CESPU
INSTITUTO UNIVERSITÁRIO
DE CIÊNCIAS DA SAÚDE

A scoping review on the resin cement layer thickness resultant from teeth root canal post fitting

Ana Sofia Rodrigues da Silva

Dissertação conducente ao Grau de Mestre em

Medicina Dentária (Ciclo Integrado)

Gandra, 24 de setembro de 2020

CESPU
INSTITUTO UNIVERSITÁRIO
DE CIÊNCIAS DA SAÚDE

Ana Sofia Rodrigues da Silva

Dissertação conducente ao Grau de Mestre em

Medicina Dentária (Ciclo Integrado)

A scoping review on the resin cement layer thickness resultant from teeth root canal post fitting

Trabalho realizado sob a orientação do Professor Doutor Júlio C. M. Souza e co-orientação do Dr. Válter Fernandes (MSc)

Declaração de Integridade

Eu, acima identificado, declaro ter atuado com absoluta integridade na elaboração deste trabalho, confirmo que em todo o trabalho conducente à sua elaboração não recorri a qualquer forma de falsificação de resultados ou à prática de plágio (ato pelo qual um indivíduo, mesmo por omissão, assume a autoria do trabalho intelectual pertencente a outrem, na sua totalidade ou em partes dele). Mais declaro que todas as frases que retirei de trabalhos anteriores pertencentes a outros autores foram referenciadas ou redigidas com novas palavras, tendo neste caso colocado a citação da fonte bibliográfica.

CESPU
INSTITUTO UNIVERSITÁRIO
DE CIÊNCIAS DA SAÚDE

Declaração do Orientador

Eu, **Júlio César Matias de Souza**, com a categoria profissional de **Professor Convidado** do Instituto Universitário de Ciências da Saúde, tendo assumido o papel de Orientador da dissertação intitulada "A scoping review on the resin cement layer thickness resultant from teeth root canal post fitting", do Aluno do Mestrado Integrado em Medicina Dentária, **"Ana Sofia Rodrigues da Silva"**, declaro que sou de parecer favorável para que a Dissertação possa ser depositada para análise do Arguente do Júri nomeado para o efeito para a Admissão a provas publicas conducentes à obtenção do Grau de Mestre.

Gandra, 24 de setembro de 2020

____

O Orientador

AGRADECIMENTOS

Deixo aqui expressos os meus agradecimentos a todas as pessoas que de algum modo contribuíram para a elaboração deste trabalho e sobretudo à concretização deste sonho.

Este percurso não seria possível sem o apoio incondicional da minha família que me ajudou a ser a pessoa que sou hoje. Por isso, agradeço profundamente à minha querida mãe por me ter dado a oportunidade de ingressar na área que desejei e por me ter apoiado desde o dia em que concorri à universidade. Obrigada por toda a paciência e força que me deste ao longo deste percurso, serei eternamente grata por tudo o que fizeste e continuas a fazer por mim. Ao meu pai, que mesmo não estando fisicamente presente, obrigada por me teres sempre ensinado a lutar e a nunca desistir dos meus sonhos. Aos meus irmãos, pelo amor e pela união que sempre foi partilhada e por todas a palavras de apoio que me fizeram crescer e permitiram ser a pessoa que sou hoje.
A toda a minha família, o meu mais sincero agradecimento por estarem sempre presentes em todos os momentos da minha vida e por me apoiarem incondicionalmente.

À minha binómia, Ana Correia, obrigada por toda a amizade, companheirismo, trabalho, mas sobretudo por todos os incríveis momentos partilhados contigo. És uma das pessoas que levarei no meu coração para a vida.

Às minha amigas, Joana, Rita, Patrícia e Nicole, por ouvirem as minhas preocupações, por me acompanharem neste percurso tornando-o ainda mais especial. Mas mais importante que tudo isso, obrigada pela vossa amizade, sei que vos levarei para a vida.

Ao meu orientador, professor Júlio Souza e ao professor Válter Fernandes, pelo apoio na elaboração desta dissertação, por todos os conhecimentos transmitidos, por toda a ajuda, simpatia e também pelo rigor e perfecionismo que me foi exigido e que me permitiu alcançar este grande objetivo. Sou eternamente grata pela vossa disponibilidade, partilha e ajuda incansável.

Às minha primas-irmãs, Marlene e Mariana, pela grande ajuda e por toda a paciência que tiveram comigo durante a realização deste trabalho. Sem dúvida que não seria o mesmo sem a vossa ajuda.

RESUMO

O objetivo deste estudo foi realizar uma revisão de literatura integrativa sobre a espessura da camada e a microestrutura dos cimentos de matriz resinosa à volta dos espigões intrarradiculares. Realizou-se uma pesquisa eletrónica na PUBMED utilizando uma combinação dos seguintes termos científicos: *intraradicular post, root intracanal post, resin cement, thickness, adaptation, endodontic post, layer thickness, fit, shape, and endodontic core.* A pesquisa identificou 154 estudos, dos quais 24 foram considerados relevantes para este estudo. Os estudos selecionados forneceram dados sobre a espessura da camada de cimento, a preparação dos dentes, tipos de espigão e o de cimento resinoso. A variabilidade anatómica dos sistemas de canais radiculares, tais como os de forma oval ou forma alargada, causa uma má adaptação dos espigões. A adaptação destes espigões a diferentes regiões do canal radicular é variável, resultando em camadas mais espessas e irregulares do cimento resinoso. Defeitos como poros e micro-fissuras foram detetados na microestrutura do cimento resinoso e representam áreas de concentração de tensão e fratura. Os espigões personalizados proporcionam uma maior área de contacto com as superfícies intracanalares o que diminui a espessura da camada de cimento resinoso. De facto, a espessura da camada do cimento resinoso depende da adaptação dos espigões endodônticos aos canais radiculares dos dentes. Um aumento desta espessura pode apresentar um maior número de defeitos tais como, poros e micro-fissuras que podem induzir concentrações de tensão e fraturas nas interfaces.

PALAVRAS CHAVE:

Espigão intrarradicular; retentor intracanalar; cimento resinoso; espessura; microestrutura.

ABSTRACT

The aim of this study was to perform an integrative literature review on the layer thickness and microstructure of resin-matrix cements around custom-made or standard teeth root intracanal posts. An electronic search was conducted on the PUBMED using a combination of the following scientific terms: intraradicular post, root intracanal post, resin cement, thickness, adaptation, endodontic post, layer thickness, fit, shape, and endodontic core.

The research identified 154 studies, of which 24 were considered relevant to this study. These studies provided important data considering cement layer thickness, tooth preparation, endodontic post, and type of resin cement. The anatomical variability of root canal systems, such as the oval or flared-shaped, represents a challenge in dental restoration with teeth intracanal posts. The fitting of intracanal posts to different regions of the root canal is variable resulting in thick and irregular layers of resin cement. Defects like pores, micro-cracks, and micro-gaps were detected in the resin-matrix cement microstructure and represent spots of stress concentration and fracture. Custom-made intracanal posts provide a proper fitting and decrease the layer thickness of resin-matrix cement. In fact, the layer thickness of resin-matrix cements depends on the fitting of endodontic posts to teeth root canals. An increase of this thickness causes more defects like pores, micro-cracks, and micro-gaps that can induce stress concentration and fractures at interfaces.

KEYWORDS:

Intraradicular post; resin cement; thickness; adaptation; root canal post; endodontic post; layer thickness; fit; shape and endodontic core.

TABLE OF CONTENTS

1. INTRODUCTION

The selection and cementation of root intracanal posts have become a decisive factor for the planning and success of restorative treatment of endodontically treated teeth involving severe loss of enamel and dentin tissues. Teeth root intracanal posts provide a retention of the restorative materials and allows the dissipation of stresses from occlusal loading (1–6). Therefore, resin-matrix cements accomplish the adhesion of the root intracanal post to the dentin tissues (2,5–11). The materials properties and design of the posts affect the stress distribution and mechanical performance of the endodontically treated teeth (1–3,7,12–15). Indeed, the fitting of the post into the teeth root canal determine the layer thickness of the resin-matrix cement to establish the retention of the teeth root canal post (11,13,16). Nevertheless, the desired fitting is not achieved in several clinical situations such as on standard post cementation, curve roots, and oval canals (5,7,10,13,15–17). That leads to an increase in the resin-matrix cement layer which can be a spot for stress concentration and mechanical failures by micro-cracks (3,7,9,11).

The debonding and fracture of teeth root intracanal have been reported in previous studies that can be associated with materials, root canal shaping, remnant tooth tissues, and cementation (13,16,18,19). Thus, causes of failures are not entirely clear in many clinical cases and therefore the teeth root intracanal post are linked to the failures (10,11,15,20). Regarding root canal preparation, in placing posts, post space preparation removes additional tooth substance and may result in reduced rigidity of the prepared teeth, depending on the post type. Consequently, the idea is to avoid intentional post space preparation by adapting the post to the existing canal space or individually shaping the post. The remaining tooth structure should not be compromised concerning thickness and shape; otherwise, thin root walls might negatively affect the mechanical properties of the endodontically treated root (3,8,13).

Considering the anatomical features of the root canals, post cementation may be influenced by the anatomical and histological characteristics of the root canal, including the density and orientation of the dentinal tubules, and by the unfavorable configuration of the root canal. Morphological differences along the root canal will lead to a mismatch between post diameter and post space, leading to increased resin cement thickness (12,15,21).

A lack of fitting on the posts to the root canals results in thicker layers of resin-matrix cements leading to risks of defects and mechanical failures (3,9,13,16). At first, thick layers of resin cements display defects like pores or micro-spaces due to the cementation technique sensitivity (9,10,13). Second, the shrinkage stresses from polymerization can generate micro-cracks and micro-gaps at the cement-to-dentin and/or to-post interfaces (3,9,10,13,22). Those defects act like spots for stress concentration and fractures on loading (3,9). At last, the low values of elastic modulus and strength of the resin-matrix cements can induce mechanical failures by the propagation of micro-cracks and ultimate fracture (1,15,20). In fact, custom-made intracanal posts a proper fitting to root canals leading to the impregnation of thinner and uniform layers of resin-matrix cement mainly in the coronal and middle third of the teeth (10,11,23). In an attempt to simplify the cementation technique, self-etching cements and adhesives have been introduced (15,20,21). These materials have physical properties to ensure a high degree of polymerization and high strength in the adhesion of intra-radicular posts to dentin surfaces (4,5).

Concerning the limitations on the cementation of endodontic posts to teeth root canals, the aim of this study was to perform a systematic integrative review on the layer thickness and microstructure of resin-matrix cements around custom-made and standard of the teeth root intracanal posts.

2. MATERIALS AND METHODS

A literature search was carried out on PubMed (via National Library of Medicine) using the following search terms: ''intraradicular" OR "endodontic" OR "root canal" AND "post" OR "core" AND "resin cement" AND "thickness" OR "microstructure" AND "adaptation" OR "fit" OR "oval shape". A manual search of the reference lists in the selected articles was also performed. The literature selection criteria accepted articles published in the English language, up to February 2019, involving *in vitro* analyses, meta-analyses, randomized controlled trials, and prospective cohort studies. Also, the following methods were evaluated: fractographic analyses; optical and scanning electron microscopy; mechanical testing; and biomechanical analysis.

Three of the authors (JCMS, VF, ASRS) independently evaluated the titles and abstracts of potentially relevant articles. The total of articles was compiled for each combination of key terms and therefore the duplicates were removed by using Mendeley citation manager. Selected full-length articles were individually read and analyzed concerning the purpose of this study. The next variables were collected for this review: author names; journal; publication year; root canal post types; root canal preparation; and microstructure, polymerization, and layer thickness of resin-matrix cements.

3. RESULTS

A total of 154 articles were identified in PubMed, as shown in Figure 1. Of these, 26 articles were duplicated. After reading and analyzing the titles and abstract of the scientific articles, 37 articles were selected and 9 of these were excluded since they did not meet the inclusion criteria. The remaining 28 studies were selected for full reading. (Fig.1). Of these articles, 4 were excluded because they did not provide relevant information according to the purpose of the present systematic review. At last, 24 studies were included in this integrative systematic review.

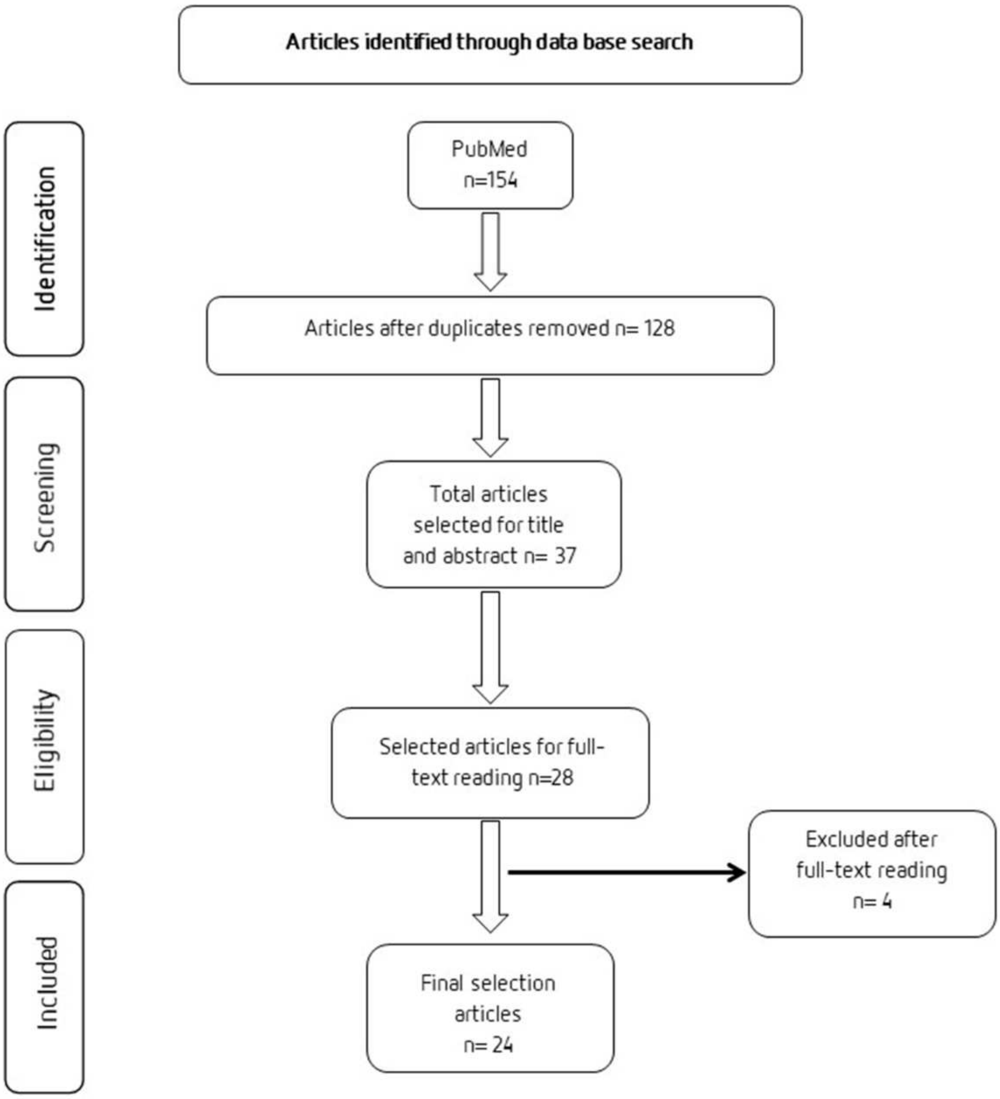

Figure 1. Schematics of the selection of studies

Of the 24 selected articles, 20 (80%) corresponded to *in vitro* studies, within 10 (50%) articles studied the thickness of the resin-matrix cement layer, 3 (15,8%) evaluated the bond strength by pull-out or push-out testing, and 3 (15%) articles measured the thickness of the hybrid adhesive layer and resin tags, 1 (5%) article evaluate the accuracy of fit ad shear strength of milled zirconia post and cores, 1 (5%) evaluated the conversion degree of the cement layer and molecular structure of the adhesive/hybrid layer dentine interface, 1 (5%) evaluate fracture strength and nanoleakage of endodontically treated teeth and 1 (5%) studied microleakage around cast and prefabricated posts. Two (8,3%) *ex vivo* studies reported morphological aspects and thickness of the dentin-resin cement interface while only one article studied the mechanical properties of a fiber post. An *in vivo* study reported the influence of the thickness of the resin-matrix cement layer between the post and the surfaces of the teeth-treated root canal.

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

- The magnitude of gap formation and the resultant bond strength within the adhesive interface was dependent on the fiber post fitting to the root canal. (3,10). For instance, the push-out bond strengths were significantly higher on 1.5 mm post diameter than on 1.2 mm post diameter regarding the same dimensions of intracanal space (7).
- Placement of standard fiber-reinforced dowels in excessively flared canals results in an excessively thick resin-matrix cement layer (7,9,10,13). A thick resin-matrix cement layer reveals more structural discontinuities, such as pores, micro-cracks, and micro-gaps. These defects are expected spots for stress concentration, which will act as sites of crack propagation and fractures (3,10,13).
- Relining fiber-reinforced dowels using resin-matrix composite increases the fitting of the dowel to teeth root walls and reduces the resin-matrix cement thickness. Thin layers of resin cement reveals fewer defects (10,13). Fitting intracanal posts to the teeth root canal decrease the risks of fracture at the interfaces (9,13).
- The application of a large volume of resin-matrix cement in the root canal induces higher polymerization shrinkage that could lead to debonding (3,13). Light transmission in thicker layers may not be enough, thus the polymerization of resin-matrix cement in thicker layers may have relied only on the chemical activation

produced by the self-curing component of the dual polymerization system. That resulted in resin-matrix cement layers with reduced mechanical properties as well as lower bond strength to the root canal (3).

- The stiffness (elastic modulus) of the intracanal post and resin-matrix cement had considerable effect on the stress distribution through the endodontically treated teeth. A proper fitting of the glass fiber reinforced composite posts with a thin resin cement layer thickness reduced concentration of stresses at the interfaces, decreasing the risk of fracture and debonding (24).
- However, a few studies reported that the increase resin-matrix cement thickness surrounding the fiber-reinforced composite posts did not significantly affect the bond strength of the endodontic post to the teeth root canal (5,19). Relining fiber-reinforced dowels using resin-matrix composite increases the fitting of the dowel to teeth root walls and reduces the resin-matrix cement thickness. Thin layers of resin cement reveals fewer defects (10,13).

Table 1. Relevant data gathered from the selected studies.

Author (year)	Purpose	Study design/Methods	Tooth type	Root canal post types and Resin Cement	Resin cement layer thickness (μm)/ Hybrid layer thickness and Resin Tags
Nova et al., (2013) [5]	Evaluating the effects of various self-adhesive resin cements with different thickness on the pull-out bond strength of glass fiber-reinforced composite posts.	In vitro/ Pull-out test evaluation; Stereomicroscopy.	Bovine mandibular incisors.	Glass fiber-reinforced composite posts (GFR) 60% wt. glass fibers embedded in a cured epoxy-resin matrix containing zirconia filler - RelyX Fiber Post (3M ESPE, Germany). Resin Cement: G-CEM, (GC Corporation, Japan); Maxcem Elite (Kerr Company, USA); Multilink Automix, (Ivoclar Vivadent, Liechtenstein); RelyX Unicem, (3M ESPE, Germany); SmartCem 2, (DENTSPLY Caulk, USA).	Thickness 1- thin Thickness 2- thick
Marigo et al., (2012)[14]	Evaluating of the resin-root canal dentin interface of four "etch and rinse" adhesive systems, commonly used during the cementation of fiber posts.	In vitro/ Confocal Laser Scanning Microscope (CLSM).	Human upper anterior teeth (central incisors and canines).	DT Light Post Illusion fiber posts, epoxy resin matrix (40 vol%), quartz fibers (60 vol%) – DT Light Post Illusion (Dentsply, UK). Resin Cement: Surgi Dual Fló Core (Surgi MC Italia, Italy).	Hybrid layer thickness and Resin tags: HL Coronal: Group 1: 3.28 Group 2: 4.56 Group 3: 6.26 Group: 6.92 Apical: Group 1: 2.44 Group 2: 3.55 Group 3: 4.62 Group: 5.48 RT Coronal: Group 1: 20.19 Group 2: 16.00 Group 3: 14.75 Group: 19.00 Apical Group 1: 16.69 Group 2: 12.06 Group 3: 10.19

					Group: 14.31
Marques de Melo et al., (2012)[4]	Study the mechanical properties of bonded endodontic restorations, considering the degree of conversion of the cement layer and the molecular structure of the adhesive/hybrid layer dentine interface.	In vitro/ Push-out testing; μ-Raman spectroscopy.	Human maxillary incisors and canines.	Glass fibre-reinforced composite posts, Dimethacrylates (ethoxylated bisphenol A dimethacrylate, BisGMA, and 1,4-butanediol dimethacrylate) - FRC Postec Plus post system (Ivoclar Vivadent, Schaan, Liechtenstein). Resin Cement: Duo-link (BISCO).	≈ 10-250
Spazzin et al., (2009)[24]	Evaluated the influence of two different post systems and the elastic modulus and film thickness of resin cement on the stress distribution.	The finite element analysis (FEA) using a simulation in a computerized model.	A model of a Maxillary Central Incisors with a coronary fracture.	A model of a prefabricated glass fiber (GF) posts and zirconia ceramic (ZC) posts. Resin Cement was also modeled.	GF Model 1: 70 Model 2: 70 Model 3: 200 Model 4: 200 ZC Model 5: 70 Model 6: 70 Model 7: 200 Model 8: 200
Ravanshad et al., (2003)[6]	Compare the microleakage around custom-made (cast) and prefabricated posts.	In vitro/ Using a dye penetration method with Indian ink.	Single-rooted human teeth.	Prefabricated post (Dentatus, Sweden); Cast post. Resin Cement: Fuji Type I GIC (GC Corporation, Japan); Durelon polycarboxylate cement (Espe, Germany); Variolink II (Vivadent, Liechtenstein).	—

Egilmez et al., (2013)[7]	Evaluate the bond strength of different post diameters in post spaces of the same diameter on the bond strength of tooth-colored endodontic posts, prior to and after being submitted to thermal cycling.	In vitro/ Scanning electron microscopy (SEM) analysis; Push-out test.	Single-rooted human mandibular premolar teeth.	CAD/CAM zirconia posts manufactured from pre-sintered Y-TZP disc shaped blocks (Copran ZR, WhitePeaks Dental GmbH & Co. KG, Germany); Individually glass fiber reinforced composite posts, silanated E glass fiber impregnated with polymethylmethacrylate (PMMA) and bis-GMA – IPN (everstick®, Sticknet Ltd, Finland). Resin Cement: Clearfil SA Cement, Kuraray Medical Co., Japan).	<u>Groups :</u> ZR/1.5/TC : ≈ 84-290 ZR/1.2/CON : ≈125-500 IPN/1.5/TC: ≈165-500 IPN/1.2/CON: ≈125-415
Bittner et al., (2010)[25] (25)	Evaluate the accuracy of fit of milled zirconia posts and cores and to compare the shear strength with other post-and-core systems.	In Vitro.	Maxillary central incisors and canines.	Cast gold post and core (Au); 1-piece milled zirconia post and core (Zr); Prefabricated zirconia post with heat-pressed ceramic core (Zr/Cer); Titanium post and composite resin core (Ti); Fiber/zirco-nia post with composite resin core (Fiber/Zr). Resion Cement : Multilink (Ivoclar Vivadent, Inc).	———
Schmage et al., (2005)[22]	Evaluated the cement gap between the post surface and the root canal.	Histological study.	Human anterior teeth.	Cylindro conical post system (Cendres et Métaux SA, Switzerland) ; Erlangen post system (Messes. Brassier, Germany) ; Dr Mooser post system (Cendres Et Métaux SA,	Cylindro conical post system: 62±23 Erlangen post system: 41±6 Dr Mooser post system: 48±13 MP Pirec post systeml: 34±16

				Switzerland); MP Pirec post system (Metalor, Switzerland); Velva Post system (Maillefer, Switzerland). Resin Cement : Zinc phosphate Cement (Tenet, Vivadent, NY).	Velva Post system: 33±14
Lo Giudice et al., (2019)[18]	The aim of our research is to describe the characteristics of a post-endodontic restoration system that used a metallic carrier for the resin cement injection. The study compares the mechanical proprieties between empty and resin filled hollow posts.	Pilot study/ Three-point test; Scanning electron microscopy (SEM) analysis.	———	Hollow endodontic posts, made of epoxy resin and reinforced with silica microfibers of cylindrical-conical shape with rounded tip and a diameter of 1.2 mm in the cylindrical portion. The structure is characterized by the presence, for more than 60% of the volume, of tensioned silica fibers parallel to the longitudinal axis of the post (Techole, Isasan, Italy). Resin Cement: Clearfil DC Core Plus, Kuraray Noritake Dental, Japan).	———
Souza-Gabriel et al., (2016)[27]	Evaluate pretreatment of root canal dentin with Er,Cr:YSGG laser on fiber posts bonded with self-adhesive resin cement, combined or not with NaOCl, analyzing morphological characteristics of adhesive interface.	In vitro/ Scanning electron microscopy (SEM) analysis; Confocal laser scanning microscopy (CLSM).	Bovine incisors.	Fiber posts, glass fibers (80%); pigmented resin (19%), stainless steel filament (1%) - REFORPOST (ÂNGELUS, Brazil). Resin Cement : RelyX U200 (3M ESPE, USA).	**Cervical** NAOCL: 116.98 ± 73.53 (100.82) Er,Cr:YGSS laser: 156.71 ± 98.73 (125.47) NAOCL + Er,Cr:YGSS laser: 184.30 ± 144.15 (141.06) **Middle** NAOCL: 103.25 ± 48.77 (86.76) Er,Cr:YGSS laser: 159.46 ± 116.24 (102.43) NAOCL + Er,Cr:YGSS laser: 100.97 ± 75.29 (88.00) **Apical** NAOCL: 58.96 ± 45.60 (50.99)

					Er,Cr:YGSS laser: 104.75 ± 63.86 (79.61) NAOCL + Er,Cr:YGSS laser: 98.53 ± 39.83 (107.69)
Bitter et al., (2009)[20]	Analyze the morphological characteristics of the resin–dentin interface of five different resin cements and the corresponding adhesive systems with respect to the thickness of the hybrid layer, the penetration of adhesive and resin cement into the dentinal tubules, and the number of fractured resin tags amd investigate the bond strengths of the microscopically analyzed samples.	In vitro/ Confocal laser scanning microscopy (CLSM); Micro push-out test.	Human upper central anterior teeth.	Glass fiber Posts, Dimethacrylates (ethoxylated bisphenol A dimethacrylate, BisGMA, and 1,4-butanediol dimethacrylate) - FRC Postec Plus (Ivoclar Vivadent, Liechtenstein). Resin Cement: Panavia F 2.0 (Kuraray, Japan); PermaFlo DC (Ultradent, USA); Variolink II (Ivoclar Vivadent); RelyX Unicem (3M ESPE, Germany); Clearfil Core (Kuraray).	**Hybrid layer thickness:** Panavia F 2.0: 1.2 PermaFlo DC: 3.4 Variolink II: 2.1 RelyX Unicem: 0.0 Clearfil Core: 2.7 **Number of penetration dentinal tubules:** Panavia F 2.0: 16.0 PermaFlo DC: 16.6 Variolink II: 27.8 RelyX Unicem: 1.0 Clearfil Core: 24.0 **Number of fractured tags:** Panavia F 2.0: 0.0 PermaFlo DC: 0.6 Variolink II: 2.0 RelyX Unicem: 0.0 Clearfil Core: 0.0
Souza et al., (2016)[10]	Evaluate the thickness of resin cements in the different root thirds when using relined fiberglass posts (RP) and conventional fiberglass posts (CP) in weakened roots. And evaluate the morphological characteristics of the dentin-resin interface.	Ex vivo/ Confocal laser scanning microscopy (CLSM).	Human maxillary anterior teeth.	Fiber glass posts, glass fibers (80%); pigmented resin (19%), stainless steel filament (1%) – Reforpost (ÂNGELUS, Brazil); Relined fiberglass posts with composite resin Z350 (3M, St. Paul, USA). Resin Cement: RelyX ARC (3M, St. Paul, USA); RelyX U200 (3M, St.Paul, USA).	RP U200 Cervical: 49.85±9.00 Middle: 85.36±5.00 Apical: 125.09±10.00 CP U200 Cervical: 484.51±30.00 Middle: 320.82±22.00 Apical: 129.81±17.00 RP ARC Cervical: 40.58±5.00 Middle: 83.42±5.00 Apical: 129.65±9.00 CP ARC Cervical: 401.61±28.00 Middle: 303.40±15.00 Apical: 127.34±11.00

Gomes et al., (2014)[3]	Evaluate the effect of resin cement thickness (RCT) on BS between the glass fiber post and root dentin and gap formation (GF) at the cement/dentin and cement/post interfaces.	In vitro/ Scanning electron microscopy (SEM) analysis; Push-out test.	Human mandibular premolars	Fiber glass posts, glass fiber: 80,0 ± 5,0%, Resin Epoxy: 20,0 ± 5,0%) – Whitepost DC (FGM, Joinville, Brazil). Resin Cement: Variolink II (Ivoclar Vivadent).	Groups: Well adapted: 75.2±17.9 Moderately well adapted: 341.9±8.5 Poorly adapted: 628.9±24.4
Onay et al., (2010)[21]	To compare interfacial strength in different thirds of the root canal amongst glass–fiber endodontic posts luted with different luting agents.	In vitro/ Scanning Electron Microscopy (SEM); Push-out test.	Human incisiors with one straight root.	Glass-fibre posts, glass fibres (80,0 ± 5,0%), Resin Epóxi (20,0 ± 5,0%) - Whitepot DC (FGM, Joinville, Brazil). Resin Cement: Duo-link (Bisco, Inc, Schaumburg); BisCEM (Bisco, Inc, Schaumburg); Clearfil Esthetic Cement (Kuraray Medical Inc).	BisCEM: ≈ 167-240 All Bond SE/DuoLink: ≈107 All Bond 3/DuoLink: ≈220 Clearfil ED primer II/ Clearfil Esthetic Cement: ≈87-133
Penelas et al., (2016)[9]	Compared the influence of cement film thickness (CFT) on bond strength (BS) and fracture resistance (FR) of fiber-reinforced composite (FRC) posts to root canal.	In vitro/ Push-out test; Stereomicroscope.	Single-rooted bovine teeth.	Fiber- reinforced composite (FRC) posts, glass fiber: 80,0 ± 5,0%, Resin Epoxy: 20,0 ± 5,0%) – Whitepost DC (FGM, Joinville, Brazil). Resin Cement: RelyX ARC, 3M ESPE, St. Paul, USA).	Groups: WP0.5: 0.42 WP1: 0.24 WP2: 0.21 WP3: 0.15 WP4: 0.09
Amin et al., (2014)[13]	Evaluate fracture strength and nanoleakage of endodontically treated weakened teeth after being restored with relined glass fiber – reinforced dowels and two types of cores.	In vitro/ Ultramorphological analysis by ESEM/EDAX.	Human maxillary central incisors.	Fiber glass posts: 100% biocompatible-epoxy free - UNIC fiber posts (Harald Nordin sa); UNIC fiber pots relined with Composan Ceram (Promedica, Germany). Resin Cement: Corposit (Harald Nordin Sa).	———

Da Silveira Teixeira et al., (2008)[2]	To evaluate the bonding interface in experimentally weakened roots reinforced with adhesive restorative materials and quartz fibre posts varying the light- exposure time of the composite resin used for root reinforcement.	Ex vivo/ Scanning electron microscopy analysis.	Human maxillary central incisors.	Fiber post DT Light Post: epoxy resin matrix (40 vol%), quartz fibers (60 vol%) – DT Light Post Illusion (Bisco Inc, Schaumburg, USA). Resin Cement: Duo-link (Bisco, Inc.).	
Allabban et al., (2019)[12]	Evaluate the bond strength between esthetic posts and dentin at different regions of the root canal in passive mode or push-out active mode.	In vitro/ Push-out test; Scanning electron microscope at magnification.	Single-rooted human mandibular first premolar teeth.	Glass fiber posts, glass fibre type: ahlstrom R-338, Matrix: Epoxy resin with apx. 65 % glass fibre content - Glassix plus, Switzerland); Ceramic posts system. Zirconium dioxide ceramic post system, Atomic composition: $ZiO_2 + 3\% \ Y_2O_3$ – Zirix, Harald Nordin. Resin Cement: Variolink N (Ivoclar Vivadent, Liechtenstein); Multilink Speed (Ivoclar Vivadent).	———
Moura et al., (2017)[8]	Investigate the influence of different root dentin treatment protocols, with the use of NaOCl alone or combined with EDTA, with and without ultrasonic activation, on the push-out BS of fiber-reinforced posts cemented with Self-etch (Panavia F) and self-adhesive (RelyX U200) dual cure cements in experimentally weakened roots.	In vitro/ Confocal laser scanning microscopy; Dentin Microhardness (Knoop) analysis; Push-out test.	Human permanent maxillary Canines.	Fiber- reinforced composite (FRC) posts, glass fiber: 80,0 ± 5,0%, Resin Epoxy: 20,0 ± 5,0%) – Whitepost DC (FGM, Joinville, Brazil). Resin Cement: RelyX U200 (3M ESPE, USA); Panavia F (Kuraray Noritake, Japan).	———

Rodrigues et al., (2017)[15]	Evaluate the effect of different dual polymerizing cementation systems on the bond strength of GFPs relined with composite resin to root dentin at increasing depths (from cervical to apical).	In vitro/ Push-out bond strenght test (PBS); Scanning electron microscopy.	Bovine teeth.	Fiber- reinforced composite (FRC) posts, glass fiber: 80,0 ± 5,0%, Resin Epoxy: 20,0 ± 5,0%) – Whitepost DC (FGM, Joinville, Brazil); Relined glass fiber posts (RGFP) with GFP composite resin (Z100 shade A2, 3M ESPE). Resin Cement: RelyX Ultimate (3M, ESPE); RelyX Unicem 2 (3M, ESPE); RelyX ARC (3M, ESPE).	———
Bitter et al., (2004)[1]	Evaluate the resin–dentine interface of different adhesive systems and corresponding luting cements proposed for bonding fibre posts within root canals.	In Vitro/ Confocal laser scanning microscope.	Maxillary canines and central incisors.	Fiber posts- "MirafitWhite" (Hager & Werken, Germany), 100% biocompatible - no epoxy. Resin cement: Clearfil Core (Kuraray, Japan); Multilink (Vivavdent, Liechtenstein); Panavia 21 (Kuraray, Japan); PermaFlo DC (Ultradent Salt Lake City, USA); Variolink II (Vivadent, Liechtenstein).	———
Perez et al., (2006)[19]	Evaluate the influence of cement thickness on the push-out bond strength a fiber – reinforced composite (FRC) post system to the root dentin.	In vitro/ Push-Out Bond Test.	Single-rooted human teeth.	Cylindric fiber-reinforced composite (FRC) posts, fiber type: 70% by weight pre-impregnated unidirectional quartz fibers in 30% by weight epoxy resin – Light Post (Bisco). Resin Cement: Duolink (Bisco).	Group 1: 87.4 ± 49 Group 2: 316.7 ± 58

Coniglio et al., (2009)[16]	Evaluate cement thickness around oval and circular post luted into oval post-spaces prepared with different drill tips.	In vitro/ Scanning electron microscopic (SEM).	Human single rooted premolars	Fiber posts with oval section; Fiber posts with circular section, epoxy resin matrix (40 vol%), quartz fibers (60 vol%) – DT Light Post Illusion (Dentsply, UK). Resin Cement: Fluorocore 2	Medium grit tip + oval posts Apical: 292.70 Middle: 253.35 Coronal: 294.65 Fine grit tip + oval posts Apical: 91.50 Middle: 122.15 Coronal: 138.65 MTwoPF + circular posts Apical: 266.00 Middle: 367.25 Coronal: 456.10
Tsintsadze et al., (2018)[11]	The present study assessed the in vitro performance of CAD/CAM-fabricated fiber posts inserted into ovalshaped root canals. The posts were fabricated by using three different procedures for digital data acquisition.	In vitro/ Push-out bond strength.	human single-rooted premolars	CAD/CAM-fabricated fiber posts. Resin Cement: Gradia Core (GC).	Direct scanning: 162 ± 25 Impression scanning: 187± 50 Model scanning: 259±78

4. DISCUSSION

4.1 - Teeth Root Intracanal Posts

The restoration of endodontically treated teeth is a challenge in dentistry concerning the properties of intracanal posts and resin-matrix cements (3,18,26–28). Endodontically treated teeth have a lower mechanical strength compared to teeth and therefore the crown restoration is dependent on the remnant teeth structures (7,8,12). Thus, the intracanal post provides the retention of the crown restorative material (1,4,6) and allow the dissipation of occlusal forces along the remnant dental structure, as seen in Figure 2 (3,4,13,29,30). The success of this treatment depends on both the quality of the teeth canal treatment procedure and the further coronary restoration (8,9,31).

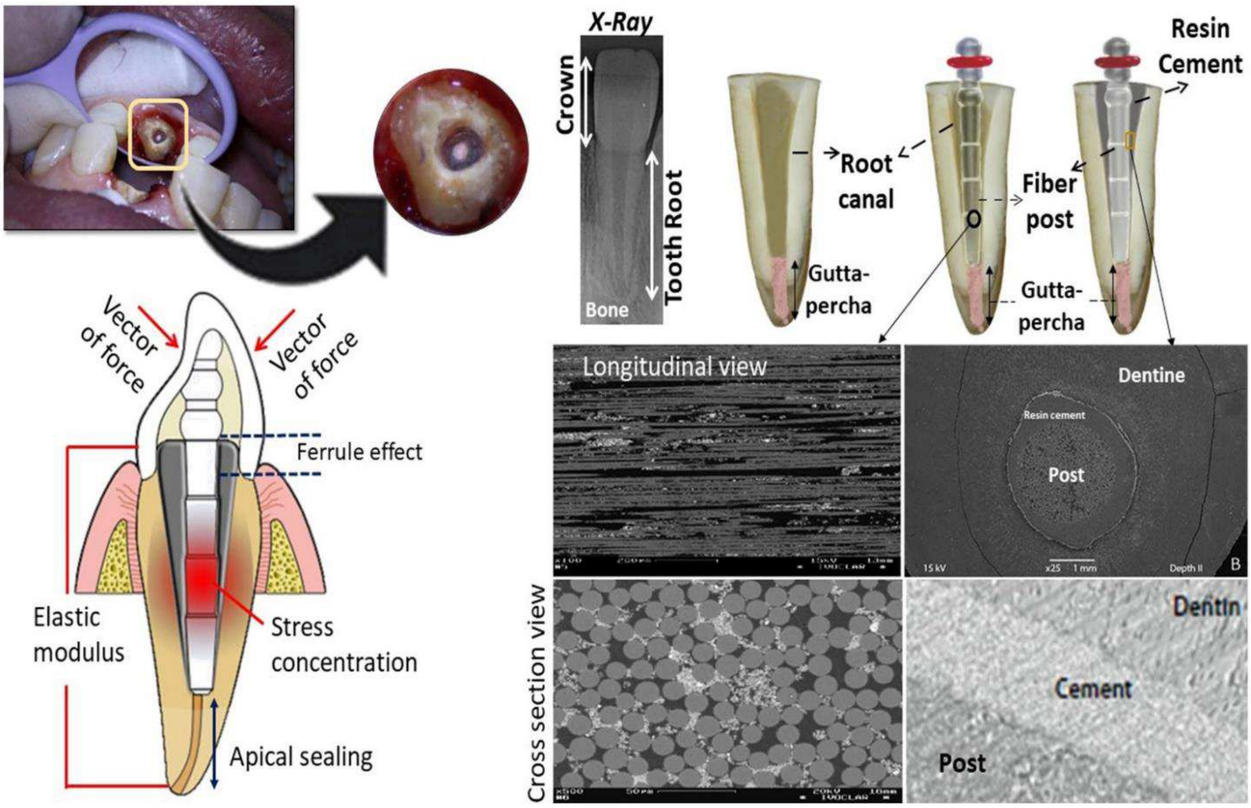

Figure 2. Schematic illustration of endodontic posts and the intracanal interfaces.

Many different types of posts systems are available for the reconstruction of endodontically treated teeth with large tooth structure loss (4,22). Cast or standard shape posts composed of metal were used over several past years due to their high strength (15,32,33). However, the use of this type of retention is associated with an increased rate of catastrophic fractures with consequent loss of the remnant teeth structures (10,15,32,34). Regarding mechanical, clinical, and aesthetic outcomes, easy-handling and low-cost posts were introduced, such as standard posts (7,9,15).

Standard shape posts can be classified according to their surface condition, such as: threaded, striated or smooth/polished (35). On the anatomical shape, the posts are classified as conical, cylindrical, truncated cone, and custom-made (36,37). The posts can be classified regarding the processing material: glass fiber, carbon fiber, ceramic, or metal. On the mode of retention or adjustment of the post into the root canal, they are classified as: active (mechanically retained by friction) or passive (retained only by cement) (22,36,38). Some studies claim that cylindrical posts are more retentive than conical posts and induce less root stress (36,37,39). However, cylindrical posts require excessive dentin removal, which may result in a decrease in strength and larger probability of root fracture (40–42).

To overcome mechanical issues, the truncated conical posts were designed with a larger diameter at the cervical third region and a smaller diameter at the apical third region. This last type of post allows a significant preservation of the root structure due to its apical portion leading to a proper distribution of stresses though the teeth root (37,39). The oval section fiber-based posts have emerged, in an attempt to promote a proper fitting in oval canals (16).

In response to a growing need for aesthetics, several types of standard fiber-based posts became commercially available (12). Currently, fiber-reinforced posts are the first choice in post-endodontic rehabilitation (10,15,18) and differ from other posts systems for showing dentin-like mechanical properties (1,2,8,11,13,15,19,43), proper stress distribution (1–3,11,13,15), higher conservation of teeth structures and fitting (8).

Fiber-reinforced posts are predominantly composed of composite structures in which the silanized fibers are positioning aligned and embedded in a polymer-matrix, namely epoxy or methacrylate resin (44). The fibers can be produced from polyethylene, kevlar, glass, carbon, or quartz (45,46). In fact, the fibers are responsible for mechanical properties such as elastic modulus and strength, while the polymer-matrix is responsible for the stress transferring and fiber's positioning. The overall mechanical properties are dependent on the length, type, orientation, and proportion of the fibers once that a higher fiber density improve the mechanical properties (47,48).

One of the relevant problems that clinicians face in restoring endodontically treated teeth is the mismatch between the diameter of the post and post space (3,7,10,13,15,17,49). Although the use of drills with compatible sizes, provided by the post manufacturers, provides a good fitting of the posts to the root canal walls, root canals may have different formats (16), causing variations in the thickness of the resin cement layer around the post (15–17). In addition, root canals that exhibit extensive tissue destruction due to carious lesions, previous restoration with excessive post and core diameters, endodontic over-instrumentation, incomplete physiological root development due to traumatic impacts, internal resorption, developmental anomalies, or even oval-shaped root canals can also compromise the adaptation of the posts to canal walls (3,7,17). In order to improve the adaptation of the posts to this type of root canals it has been proposed to manufacture customized fiber posts (10,11,13).

The use of custom-made posts and cores, produced by Computer-aided Design/Computer-aided Manufacturing (CAD/CAM) technology, allows a better adjustment to different portions of the root canal and minimize the cement layer thickness of the resin-matrix (11,50). This technology allows a complete digital workflow and provides a better mechanical retention of the post and core in the root canal (11,51). The use of this method, in the execution of the post and crown in a single body, presents the advantage of eliminating an interface, decreasing the risks of fracture at the interfaces and mechanical failure of the root canal system (52).

A remnant thickness of teeth structures between 1.5-2 mm uniformly maintained around the cervical root canal provides a gradual stress distribution, namely ferrule effect (36). The decrease in the thickness of the remnant teeth result in an abrupt distribution and concentration of stresses that can lead to failures such as root fractures and/or detachment or fracture of the post and resin-matrix cement (11,53).

4.2 - Resin-Matrix Cements

The final goal of post-endodontic rehabilitation is an adequate integration between the dentin and the restorative material in order to ensure a correct distribution of the forces to which the tooth is subjected (1). The main reason for failure of posts is debonding, which occurs mainly because of the difficulties in achieving proper adhesion to intraradicular dentin and to the post, as seen in Figure 2 (5,15,20). As a result, the selection of cement as well as the cementation method has a direct influence on the stability and longevity of endodontically treated tooth restorations (4,9,54).

The post is retained in the root canal by macro and micro-retentions on a micrometric scale (5,8,55). 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 (6).

Resin cements are widely used as intraradicular posts cementation materials, since they tend to have less microfiltration than the remaining cements, provide root strengthening in the short term and promote increased retention, and this is mainly due to their adhesive properties to the root dentin (5,13). 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. Canforquinone is included as a photo-initiator for light-curing while benzoyl peroxide is the chemical initiator which coupled to a tertiary amine. The inorganic particles provide an increase in strength and viscosity of the resin-matrix (20). The following inorganic particles can be found in the resin cements: barium silicate, ytterbium trifluoride, colloidal silica, zirconium silicates (1,20).

Recently, self-adhesive resin-matrix cements have been used as a way to simplify the adhesive procedures, dispensing the use of dentin conditioning as a separate pre-step (7,15,21). Such supposed simplification of steps decreases the technique sensitivity since the root canal is a confined narrow space, where there is lack of clinical view and the humidity control is limited (4,5,10,12,20). Self-adhesive resin cements have multifunctional hydrophilic monomers with phosphoric acid groups in their chemical composition that promote a chemical bonding to ceramic and composite post surfaces. Self-etching adhesive resin cements have also an acidic pH leading to a partly dissolution of the smear layer and to the flowing into micro-regions and the dentinal tubules. (15,20). That establishes a mechanical interlocking of the resin-matrix cement after polymerization (4,12,15,56).

On the mode of polymerization, they can be classified as light-curing, self-curing, or dual-curing. Given the anatomical limitations, self-curing or dual-curing resin cements are preferable to solely light-curing resin cements. Light propagation in the teeth root canal is a challenge and has tends to decrease in the apical direction (2). Light-curing resin cements shows a risk of low degree of conversion of monomers, which impairing the retention of the endodontic post and toxic effects into the periapical region. As these resin cements have a slower conversion rate, the polymerization shrinkage is also lower, that allows the dissipation of stresses at the interfaces during polymerization (15).

The success of the root dentine adhesive restorative technique is directly associated with the quality and uniformity of the resin–dentine interdiffusion zone (hybrid layer), resin tags and adhesive lateral branches produced upon infiltration of the adhesive system within the demineralized dentine substrate as well as the formation of a gap-free interface between the resin material and the canal walls (1,2,14). Due to the histological characteristics of the root canal, there is a decrease in the number of dentin tubules in the coronary-apical direction (1). By conditioning the root canal and using an etch & rinse adhesive, it is observed that the thickness of the hybrid layer is superior at the cervical level compared to the apical region (14). Similarly, resin tags in the apical region are also less numerous (1,14,20). Different types of adhesives also lead to different thicknesses of the hybrid layer. In a confocal laser scanning microscopy study, the application of etch & rinse adhesive resulted in a higher number of resin labels and an increase in the thickness of the hybrid layer compared to self-adhesive systems (1,4,14).

The literature reunites some consensus in the inexistence of a cement that gathers the ideal properties for intracanalar adhesion, however the cements and self-etch adhesives are the ones that present the best characteristics to guarantee values of resistance to traction and shear as well as a higher degree of polymerization in the cementation of intraradicular posts because they generate less stress in the polymerization of cement. Their chemical initiators polymerizes the cement in deep areas where blue light irradiance is decreased because of scattering and absorption by dental substrates (15).

The adhesion to coronary dentin is relatively stable, although it can be influenced by several factors, such as the endodontic irrigations solutions used during chemical-mechanical preparation (e.g. sodium hypochlorite, EDTA, hydrogen peroxide), that seems to have an unfavorable effect to the post cementation (8,28,57). The smear layer resulting from canal preparation also proved to negatively influence adhesion and consequently intra-canal retention (8). Also, the anatomical aspects of the root canal affect adhesion, specifically, the number, diameter, and orientation of dentin microtubules in different regions of the root canal.

Dentinal tubules in the root are straighter, less divergent, and not as numerous as in the crown region. The number of dentinal tubules decreases from the cervical to the apical part of the root resulting in a varied dentine bonding amongst different regions of the same root canal. Mineralization and obliteration of tubules (sclerosis) of dentin, changes in the proportion of organic and mineral phases with volumetric variations of root space and primary, secondary and tertiary dentin (5,10,12,15,21). These structural variations are responsible for distinct responses to the adhesion process in different portions of the root canal.

Moreover, the low light irradiance of the light-curing source and the limited region for clinical handling and cementation are amongst the clinical issues to establish a proper post retention (12) . Microscopic observations of the cementation layer have confirmed the chemical interaction between the acidic resin monomers and oxygen, decreasing the cement polymerization. The acidic monomers are hydrophilic and can also form water channels across the adhesive layer, leading to a inhibition of polymerization and hydrolysis of the adhesive–dentine interface (4).

Thus, the adhesion between the resin-matrix cement and the post is significantly lower than the adhesion between the resin cement and dentin structures. Some studies have reported low values of bond strength between resin-matrix cement and post due to several factors related to the resin-matrix cement and post surface (5). While the configuration factor varies from 1 to 5 in intracoronary cavities, the factor C may exceed 200 within the root intracanal. That induces a large increase of polymerization shrinkage and stress concentration at the resin-matrix cement layer (3,9). The modification of post surfaces to increase adhesion (e.g. grit-blasting) also promote an increase in the layer thickness of the resin-matrix cements (55). Additionally, the lack of fitting of the post to the intracanal space results in a thick layer of the resin-matrix cement that is reported by the previous studies as follow (3,9,10,13,15,16).

4.3 - Layer Variation of the Resin Cements

In the selected studies, different parameters were evaluated such as retention, fitting, or strength of the teeth root intracanal post. Nevertheless, the review focused on the thickness evaluation of the resin-matrix cements depending on the fitting of the teeth root intracanal posts (Table 1).

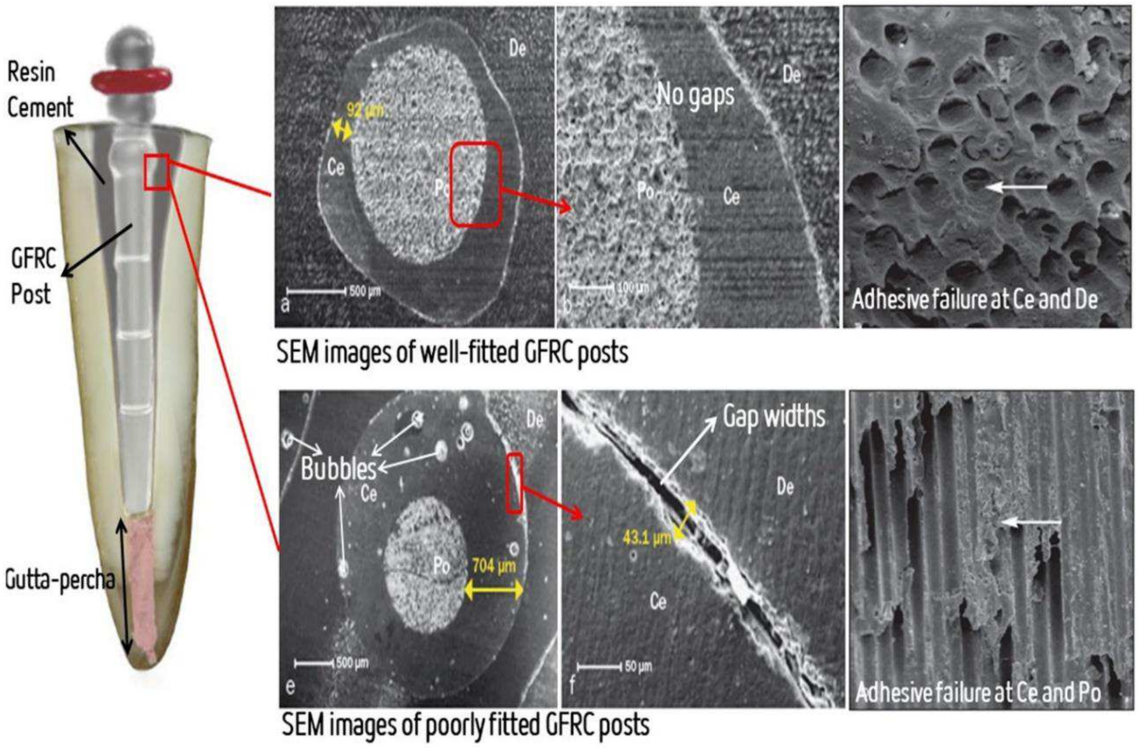

Figure 2. Schematic illustration of well-fitted endodontic posts and a poorly fitted endodontic post.

An in vitro study evaluated the influence of a dual-curing resin cement thickness on the pulling-out of a glass fiber reinforced composite (GFRC) root intracanal post. Bovine teeth roots were randomly distributed into two groups regarding the intracanal space diameter: 1.3 and 1.9 mm (5). GFRC posts (0.70 mm) were cemented using self-etching and dual-curing resin-matrix cements as seen in Table 1. The samples were submitted to pull-out tests and the fracture region of the specimens was evaluated by scanning electron microscopy (SEM).

The study demonstrated that type of the resin-matrix cement significantly affected the pull-out bond strength of the GFR posts. However, the thickness of layer 1 (thin) and the thickness of layer 2 (thick) of the resin-matrix cements did not reveal any statistical difference in the bond strength between the test groups (5). Another in vitro study reported any influence of the layer thickness of the resin-matrix cements (19). Root canals of human teeth were prepared with calibrated drills (2.2 mm) for the cementation of GFRC posts (Ø apical = 1.4mm; Ø middle-coronal = 2.2 mm for group 1 and (Ø apical = 1.0mm; Ø middle-coronal = 1.4 mm for group 2). Cementation was performed with a self-etching adhesive and a dual-curing resin-matrix cement system. Two cement layer thicknesses of the resin-matrix cements were assessed: 87.4 ± 49μm and 316.7 ± 58 μm. The layer thickness of the resin-matrix cement was measured using digital images obtained by an optical microscope after parallelly cross-sectioning the teeth at their long axis and then the push-out test was performed on other test groups. Although the layer thickness of the resin-matrix cements was statistically different between groups, there were no significant differences in the push-out bond strength. The dominant mode of failure occurred between the GFRC post and the resin-matrix cement in both groups, indicating a poor adhesion probably due to the lack of surface modification of the GFRC post (19).

Nevertheless, other studies revealed opposite results and validated the influence of the layer thickness on the retention of the teeth intracanal posts (3,7,9). Different types of custom-made and standard (zirconia or GFRC) posts were assessed regarding thermal cycling and push-out testing (7). In this study, human lower premolars were randomly divided into two groups according to the type of posts and the diameter (1.5 and 1.2 mm) of the teeth root intracanal space after drilling and shaping. All posts were cemented with a self-adhesive dual-curing resin-matrix cement system and therefore half of the samples were subjected to thermal cycling. The specimens were cross-sectioned parallelly to their long axis after the thermal cycling and or push-out test and examined by optical microscopy and SEM.

The results of this study showed that the lowest bond strength values were recorded on the groups with thickest layer (125-500 µm) of resin-matrix cements (Table 1). Bond strength results of posts with 1.5mm diameter (7.8 ± 3.5 MPa) were found to be statically higher than the 1.2 mm post diameter results (6.2 ± 3.3 MPa), being significantly influenced by the preparation diameter. The adhesive failure occurred between dentin and resin-matrix cement for zirconia posts, while mixed failures were noticed for GFRC posts. Results revealed that the increase in bond strength could be related to the post-cure effect under thermal cycling (7).

In another study, bovine incisors were assessed regarding five layer thickness values (0.42 µm, 0.24 µm, 0.21 µm, 0.15 µm, 0.09 µm) of resin-matrix cements and a GFRC post. Different resin cement thickness was achieved by the drilling and shaping preparation of the teeth root canal. Indeed, the bond strength was significantly affected by the layer thickness of the resin-matrix cement layer once well-fitted GFRC posts showed higher bond strength values. No significant differences in bond strength were detected along the teeth root canal regions (9). On human lower premolar, well fitted GFRC posts also resulted in small thickness values (75.2 ± 17.9 µm) of resin-matrix cements and the highest values of bond strength to GFRC posts and intracanal dentin (3). Thick layers of resin cements showed noticeable more structural defects, such as pores, micro-spaces, cracks or gaps. Those defects are responsible for stress concentration leading to fracture, and therefore a decrease in the bond strength of the GFRC post to root canals. The appearance of pores and micro-spaces depends on the resin cement application as well as the fitting and surface modification of the GFRC posts (3). An increase in the amount of resin cement thickness may negatively affect the light-curing absorption, and therefore the polymerization reaction of resin-matrix cement, leading to a decrease in light transmission through the GFRC post. As a result, the polymerization of thick layers of resin cements might depend only on the chemical activation produced by the self-curing component of the dual cure system, leading to a decrease in the mechanical properties of resin cement. The widest gap length percentage (%) was recorded for the GFRC post group with poorly fitting to the root canal (3).

Other studies evaluated the relationship between the fitting and the layer thickness of the resin cement by varying the preparation for the teeth root intracanal space and post type (10,16,24). Oval post-spaces in single-root human premolars were prepared with different drills and tips with comparable diameters (16). After post space preparation, the posts were cemented with a dual curing resin cement system and distributed into three groups according to tips/drills and the type of fiber post. The samples were cross-sectioned to obtain horizontal slices of 1mm thickness for SEM inspection. Group submitted to circular drilling and circular posts reached the highest values (in apical third: 266.00 μm, in middle third: 367.25 μm and coronal third: 456.10 μm) of resin cement thickness around the posts. The preparation of oval root canals with diamond-shaped ultrasound tips associated with the canal-compatible shape post promoted a proper fitting and smaller amount of resin cement (16).

In another study, sixty human teeth third molars were prepared with a dowel intracanal space shape (13). Different teeth intracanal posts were cemented to the dowel spaces and cross-sectioned for evaluation of the resin cement layer thickness by using environmental scanning electron microscope and energy dispersive analytical X-ray. The highest fracture strength values were recorded for well-fitted dowel post to the teeth root canal due to the decrease in the resin cement thickness. Thin layers of resin cement revealed lesser defects (e.g. pores and micro-spaces) than thick ones. In addition, a large volume of cement in the root canal induced higher polymerization shrinkage that could lead to debonding (13).

In an *ex vivo* study, the thickness of resin cement was evaluated around standard or custom-made intracanal posts in human third molar treated canal roots (10). There were significant differences in the layer thickness of the resin cement regarding the different posts, since the thickness values were lower (in cervical third: 49.85 ± 9.00μm, in middle third: 85.36 ± 5.00μm and apical third: 125.09 ± 10.00μmm for RelyX U200 and in cervical third: 40.58 ± 5.00μm, in middle third: 83.42 ± 5.00μm and apical third: 129.65 ± 9.00μmm for RelyX ARC) around custom made posts than those (in cervical third: 484.51 ± 30.00μm, in middle third: 320.82 ± 22.00μm and apical third: 129.81 ± 17.00μmm for RelyX U200 and in cervical third: 401.61 ± 28.00μm, in middle third: 303.40 ± 15.00μm and apical third: 127.34 ± 11.00μmm for RelyX ARC) on convention posts. However, there were no differences in the layer thickness of resin cement between the posts in the apical third region of the root canal. The diameter of the GFRC post is enough to fitting the apical third region because low anatomical and shaping variation. On standard posts, a high thickness of resin cement was recorded at the middle and cervical third regions. They also concluded that there were significant differences in layer thickness between conventional and self-adhesive cements. According to these authors there were significant differences between the third regions of the root canal for both GFRC posts. For RP, on custom made posts, the layer thickness of resin cement decreased from the apical third to the cervical third region indicating a proper fitting to the root canal in the cervical third region (10).

In another study, three-dimensional modeling was performed to evaluate the thickness effect of resin cement on central maxilla incisor treated with standard intracanal posts (24). Results showed that the stiffness of the intracanal post and resin cement layer had a considerable effect on the stress distribution through the endodontic treated teeth. In fact, the fitting of GFRC posts and low thickness of resin cement decrease the stress concentration at the interfaces leading to an improvement of the mechanical performance (24).

5. CONCLUSIONS

In this integrative systematic review, relevant outcomes have been reported by previous studies regarding the effect of the layer thickness of resin-matrix cements around teeth intracanal posts. The main conclusions of the selected studies can be drawn as follows:

- Custom-made glass fiber reinforced composite posts showed proper fitting and elastic modulus when compared to standard monolithic intracanal posts. A poor fitting leads to stress concentration at the interfaces involving the resin-matrix cement. Also, the mechanical properties of the teeth intracanal posts and resin-matrix cements influence the mechanical performance of the endodontically treated teeth.

- The lack in fitting of the intracanal post results in wide gaps and thick layers of resin cements. The increase in microgaps and thickness of the resin-matrix cement commonly occurred at the cervical third regions around standard intracanal posts. Nevertheless, custom made intracanal posts with accurate fitting increased the surface contact region between the posts and intracanal walls leading to a high retention. Consequently, the layer thickness of the resin cements decrease that guarantee a polymerization and distribution of stress through the posts to the root canal dentin.

- Self-etching adhesive applied to the root canal dentin prior to the cementation of intracanal posts provides the formation of the dentin hybrid layer and adhesive tags. The flowing and deep infiltration of the adhesive system into the dentin irregularities and tubules within numerous adhesive tags results in high mechanical interlocking and strong bonding of the post to the root dentin.

- Thick layers of adhesive and resin cement can involve defects such as pores, voids, micro-gaps, and cracks. Defects are spots for stress concentration and mechanical failures by fracture on cyclic occlusal loading. Also, nanoleakage of oral fluids and bacteria through the defects speeds up the degradation of the interface and the occurrence of secondary caries.

In conclusion, the sensitivity of the teeth root canal preparation and cementation of standard or custom-made posts are critical for the long-term mechanical performance of endodontically treated teeth. It should be emphasized the limitations of mechanical performance in endodontically treated teeth due to dissimilar properties in mechanical properties of teeth intracanal posts and resin cements. Further studies are required to evaluate novel fiber reinforced composite posts and resin-matrix cements in function of the technological advancement in materials.

REFERENCES

1. Bitter K, Paris S, Martus P, Schartner R, Kielbassa AM. A Confocal Laser Scanning Microscope investigation of different dental adhesives bonded to root canal dentine. Int Endod J. 2004 Dec;37(12):840–8.

2. da Silveira Teixeira C, Santos Felippe MC, Silva-Sousa YTC, de Sousa-Neto MD. Interfacial evaluation of experimentally weakened roots restored with adhesive materials and fibre posts: an SEM analysis. J Dent. 2008 Sep;36(9):672–82.

3. Gomes GM, Rezende EC, Gomes OM, Gomes JC, Loguercio AD, Reis A. Influence of the resin cement thickness on bond strength and gap formation of fiber posts bonded to root dentin. J Adhes Dent. 2014 Feb;16(1):71–8.

4. Marques de Melo R, Bottino MA, Galvao RKH, Soboyejo WO. Bond strengths, degree of conversion of the cement and molecular structure of the adhesive-dentine joint in fibre post restorations. J Dent. 2012 Apr;40(4):286–94.

5. Nova V, Karygianni L, Altenburger MJ, Wolkewitz M, Kielbassa AM, Wrbas K-T. Pull-out bond strength of a fibre-reinforced composite post system luted with self-adhesive resin cements. J Dent. 2013 Nov;41(11):1020–6.

6. Ravanshad S, Ghoreeshi N. An in vitro study of coronal microleakage in endodontically-treated teeth restored with posts. Aust Endod J. 2003 Dec;29(3):128–33.

7. Egilmez F, Ergun G, Cekic-Nagas I, Vallittu PK, Lassila LVJ. Influence of cement thickness on the bond strength of tooth-colored posts to root dentin after thermal cycling. Acta Odontol Scand. 2013 Jan;71(1):175–82.

8. Moura AS, Pereira RD, Rached FJAJ, Crozeta BM, Mazzi-Chaves JF, Souza-Flamini LE, et al. Influence of root dentin treatment on the push-out bond strength of fibre-reinforced posts. Braz Oral Res. 2017 Apr;31:e29.

9. Penelas AG, Piedade VM, Borges ACO da S, Poskus LT, da Silva EM, Guimaraes JGA. Can cement film thickness influence bond strength and fracture resistance of fiber reinforced composite posts? Clin Oral Investig. 2016 May;20(4):849–55.

10. Souza NC de, Marcondes ML, Breda RV, Weber JBB, Mota EG, Spohr AM. Relined fiberglass post: an ex vivo study of the resin cement thickness and dentin-resin interface. Braz Oral Res. 2016 Aug;30(1).

11. Tsintsadze N, Juloski J, Carrabba M, Tricarico M, Goracci C, Vichi A, et al. Performance of CAD/CAM fabricated fiber posts in oval-shaped root canals: An in vitro study. Am J Dent. 2017 Oct;30(5):248–54.

12. Allabban MNM, Youssef SA, Nejri AAM, Qudaih MAA. Evaluation of Bond Strength of Aesthetic Type of Posts at Different Regions of Root Canal after Application of Adhesive Resin Cement. Open access Maced J Med Sci. 2019 Jul;7(13):2167–72.

13. Amin RA, Mandour MH, Abd El-Ghany OS. Fracture strength and nanoleakage of weakened roots reconstructed using relined glass fiber-reinforced dowels combined with a novel prefabricated core system. J Prosthodont. 2014 Aug;23(6):484–94.

14. Marigo L, Lajolo C, Castagnola R, Angerame D, Somma F. Morphological confocal laser scanning microscope evaluation of four different "etch and rinse" adhesives in post endodontic restoration. Dent Mater J. 2012;31(6):988–94.

15. Rodrigues RV, Sampaio CS, Pacheco RR, Pascon FM, Puppin-Rontani RM, Giannini M. Influence of adhesive cementation systems on the bond strength of relined fiber posts to root dentin. J Prosthet Dent. 2017 Oct;118(4):493–9.

16. Coniglio I, Garcia-Godoy F, Magni E, Carvalho CA, Ferrari M. Resin cement thickness in oval-shaped canals: oval vs. circular fiber posts in combination with different tips/drills for post space preparation. Am J Dent. 2009 Oct;22(5):290–4.

17. D'Arcangelo C, Cinelli M, De Angelis F, D'Amario M. The effect of resin cement film thickness on the pullout strength of a fiber-reinforced post system. J Prosthet Dent. 2007 Sep;98(3):193–8.

18. Lo Giudice G, Ferrari Cagidiaco E, Lo Giudice R, Puleio F, Nicita F, Calapaj M. Evaluation of Mechanical Properties of a Hollow Endodontic Post by Three Point Test and SEM Analysis: A Pilot Study. Mater (Basel, Switzerland). 2019 Jun;12(12).

19. Perez BEM, Barbosa SH, Melo RM, Zamboni SC, Ozcan M, Valandro LF, et al. Does the thickness of the resin cement affect the bond strength of a fiber post to the root

dentin? Int J Prosthodont. 2006;19(6):606–9.

20. Bitter K, Paris S, Pfuertner C, Neumann K, Kielbassa AM. Morphological and bond strength evaluation of different resin cements to root dentin. Eur J Oral Sci. 2009 Jun;117(3):326–33.

21. Onay EO, Korkmaz Y, Kiremitci A. Effect of adhesive system type and root region on the push-out bond strength of glass-fibre posts to radicular dentine. Int Endod J. 2010 Apr;43(4):259–68.

22. Schmage P, Ozcan M, McMullan-Vogel C, Nergiz I. The fit of tapered posts in root canals luted with zinc phosphate cement: a histological study. Dent Mater. 2005 Sep;21(9):787–93.

23. Macedo VC, Faria e Silva AL, Martins LRM. Effect of cement type, relining procedure, and length of cementation on pull-out bond strength of fiber posts. J Endod. 2010 Sep;36(9):1543–6.

24. Spazzin AO, Galafassi D, de Meira-Junior AD, Braz R, Garbin CA. Influence of post and resin cement on stress distribution of maxillary central incisors restored with direct resin composite. Oper Dent. 2009;34(2):223–9.

25. Bittner N, Hill T, Randi A. Evaluation of a one-piece milled zirconia post and core with different post-and-core systems: An in vitro study. J Prosthet Dent. 2010 Jun;103(6):369–79.

26. Bakaus TE, Gruber YL, Reis A, Gomes OMM, Gomes GM. Bond strength values of fiberglass post to flared root canals reinforced with different materials. Braz Oral Res. 2018 Mar;32:e13.

27. Bitter K, Paris S, Mueller J, Neumann K, Kielbassa AM. Correlation of scanning electron and confocal laser scanning microscopic analyses for visualization of dentin/adhesive interfaces in the root canal. J Adhes Dent. 2009 Feb;11(1):7–14.

28. Souza-Gabriel AE, Sousa-Neto MD, Ururahy MSL, Andrade LM, Faraoni JJ, Romeo U, et al. Analysis of adhesive interface in root canals irradiated by Er,Cr:YSGG laser after luting a fiber post. Microsc Res Tech. 2016 Nov;79(11):1090–6.

29. Bru E, Forner L, Llena C, Almenar A. Fibre post behaviour prediction factors. A review of the literature. J Clin Exp Dent. 2013 Jul;5(3):e150-3.

30. Ibrahim AMBR, Richards LC, Berekally TL. Effect of remaining tooth structure on the fracture resistance of endodontically-treated maxillary premolars: An in vitro study. J Prosthet Dent. 2016 Mar;115(3):290–5.

31. Perdigao J, Geraldeli S. Bonding characteristics of self-etching adhesives to intact versus prepared enamel. J Esthet Restor Dent. 2003;15(1):32–41; discussion 42.

32. Zhou L, Wang Q. Comparison of fracture resistance between cast posts and fiber posts: a meta-analysis of literature. J Endod. 2013 Jan;39(1):11–5.

33. Rippe M, Santini M, Bier C, Baldissara P, Valandro L. Effect of root canal preparation, type of endodontic post and mechanical cycling on root fracture strength. J Appl Oral Sci. 2014 Jun 1;22:165–73.

34. Schmitter M, Hamadi K, Rammelsberg P. Survival of two post systems--five-year results of a randomized clinical trial. Quintessence Int. 2011;42(10):843–50.

35. Cheung W. A review of the management of endodontically treated teeth. Post, core and the final restoration. J Am Dent Assoc. 2005 May;136(5):611–9.

36. Fernandes AS, Shetty S, Coutinho I. Factors determining post selection: a literature review. J Prosthet Dent. 2003 Dec;90(6):556–62.

37. Maroli A, Hoelcher KAL, Reginato VF, Spazzin AO, Caldas RA, Bacchi A. Biomechanical behavior of teeth without remaining coronal structure restored with different post designs and materials. Mater Sci Eng C Mater Biol Appl. 2017 Jul;76:839–44.

38. Miller AW. Post and core systems: Which one is best? J Prosthet Dent [Internet]. 1982;48(1):27–38. Available from: http://www.sciencedirect.com/science/article/pii/0022391382900439

39. Gonzaga C, Campos E, Baratto Filho F. Restoration of endodontically treated teeth. RSBO. 2011 Jan 1;8:33–46.

40. Maccari PCA, Conceicao EN, Nunes MF. Fracture resistance of endodontically treated teeth restored with three different prefabricated esthetic posts. J Esthet Restor Dent.

CESPU
INSTITUTO UNIVERSITÁRIO
DE CIÊNCIAS DA SAÚDE

2003;15(1):25–30; discussion 31.

41. Qualtrough AJE, Chandler NP, Purton DG. A comparison of the retention of tooth-colored posts. Quintessence Int. 2003 Mar;34(3):199–201.

42. Teixeira ECN, Teixeira FB, Piasick JR, Thompson JY. An in vitro assessment of prefabricated fiber post systems. J Am Dent Assoc. 2006 Jul;137(7):1006–12.

43. Santos-Filho PCF, Veríssimo C, Soares PV, Saltarelo RC, Soares CJ, Marcondes Martins LR. Influence of ferrule, post system, and length on biomechanical behavior of endodontically treated anterior teeth. J Endod. 2014 Jan;40(1):119–23.

44. Goracci C, Ferrari M. Current perspectives on post systems: a literature review. Aust Dent J. 2011 Jun;56 Suppl 1:77–83.

45. Bell-Rönnlöf A-MLE, Jaatinen J, Lassila L, Närhi T, Vallittu P. Transmission of light through fiber-reinforced composite posts. Dent Mater J. 2019 Dec;38(6):928–33.

46. Ellakwa AE, Shortall AC, Marquis PM. Influence of fiber type and wetting agent on the flexural properties of an indirect fiber reinforced composite. J Prosthet Dent [Internet]. 2002;88(5):485—490. Available from: https://doi.org/10.1067/mpr.2002.129303

47. Frater M, Lassila L, Braunitzer G, Vallittu P, Garoushi S. Fracture resistance and marginal gap formation of post-core restorations: influence of different fiber-reinforced composites. Clin Oral Investig. 2019 May 16;24.

48. Grandini S, Goracci C, Monticelli F, Borracchini A, Ferrari M. SEM evaluation of the cement layer thickness after luting two different posts. J Adhes Dent. 2005;7(3):235–40.

49. Rocha AT, Gonçalves LM, Vasconcelos AJ de C, Matos Maia Filho E, Nunes Carvalho C, De Jesus Tavarez RR. Effect of Anatomical Customization of the Fiber Post on the Bond Strength of a Self-Adhesive Resin Cement. Int J Dent. 2017;2017:5010712.

50. da Costa RG, Freire A, Caregnatto de Morais EC, Machado de Souza E, Correr GM, Rached RN. Effect of CAD/CAM glass fiber post-core on cement micromorphology and fracture resistance of endodontically treated roots. Am J Dent. 2017 Feb;30(1):3–

8.

51. Eid RY, Koken S, Baba NZ, Ounsi H, Ferrari M, Salameh Z. Effect of Fabrication Technique and Thermal Cycling on the Bond Strength of CAD/CAM Milled Custom Fit Anatomical Post and Cores: An In Vitro Study. J Prosthodont Off J Am Coll Prosthodont. 2019 Oct;28(8):898–905.

52. Liu P, Deng X-L, Wang X-Z. Use of a CAD/CAM-fabricated glass fiber post and core to restore fractured anterior teeth: A clinical report. J Prosthet Dent. 2010 Jun;103(6):330–3.

53. Corrêa G, Brondani L, Wandscher V, Pereira GKR, Valandro L, Bergoli C. Influence of remaining coronal thickness and height on biomechanical behavior of endodontically treated teeth: Survival rates, load to fracture and finite element analysis. J Appl Oral Sci. 2018 Apr 26;26.

54. Brasil DM, Yamasaki MC, Santaella GM, Guido MCZ, Freitas DQ, Haiter-Neto F. Influence of VistaScan image enhancement filters on diagnosis of simulated periapical lesions on intraoral radiographs. Dentomaxillofac Radiol. 2019 Feb;48(2):20180146.

55. Maroulakos G, He J, Nagy WW. The Post-endodontic Adhesive Interface: Theoretical Perspectives and Potential Flaws. J Endod [Internet]. 2018;44(3):363—371. Available from: https://doi.org/10.1016/j.joen.2017.11.007

56. Goracci C, Sadek FT, Fabianelli A, Tay FR, Ferrari M. Evaluation of the adhesion of fiber posts to intraradicular dentin. Oper Dent. 2005;30(5):627–35.

57. Farina AP, Cecchin D, Barbizam JVB, Carlini-Junior B. Influence of endodontic irrigants on bond strength of a self-etching adhesive. Aust Endod J. 2011 Apr;37(1):26–30.