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Coorientadora: Prof.ª Dr.ª Maria Antonieta Veloso Carvalho de Oliveira

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ATA DE DEFESA - PÓS-GRADUAÇÃO

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Defesa de:	Dissertação de Mestrado Acadêmico, número 374, PPGO				
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Iniciando os trabalhos o(a) presidente da mesa, Dr(a). Luís Henrique Araújo Raposo, apresentou a Comissão Examinadora e o candidato(a), agradeceu a presença do público, e concedeu ao Discente a palavra para a exposição do seu trabalho. A duração da apresentação do Discente e o tempo de arguição e resposta foram conforme as normas do Programa.

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Nada mais havendo a tratar foram encerrados os trabalhos. Foi lavrada a presente ata que após lida e achada conforme foi assinada pela Banca Examinadora.

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DEDICATÓRIA

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“Chegará o dia em que a maior virtude de um cirurgião-dentista não será sua capacidade de realizar belas restaurações, mas sim, sua competência em torná-las desnecessárias”

Leandro Augusto Hilgert

SUMÁRIO

RESUMO

Este estudo objetiva testar se a composição de quatro tipos de cimentos endodônticos interfere nas propriedades adesivas do cimento resinoso dual autoadesivo usado para a cimentação de pinos de fibra de vidro à dentina radicular. Sessenta raízes de incisivos bovinos foram divididas em quatro grupos de acordo com o cimento endodôntico (n = 15): ZOE - base de óxido de zinco eugenol; CH - base de hidróxido de cálcio; ER - base resinosa; e BC - base biocerâmica. Os canais foram instrumentados pela técnica escalonada e obturados com gutta-percha e cimento endodôntico. Após 1 semana foram preparados e os pinos foram cimentados com cimento resinoso dual autoadesivo dual. Dez raízes (n=10) foram seccionadas transversalmente obtendo-se dois discos para cada terço do canal: cervical, médio e apical. Esses discos foram submetidos ao teste de micro push-out (MPO). Secções transversais, idênticas às do teste de MPO, foram realizadas para análise em MEV (n=2) e microscopia confocal (sem a cimentação dos pinos) (n=2). Secções longitudinais foram avaliadas em MEV (n=1). Os dados foram analisados por ANOVA e teste t de Bonferroni ($p<0,05$). As variáveis cimento endodôntico ($p<0,001$) e terço radicular ($p<0,001$), afetaram os valores de força de união do push-out. Foi encontrada interação significante entre as variáveis cimento endodôntico e terço radicular ($p<0,001$). O grupo BC apresentou diferença significante quando comparado aos demais grupos, com os menores valores de força de união. Conclui-se que o cimento endodôntico utilizado pode influenciar na adesão de pinos de fibra de vidro cimentados com cimento resinoso dual autoadesivo à dentina radicular; e quanto mais profundo o terço, menor a resistência adesiva.

PALAVRAS-CHAVE: cimentos endodônticos, cimento resinoso, dentina, força de união, pinos de fibra de vidro.

ABSTRACT

The study aimed to test if the composition of four different endodontic sealers influence the adhesive properties of a resin cement used for luting glass fiber posts to root canal dentin in all root thirds. Sixty bovine roots were divided into four groups according to the endodontic sealer (n=15): ZOE - zinc oxide eugenol-based; CH - calcium hydroxide-based; ER - epoxy resin-based; and BC - bioceramic-based. The canals were prepared using passive step-back technique and sealed with gutta-percha and endodontic sealer. Then were prepared, cleaned, dried and posts were cemented with self-adhesive dual-cure resin cement after one week. Roots (n=10) were cross-sectioned to obtain two discs for each canal third: cervical, middle and apical. These slices were submitted to a push-out test. Cross sections, same as the push-out slices, were evaluated under scanning electron microscopy (SEM) (n=2) and confocal laser scanning microscopy (without post cementation) (n=2). Longitudinal sections (n=1) were evaluated under SEM. Data were analyzed using ANOVA and Bonferroni t-test ($p<0.05$). The variable endodontic sealer affected the push-out bond strength values ($p<0.001$), as well as the variable root third ($p<0.001$). Significant interaction was found between the endodontic sealer and root third variables ($p<0.001$). The BC group was the only to present significant differences compared to the other groups, with the lowest bond strength values. It can be concluded that the endodontic sealer may influence the adhesion of glass fiber posts luted with self-adhesive resin cement to root canal dentin; and that the apical third presents lower bond strength values.

KEYWORDS: bond strength, endodontic sealer, fiberglass post, resin cement, root dentin.

1. INTRODUÇÃO E REFERENCIAL TEÓRICO

O tratamento restaurador de dentes tratados endodonticamente é um tema de extenso estudo e que se apresenta controverso, ainda, em alguns aspectos práticos. A perda de integridade estrutural da dentina, quando associada ao acesso coronário, pode ocasionar maior quantidade de fraturas em dentes tratados endodonticamente se comparados com dentes que não passaram por este tratamento (Reeh, 1989). Essa evidência pode ser analisada no estudo de incidência de Fennis et al. (2002), com mais de 46.000 pacientes, que reportou fraturas dentais significantemente maiores em dentes com tratamento endodôntico. Devido essa interpretação, infere-se que restaurações que promovam uma melhor integridade estrutural da dentina são preditoras de uma melhora no prognóstico de tratamento desses dentes.

Além do tratamento endodôntico, há outras características clínicas que podem reduzir o prognóstico de um elemento dental, como é o caso de grandes perdas de estrutura coronária. Schwartz & Robbins (2004) realizaram uma revisão de literatura em que foi encontrado consenso de que os retentores intrarradiculares devem ser utilizados em casos que haja essa necessidade de retenção da restauração coronária perdida. Frente a isso, a preservação de estrutura dental em todas as etapas de tratamento é um dos principais fatores para se evitar complicações com a retenção intrarradicular (Fokkinga et al., 2007).

Soares et al. (2012) demonstrou, em sua revisão de literatura, que a taxa de sobrevivência clínica de pinos reforçados por fibra de vidro apresenta-se semelhante à dos metálicos; e que esses últimos, entretanto, apresentam maiores índices de falhas irreversíveis quando comparados com os primeiros. Ainda, restaurações em dentes tratados endodonticamente sem a utilização de metais e com materiais quimicamente homogêneos e que apresentem propriedades físicas similares à dentina, tem sido um dos principais objetivos da odontologia restauradora (Akkayan et al, 2002). Tal objetivo é reforçado por estudos como o de Golberg & Burstone (1992), que evidenciam que a composição da estrutura de pinos reforçados por fibra de vidro por matriz de resina não afeta o seu módulo de elasticidade próximo ao da dentina.

A utilização de pinos de fibra de vidro, em contrapartida, tem na retenção entre a dentina radicular e o cimento resinoso um dos pontos mais críticos na fixação de tais pinos, já que a interferência na área de adesão cimento-dentina afeta a longevidade da restauração (Oliveira et al., 2018). Portanto, um entendimento das propriedades dos materiais e substratos envolvidos nas restaurações dentais é essencial para assegurar longevidade às interfaces adesivas (Mecholsky, 1995). Resíduos na parede dentinária do canal radicular também podem afetar essa adesividade, como é o caso dos resíduos do cimento obturador endodôntico, que podem interferir na fotopolimerização do cimento resinoso (Cecchin, 2011). Suzuki et al. (2015) confirma que a presença desses resíduos pode criar áreas de enfraquecimento na interface adesiva e diminuir a resistência adesiva da restauração.

Materiais à base do composto fenólico eugenol ou até mesmo presença de resíduos de hidróxido de cálcio, por exemplo, são fatores que comprovadamente influenciam de forma negativa neste processo de adesão (Paul & Schärer, 1997; Cohen et al., 2002). Além disso, os cimentos endodônticos à base de hidróxido de cálcio apresentam-se com mais dificuldade de remoção das paredes do canal radicular, deixando resíduos que interferem posteriormente na adesividade (Skupien et al., 2015). A compatibilidade entre os diferentes materiais empregados no tratamento do canal radicular, obturação e fixação dos retentores constitui-se um aspecto importante a ser considerado na reabilitação do elemento dental (Cohen et al., 2002). A necessidade de estudos com os novos tipos de cimentos endodônticos presentes no mercado se torna indispensável frente a tais considerações, como já previamente considerado, pois cimentos resinosos e biocerâmicos ainda não possuem estudos científicos nesse âmbito de análise (Menezes et al., 2008).

Os cimentos endodônticos biocerâmicos têm uma excelente biocompatibilidade e propriedades que o conferem como o cimento endodôntico ideal (Nasseh, 2009). Ele apresenta propriedades antimicrobianas e atividade biológica, devido ao seu pH alcalino de 12,7 (similar ao hidróxido de cálcio) e ao aumento da precipitação de cristais de apatita com o tempo, respectivamente (Ree & Schwartz, 2014). Ainda, estudos demonstram sua habilidade de promover um excelente selamento apical hermético em ambiente úmido, fato que vem ao encontro de um dos objetivos da etapa obturadora endodontia, apresentando como um potencial candidato à condição de padrão-ouro de cimentos endodônticos (Kossev & Stefanov, 2009). Entretanto, deve-se salientar a necessidade de estudos mais aprofundados a respeito desse novo tipo de cimento endodôntico, além da sua interação com as demais etapas do processo restaurador.

A interação entre o cimento resinoso e o pino de fibra de vidro apresenta características que os assemelham à estrutura dentária, caracterizando o biomimetismo esperado e favorecendo as distribuições de tensões pela estrutura radicular (Qualtrough & Mannocci, 2003). A fixação do pino, realizada com cimento resinoso, entretanto, é dependente da união efetiva entre o componente adesivo e o substrato dentinário, que é comprometida, entre outros fatores, pela dificuldade de irradiação direta da luz em regiões profundas, sendo necessária a utilização de cimentos resinosos de dupla ativação (Foxton et al, 2003).

Diante deste contexto, a hipótese nula gerada é que os diferentes tipos de cimentos endodônticos obturadores não influenciarão na resistência de união de retentores reforçados por fibra fixados a raízes bovinas. O objetivo do estudo, portanto, será analisar, por meio de ensaio mecânico de micro-push-out, a influência de diferentes tipos de cimentos endodônticos na resistência de união de retentores intrarradiculares reforçados por fibra de vidro à dentina intrarradicular nos terços cervical, médio e apical de raízes bovinas obturadas com guta-percha e quatro diferentes tipos de cimentos endodônticos: ZE – a base de óxido de zinco e eugenol, HC – a base de hidróxido de cálcio, CR – resinoso e CB – biocerâmico.

2. CAPÍTULO 1

INFLUENCE OF DIFFERENT ENDODONTIC SEALERS ON THE LUTING OF GLASS FIBER POSTS TO ROOT CANAL DENTIN

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TITLE: INFLUENCE OF DIFFERENT ENDODONTIC SEALERS CEMENT ON THE ADHESION LUTING OF GLASS FIBER POSTS TO ROOT CANAL DENTIN

SHORT TITLE: INFLUENCE OF ROOT SEALERS ON FIBER POST ADHESION

~~The first page of the manuscript must contain: title of the manuscript, short tile with no more than 40 characters, and NO authors' names or identification.~~

SUMMARY

The study aimed~~s~~ to test ~~the hypothesis that~~if the composition of four different ~~types of~~ endodontic sealers~~ cements~~ ~~interferes~~ influence~~in~~ the adhesive~~on~~ properties of a resin cement used for luting glass fiber posts to root canal dentin in all root thirds~~ when cementing fiberglass posts in the three thirds of the canal~~. Sixty bovine roots were divided into four groups according to the endodontic sealer (n=15): ZOE - zinc oxide eugenol-based; CH - calcium hydroxide-based~~ sealer~~; ER - epoxy resin-based~~ sealer~~; and BC - bioceramic-based~~ — sealer~~. The canals were prepared using passive step-back technique[LR1][LR2] and sealed with gutta-percha and endodontic sealer. Then were prepared, cleaned, dried and ~~T~~posts were cemented with self-adhesive dual-cure resin cement after one week. ~~Ten r~~Roots (n=10) were cross-sectioned to obtain two discs for each canal third: cervical, middle and apical~~third~~. These ~~posts~~ slices were submitted to a push-out test[LR3][LR4]. ~~Three teeth~~ Cross sections, same as the push-out slices, were evaluated ~~in the~~under scanning electron microscopy~~e~~ (SEM) (n=2) and~~ two teeth were evaluated in~~ confocal laser scanning microscopy (n=2). Longitudinal sections (n=1) were evaluated under SEM. Data were analyz~~s~~ed using ANOVA and Bonferroni t-test ($p<0.05$). The variable endodontic sealer ~~composition~~ affected the push-out bond strength values ($p<0.001$), as well as the variable root third ($p<0.001$). ~~The presence of statistically s~~Significant interaction was found between ~~group~~ the endodontic sealer and root third variables ($p<0.001$)~~ was also found~~. The ~~bioceramic-based sealer~~BC group was the only ~~one that~~to present~~ed~~ ~~statistically~~ significant differences ~~when~~ compared to the other ~~ones~~groups, ~~presenting~~ with the lowest bond strength values. It can be concluded that the endodontic sealer ~~i~~may influence ~~in its~~the adhesion of glass fiber posts luted with self-adhesive resin cement to root canal dentin; ~~that~~ and that the apical third~~s~~ presents lower ~~adhesive force~~bond strength values.~~; and that the bioceramic-based sealer showed the lower values and was the only one with significative difference between the other groups.~~

KEY WORDS:[LR5] adhesion, bond strength, endodontic sealer, fiberglass post, root dentin.

INTRODUCTION

Teeth that are compromised, but adequately endodontically treated, restored and maintained, has long-term survival rates (over 15 years), presenting a less invasive, more psychologically acceptable and with biological low cost, this is a cost-effective alternative to tooth extraction and implant placement (1). To endodontically treated teeth with substantial tissue loss, the post application is essential to increase retention to the coronal restoration and provide its resistance (2). Based on the evidence from randomized controlled trials, fiber post shows a higher medium-term survival rates (3 to 7 years) than metal posts in restoration of endodontically treated teeth with great loss of tissue (3).

~~So~~Thus, the adhesion between root canal dentin and resin cements, needed for the cementation of fiber posts, is recognized as one of the most critical points in the fixation of ~~fiber~~these retainers ~~reinforced retainers~~, since ~~the~~ interferences in the cement-dentin adhesive interface~~on area is~~ can directly ~~related to~~influence the longevity of the final restoration (4). For this purpose, adhesive restorative materials, which present similar mechanical properties to dentin and enamel have been indicated as one of the main goals ~~of~~ in the restoration of endodontically treated teeth ~~restorative dentistry~~ (5).

The presence of any sort of residues in the mineralized tooth tissues can create areas of weakness at the adhesive interface and decrease the bond strength of the restoration (6). The remnants of endodontic sealers, for example, can interfere in the polymerization kinetics of the resin cements used for luting intrarradicular posts, affecting bond strength (7).[LR6] The presence of these residues can create areas of weakness at the adhesive interface and decrease the bond strength of the restoration (7). ThusTherefore, the compatibility between the different materials employed in the treatment/ and obturation of root canals and those used for the fixation of the intrarradicular retainers posts is an important aspect to be considered in dental element the rehabilitation of endodontically treated teeth (8).

Among the most used endodontic sealers, it is usual to assess, trough adhesion tests, the negative interactions that they can cause between cemented fiberglass post and root dentin (9). However, a new class of bioceramic-based endodontic sealers was recently introduced in the market. Their biological effects, as well as their antibacterial properties, when compared with the other types of endodontic sealers available, have been studied and evaluated (10), indeed evidence is still lacking about the interactions resulting from the use of these products with the conventional restorative materials for the use of fiber posts.

In this contextTherefore, the null hypothesisi generated in this study was that theeat the different types of obturating endodontic cements willsealers would not influence the bond strength of glass fiber posts reinforced retainers fixed luted with a self-adhesive resin cement regardless of the distinct root canal thirds (cervical, middle, apical).

MATERIAL AND METHODS

A pilot study assessment were was conducted using 10 bovine lower incisor teeth (n=10) with the purpose of creating, refining and standardizeing the different laboratory techniquesprocedures and train, besides the calibration of both the operator involved in this study.

Specimen preparation

The experimental unit used were sSingle-rooted bovine teeth, preselected by closed apex and similar dimensions, were cleaned in the outterexternal root surface with periodontal hand curettesscalers, stored in deionized aqueous solutionwater and cutted sectioned into 15.0 mm root remnant from the apical portion of each root. A sample of 60 roots was obtained. Then, the samples specimens were, then, prepared chemomechanically prepared. For the coronal portion, #2-4 Gattes-Gliden drills (Angelus, Londrina, ~~Paraná~~PR, Brazil) ~~sizes 2, 3 and 4,~~ were used in the depth of 10.0 mm. After, #15 K-file ~~size 15 K-file~~ (Dentsply Indústria e Comércio Ltda., Pirassununga, SP, Brazil) ~~were~~ was selected as the first ~~size~~ instrument for the passive step-back technique, by Torabinejad (11)~~, and they were~~ up to a ~~size~~ #55 ~~K~~ file. The irrigation ~~were~~ was made using 1.0% NaOCl during all the steps of the preparation. At the end, the ~~samples~~ specimens were filled with 17% EDTA for 5 minutes, flushed with 0.9% isotonic sodium chloride solution and dried with absorbent paper points (Dentsply Indústria e Comércio Ltda.).

The ~~study fator were four level~~specimens were then allocated by simple randomization into 4 experimental groups (n=15) according to the endodontic sealer~~cement~~: ZOE – zinc oxide eugenol-based ~~sealer~~ (Pulp Canal Sealer EWT; European Union Representative Kerr Italia, Scafati, SA, Italy), CH – calcium hydroxide-based ~~sealer~~ (Sealer 26; Dentsply Indústria e Comércio Ltda.), ER – epoxy resin-based ~~sealer~~ (AH Plus; Dentsply DeTrey GmbH, Konstanz, Germany) and BC – bioceramic-based sealer (BIO-C Sealer[BdAM7]; Angelus). The endodontic sealers used are described in Table 1. ~~Therefore, the roots were randomly allocated into 4 groups (n=15), according to the endodontic sealer.~~ The ~~groups~~ specimens were used according to the~~divided in tree subgroups of~~ methods of analysis: push-out test (n=10), scanning electron microscopy~~e~~ (n=3) and confocal microscopy ~~assay~~ (n=2). The schematic illustration of the experimental design is in Figure 1. After the instrumentation, the root canals were filled ~~according to the group of each sample. The samples were filled~~ with the respective endodontic sealers associated to~~a size~~ #55 master gutta-percha cone and accessory gutta-percha cones (Dentsply Indústria e Comércio Ltda.), using lateral and vertical compaction. The handling of endodontic sealers was performed according to the manufacturer's instructions. ~~All the specimens were prepared for the fiber post cementation, except 1 sample of each group (stored for confocal microscopy).~~ All the ~~samples~~ specimens were sealed with a provisional restoration villevie (Dentalville do Brasil LTDA, Joinville, Santa Catarina, Brazil).[LR8][LR9] The provisional restoration used are described in Table 1[LR10].

After 1 week, all the specimens were prepared for the fiber post cementation, except 2 specimen per group, which was stored for confocal microscopy analysis. ~~A week~~

~~later~~Root canal preparation for fiber posts consisted of canal prepare ~~were completelly removed~~ with ~~a size~~ #3 and ~~a size~~ 4 Largo drills (Angelus) to a depth of 10.0 mm, leaving a ~~(~~ 5.0 mm apical sealing remnant~~)~~. After cleaning the root canals with physiologic saline[LR11][LR12] and drying with paper points, ~~T~~the fiber posts were~~as~~, then, cemented ~~in all samples designed for it~~as follows. ~~T~~The glass fiber posts (Exacto, #1, Angelus) were cleaned with ~~a~~ 35% hydrogen peroxide (FGM, Joinville, Santa Catarina, Brazil), using a ~~microbrush~~disposable applicator and let to react for 1 min~~, was passed on the pin surface for its conditioning and let dry for 1 minute~~, followed by water rising and air jets ~~a jet o fair for dry~~. ~~With the dry post, there was applied a adhesion promoter for glass fiber, the~~A silane coupling agent (Angelus)~~,~~ was then actively applied on the post surface and left to react for 1 min~~according to the manufacturer's indications~~. Next, ~~using a microbrush as well,~~the bond component of a multi-step etch-and-rinse adhesive system (Adhesive, Scotchb~~B~~ond Multipurpose, 3M ~~-~~ESPE~~, Irvine, California, USA~~) was applied on the post surface (12) and light-cured for 40 s using an LED light-curing unit (Radii Cal; SDI, Melbourne, Victoria, Australia)[LR13][LR14].[LR15] The self-adhesive dual-cure resin cement (RelyX U200; 3M ESPE Deutschland GmbH, Neuss, Germany~~, Neuss, Düsseldorf, Germany~~) was prepared according to the manufacturer´s directions and inserted~~, taken~~ into the root canal ~~with a size~~ using a #15 K-file (Dentsply Indústria e comércio Ltda.) followed by the glass fiber post. The resin cement used is described in Table 1. ~~and, a~~After 5 minutes (chemical setting time) (13), the ~~fiber post (Exacto, Angelus) was inserted in a single movement. The~~ cement was light-cured for 40 s in each surface using an LED light-curing unit (Radii Cal, SDI) and perpendicular to the post. A single operator performed all procedures ~~to avoid bias~~.

Push-out bond strength test (PBS)

The ~~response variables were the~~ bond strength (MPa) of the dentin/cement/post restorative interface was verified~~, acquired~~ through ~~the~~ push-out test. For ~~its preparation~~this purpose, 10 ~~samples~~ specimens of each group ~~was~~ were selected and fixed on an~~the~~ acrylic base of a sectioning machine (IsoMet 1000 Precision Saw, Buehler, Lake Bluff, Illinois, USA) and sliced with a diamond wafer blade of 102mm x 0.3mm x 12.7mm (EXTEC DIA, EXTEC CORP, Enfield, Connecticut, USA). The first cervical slice (1.0 mm) was discar~~t~~ded due to the excessive cement and, then six ~~three~~ slices[LR16][LR17] (1.0 mm) were ~~taken~~ obtained per specimen, 2 in each third (cervical, middle, apical), totalizing~~getting up in the end with 30~~ 60 slices per group. The push-out test was performed in a universal testing machine (Emic DL-2000; Emic, São José dos Pinhais, ~~Paraná~~PR, Brazil) at a crosshead speed of 0.5 mm/min. The slice of cervical and middle areas was positioned, with the most coronal portion based downward, on a metallic device with a central ~~opening~~ hole (∅=2.5 mm); and the slices of apical areas ~~was~~ were positioned the same way, but in a device with a minor central opening (∅=2.0 mm). For the test, a metallic cylinder with different extremity for each area (∅=1.0 mm for cervical and ~~mesial~~middle thirds; ∅=0.5 mm for apical third) induced a load (50 KgF) only on the post, avoiding to apply~~ing~~ any pressure directly to the dentin or resin cement. The bond strenght (σ) was obtained ~~in~~ (MP~~p~~a), ~~with~~ using the following formula: ($\sigma=F/A$), where F is the load necessary for the specimen rupture (N), obtained in the test, and A is~~r~~ the bonded area of each slice (mm^2), ~~calculated~~ which was previously measured using~~by~~ a digital caliper (Digimess, São Paulo, São Paulo, Brazil). The data obtained was registered and tabulated.

Failure mode[LR18]

After the push-out test, the failure mode of all specimens was analyzed in a measuring microscope (STM, Olympus Optical Co, Tokyo, Japan) at 25×[LR19] magnification. According to the failures the specimens were categorized in the following failure modes using an adapted criterion (14): I- Adhesive failure between dentin and resin cement; II- adhesive failure between resin cement and post; III- cohesive failure within resin cement; IV- Cohesive failure within dentin; V- mixed failure.

Scanning electron microscopy (SEM)

For the SEM analysis, ~~three~~ representative specimens of each group were sliced (n=3), one longitudinally and two transversely~~, the samples were metallized and submitted to standardized magnifications of 1000x.~~ . The specimens were cleaned in ultrasonic bath, dried and fixed on aluminum stub with double-sided carbon tape (Electron Microscopy Sciences, Washington, DC, USA). Then, the specimens received metallic coverage with a layer of gold/palladium (Denton Vacuum Desk II Sputtering, Denton Vacuum, Cherry Hill, NJ, USA). The specimens were placed in the scanning electron microscope (SEM - VEGA3, TESCAN ORSAY HOLDING, Kohoutovice, Czech Republic) in high vacuum mode with 5 kV voltage acceleration, working distance ranging from 29 mm to 33 mm e view field of 208 μm,[LR20] for illustrating the restorative complex and the interactions between the materials and root canal dentin, evaluating the presence of gap in this interface.

Confocal laser scanning microscopy (CLSM)

Otherwise, fFor the confocal microscopy, the colorant Rhodamine B (Sigma, St Louis, MO, USA) will bewas used as a source of excitation, being mixed with the endodontic cement used previously to obturation with the percentage of 1% in relation to the sealer, promoting the red color of the final images. After 7 days of cementation, the two specimens (n=2) were prepared with a #3 and 4 Largo drills (Angelus) to a depth of 10.0 mm, leaving a 5.0 mm apical sealing remnant. Then, were sliced transversely, 1.00-mm thick, both without the post cementation. The acquisition of images will bewas performed using the 10× x objective, with 2 x 2 mm field of view, under a confocal laser scanning microscopy (LSM 510 Meta, Zeiss, Oberkochen, Germany). The rhodamine B was excited at 543 nm excitation line of helium ion laser and each resin-dentin interface was completely investigated, and then representative optical images were captured (10X magnification), in order to assess the penetration of sealer inside the dentinal tubules and the presence of remaining sealer in dentin walls.

Statistical analysis

The Sigma Plot (version 14.0, Systat Software, Inc., San Jose, CA, USA) statistical package was used for statistical analysis of the data. Homogeneity and normality of samples were tested by Brown-Forsythe's test and Shapiro-Wilk's test, respectively. The outcome data were analyzed statistically by two-way analysis of variance (ANOVA), comparing the variables: sealers and root canal thirds. Post hoc pair-wise multiple comparisons were performed using Bonferroni t-test. The level of statistical significance was set at α=0.05. In the software Sigma Plot DQualitative descriptive analysis was used for SEM, confocal radiographymicroscopy[LR21] and failure mode.

RESULTS

The comparison between endodontic sealers and root thirds is shown in Table 2. The variable endodontic sealer composition affected the bond strength values (p<0.001), as well as the variable root third (p<0.001). The presence of significant interaction between endodontic sealer and root third was also found (p<0.001).

~~Comparing the different~~Significant differences between the bond strength of the distinct root thirds were found for all groups, with higher values for the cervical third, followed by the middle third, and lastly by the apical third (p<0.001), irrespective of the ~~for the same endodontic sealer, there were differences for all four tested~~ endodontic sealer~~s~~ (p<0.05).~~, which are the zinc oxide eugenol-based, the epoxy resin-based, the calcium hydroxide-based sealer and the bioceramic-based. In this difference, all the cervical thirds were superior to the mesial ones, wich were superior to the apical thirds (P<0.001).~~ The BC group presented the lower bond strength values. CH and ZOE groups presented the higher bond strength values and were similar to ER group.

~~Adhesive~~ The most prevalent failure mode occurred between the ~~cement and the~~ root dentin and resin cement ~~was predominant~~ (Type I, 91.3%), followed by mixed failures (Type V, 7.4%) and, at least, by the adhesive failure between the resin cement and post (Type II, 1.3%). ~~There was not found~~No cohesive failures were found in the ~~any~~ post, resin cement or root dentin ~~cohesive failures~~.

The SEM analysis is illustrated in Figure 2 and Figure 3. In Figure 2, it can be analyzed the adhesive interface between the root dentin and the cement for all the thirds (it was used the ER group for illustration). In Figure 3, the same interface is shown for all the four different groups (it was used the apical third for illustration). By these images, it can be observed that the gap seems bigger in the ZOE and ER groups. Also, the surface of the cement seems more uniform in the CH and ER groups, when compared to the root dentin.

The CLSM analysis is illustrated in Figure 4 for all the groups (it was used the middle third for illustration). In these images, it can be observed the penetration of endodontic sealer in the dentinal tubules of all the four groups, even after the filling material were complete~~l~~ly removed for the post cementation. The BC and ZOE groups present a more significative penetration of sealer than the other two groups when the images are analyzed by the amount of colorant. They are also the groups that seem to leave the major amount of remnants sealer in the root dentin walls after canal relief.

DISCUSSION[LR22]

The null hypothesis tested was rejected, since the different types of endodontic sealers have influenced the bond strength of glass fiber posts luted with a self-adhesive resin cement to the root canal dentin and that different bond strength was observed for all the root canal thirds (cervical, middle, apical).

There is an increasing interest in the adhesion process of dental materials to dentin, since this property is important for treatment longevity (15). The presence of an intact, clean and with unaltered structure dentin, allows adequate entanglement of materials, fundamental for hybrid layer formation, characterized as the space corresponding to resin infiltration within the collagen matrix (16). Conversely, the remnant of different endodontic sealer in the dentin walls significantly interfered in the bond strength values tested in the push-out test results. This found is in accordance to the literature (9, 17), where this difference is proven. It can be explained by the high levels of penetration in dentin tubules of all types of endodontic sealers, according to the CLSM images, which make the cleaning process of root canals a challenging procedure, even to experienced practitioners. This is in accordance with a previous investigation, which used confocal microscopy to prove this difficulty (18). Therefore, an effective cleaning protocol is necessary for establish the safest way to prepare root canals prior to post cementation.

Endodontic sealers based on phenolic compounds, such as eugenol, for example, is a material that have been shown to negatively influence the adhesion process to root dentin, which is demonstrated in the systematic review and meta-analysis of Altmann et al. (19~~,8~~). These findings, however, are in contradiction with the results of the push-out test, in which the adhesion values of ZOE group showed a statistically equality to the other two groups: CH and ER. This can be explained by the fact that the roots where cemented after 7 days of the obturation and not immediately, which is proven to be the time required for the elimination of the eugenol component (9), therefore, there is no negative interference in adhesiveness. Accordingly, when using a zinc oxide and eugenol-based sealer, it is recommended to prepare the canal and cement the fiberglass post after 7 days of the obturation.

The Bio-C Sealer (Angelus) is a new, premixed bioceramic sealer developed for permanent filling and sealing during root canal treatment. Calcium silicate–based materials have been proposed as root canal sealers for root canal treatment, as advantages it has a better cytocompatibility in terms of cell viability, migration, cell morphology, cell attachment, and mineralization capacity (20). Also, these sealer has a short setting time, alkalization ability, great radiopacity and highest flow rate among the other types of sealer (21). Its high flow property may explain the bigger level of penetration found in the CLSM images of the BC group when compared to the other ones, even all the groups showing penetration in dentinal tubules. This high flow presents itself as a good property for the promotion of endodontic sealing, despite being a difficult factor in its removal, which demonstrates the need for a more effective root canal cleaning protocol. Also, this may explain the lowest bond strength value found in the push-out test, assuming that this type of sealer is harder to remove at the time of canal prepare, promoting more negative influence in the interface dentin-resin cement.

The fixation of glass fiber posts ~~reinforced retainers,~~ performed with resin cements~~,~~ is dependent on the effective union between the adhesive component and the dentin substrate, and may be compromised by the difficulty of direct light irradiation in deeper root regions, requiring the use of chemically activated or dual-cure ~~activation~~ resin cements (22). ~~There are a~~A decrease in the amount ~~of radial transmition~~ of luminous energy transmitted at the deeper ~~depths~~ regions of the root canal was observed by a previous investigation~~in the same element~~ (23). This fact can help to explain the differences found in the push-out bond strength values ~~between~~ among the ~~three~~ distinct root thirds evaluated in this study ~~studied~~, even when using ~~in the presence of~~ a dual-cure resin cement.

The higher~~st~~ incidence of adhesive failures (91.3%) between the resin cement and ~~the~~root canal dentin observed in the present investigation~~, compared to the other types,~~ is in agreement with other study~~the literature~~, ~~that~~ which report~~s~~ it due to the ~~frailty connection~~fragile interaction of the components in this interface (24). This fact can be better explained by ~~the many~~ joint action of some factors~~prese~~, such as the presence of endodontic sealer remnants ~~cement~~ used in the root canal filling procedure and the decreased intensity of ~~the~~ light transmission through the root canal thirds, as already discussed and observed by the results of this study. This finding was also confirmed by the analysis of SEM images, which showed the constant presence and its differences in the gap of the interfaces between dentin and resin cement.

The present study present intrinsic limitations, such as using specimens that were not submitted to cyclic and thermal fatigue previously to bond strength tests and the fact of a single self-adhesive dual-cure resin cement has been used for luting the glass fiber posts. Despite these facts, the focus of the study was to assess the influence of endodontic sealers of different compositions on the bond strength of glass fiber posts luted with resin cement to root canal dentin. Therefore, ~~A~~according to the conditions ~~presented~~ tested in this ~~*experimental*~~ *in vitro* study, it can be concluded that the type of endodontic sealer used ~~in the~~ for root canal filling may influence ~~in its~~the adhesion of glass fiber posts luted with a self-adhesive resin cement to root canal dentin. It can also be inferred that the apical third~~s~~ presents the lower ~~adhesive force~~bond strength value verified and that~~and that t~~ the bioceramic-based sealer was the only to present significant differences compared to the other groups, with the lowest bond strength values observed.~~sealer showed the lower values and was the only one with significative difference between the other groups.~~

SUMMARY IN PORTUGUESE[LR23]

Este estudo objetiva testar se a composição de quatro tipos de cimentos endodônticos interfere nas propriedades adesivas do cimento resinoso autoadesivo dual usado para a cimentação de pinos de fibra de vidro à dentina radicular. Sessenta raízes de incisivos bovinos foram divididas em quatro grupos de acordo com o cimento endodôntico (n = 15): ZOE - base de óxido de zinco eugenol; CH - base de hidróxido de cálcio; ER - base resinosa; e BC - base biocerâmica. Os canais foram instrumentados pela técnica escalonada e obturados com gutta-percha e cimento endodôntico. Após 1 semana foram preparados e os pinos foram cimentados com cimento resinoso autoadesivo dual. Dez raízes (n=10) foram seccionadas transversalmente obtendo-se dois discos para cada terço do canal: cervical, médio e apical. Esses discos foram submetidos ao teste de micro push-out (MPO). Secções transversais, idênticas às do teste de MPO, foram realizadas para análise em MEV (n=2) e microscopia confocal (n=2). Secções longitudinais foram avaliadas em MEV (n=1). Os dados foram analisados por ANOVA e teste t de Bonferroni ($p<0,05$). As variáveis cimento endodôntico ($p<0,001$) e terço radicular ($p<0,001$), afetaram os valores de força de união do push-out. Foi encontrada interação significante entre as variáveis cimento endodôntico e terço radicular ($p<0,001$). O grupo BC apresentou diferença significante quando comparado aos demais grupos, com os menores

valores de força de união. Conclui-se que o cimento endodôntico utilizado pode influenciar na adesão de pinos de fibra de vidro cimentados com cimento resinoso autoadesivo dual à dentina radicular; e quanto mais profundo o terço, menor a resistência adesiva.

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TABLES

Table 1 – Materials used in the experimental procedures, with their respective batch number, manufacturer and composition.

Material	*Batch number*	*Manufacturer*	*Composition*
Sealer 26	351914K	Dentsply Indústria e comércio Ltda., Pirassununga, SP, Brazil	Powder: bismuth trioxide, calcium hydroxide, hexamethylenetetramine and titanium dioxide. Paste: bisphenol epoxy resin
AH Plus	Paste A: 1809000415 Paste B: 1809000318	Dentsply DeTrey GmbH, Konstanz, Germany	Paste A: Bisphenol-A epoxy resin, Bisphenol-F epoxy resin, calcium tungstate, zirconium oxide, silica, iron oxide pigments. Paste B: dibenzyldiamine, aminoadamantane, tricyclodecane-diamine, calcium tungstate, zirconium oxide, silica and silicone oil.
Pulp Canal Sealer EWT	Powder: 6923009 Liquid: 6909837	European Union Representative Kerr Italia,	Powder: silver powder, zinc oxide, thymol iodide, dimeric acid resin. Liquid: clove oil, Canada balsam.

		Scafati, SA, Italy	
BIO-C Sealer	49113	Angelus Indústria de Produtos Odontológicos S/A, Londrina, PR, Brazil	Calcium silicate, calcium aluminate, calcium oxide, zirconium oxide, iron oxide, silicon dioxide and dispersing agent.
RelyX U200	5761568	3M ESPE Deutschland GmbH, Neuss, Germany	Base Tube: silane treated glass powder, 2-propenoic acid, 2-methyl1,1 [1-(hydroxymethyl) -1,2-ethanodlyl] ester, triethylene glycol dimethyl acrylate, silane treated silica, fiberglass, sodium persulfate and t-butyl per-3,5,5-trimethylhexanoate. Catalyst Tube: silane-treated glass powder, substitute dimethacrylate, silane-treated silica, sodium p-tulenesulfonate, 1-benzyl-5-phenyl baric acid, calcium salts, 1,12-dodecane dimethacrylate, calcium hydroxide and titanium dioxide.
Provisional Restoration Villevie	474	Dentalville do Brasil LTDA, Joinville, SC, Brazil	Zinc oxide, calcium sulfate, red iron oxide, thickener, sodium fluoride, zinc sulfate, silicone oil, flavoring and orthodontic plaster.

Table 2 – Mean ~~B~~bond strength ~~mean~~ values (MPa) and standard deviation (±) for the dentin/resin cement/post interface according to the endodontic sealers and root thirds.

Experimental Group	*Bond Strength~~Mean~~*			
	Cervical	*Middle*	*Apical*	*Total mean*
Zinc Oxide Eugenol (ZOE)	58.00±1.65 Aa	41.80±2.04 Ba	16.00±1.64 Ca	38.60a
Calcium Hydroxide (CH)	49.30±1.99 Ab	34.50±1.77 Bab	12.40±2.11 Cab	32.06a
Epoxy Resin (ER)	45.60±1.51 Ab	26.20±1.40 Bbc	19.20±1.83 Ca	30.33ab
Bioceramic (BC)	43.20±2.01 A[LR25]b	16.00±1.92 Bc	3.80±1.78 Cb	21.00b

*Different letters indicate statistically significant difference ~~at~~ (α=0.05)~~%~~. Capital letters indicate difference between lines (thirds) and small letters indicate difference between columns (endodontic sealers).

FIGURE CAPTIONS

Figure 1 - Schematic illustration of the experimental design.

Figure 2 – Representative SEM images showing the difference of adhesive interface between the distinct root canal thirds: Cervical third (A); ~~Mesial~~ Middle third (B); Apical third (C). All the images are from the ER group with a 1.00 kx magnification. D: dentin; RC: resin cement.

Figure 3 – Representative SEM images showing the differences of the adhesive interface ~~between~~ for the experimental groups: Zinc Oxide Eugenol (A); Calcium Hydroxide (B); Epoxy Resin (C); Bioceramic (D). All the images are from the apical third of the groups with a 1.00 kx magnification. D: dentin; RC: resin cement.

Figure 4 – Representative CLSM images of the depth penetration of the different endodontic sealers in root canal dentin after the canal preparation: Zinc Oxide Eugenol (A); Calcium Hydroxide (B); Epoxy Resin (C); Bioceramic (D). All the images are from the middle third of a root canal with a 400x magnification. Note the presence of remnant

sealer in the dentin walls and dentinal tubules of the groups. D: dentin; CL: channel light; RS: remnant sealer.

FIGURES

Figure 1

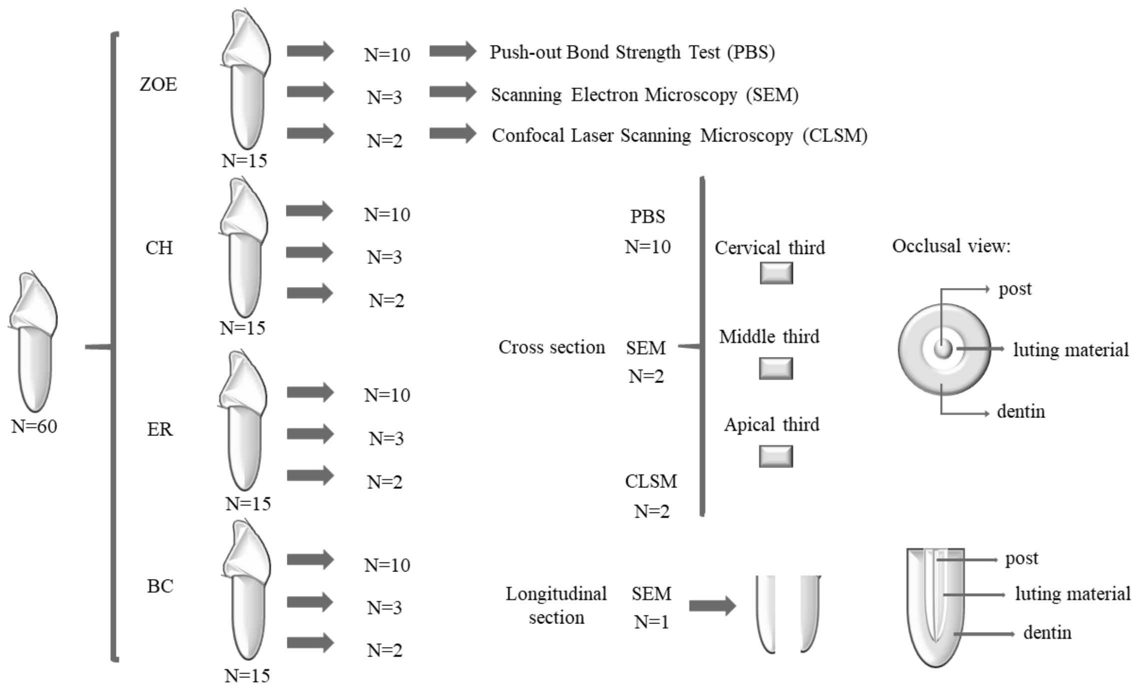


Figure 2

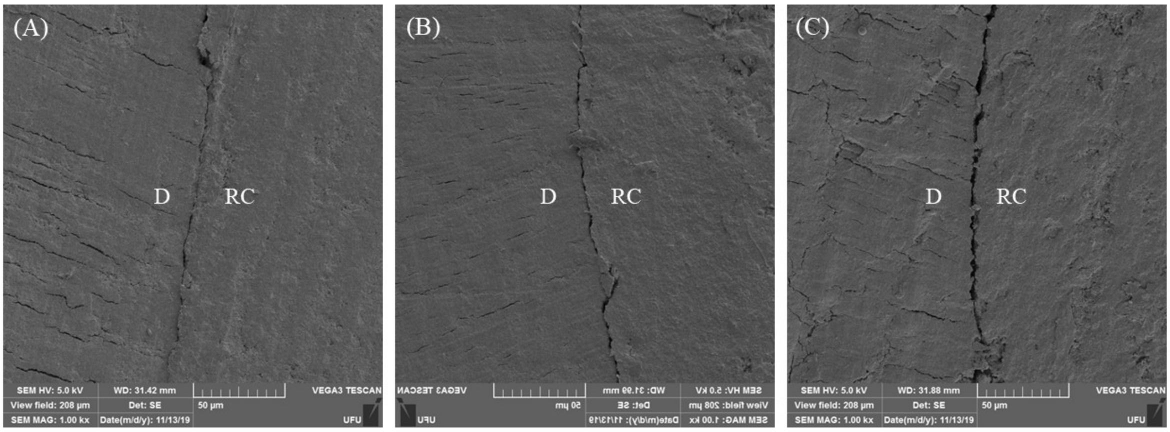


Figure 3

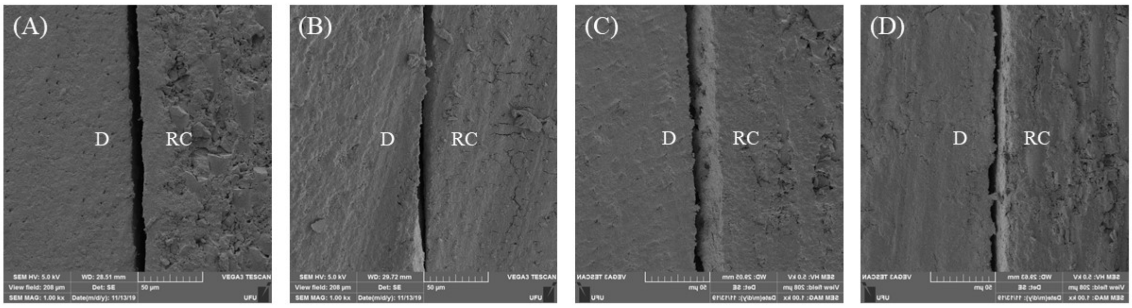
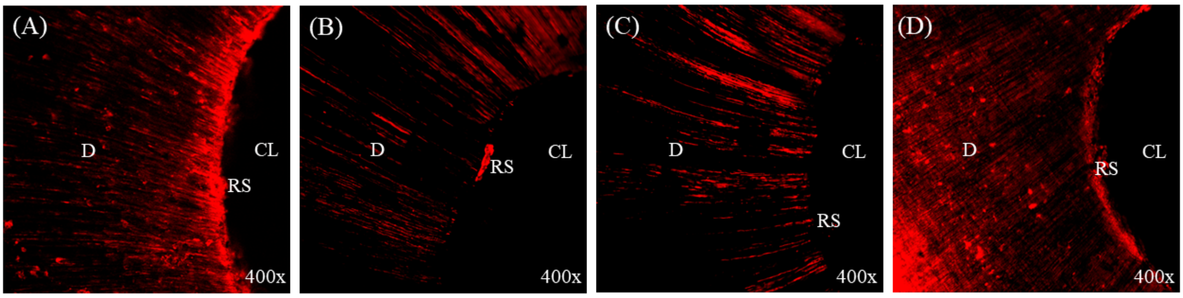


Figure 4



CONSIDERAÇÕES FINAIS

O presente estudo apresenta limitações intrínsecas, como o uso de amostras que não foram submetidas à fadiga cíclica e térmica anteriormente para o teste de resistência de união; e o fato de um único cimento resinoso autoadesivo dual ter sido utilizado para a cimentação dos pinos de fibra de vidro. Apesar disso, o foco do estudo foi avaliar a influência de cimentos endodônticos de diferentes composições sobre a resistência de união de pinos de fibra de vidro cimentados com cimento resinoso à dentina do canal radicular. Portanto, de acordo com as condições testadas neste estudo *in vitro*, pode-se concluir que o tipo de cimento endodôntico utilizado para o preenchimento do canal radicular pode influenciar a adesão de pinos de fibra de vidro. Também se pode inferir que o terço apical apresenta o menor valor de resistência adesiva verificado e que o selante à base de biocerâmica foi o único a apresentar diferenças significativas em relação aos demais grupos, com os menores valores de resistência adesiva observados.

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