post (Glass fiber reinforced Composite, methacrylate resin) 3M ESPE, St. Paul, MN, USA	GR: dual cure composite core, Grandio Core DC (Matrix: Bis-GMA, UDMA resins. Filler: silica/Ba-glass ceramics (77%, wt). Amines, benzoyl peroxide, BHT) VOCO, Cuxhaven, Germany F60: composite resin material, Filtek P60 (Matrix: Bis-GMA, UDMA, Bis-EMA resins. Filler: zirconia/silica (61%, vol., 83%, wt). Particle size	μPush out test (Model TT-B, Instron Corp., Canton, MA, USA).	Mean bond strength (MPa) G1 RP/GR: 16.2 RP/F60:9.4 RX/GR :12.1 RX/F60: 10.0 G2 RP/GR: 17.4 RP/F60: 9.6 RX/GR : 12.2 RX/F60: 10.2 G3 RP/GR: 18.9 RP/F60: 10.1 RX/GR: 13.3 RX/F60: 11.4 G4 RP/GR: 20.8 RP/F60: 11.1 RX/GR : 16.3 RX/F60: 11.9 G5 RP/GR: 23.2 RP/F60: 16.9 RX/GR : 18.5 RX/F60: 17.2 G6 RP/GR: 24.4 RP/F60: 17.5 RX/GR: 20.3 RX/F60: 18.3 G7 RP/GR: 25.9 RP/F60: 18.3 RX/GR : 19.8 RX/F60: 18.5 G8 RP/GR: 26.4 RP/F60: 20.3 RX/GR : 21.1 RX/F60: 19.4 The bond strength was significantly affected by the type of fiber post, by surface treatment.

				range of 0.01–3.5 _m. Initiators, inorganic pigments) 3M ESPE, St. Paul, MN, USA		10% H_2O_2 for 5 or 10 min did not have a significant effect on the post/core bond strength as compared with the control and silanization groups. 30% H_2O_2 for 5 and 10 min were significantly higher compared with the control and silanization groups for both types of posts with the core materials tested.
					Failure analysis: stereomicroscope (Olympus SZX-ILLB100-Olympus Optical Co. Ltd., Tokyo, Japan)	Most failure modes were adhesive type of failures between post and core material (93.5%). In addition, mixed failures (5.1%), cohesive failures within the core material (1.1%), and cohesive failures within the post (0.3%) were also observed
					Surface topographical analysis: SEM evaluation (JEOL; JXA-840A, JEOL, Tokyo, Japan).	Control group Rather rough surface with some glass fibers exposed for the untreated RP, providing potential for micro-mechanical retention compared with the untreated RX posts which showed a smooth surface. H_2O_2 and CH_2Cl_2 groups The surface topography of posts was modified. The surface treatments dissolved the resin matrix of the posts and exposed the glass fibers of the posts. The exposed glass fibers were not damaged or fractured by the surface treatments. Silane group No changes on the post surface morphology compared with the control group.

Table 1. Relevant data and results extracted from the selected studies.

5. Discussion

The present integrative review reported the major results of relevant previous studies taking into account the effect of hydrogen peroxide on the surface topography and bond strength of FRC posts to resin cores. The etching with hydrogen peroxide modifies the surface of the fiber post and improve the bond strength between the fiber post and the resin cement. Thus, the null hypothesis tested was rejected. A detailed discussion is provided as follow.

5-1 Post-endodontic restauration

Restoration of endodontically treated teeth is a daily clinical decision in restorative dentistry practice. Loss of a large proportion of coronal tooth structure due to caries, previous restorations, and endodontic access cavity preparation, results in an increased need for the placement of intra-radicular posts during the restoration of endodontically treated teeth. [21] The primary function of an intra-radicular post is to provide retention for a core, which replaces lost coronal tooth structure and retains the final restoration without compromising the apical seal of the endodontic filling. These post and core restorations are subjected to repeated tension, compression and torqueing forces. Most forces clinically manifest themselves as tensile forces or shear stress on the post-cement-dentin interfaces. It is therefore important to select a post system that provides maximum retention yet removes as little as possible of the remaining subgingival tooth structure. [22]

Until the early 1990s, accepted methods to fabricate intra-radicular posts included custom-made cast metal posts and cores or prefabricated metal posts in combination with different core materials. [21] These combinations often led to irreversible vertical root fractures, which were associated with a high stress concentration acting along the bonded interface between post and dentin. [23] Disadvantages of metallic posts (such as the risk of corrosion, root fractures, loss of retention), coupled with growing interest in esthetic dental restorations and adhesive dentistry led to the development of posts made of aesthetic materials such as ceramic zirconia, fiber-reinforced composites, and polyetherketoneketone.[21] Among these, fiber-reinforced posts attracted the attention of researchers and clinicians alike, resulting in increased use of these posts in clinical situations. The increased demand for fiber-reinforced posts resulted in the development of an enormous variety of fiber-reinforced posts. (21) They are essentially composed of pre-stretched fibers at 60% bounded by methacrylate or epoxy-polymer matrix at 40%. The fibers offer strength and stiffness, while the polymer matrix transfers forces to the fibers and also protects them from the moisture of the oral environment. (24)

The first introduced fiber-reinforced posts consisted of carbon/graphite fibers embedded in an epoxy resin matrix. They were characterized by good mechanical properties (such as high stiffness and tensile strength, in addition to electrical conductivity and comparatively low toxicity). However, their main drawbacks were their black color limiting their use under all-ceramic and composite restorations in areas of high aesthetic demand, and their radiolucency, which made it difficult to identify these posts on radiographs due to the carbon content. (21) These limitations of carbon fiber-reinforced posts led to the development of fiber-reinforced posts with more esthetic properties using silica fibers in the form of quartz or glass fibers. The incorporated glass or quartz fibers imparted similar biomechanical properties, as carbon-fiber-reinforced posts, including elasticity, high tensile strength, low electrical conductivity, resistance to solubility and biochemical degradation. (21) Fiber-reinforced posts was that they were more flexible than metal posts and had approximately the same modulus of elasticity (stiffness) as dentin.(25) The similarity between the elastic modulus of fiber-reinforced posts and dentine will distribute the stress and less likely to cause root fracture in endodontically treated teeth as compared to metal posts (Figure.3). (21) Fiber-reinforced posts also overcome limitations of metal posts like the possibility of corrosion and associated possible biocompatibility concerns that may trigger allergic reactions. The use of fiber-reinforced posts simplified clinical procedures by eliminating the need for laboratory steps and facilitated re-treatment in cases of endodontic failure as a result of their easier removal techniques and nowadays they are often first clinician choice. (21,24)

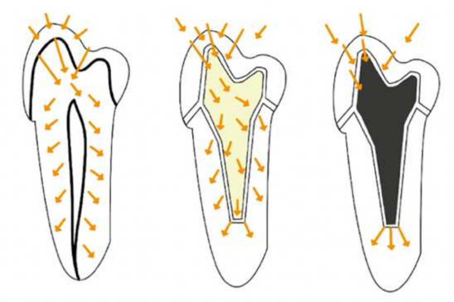

Figure 3 - Stress distribution. (A) Natural tooth, (B) post core with fiber post, (C) post core with metal post

Despite the advantages of fiber posts, several studies report debonding as a frequent complication. Debonding is the most common kind of failure and results as a consequence of the fiber post characteristics (design, length, diameter) [26], of the cement and interaction of cement-post and cement-dentin. [27]

Relatively to the posts, as length of the post increases so does its retention. A post that is too short is bound to fail. Ideally, the post should be as long as possible without jeopardizing the apical seal and integrity of remaining root structure. However, if a post is too long, it may damage the seal of root canal or risk perforation. [22] Several in vitro studies have confirmed the importance of the remaining bulk of tooth structure with regard to strength and resistance to root fracture. Increasing the diameter of the post does not provide a significant increase in the retention of the post however, it can increase the stiffness of the post at the expense of the remaining dentin and the fracture resistance of the root. Therefore, post diameter must be controlled to preserve radicular dentin, reduce the potential for perforations, and permit the tooth to resist fracture. [28] The influence of post design and surface structure on retention has been demonstrated, and in vitro and in vivo studies report that parallel-sided posts have higher values of retention than tapered post apical ends. On the other hand, they require a bigger dentin destruction on post preparation, weakening the post. [21,27]

All posts, to a greater or lesser extent, gain their final retention by cementation into the tapered root canal. One criterion for selection of the cementing medium would be that the one chosen has the greatest retention. Many dental cements do not exhibit any real adhesion to the dentine or enamel surfaces. Their retention is essentially a locking of thin cement layer into irregularities of both the post and the canal. [21] The ability of a cement to retain a post influences the prognosis of the restoration. [21] The choice of cement and the method used for cementation is a very important step for the success of the procedure. There is a wide variety of cements and according to their constitution they can be classified as: zinc phosphate cements, zinc polycarboxylate cements, glass ionomer cements, resin modified glass ionomer cements and resin cements. [29] Of these dental cements, zinc phosphate has had the longest history of success. In addition to having an extended working time, it is compatible with zinc oxide eugenol (ZOE), which is contained in most root canal sealers.[30] The use of resinous cements has increased, and studies have reported higher retention values and resistance to fatigue for these cements compared to brittle zinc phosphate cements used widely in the past. The modulus of elasticity of resin cements approaches that of dentin, and therefore they may have the potential to clinically reinforce thin-walled roots. The most important drawback is the error-sensitive technique because of their short working time, the number of operating steps involved, and the sensitivity to moisture, compared to zinc phosphate cements. [24] Nowadays self-adhesive resin cements are available. They were introduced in 2002 and were 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. These luting agents do not require any pretreatment of the tooth surface and their application is accomplished through a single clinical step. This occurs due to the presence of acid monomers in its structure, which dissolve the smear layer and allow cement to infiltrate dentinal tubules, resulting in micromechanical adhesion/ retention. [14,31]

Immediately after fiber post cementation and core build-up, the restoration has to resist the stresses transmitted during core trimming to adapt the provisional crown. At the coronal level, the amount of residual tooth structure still offers more favorable conditions for ensuring strong adhesion and retention. At the post-core interfacial level, only the chemical interaction between the fiber post surface and the composite may ensure the bond of the core material around the post.[8] One difficulty with some of the available prefabricated fiber posts is that the polymer matrix between the post material fibers is highly cross-linked and, therefore, less reactive. This makes it difficult for these posts to bond to resin luting agents and tooth structure. [32] In an attempt to maximize resin bonding to fiber posts several surface treatments have been recently suggested. These procedures fall into three categories: 1) treatments that result in chemical bonding between a composite and post (coating with priming solutions); 2) treatments that intend to roughen the surface (sandblasting and etching) or 3) combine micromechanical and chemical components either by using the two above mentioned methods or a unique system (such as Co-Jet).[5]

Silanization and/or adhesive application is undoubtedly the most thoroughly investigated fiber post-surface treatment in the current literature.[8] Silane coupling agent is a hybrid organic-inorganic compound that can mediate adhesion between inorganic and organic matrices through intrinsic dual reactivity capability to increase surface wettability, creating a chemical bridge with OH-covered substrates, such as glass. A chemical bond may be achieved between the core resin matrix and the exposed glass fibers of the post at the interface level. [24] Studies focusing on this topic revealed controversial results. Shori and colleagues [12] and Prado and colleagues [14] confirmed the benefit of silane application for enhancing the bond strength resin core material to translucent fiber posts, whereas other studies [1, 10, 13] did not detect any difference between silanated and untreated control posts.

Generally, sandblasting is used for pretreating acid-resistant materials. [8] Sandblasting post surfaces with abrasive particles consists of tribological surface treatment that primarily promotes micro-retentions on the superficial epoxy resin. Despite the efficiency of this method in roughening post surface, the application of abrasive particles on the surface of posts may promote damages and/or fiber fractures, impairing the physical and mechanical properties of posts and consequently the clinical performance of fiber posts. The sandblasting treatment improves the bond strength immediately after the post cementation; however, this effect is reduced with time, probably due to the impact in the mechanical properties of the post.[33] These results were confirmed by Kulunk and colleagues[18] who Evaluate the effect of mechanical and chemical surface treatment methods on the bond strength of resin cement to fiber post. In this study, thirty-six fiber posts were randomly divided into six groups, each containing six posts, and were subjected to surface pre-treatments including air abrasion with 30 mm aluminum oxide particles modified by silica (SiOx) and silanization; air abrasion with 50 mm alumina oxide particles

(Al_2O_3) and silanization; and air abrasion with 1–3 mm synthetic diamond particles (Micron+MDA) and silanization. The air abrasion procedure was performed using an intra-oral air abrasion device at an air pressure of 2.5 bars for 10 s from 10 mm distance. SEM examination showed that application of surface pre-treatments affected the surface morphology of fiber posts. Silica coating with 30 mm SiOx and air abrasion with 50 mm Al_2O_3 particles removed and abraded the epoxy resin matrix and fractured quartz fiber in some areas.

Hydrofluoric acid has recently been proposed for etching fiber posts. Although the satisfactory bond strength results achieved with this surface treatment, the use of this acid produce substantial damage to the fibers and affected the integrity of the post. The effect of the acid has been proven to be time-dependent and influenced by the post composition (type of matrix and/or fibers). [8] This was confirmed by the study of Naves and colleagues [5]. In this study, SEM micrographs showed the presence of a reaction product precipitate along the resin matrix-glass fiber interface. The authors conjecture that it is possible that this by-product has a glassy nature. HF acts on fiber glass surface (at SiO_2 bonds), and this reaction results in tetrafluoro silane and water. On the other hand, CC covalent bonds present on carbon fibers are practically inert to HF acid, unless the fibers present some kind of impurities that could be acid susceptible. The epoxy polymer matrix seems also unmodified after the same treatment on this fiber. Thus, care should be taken in using HF for etching Glass fiber posts surfaces. In addition to these damage possibilities, this surface treatment presents lower bond results compared to other treatments, such as sandblasting. This variation may be explained due to the non-standardized protocols available, either in acid concentration or application period. [33] As a consequence, it is not possible to suggest general guidelines for using hydrofluoric acid in the surface etching of aesthetic fiber posts. [4]

Because these above-mentioned techniques can sometimes damage the glass fibers and affect the integrity of the posts, substances that selectively dissolve the epoxy matrix without interfering with the fibers have been studied. [24]

5-2 Hydrogen peroxide pretreatment of FRC posts

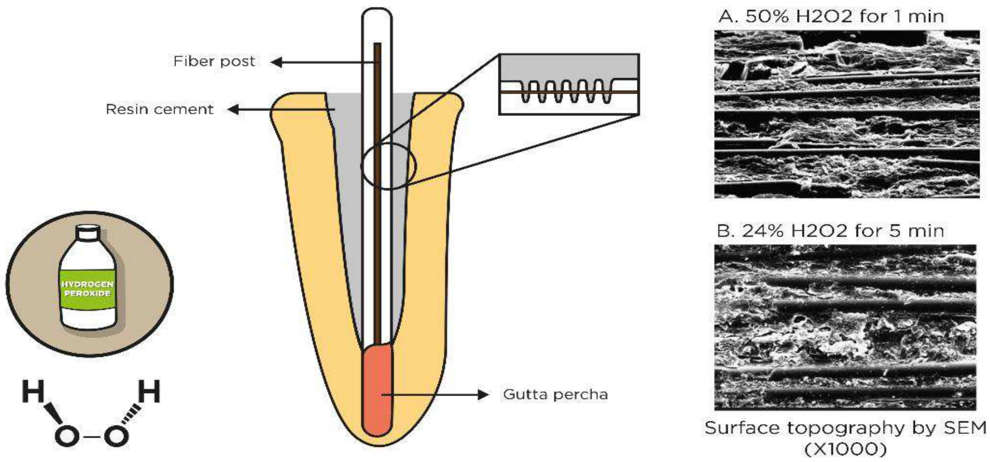

Figure 4- Post surface treatment with H_2O_2. Representative SEM images A) 50%H_2O_2 for 1min; B) 24% H_2O_2 for 5min

First recognized as a chemical compound in 1818, hydrogen peroxide is the simplest member of the class of peroxides (a chemical with an oxygen–oxygen single bond). It is an odorless, colorless liquid and it is slightly more viscous than water. He has chemical applications, biological function, domestic uses, and therapeutic use, including use as an antimicrobial and oxidizing agent.[34] Indeed, hydrogen peroxide is commonly employed in immunological electron microscopy to partially dissolve the resin surface of epoxy resin-embedded tissue sections and expose tissue epitopes for immunolabeling enhancement. A similar H2O2 etching procedure may be employed to improve the micromechanical retention between the epoxy resin matrix of fiber posts and methacrylate-based resin composites.[35]

Fiber integrity and homogeneity along the treated surface with hydrogen peroxide and at the resin-matrix fiber interface was thoroughly analyzed along the entire post surface extension with SEM. [1,5,14,16,17,18,19] It was revealed that the non-abraded posts had a relatively smooth surface area, which limited mechanical interlocking between the post's surface and resin cement. [12] The H_2O_2 etching promoted the morphological alteration of the post surface by the dissolution of epoxy resin and exposure of the superficial fibers, resulting in a cleaner surface. Exposed fibers did not appear to be damaged by the action of hydrogen peroxide and no defects or fractures were evident on their surfaces. [1,5,14,16] A uniform distribution of micro-spaces was evident among the exposed fibers. The spaces created between these fibers provide additional sites for micromechanical retention of the resin composites. [5] This retention concept is reminiscent of the creation of hybrid layers in dentin, as the interface is contributed by both the fibers from the post and the methacrylate resin matrix. [8]

It has been documented that the use of peroxides during endodontic procedures might compromise the adhesive cementation of posts. This effect is attributed to the presence of residual oxygen into dentinal tubules interfering with the polymerization of the adhesive resin. [17] However, some authors [10,11,12,15,16,18,20] have found that etching with H_2O_2 in combination with a coupling agent increases the bond strength of the adhesive core of resin composite materials to fiber posts. The deleterious effect of the peroxide was probably not observed because of the absence of residual oxygen into the post structure. [17]

The results obtained by Prado and colleagues[14] and Mosharrraf and colleagues[13] were inconsistent with the evidence found in other studies. Indeed, Prado and colleagues[14] who evaluate the effect of different surface treatments (i.e. Silane, H_2O_2, sandblasting, NH_3 plasma, HMDSO plasma) on fiber post cemented with a self-adhesive system observe that the surface treatment with 24% hydrogen peroxide for 1 minute showed POBS values statistically similar to control. The inferior results of H_2O_2 when compared with other treatments can be due to morphology of surface and the interaction of H_2O_2 with resin cement. Similary, Mosharraf and colleagues[13] who evaluate the effects of some surface treatment methods (i.e., Silane, sandblast, H_2O_2) on the TBS between fiber post and composite core, demonstrate that application of H_2O_2 for 10 minutes had no significant effect on bonding strength. Indeed, in this study, the H_2O_2 group had the least TBS mean value even in comparison with the control group. This can be due to this fact the bonding agent was used immediately after H_2O_2 application (without silane coupling agent as a mediator). The controversy and inconsistency of the findings of the two previous studies are likely to be related to the differences in surface treatment protocols, the composition of posts, core materials, application time and concentrations of chemical treatments, and methods of testing. [13]

It would be reasonable to think that the oxidizing effect of H_2O_2 and its ability to affect the bond strength of the fiber posts to the resin cores would depend on several factors such as its concentration (concentration of radicals that it releases such as radicals without oxygen, without hydrogen, water and peridroxyl) [19] its time and mode of application.

Elsaka and colleagues [1]; who evaluate the effect of fiber post surface treatment with CH_2Cl_2 and H_2O_2 (10% and 30%) for 5 and 10 minutes on the morphological aspects of the post surface, and on the micro push-out bond strength of fiber posts to different composite resins for core-build up; revealed that 10% H_2O_2 surface treatment for 5 or 10 minutes did not have a significant effect on the post/core bond strength as compared with the control groups unlike the 30% H_2O_2 surface treatment for 5 or 10 minutes. This could be attributed to the concentration of H_2O_2 was not sufficient to improve the bond strength. However, the results of this study conflict with the study by De Sousa Menezes and colleagues.[17] The latter Evaluate the effect of concentration (24% and 50%) and application time (1, 5, 10 minutes) of hydrogen peroxide on the surface topography and bond strength of glass fiber posts to resin cores. They observed that both 24% and 50% H_2O_2 were able to partially dissolve the epoxy resin and expose the glass fibers after a 1-minute exposure. Despite the slight etching obtained by 24% H_2O_2 after 1 minute exposure, it was sufficient to produce bond strength similar to that obtained with higher concentrations or longer application times. They concluded that the concentration and application time of H_2O_2 did not affect the bond strengths. Based on the results of this study, the lower concentration (24%) of H_2O_2 used for just 1 minute is preferable in clinical use. Indeed, lengthy application time is a waste of valuable clinical time with no enhancement in bond strength. [17]

Menezes and colleagues[19] also determine the effect of the concentration (24% and 35%) and application mode (i.e., immersion, application) of hydrogen peroxide on the surface topography and bond strength of resin composite to glass fiber posts. They concluded that that the effect of the mode of application of H_2O_2 depended on its level of concentration. 35% H_2O_2 is effective in improving bond strength independent of the application mode. To the contrary, 24% H_2O_2 increased the bond strength of resin composite to fiber post compared with the control only when the post was immersed in the solution.

The application of 24% H_2O_2 resulted in similar values to those observed by the control. A possible explanation is that a single layer of peroxide applied on the post only reacted superficially with the epoxy resin once there was no replacement of radicals by oxidation. This replacement probably occurred when the post was immersed in 24% H_2O_2 solution, thus increasing the potential for etching.

After performing the bond strength test, five studies [1, 13, 14, 18, 20] examined the samples using a stereomicroscope at different magnifications in order to classify the mode of failure. Failures are distributed as: post cohesive (failure located within the post structure), resin cohesive (failure located within the composite resin structure), adhesive (failure at the interface between the post and composite resin) or mixed (when more of a type of failure can be visualized in the same sample).

In the study by Elsaka and colleagues [1], failure mode analysis revealed that adhesive failure between the post and luting cement was the predominant failure. This finding is consistent with those of Mosharraf and colleagues [13] Kulunk and colleagues [18], and Goncalves and colleagues [20]. These results are in disagreement with Prado and colleagues [14] who found that the predominant mode of failure was cohesive within the post and the cement.

The fact that the failures were mostly interfacial is likely due to the absence of relatively aggressive treatments (prolonged exposure times), without which adhesion occurs through shallow keying of the cement with the surface combined with chemical coupling via siloxane bonds. In this situation, there is no actual hybridization or interphase formation, and fractures tend not to be directed into the bulk of the epoxy substrate or cement but rather to concentrate at the bonding interface. [20]

High bond strength between composite cores and posts is definitely desirable; however, the debonding of the post from the core could be clinically more favorable failure mode than fracture of the post. The fracture of composite core could be repaired by adding composites while a post fracture can only be repaired by entirely removing the fractured post, which is a more challenging procedure, and associated with some risk of root perforation and weakening of the root structure. [1]

6. Limits

This systematic integrative review has some limitations. The limitation of the language may have contributed to the loss of some potentially relevant articles. However, the English language is irrefutably the universal language and most of the articles found throughout the research were in that language. Thus, we consider this parameter the least problematic and conditioning.

The search methodology may have excluded relevant articles because we used a single database (PubMed). This problem was minimized when searching the bibliographic references of the selected studies.

Regarding the included studies, all published articles are based on in vitro investigations. [(8)] The data does not give an exact prediction whether the in vitro performance of the fiber posts is the same as the performance in vivo. [(4)] Thus, in vivo studies are necessary to evaluate whether the positive performance of the treated fiber posts is similar as the performance in vitro. [(1)]

According to the results described in the table 1, it can be noted that there is no coherence between the averages in MPa acquired in the analyzed articles. This finding leads us to reflect on the need to better describe the methodologies used, with emphasis on the factors that interfere in the adhesion force, such as, for example, the ambient temperature.

Future studies with larger study groups are also required for further exploration of this field of restorative dentistry, so as to establish certain concrete and authentic guidelines in this perspective. [(11)]

In the majority of study, only one type of adhesive resin cement and fiber post was used. Different results might be obtained with different type resin cements, fiber posts and in different storage conditions. Besides, the effect of surface pre-treatment methods on the mechanical properties of fiber posts might be evaluated. Further research is needed in this area. [18]

The selected investigations have been primarily performed using bond strength tests in combination with microscopic analysis. [8 The surface characteristics of the posts were analyzed under scanning electron microscope. Additional analyzes should be done such as surface roughness of fiber posts measured with a profilometer.

Finally, the pre-treatment of the post was immediately followed by the application of the resin composite for the core build-up. Further in vitro and in vivo studies are necessary to evaluate whether the positive effect on post-core bond strength is still retained by pre-treating the post surface well in advance of the clinical use. Evaluation of such a strategy will enable manufacturers to supply pretreated fiber posts in pre-sealed sachets, as well as saving clinicians valuable chair-time. [4]

7. Conclusion

Within the limitations of the in vitro selected studies, the following concluding remarks can be drawn as follow:

- Conditioning with H_2O_2 acts by removing a superficial layer of epoxy resin and, therefore, larger surface areas of fibers exposed for silanization.
- In combination with a silane coupling agent, this is an easy, effective and clinically feasible method for enhancement of interfacial strengths between fiber posts and resin composites, without the need of employing extremely corrosive liquids in a clinical setting.
- Further evaluations on factors such as its concentration, time and mode of application are required before making any clinical recommendations.

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