

UNIVERSIDADE FEDERAL DE UBERLÂNDIA

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*Influência de métodos de limpeza do canal radicular na resistência de união de pinos de fibra de vidro após a obturação e fixação empregando diferentes materiais*

Uberlândia

2024

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*Influência de métodos de limpeza do canal radicular na resistência de união de pinos de fibra de vidro após obturação e fixação empregando diferentes materiais*

Dissertação apresentado à Faculdade de Odontologia da Universidade Federal de Uberlândia como requisito parcial para obtenção do título de mestre em Odontologia na área de Clínica Odontológica Integrada.

Orientador: Paulo César Freitas Santos Filho

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Uberlândia

2024

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|              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| N323<br>2024 | <p>Naves, Amanda Miranda de Almeida, 1998-<br/>Influência de métodos de limpeza do canal radicular na<br/>resistência de união de pino de fibra de vidro após a<br/>obturação e fixação empregando diferentes materiais<br/>[recurso eletrônico] / Amanda Miranda de Almeida Naves.<br/>- 2024.</p> <p>Orientador: Paulo César Freitas Santos Filho.<br/>Dissertação (Mestrado) - Universidade Federal de<br/>Uberlândia, Pós-graduação em Odontologia.<br/>Modo de acesso: Internet.<br/>Disponível em: <a href="http://doi.org/10.14393/ufu.di.2024.18">http://doi.org/10.14393/ufu.di.2024.18</a><br/>Inclui bibliografia.</p> <p>1. Odontologia. I. Santos Filho, Paulo César Freitas<br/>,1983-, (Orient.). II. Universidade Federal de<br/>Uberlândia. Pós-graduação em Odontologia. III. Título.</p> <p>CDU: 616.314</p> |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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|                                    |                                                                                                                                                                  |                 |       |                       |       |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-------|-----------------------|-------|
| Programa de Pós-Graduação em:      | Odontologia                                                                                                                                                      |                 |       |                       |       |
| Defesa de:                         | Dissertação de Mestrado Acadêmico, nº 439, PPGODONTO                                                                                                             |                 |       |                       |       |
| Data:                              | Dezenove de Janeiro de Dois Mil e Vinte e Quatro                                                                                                                 | Hora de início: | 08:00 | Hora de encerramento: | 10:40 |
| Matrícula do Discente:             | 12122ODO003                                                                                                                                                      |                 |       |                       |       |
| Nome do Discente:                  | Amanda Miranda de Almeida Naves                                                                                                                                  |                 |       |                       |       |
| Título do Trabalho:                | Influência de métodos de limpeza do canal radicular na resistência de união de pino de fibra de vidro após a obturação e fixação empregando diferentes materiais |                 |       |                       |       |
| Área de concentração:              | Clínica Odontológica Integrada                                                                                                                                   |                 |       |                       |       |
| Linha de pesquisa:                 | Propriedades Físicas e Biológicas dos materiais Odontológicos e das estruturas dentais                                                                           |                 |       |                       |       |
| Projeto de Pesquisa de vinculação: | Propriedades Físicas e Biológicas dos materiais Odontológicos e das estruturas dentais                                                                           |                 |       |                       |       |

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## AGRADECIMENTOS

Agradecimentos são insuficientes frente ao Criador da Vida. Querido Pai, obrigada por toda força e capacitação que me deu para finalizar esta etapa, meu agradecimento mais sincero.

Sou grata aos meus pais e irmãos, e ao meu querido esposo, incentivadores, carinhosos e sempre me oferecerem o colo de segurança, meu muito obrigada. Chegamos ao fim e este é o resultado do nosso trabalho em equipe! Eu amo vocês por toda a nossa eternidade.

Sou grata ao Prof. PC, meu orientador, por toda paciência e disponibilidade que estavam presentes sempre que te procurava, mesmo em meio a prazos e afazeres, por todo conhecimento passado que com certeza me fez evoluir.

Ao meu coorientador, Prof. Raposo meu profundo agradecimento, por toda paciência, conhecimento e todas as instruções que fizeram tanta diferença na evolução desse trabalho.

Agradeço a cada um dos mestres e doutores com os quais tive o imenso prazer de aprender e poder absorver um pouco sobre a incrível lição da docência.

À Faculdade de Odontologia da Universidade Federal de Uberlândia, e principalmente ao Programa de Pós Graduação (PPGO) pelo incentivo e fomento a esse trabalho.

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## RESUMO

Para o tratamento restaurador de dentes tratados endodonticamente, muitas vezes faz-se necessário o uso de retentores intrarradiculares, como os reforçados por fibra de vidro. Novos materiais têm sido indicados para essas situações, como é o caso dos cimento endodônticos biocerâmicos para obturação dos canais radiculares, considerado um cimento ideal, e o cimento resinoso universal para fixação dos retentores, que promete melhor adesão. Assim, o objetivo deste estudo foi comparar por meio a resistência de união de pinos de fibra de vidro à dentina de canais obturados com diferentes cimentos endodônticos, sendo os retentores fixados com cimentos resinosos distintos, após processo de limpeza convencional ou adicional pós-alívio. Para isso, 80 incisivos bovinos foram instrumentados com limas manuais e divididos de acordo com: tipo de cimento endodôntico, à base de hidróxido de cálcio (HC) ou biocerâmico (BC); método de limpeza, convencional (CN) ou com sistema Easy Clean (EC); e tipo de material de fixação, cimento resinoso autoadesivo RelyX U200 (R2) ou cimento resinoso universal RelyX Universal (RU). Os espécimes foram seccionados, resultando em duas fatias (1,0 mm) para cada terço radicular, e os valores de resistência de união foram verificados por teste de micro-push out e os modos de falhas analisados. Os dados foram verificados utilizando análise de variância de três fatores em medidas repetidas seguido de teste de Tukey HSD( $p < 0,05$ ). O fator método de limpeza afetou os valores de resistência de união ( $p = 0,007$ ), com melhores resultados para os grupos submetidos a limpeza adicional (EC). Em relação a variável cimento endodôntico, os grupos obturados com cimento biocerâmico (BC) apresentaram os maiores valores de resistência de união ( $p < 0,001$ ). Não houve interação significativa entre os cimentos resinosos ( $p = 0,359$ ), e nem diferenças significativas na resistência de união para os diferentes terços radiculares ( $p > 0,005$ ), independentemente do cimento endodôntico. O cimento biocerâmico obteve valores superiores de resistência de união, os protocolos de limpeza por meio da agitação das soluções com limas easy clean influenciaram positivamente na adesão dos pinos de fibra de vidro, o novo cimento resinoso RelyX Universal foi capaz de obter resultados de resistência de união semelhantes ao padrão-ouro RelyX U200.

Palavras-chave: cimento biocerâmico, cimento resinoso, dentina, pinos de fibra, resistência de união.

## ABSTRACT

For the restorative treatment of endodontically treated teeth, it is often necessary to use intraradicular retainers, such as those reinforced by fiberglass. Different materials have been recommended for these situations, such as bioceramic endodontic cement for filling root canals, considered an ideal cement, and universal resin cement for fixing retainers, which promises better adhesion. Thus, the objective of this study was to compare the bond strength of fiberglass posts to the dentin of canals filled with different endodontic cements, with the retainers being fixed with different resin cements, after a conventional or additional post-relief cleaning process. For this, 80 bovine incisors were instrumented with manual files and divided according to: type of endodontic cement, based on calcium hydroxide (HC) or bioceramic (BC); cleaning method, conventional (CN) or with Easy Clean system (EC); and type of fixation material, self-adhesive resin cement RelyX U200 (R2) or universal resin cement RelyX Universal (RU). The specimens were sectioned, resulting in two slices (1.0 mm) for each root third, and the values of bond strength were verified by micro-push out test and failure modes analyzed. Data were verified using three-way analysis of variance in repeated measures followed by Tukey HSD test ( $p < 0.05$ ). The cleaning method factor affected the bond strength values ( $p = 0.007$ ), with better results for the groups subjected to additional cleaning (EC). Regarding the endodontic cement variable, the groups filled with bioceramic cement (BC) presented the highest bond strength values ( $p < 0.001$ ). There was no significant interaction between resin cements ( $p = 0.359$ ) and no significant differences in bond strength for the different root thirds ( $p > 0.005$ ), regardless of the endodontic cement. The bioceramic cement achieved superior bond strength values, the cleaning protocols by agitating the solutions with easy clean files positively influenced the adhesion of the fiberglass posts, the new RelyX Universal resin cement was able to obtain results of bond strengths similar to the gold standard RelyX U200.

**Keywords:** bioceramic cement, bond strength, dentin, fiber posts, resin cement

## 1. INTRODUÇÃO E REFERENCIAL TEÓRICO

A reabilitação de dentes tratados endodonticamente é um tema de amplo estudo e se torna um desafio, principalmente nos casos de elementos que possuem perda coronária avançada causada por cáries, traumas ou pelo acesso endodôntico (Marchionatti, A. M. E, et al., 2019; Thakur A, et al., 2019). Retentores reforçados por fibra de vidro são uma alternativa para esses casos e com base nas evidências de trabalhos científicos, possuem maior longevidade a médio prazo (3 a 7 anos) comparados aos pinos metálicos, além de menores índices de falhas irreversíveis (Soares et al. 2012).

O sucesso do tratamento restaurador com pinos de fibra de vidro depende de uma adesão efetiva entre o retentor intra-radicular, a dentina e o agente de fixação. Todavia, insucessos como fratura da raiz ou falta de adesão entre o cimento resinoso e a dentina e/ou pino são relatados na literatura (Oliveira et al., 2016). A presença de resíduos de tecidos no canal radicular e de cimentos obturadores endodônticos, que podem afetar a polimerização dos cimentos resinosos e gerar áreas de enfraquecimento na interface adesiva,, estão entre os principais fatores relatados nos insucessos restauradores desses elementos (Suzuki et al., 2015).

Materiais mais recentes têm sido indicados para uso no tratamento endodôntico, como é o caso do cimento biocerâmico, um obturador endodôntico com propriedades como biocompatibilidade, bioatividade, reparação dos tecidos radiculares, capacidade osteogênica e de formação de hidroxiapatita de cálcio (Donnermeyer D, et al., 2019). Porém, alguns estudos demonstram que os remanescentes dos obturadores biocerâmicos são mais difíceis de serem removidos da parede radicular (Cesario F, et al., 2018), tornando a desobturação um processo crítico (Rosatto et al., 2020), por isso, novos protocolos de limpeza estão sendo propostos na literatura.

A irrigação dos condutos pós-alívio para obtenção do espaço do retentor é frequentemente indicada com soluções de limpeza, como é o caso do hipoclorito de sódio (NaOCl), irrigante antimicrobiano e de baixo custo que remove a camada orgânica de "smear layer" do conduto radicular (Tonini R, et al 2022) e o ácido etilenodiamino tetra-acético (EDTA), agente quelante utilizado para a remoção da camada de smear layer, que age com os íons cálcio na dentina formando quelatos de cálcio solúveis e promovendo descalcificação na dentina (Agarwal S, et al., 2020). Os protocolos de irrigação podem ser potencializados quando ativados por irrigação ultrassônica passiva (PUI) ou sistema rotatório (Easy Clean (EC), Easy Dental Equipment, Belo Horizonte, MG, Brasil), sendo a EC, uma alternativa mais simples e vantajosa em relação ao PUI

(Rosatto, et al., 2021.) A literatura (Rosatto CMP, et al., 2021) evidenciou melhores efeitos na remoção de resíduos obturadores quando EC é associada às soluções de EDTA e NaOCl, porém evidências sobre a influência desses protocolos na resistência de união dos pinos de fibra de vidro à dentina radicular empregando diferentes agentes de fixação resinosos, ainda se fazem necessárias.

Diversos cimentos resinosos estão disponíveis no mercado atualmente, e os agentes de fixação autoadesivos têm sido comercializados com proposta de simplificar os procedimentos adesivos na rotina clínica. O cimento resinoso RelyX universal foi recentemente introduzido com a premissa de ser simples e versátil ao poder ser utilizado em várias situações clínicas, tanto em restaurações indiretas, quanto na cimentação de pinos de fibra de vidro (3M ESPE Deutschland GmbH, Neuss, Germany.). Entretanto, estudos sobre sua interação com outros materiais restauradores e influência na resistência de união dos pinos de fibra de vidro se fazem necessários.

Diante deste contexto, o objetivo deste trabalho foi comparar a resistência de união de pinos de fibra de vidro à dentina radicular de canais obturados com diferentes cimentos endodônticos (BIO C Sealer ou Sealer 26), sendo os retentores fixados com cimentos resinosos distintos (RelyX U200 e RelyX Universal), após processo de limpeza convencional ou adicional pós-alívio. A hipótese nula gerada é que a resistência de união dos retentores reforçados por fibra não é influenciada pelo método de limpeza, ou obturador endodôntico quando fixados com diferentes cimentos resinosos.

## 2 CAPÍTULO 1

### **Effect of root canal cleaning methods on the adhesion of fiberglass posts using different endodontic cements**

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**Abstract:** For the restorative treatment of endodontically treated teeth, it is often necessary to use intraradicular retainers, such as those reinforced by fiberglass. Different materials have been recommended for these situations, such as bioceramic endodontic cement for filling root canals, considered an ideal cement, and universal resin cement for fixing retainers, which promises better adhesion. Thus, the aim of this study was to compare the bond strength of fiberglass posts to the dentin of canals filled with different endodontic cements, with the retainers being fixed with different resin cements, after a conventional or additional post-relief cleaning process. For this, 80 bovine incisors were instrumented with manual files and divided according to: type of endodontic cement, based on calcium hydroxide (HC) or bioceramic (BC); cleaning method, conventional (CN) or with Easy Clean system (EC); and type of fixation material, self-adhesive resin cement RelyX U200 (R2) or universal resin cement RelyX Universal (RU). The specimens were sectioned, resulting in two slices (1.0 mm) for each root third, and the values of bond strength were verified by micro-push out test and failure modes analyzed. Data were verified using three-way analysis of variance in repeated measures followed by Tukey HSD test ( $p < 0.05$ ). The cleaning method factor affected the bond strength values ( $p = 0.007$ ), with better results for the groups subjected to additional cleaning (EC). Regarding the endodontic cement variable, the groups filled with bioceramic cement (BC) presented the highest bond strength values ( $p < 0.001$ ). There was no significant interaction between resin cements ( $p = 0.359$ ) and no significant differences in bond strength for the different root thirds ( $p > 0.005$ ), regardless of the endodontic cement. The bioceramic cement achieved superior bond strength values, the cleaning protocols by agitating the solutions with easy clean files positively influenced the adhesion of the fiberglass posts, the new RelyX Universal resin cement was able to obtain results of bond strengths similar to the gold standard RelyX U200.

**Keywords:** Bioceramic Cement; Bond Strength; Dentin; Fiberglass posts; Resin Cement.

## Introduction

Fiberglass-reinforced retainers are an alternative in cases of endodontically-treated teeth with extensive coronal destruction due to caries, fractures, or access methods for endodontic treatment.<sup>1</sup> Based on scientific evidence, fiberglass posts have higher medium-term (3 to 7 years) overall survival rates than metal posts.<sup>2</sup>

The success of restorative treatment using fiberglass posts depends on the effective adhesion between the intraradicular post, dentin, and cement.<sup>3</sup> However, failures such as root fractures or lack of adhesion between the resin cement and dentin or between the resin cement and the post have been reported.<sup>4</sup> Different factors, including residual tooth tissue and endodontic filling cement, negatively affect the bonding interface and hence the bond strength.

Different materials for the rehabilitation of endodontically treated teeth are available on the market, such as calcium silicate-based cements<sup>5</sup>. These bioactive materials have been successfully applied due to their properties, such as biocompatibility, bioactivity, root tissue repair, osteogenic capacity, and formation of calcium hydroxyapatite.<sup>5</sup> However, previous investigations have shown that bioceramic remnants are challenging to remove from the root wall, making the canal cleaning process difficult and negatively influencing the bond strength of fiberglass posts<sup>6,7</sup>.

Cleaning protocols have been proposed for post-space irrigation after the intraradicular post-space preparation, using sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA). These irrigants are enhanced when activated by passive ultrasonic irrigation (PUI) or rotary systems (Easy Clean system – EC) (Easy Dental Equipment, Belo Horizonte, MG, Brazil). The EC system employs a plastic acrylonitrile butadiene styrene instrument, size 25/0.04, with a cross-sectional shape resembling an aircraft wing. It is designed to be used in both reciprocating and continuous rotation movements.<sup>8</sup> Therefore, EC is a simpler and more advantageous alternative compared to PUI, as the literature has shown better effects in removing filling residues when this technique is associated with EDTA or NaOCl solutions.<sup>9</sup> Nevertheless, evidence of the influence of these protocols on the bond strength of fiberglass posts to root dentin using different resin luting agents is still needed.

Several resin cements are currently available on the market, and self-adhesive luting agents have been commercialized to simplify adhesive procedures in clinical routine. RelyX Universal resin cement, an evolution of the gold standard self-adhesive resin cement RelyX

U200, was recently developed and emerged with the purpose of being simple and versatile. The resin cement is indicated in several clinical situations, reducing the need for stocks of varied materials. These agents can be used in both direct and indirect restorations and also in fiberglass post cementation (3M ESPE Deutschland GmbH, Neuss, Germany.). However, investigations on its interaction with other restorative materials and the effect on the bond strength of fiberglass posts are still required.

Thus, this study aimed to compare the bond strength of fiberglass posts to the dentin of canals filled with different endodontic cements (BIO C Sealer or Sealer 26), with the retainers being fixed with different resin cements (RelyX U200 and RelyX Universal), after a conventional or additional post-relief cleaning process. The null hypothesis of our study is that the bond strength of fiber-reinforced retainers is not affected by the cleaning method or endodontic sealer when fixed with different resin cements.

## **Methodology**

A pilot study was conducted using 24 bovine incisors to standardize, define, and refine the different laboratory techniques, in addition to calibrating the operators involved.

## **Specimen preparation**

After sample calculation, a total of 80 bovine incisor teeth were selected and stored in deionized water solution. The selection criterion adopted was the similarity of the external and internal anatomical morphology, with an apical canal diameter corresponding to a #30 Kerr file, an apex with complete rhizogenesis, and without resorption. The teeth were debrided with scalpel blades and periodontal curettes, and the coronal part was removed with a double-sided diamond disc, under refrigeration, through a cut perpendicular to the long axis of the tooth, resulting in a 15 mm root remnant from the apical region of each root.

The teeth were instrumented and the pulp was removed using endodontic files under abundant irrigation with 2.5% NaOCl to suspend organic matter. The working length was determined with a #10 Kerr file (Dentsply Sirona, Rio de Janeiro, Brazil), introduced until its tip was visible at the apical foramen. The roots were instrumented 1.0 mm from the apex using Gates-Glidden burs (Ângelus, Londrina, PR, Brazil), numbers 3 and 4, with diameters of 0.9 and 1.1 mm, respectively. The canals had a diameter of 1.1 mm in the cervical third and 0.9 mm in the middle and apical thirds. The apical third was instrumented with Kerr files

(Dentsply Sirona), using the conventional and step-back techniques. The canal was irrigated with 2.5% NaOCl throughout biomechanical preparation. After instrumentation, all specimens, regardless of their group, were irrigated with 12 ml of 2.5% NaOCl and 1 ml of 17% EDTA, followed by a final flush of 5 ml of 2.5% NaOCl and stirred with Easy Clean (Easy Dental, Equipamentos, Belo Horizonte, MG, Brazil) in 3 cycles of 20 seconds for each solution. Afterward, a final irrigation with 5 ml of distilled water without agitation was performed, and the canals were dried with absorbent paper tips (Dentsply Sirona). Specimens were stored in a humid environment at 37°C. After 7 days, the canals, regardless of their group, were prepared to receive the intraradicular retainer, using Gates Glidden burs (Ângelus, Londrina, PR, Brazil), numbers 2 and 3, followed by the post system drill, leaving 5.0 mm of obturation material from the working length. Then, a new vertical condensation was performed. The specimens from the EC groups received an additional cleaning step to reduce remnants of obturation material by activating 2.5% NaOCl in 3 cycles of 20 seconds and 17% EDTA in 3 cycles of 20 seconds, respectively, using the EC system. Next, a final flush was performed with distilled water using back-and-forth movements, following a previous protocol.<sup>9</sup> The irrigants were applied with a 30 g open-ended needle (NaviTip, Ultradent, South Jordan, EUA). Specimens that did not undergo additional cleaning had their ducts unobstructed and only one final irrigation with distilled water.

For fiberglass post cementation, the canals were rinsed with distilled water and dried with absorbent paper points. The fiberglass post surface preparation (Exacto, Angelus) was initially carried out with the application of 35% hydrogen peroxide (FGM, Joinville, Santa Catarina, Brazil) for 1 minute using a microbrush, followed by rinsing with running water and air drying for 1 minute.<sup>10</sup> Then, a silane agent (Ângelus, Londrina, PR, Brazil) was applied for 1 min. In all groups, the resin cements were manipulated and introduced into the canal using automix tips, followed by fiber post insertion, held in position with digital pressure. Excess cement was removed after 1 minute. Five minutes after insertion (chemical setting time), photoactivation (Valo Cordless Grand) was performed for 40 seconds on the cervical face, along the long axis of the root, and diagonally, simulating the incisal, buccal, and palatal surfaces, totaling 120 seconds. Rely X Universal resin cement was used in its self-adhesive mode. Lastly, the samples were stored in distilled water at 37 °C for 24 hours. The description of the materials used to fill the canals and fix the retainers is in table 1.

### **Bond strength (micro push-out)**

The bond strength (MPa) of the post/cement/dentin interface was verified using the micro push-out test. The specimens were cross-sectioned into six slices, with a double-sided diamond disc in a precision cutter (IsoMet 1000 Precision Saw, Buehler, Lake Bluff, Illinois, USA) under water cooling. Two 1.0 mm thick discs were obtained from the cervical (CT), middle (MT), and apical (AT) third regions. The slices were obtained with a single cut, ensuring flat surfaces.

The specimens were positioned in a device consisting of a stainless steel metal base, 3.0 cm in diameter, with a 2.0 mm orifice in the central region and a load applicator tip 1.5 mm in diameter and 2.5 mm long for the cervical and middle thirds, and tips with a 1.0 mm diameter and 2.0 mm base for the apical third attached to the mechanical testing machine.<sup>27</sup> The specimen was positioned on the test machine (EMIC, DL 2000) containing the 50 Kgf load cell, and the discs were positioned so that the load applicator tip coincided with the metal base orifice, then submitted to compression loading in the apex-crown direction at a speed of 0.5 mm min<sup>-1</sup> until system failure. The bond strength values were obtained in Newton and expressed in MPa, calculated by the following equation:

$$A = 2\pi r \times h$$

where  $\pi$  is the constant 3.14,  $r$  is the post radius, and  $h$  is the specimen thickness in mm.

### **Failure mode**

After the micro push-out test, the failure mode of all specimens was analyzed using an optical measuring microscope (STM, Olympus Optical Co, Tokyo, Japan) at 25x magnification. The failure modes were classified as follows: I- adhesive failure between dentin and cement; II - adhesive failure between cement and post; III - cohesive failure in cement; IV - cohesive failure in dentin; V - mixed failure.

### **Statistical analysis**

The normality of the push-out bond strength data was tested using the Shapiro-Wilk test. Then, a 3-way ANOVA, incorporating sealing material, cleaning method, and resin cement as variables, with repeated measures considering the root canal region, was used for

analysis. Subsequently, Tukey post-hoc multiple comparison test was conducted. The failure mode distribution was analyzed with qualitative description. The significance level was set at  $\alpha = 0.05$ . Statistical analysis was carried out using JAMOV software version 2.4 (The Jamovi Project, Sidney, Australia).

## **Results**

### **Bond strength**

The mean bond strength values (MPa) and standard deviation ( $\pm$ ) related to the experimental groups and root thirds are depicted in Table 1. The cleaning method variable significantly affected bond strength values ( $p=0.007$ ), with better results for the groups subjected to additional cleaning (Easy Clean). Significant differences were found for the endodontic cement ( $p<0.001$ ), with the highest bond strength values observed for the groups filled with bioceramic cement. No significant interaction between resin cements ( $p=0.359$ ) and no significant differences in bond strength for the different root thirds ( $p>0.005$ ) were found, regardless of the cleaning method or endodontic cement.

### **Failure mode distribution**

Figure 1 illustrates that the most prevalent failures were adhesive type 1, between dentin and resin cement, and type 2, between resin cement and post, for all groups. Mixed and cohesive failures in both cement and dentin were also observed, but to a lesser extent.

## **Discussion**

The study of the adhesive interaction of restorative materials to tooth tissues has drawn increasing attention since it is essential for the longevity of adhesive rehabilitative treatments.<sup>11</sup> Additional root canal dentin cleaning methods have been proposed to reduce the residual smear layer formed while preparing the intracanal post space.<sup>12</sup> This layer is composed of dentin debris and remnants of endodontic sealer, which may affect the cement/dentin adhesive interface.<sup>13</sup> Therefore, based on our findings, the null hypothesis was rejected, as the additional cleaning method using the Easy Clean system positively influenced the bond

strength values of the fiberglass posts to dentin, regardless of the filling cement or resin cement.

Easy Clean system was proposed as a cost-effective alternative to the cleaning procedure using passive ultrasonic irrigation (PUI), as it is used in a rotary movement at low speed. In our study, the groups subjected to the additional cleaning step post space preparation using the Easy Clean, along with NaOCl/EDTA solutions, both highly recommended as post-space irrigation solutions,<sup>14,15</sup> revealed better results in bond strength values compared to the groups subjected to the conventional cleaning method, using saline solution for final irrigation. This finding is in agreement with the literature, as it has been shown that the use of Easy Clean, under continuous rotation, produces turbulence of the irrigating solution, favoring debris removal, including from side channels<sup>16</sup>. The volume of irrigants and the number of cycles were defined based on preliminary studies that used the Easy Clean system.<sup>17,18</sup>

Epoxy resin-based cements, such as Sealer 26, have been well used by dentists, as they have high radiopacity properties; dimensional stability,<sup>19</sup> reduced solubility, antimicrobial activity that remains in the canal after filling,<sup>20,21</sup> but this properties such as high fluidity and chemical composition, in that its epoxy rings join the groups of amino acids exposed in the dentin collagen matrix<sup>22</sup>. This property may explain the high penetration of cement into lateral canals and other difficult-to-access regions<sup>20</sup>, making it difficult to remove from the root canal and its lower bond strength values.

The Bio-C Sealer endodontic sealer is a pre-mixed calcium-silicate-based sealer, developed for root canal filling and sealing. It has valuable properties, including bioactivity due to its ability to mineralize through calcium hydroxide formation and accelerated repair process owing to the increase in pH, exerting antimicrobial activity.<sup>3,10</sup> However, its high flow property explains its greater penetration into the dentinal tubules and the difficulty in cleaning the canal during restorations involving fiberglass posts, as previously reported,<sup>18</sup> and therefore, worse bond strength results would be expected. Contrary to this hypothesis, our findings showed that the Bio-C Sealer resulted in better bond strength values for all groups, even those not subjected to the additional cleaning step, compared to the groups filled with Sealer 26.

This finding can be explained by the fact that samples from all groups underwent an irrigation protocol using 17% EDTA, a chelating agent commonly used to remove the smear layer produced during canal instrumentation. A previous investigation<sup>19</sup> found that the use of 17% EDTA can be an issue when used with bioceramic sealers, as it affects the dentinal walls

and the available Ca:P ratio. Since calcium silicate sealers react with the calcium of the dentin for biomineralization, these changes may affect their adhesion. Donnermeyer et al.<sup>20</sup> associated this result with the reduction of calcium at the sealer-dentin interface or a degradation of the calcium silicate fraction in the sealer, thereby affecting the adhesion and bond strength values between the bioceramic sealer and dentin, which could facilitate its removal even when the additional post-space cleaning protocol (relief) for the post is not performed. However, this study did not show disadvantages in associating the post-space cleaning step using 17% EDTA in groups filled with bioceramic sealer.

Different types of resinous agents have been recommended for intraradicular retention, such as conventional resin cements, which require pre-treatment of the dentin substrate with adhesive systems, and self-adhesive resin cements, which do not require this type of intervention. RelyX U200 is a dual-cured self-adhesive resin cement with well-established use in the literature for fixing fiberglass posts, demonstrating adequate bond strength values.<sup>21</sup> Recently, the same manufacturer released RelyX Universal resin cement, which can be conventionally used with adhesive or self-adhesive systems, with the purpose to be useful and applicable in various clinical situations.

In our study, dual-cured self-adhesive resin cements (RelyX U200 and RelyX Universal) were used for intraradicular retention in all groups, and no significant differences were found in the bond values when comparing these materials. However, we expected that the bond strength values could be compromised in deeper root regions due to the decreased intensity of light transmission through the root thirds, as previously demonstrated.<sup>22</sup> Contrary to this expectation, no statistical differences were found in the bond strength values between the different root regions (thirds). Previous investigations,<sup>23</sup> in which fiberglass post cementation was performed after 7 days of root canal filling, also reported equivalent bond strength between the thirds when using dual-cured self-adhesive cement.

Therefore, the use of self-adhesive cements instead of conventional ones ensures that the root thirds do not have statistical differences in bond strength values, as when using a conventional cement, access and procedures such as acid etching, drying, and adhesive application are more complicated in the apical region of root.<sup>24</sup> This explains the difficulty to achieve adequate adhesive strength in this region.<sup>25</sup> Another hypothesis for this finding would be the use of automix tips/endotips for handling and inserting the cement into the root canal. Notably, the protocol of introducing the cement is a crucial factor in guaranteeing material homogeneity, avoiding incorporating bubbles in the cement layer, and negatively interfering

in the dentin/resin cement/post bond, also reflecting a lower number of cohesive failures in cement.<sup>9,15</sup>

The higher incidence of adhesive failures between the resin cement and dentin for all experimental groups of this investigation is in line with a previous study. The authors reported the fragile interaction of the components at this interface and reinforced that the most sensitive interface is between the dentin and the resin cement, as it is the region with the highest stress concentration.<sup>26</sup>

This study has intrinsic limitations, such as the use of specimens that were not subjected to thermomechanical cycling prior to the bond strength test. However, we focused on assessing the influence of the additional cleaning method post-retention space preparation (relief) on the bond strength of fiberglass posts fixed with two types of resin cement to the root canal dentin previously filled with different endodontic cements.

## **Conclusions**

It is concluded that, under the conditions tested in vitro, the cleaning method using Easy Clean tips positively influenced the bond strength of fiberglass posts fixed with different resin cements to the root dentin. Furthermore, no significant differences were found between bond strength values considering the different root regions (thirds). The type of resin cement used did not influence the observed bond strength values, and the bioceramic endodontic cement resulted in better bond strength values. Further studies are necessary to better understand the interaction of these materials in different aspects.

## **Acknowledgements**

The authors would like to thank the Research Center for Biomechanics, Biomaterials and Cellular Biology (CPBio) of the Dental School - Federal University of Uberlândia for providing the infrastructure and equipment needed to develop this research. This study was supported by the Postgraduate Program of the Faculty of Dentistry of the Federal University of Uberlândia.

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

| Material               | Batch number | Manufacturer                                                          | Composition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------------|--------------|-----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Sealer 26</b>       | 3815220      | Dentsply Indústria e comércio Ltda., Pirassununga, SP, Brazil         | Powder: bismuth trioxide, calcium hydroxide, hexamethylenetetramine, and titanium dioxide.<br>Paste: bisphenol epoxy resin.                                                                                                                                                                                                                                                                                                                                                                              |
| <b>RelyX Universal</b> | 974046       | 3M ESPE Deutschland GmbH, Neuss, Germany                              | Catalytic paste: ytterbium fluoride, triethylene glycol dimethacrylate (TEGDMA), silanized silica, initiator, pigments, e.g. titanium dioxide, methacrylate (HEMA).<br>Base paste: triethylene glycol dimethacrylate (TEGDMA), silanized silica, urethane dimethacrylate (UDMA), hydroperoxide.                                                                                                                                                                                                          |
| <b>BIO-C Sealer</b>    | 67836        | 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.                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>RelyX U200</b>      | 2113200890   | 3M ESPE Deutschland GmbH, Neuss, Germany                              | Base Tube: silane treated glass powder, 2-propenoic acid, 2-methyl-1,1 [1- (hydroxymethyl) -1,2-ethanodilyl] ester, triethylene glycol dimethyl acrylate, silane treated silica, fiberglass, sodium persulfate, and t-butyl per-3,5,5-trimethylhexanoate.<br>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. |

**Table 2.** Mean push-out bond strength (MPa) and standard deviation (SD) of glass fiber posts to root dentin at different root canal regions according to cleaning method, endodontic sealer, and resin cement.

|                 | Conventional       |                    |                   |                   | Easy Clean          |                         |                    |                    |
|-----------------|--------------------|--------------------|-------------------|-------------------|---------------------|-------------------------|--------------------|--------------------|
|                 | Bio-C              |                    | Sealer 26         |                   | Bio-C               |                         | Sealer 26          |                    |
|                 | U200               | UNIV               | U200              | UNIV              | U200                | UNIV                    | U200               | UNIV               |
| <b>Cervical</b> | 8.21 (1.68)<br>AaΥ | 7.60 (2.94)<br>AaΥ | 7.40 (1.56)<br>Aa | 6.56<br>(1.38) Aa | 7.99 (1.46)<br>Aa*Υ | 9.89 (3.18)<br>Aa*Υ     | 7.02 (2.33)<br>Aa* | 7.44 (2.15)<br>Aa* |
| <b>Middle</b>   | 7.96 (2.47)<br>AaΥ | 8.16 (2.26)<br>AaΥ | 7.52 (2.92)<br>Aa | 7.18<br>(2.84) Aa | 8.85 (2.11)<br>Aa*Υ | 10.74<br>(2.26)<br>Aa*Υ | 8.99 (3.79)<br>Aa* | 8.13 (2.77)<br>Aa* |
| <b>Apical</b>   | 9.69 (3.53)<br>AaΥ | 8.79 (3.40)<br>AaΥ | 4.82 (3.03)<br>Aa | 6.52<br>(2.29) Aa | 9.14 (2.15)<br>Aa*Υ | 8.95 (2.10)<br>Aa*Υ     | 7.16 (3.13)<br>Aa* | 9.10 (2.12)<br>Aa* |

Capital letters indicate significant differences between root thirds (within columns, vertical). Lowercase letters indicate significant differences between endodontic cements for each resin cement (within rows, horizontal). Greek symbols (Υ) indicate significant differences between resin cements for each endodontic cement (within rows, horizontal). Symbols (\*) indicate significant differences between cleaning methods for each endodontic cement and resin cement (within rows, horizontal). Tukey HDS test ( $\alpha = 0.05$ ).

**Table 3.** Description of experimental groups

| Group     | Cleaning protocol | Endodontic sealer | Resin cement       |
|-----------|-------------------|-------------------|--------------------|
| <b>1A</b> | Conventional      | BIO-C SEALER      | RELYX U200         |
| <b>1B</b> | EASY CLEAN        | BIO-C SEALER      | RELYX U200         |
| <b>1C</b> | Conventional      | BIO-C SEALER      | RELYX<br>UNIVERSAL |
| <b>1D</b> | EASY CLEAN        | BIO-C SEALER      | RELYX<br>UNIVERSAL |
| <b>2A</b> | Conventional      | SEALER 26         | RELYX U200         |
| <b>2B</b> | EASY CLEAN        | SEALER 26         | RELYX U200         |
| <b>2C</b> | Conventional      | SEALER 26         | RELYX<br>UNIVERSAL |
| <b>2D</b> | EASY CLEAN        | SEALER 26         | RELYX<br>UNIVERSAL |

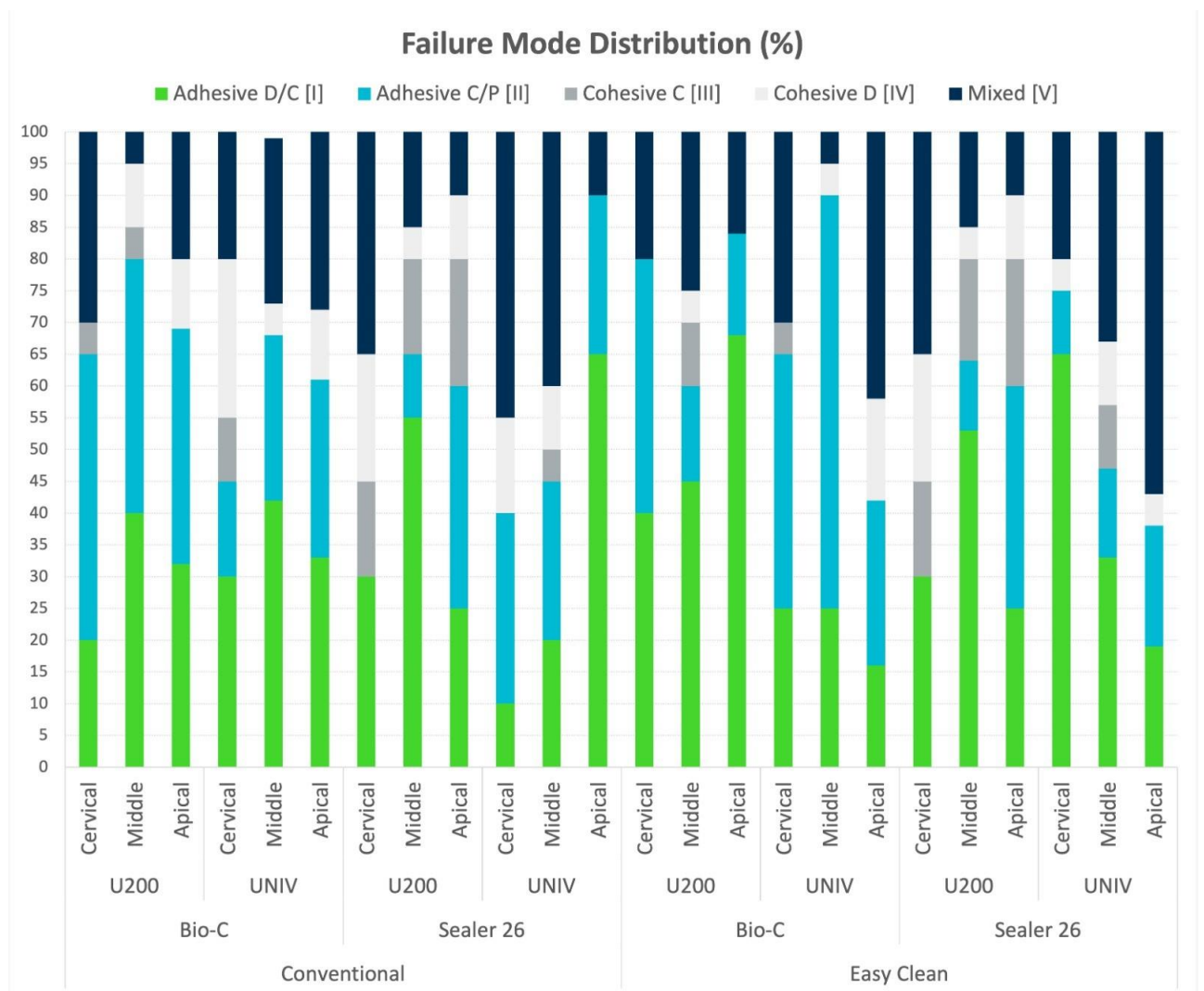


**Figure 1.** Failure mode distribution of specimens according to the experimental groups observed using optical microscopy (25x).