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Patrícia Lopes de Souza

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

Gandra, 27 de Setembro de 2020

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Trabalho realizado sob a Orientação de Dr. Júlio César Matias de Souza

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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). Mas 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.

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Declaração:

Eu, Doutor Júlio César Matias de Souza, com a categoria profissional de Professor Auxiliar Convidado do Instituto Universitário de Ciências da Saúde, tendo assumido o papel de Orientador da dissetação intitulada ***"Bond strength of endodontic post to resin cements: a integrative review".***, da Aluna do Mestrado Integrado em Medicina Dentária, Patrícia Lopes de Souza, declaro que sou de parecer favorável para que o Relatório Final de Estágio possa ser presente ao Júri para admissão a provas conducentes para obtenção do Grau de Mestre.

Gandra, 27 de Setembro, de 2020

O Orientador

____

Júlio César Matias de Souza

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A Áurea Correa, sempre presente, com um sorriso, uma palavra amiga, iluminando os dias mais escuros com seu astral, responsável pelas melhores memórias que terei desse ano de 2020, foi muito mais que uma binômia foi uma irmã e carregarei sempre em meu coração para a vida (ainda vamos rir de tudo isso!).

Não posso deixar de agradecer aos amigos que fiz (grupo de brasileiros), do qual tive a honrra de fazer parte e poder estar inserida em um ambiente de acolhimento, ajuda e reflexão. Onde demos muita risada e partilhamos momentos de angustia juntos, sempre um ajudando o outro.

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Resumo:

O objetivo principal desse estudo foi realizar uma revisão sistemática integrativa sobre a retenção de pinos de fibra a partir de testes push-out. A busca foi realizada na PUBMED (via National Library of Medicine) sobre artigos publicados até fevereiro de 2020 onde foi utilizado a aplicação das seguintes combinações de termos de busca: "intracanal post" OR "endodontic post" OR "root canal post" OR "intraradicular post" AND "resin cement" AND "adhesion" OR "bond strength" OR "shear bond strength" OR "pull out" OR "push out".

Os resultados dos estudos selecionados mostram a maior resistência de união ao push-out (22,5 MPa) entre pinos intracanais, parede dentinária e ao cimento de matriz resinosa em um pino com superfície pré-tratada de fábrica pelo processo de deposição de vapor de silano e silicato. Outro estudo mostra que, uma modificação da superfície por ataque químico com peróxido de hidrogênio e deposição de silano forneceu valores de resistência de união ao push-out de 21.5 Mpa . As superfícies não tratadas apresentaram os menores valores de resistência de união, em torno de 5 a 9 MPa. As análises de superfície dos pinos intracanais radiculares dos dentes mostraram um aumento da rugosidade após o jateamento e o condicionamento que promovem um intertravamento mecânico do adesivo e cimentos de matriz resinosa.

O tratamento combinado das superfícies do pino intracanal da raiz dos dentes por métodos físicos e químicos promove o aumento da rugosidade e da afinidade química antes da cimentação. Isso resulta em um alto embricamento mecânico dos cimentos de matriz resinosa e retenção estável dos pinos intracanais da raiz dos dentes.

Palavras-chave: "pino intracanal"; "cimento resinoso"; "adesão"; "força de adesão" e "push-out".

Abstract :

The main aim of this work was to perform an integrative systematic review on the retention of glass fiber reinforced composite posts by push-out bond strength tests. A literature search was performed on PUBMED (via National Library of Medicine) on articles published up to February, 2020, using the following combination of search terms: "intracanal post" OR "endodontic post" OR "root canal post" OR "intraradicular post" AND "resin cement" AND "adhesion" OR "bond strength" OR "shear bond strength" OR "pull out" OR "push out".

Results from the selected studies shows the highest push-out bond strength (22.5 MPa) of teeth root intracanal posts to resin-matrix cements over a factory pré-treated surface post by physical vapor deposition process of silane and silicate. In another study, a surface modification by etching with hydrogen peroxide and silane deposition provided push-out bond strength value of 21.5 MPa. Non treated surfaces showed the lowest bond strength values of around 5 to 9 MPa. Surface analyses of the teeth root intracanal posts showed an increase in roughness after grit-blasting and etching that promote a mechanical interlocking of the adhesive and resin-matrix cements.

The combined treatment of teeth root intracanal post surfaces by physical and chemical methods promote the increase in roughness and the chemistry prior a cementation. That results in a high mechanical interlocking of the resin-matrix cements and stable retention of the teeth root intracanal posts.

***Key words:** Intracanal post, resin cement, adhesion, bond strength and push out.*

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1. INTRODUCTION

The clinical procedures of the tooth root canal directly affects the prognosis of the dental restorative materials and tooth structures (1) . After endodontic treatment, the geometrical features and mechanical performance of remnant tooth tissues are often reestablished by post-retained restorations. However, the decision on teeth root intracanal post placement is mainly based on the extent of remnant tooth tissues (2). Although high success rates have been reported for glass fiber-reinforced composite (GFRC) post restorations, root fracture and loss of retention are still the most common reasons for failing these restorations(3,4). Teeth root canal treatments results in a weakening of the tooth, leading to damage of remnant tooth tissues and a high susceptibility to fracture(2,5,6). That increased the failure rates of tooth root intracanal posts. It has been estimated that 60% of the GFRC post failures occurred between the fiber post and resin-matrix cements(4). Failures may occur by several factors such as: (i) the type of resin-matrix cement used (dual or self-etching adhesive) (2,7–9); (ii) inherent polymerization shrinkage of resin-matrix cements, and the high C factor of root canals (2,10); (iii) anatomical complexity of the root canal itself (e.g. curvatures)(7,11,12); (iv) thickness and volume of remnant tooth tissues(11); (v) surface treatment of the tooth root intracanal posts (3,10,13,14).

Teeth root intracanal fiber post systems are composed of an epoxy resin matrix, which is reinforced with carbon or glass fibers. Glass fiber posts consist of around 60wt% glass fibers, which are embedded in a methacrylate- or epoxy resin matrix (about 35wt%) (4,10,12,14,15). The main components of the glass-based fibers are silicon oxide (50–60wt%) as well as calcium, boric, sodium, and aluminum oxide (4,10,12,14,15). The application of GFRC posts for restoring endodontically treated teeth with the loss coronal tooth structure has proved to be effective (2,13,14). GFRC posts in combination with resin-matrix cement and restorative resin-matrix composite materials can form a structurally and functionally homogeneous complex with root (2,10,14,16). Several surface treatment protocols (chemical and micro-mechanical modifications) have been reported to improve surface energy of GFRC posts to resin-matrix cements such as: grit-blasting, silanization, etching, and laser irradiation (1,4,5,12,17). Previous studies concluded that roughening the

GFRC surface either with micro-mechanical methods like sandblasting or application of hydrogen peroxide can improve the retention of the posts through the tooth root canal (4,8,18).

Tooth tissues namely enamel, dentin and cementum can reveal very different properties and morphological aspects of surfaces (2,17). Over the past years, the adhesion of fiber posts luted with simplified adhesive systems has been a matter of great interest(9). The retention of endodontic posts into the teeth root canal is dependent on the mechanical interlocking of the adhesive and the resin-matrix cements through the micro-scale irregularities on the surfaces of the endodontic post and intracanal dentin (1,5,17). The retention of GFRC posts is a fine procedure regarding the resin-matrix cement should have the capability of bonding to three different surfaces: GFRC, tooth tissues, and the restorative material(17). Even though the surface pretreatment, failures of GFRC posts frequently result in debonding or fracture since the resin-matrix-cement is the weakest spot of the interface (5,10,14,19).

The objective of this work was to perform an integrative systematic review on the retention of glass fiber reinforced composite posts by push-out bond strength tests. It was hypothesized that the surface conditions of tooth root intracanal posts and type of resin matrix cements play a key role on the long-term strength of the endodontic interfaces.

2. METHOD

A literature search was performed on PUBMED (via National Library of Medicine) using the following combination of search terms: "intracanal post" OR "endodontic post" OR "root canal post" OR "intraradicular post" AND "resin cement" AND "adhesion" OR "bond strength" OR "shear bond strength" OR "pull out" OR "push out". The inclusion criteria involved articles published in the English language, up to February 2020, reporting the bond strength of endodontic post to resin cements. Two of the authors (JCMS, CMTZ) independently analyzed the titles and abstracts of potentially relevant articles. The eligibility inclusion criteria used for article searches also involved: articles written in English; meta-analyses; randomized controlled trials; and prospective cohort studies. The total of articles was compiled for each combination of key terms and therefore the duplicates were removed using Mendeley citation manager. A preliminary evaluation of the abstracts was carried out to establish whether the articles met the purpose of the study. Selected articles were individually read and evaluated concerning the purpose of this study. The following factors were retrieved for this review: authors' names, journal, publication year, purpose, type and properties of resin cement, and bond strength.

3. RESULTS

The literature search identified a total of 75 articles on PubMed, as shown in Fig. 1. After reading the titles and abstracts of the articles, 13 were excluded because they did not meet the inclusion criteria. At last, 20 articles were selected for the present review.

Of the 20 selected studies, 12 (60%) investigated the effect of the surface treatment on push-out bond strength of posts to resin cements, while 15 (75%) addressed the surface conditioning of dentin wall (smear layer handling). The influence of the resin cement on the bond strength of posts were investigated by 8 (38.8%) articles. One article (4.76%) investigated the of effects of post dimensions, while the remaining article (4.76%) focused on cement application techniques. Twelve of the push-out tests were carried out at the same speed (0.5mm/min), while the remaining 8 were assessed at 1mm/min speed. Concerning slice dimensions, eleven studies opted for 1mm slices, 5 studies were performed on 2mm slices. A previous study was performed at three different slice thickness: 1.5, 1.7, 2, 3, and 4mm. Within 10 studies, specimens were harvested from cervical, middle, and apical sections of the root, 1 studies assessed the slices from cervical and apical regions, while in 9 studies tested multiple slices from the entire root, and obtained the mean value. Seventeen articles analyzed self-etch adhesives, that reveals the clinical importance of such adhesive system in operative techniques. However, three studies assessed etch and rinse adhesives.

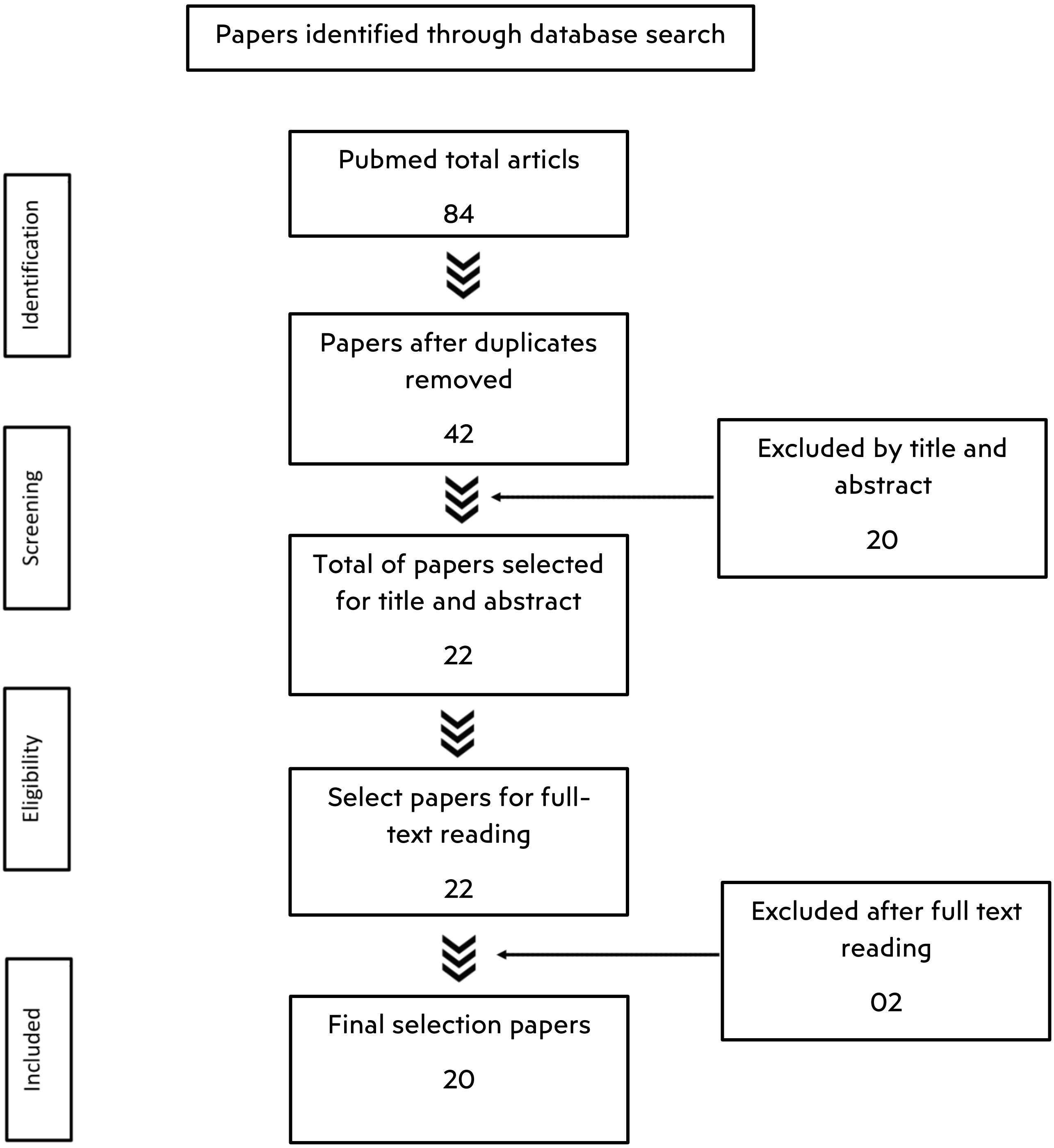

Figure 1. Flow diagram of the search strategy used in this study.

Table 1. Relevant data gathered from the retrieved studies.

<table>
<tr><th>Author
(YEAR)</th><th>Purpose</th><th>Endodontic post
(type/surface)</th><th>Resin-matrix cement
Adhesion procedure</th><th>Mechanical and
microstructural Analisis</th><th>Main outcomes</th></tr>
<tr>
<td>Uzun I, Keskin C, Özsu D, Güler B, Aydemir H

2016</td>
<td>In vitro study to evaluate the effect of Erbion-doped Yttrium aluminum garnet (Er: YAG) laser treatment of dentinal walls on the bond strength of circular and oval fiber post luted in oval canal</td>
<td>Type: oval and circular fiber posts
Surface: none</td>
<td>Lasered group Er-YAG:
Oval and Circular were irrigated 15 sec. With Er:YAG laser system(Doctor Smile Lambda Scientifica)
The luting protocol were the same for all groups , the cement RelyX Unicem, (3M ESPE), photoactivated with LED polymerization light (Elipar S10, 3M ESPE)</td>
<td>Apparatus:
Instron Universal test machine; Elista
Speed:0,5 mm/min
Slice: f 1mm,
Microscope (Carl Zeiss jena GmbH) at x10 magnification
Failure predominance:
Mix</td>
<td>Push -out results:(MPa)
<table>
<tr><th>GROUP</th><th>CERVICAL</th><th>APICAL</th></tr>
<tr><td>Lased circular</td><td>8.821</td><td>7.051</td></tr>
<tr><td>Lased oval</td><td>11.071</td><td>9.016</td></tr>
<tr><td>Non lased circular</td><td>7.031</td><td>6.047</td></tr>
<tr><td>Non lased oval</td><td>9.057</td><td>8.023</td></tr>
</table>
Pre-treatment with laser improved push-out bond strength compared to non lased group.
Oval post with oval ultrasonic type better results than circular post systems with conventional drills in coronal regions</td>
</tr>
<tr>
<td>Pereira JR, Lins Do Valle A, Ghizoni JS, Lorenzoni FC, Barbosa MR, Dos Reis Só MV

2013</td>
<td>Evaluate the push-out bond strength of glass fiber posts cemented with different luting agents on 3 segments of the root.</td>
<td>Type: Glass Fiber reinforced post with parallel walls and tapered tip (Reforpost No. 2; Angelus Dental Products, Londrina, Brazil)
Surface: silane (scotchbond ceramic primer; 3M ESPE)</td>
<td>(Rely X luting, Luting and Lining, Ketac Cem, Rely X ARC, Biscem, Duo-link,
Rely X U100, and Variolink II)

GROUP 1: Luting and Lining:
GROUP 2: Rely X luting
GROUP 3: Ketac Cem:
GROUP 4: Biscem:
GROUP 5: Rely X U100:
GROUP 6: Duo-link:
GROUP 7: Rely X ARC:
GROUP 8: Variolink II:</td>
<td>Apparatus:
A universal testing machine (DL-1000; EMIC, São José dos Pinhais, Brazil)

Speed: 0,5mm/min
Slice: 1 mm</td>
<td>Push -out Mean results:(MPa):
<table>
<tr><th>Group</th><th>Cervical</th><th>Middle</th><th>Apical</th></tr>
<tr><td>1</td><td>18.0</td><td>16.9</td><td>19.5</td></tr>
<tr><td>2</td><td>8.2</td><td>10.3</td><td>12.8</td></tr>
<tr><td>3</td><td>12.0</td><td>18.6</td><td>17.0</td></tr>
<tr><td>4</td><td>17.5</td><td>15.4</td><td>17.5</td></tr>
<tr><td>5</td><td>13.6</td><td>14.2</td><td>12.5</td></tr>
<tr><td>6</td><td>11.5</td><td>6.1</td><td>3.1</td></tr>
<tr><td>7</td><td>8.4</td><td>4.8</td><td>0.9</td></tr>
<tr><td>8</td><td>4.6</td><td>1.6</td><td>1.0</td></tr>
</table>
Self-adhesive cements and glass ionomer cements showed significantly higher values compared to dual-polymerizing resin cements.</td>
</tr>
</table>

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>In all root segments, dual-polymerizing resin cements provided significantly lower bond strength. Significant differences among root segments were found only for Duo-link cement .</td></tr>
<tr><td>Leme AA, Pinho AL, de Souza Gonçalves L, Correr-Sobrinho L, Sinhoreti MAC.

2013</td><td>Evaluate the effects of different glass-fiber post surface treatments on the bond strength to root dentin.</td><td>Type: Fiber post
Surface:G1: RelyX Ceramic primer (silane), G2: silane and solobond M, G3: silane and Scotchbond adhesive, G4: Silane and Excite (Ivoclar)</td><td>Self-adhesive RelyX Unicem (#M ESPE).
Composition: Methacrylate monomers containing phosphoric acid groups, methacrylate monomers, initiator, stabilizers</td><td>Apparatus:
A universal testing machine (model 4411, Instron; Canton, MA, USA)

speed: 0,5 mm/min

slice: 1mm
Scanning electron microscopy (SEM) (JEOL, JSM-5600LV; Tokyo, Japan).
Failure predominance:
1°: adhesive between dentin/cement
2°: mix</td><td>Push -out Mean results:(MPa)

<table><tr><th>Group</th><th>Cervical</th><th>Middle</th><th>Apical</th></tr><tr><td>CONTROL</td><td>2.39</td><td>2.78</td><td>2.92</td></tr><tr><td>1</td><td>9.65</td><td>4.11</td><td>4.04</td></tr><tr><td>2</td><td>11.21</td><td>4.53</td><td>4.38</td></tr><tr><td>3</td><td>11.23</td><td>5.96</td><td>5.12</td></tr><tr><td>4</td><td>9.43</td><td>5.26</td><td>5.26</td></tr></table>
The bonding of the self-adhesive resin cement to the glass-fiber post was improved by application of the silane coupling agent on the post surface. The application of an additional adhesive layer between the fiber post and resin cement did not have any influence on the bond strength when the silane coupling was previously used.</td></tr>
<tr><td>Mosharraf R, Ranjbarian P.

2013</td><td>Evaluate the effect of different surface conditioning on tensile bond strength (TBS) of a glass fiber reinforced post to resin cement.</td><td>Type: Glass reinforced fiber post (Hetco fiber post, Hakim Toos, Mashhad, Iran)
Surface:
<u>GROUP 1: H_2O_2 + Silane</u>: (Ultradent Porcelain Etch and Silane, Ultradent Products Inc., UT, USA)
<u>GROUP 2: Sandblast + Silane</u>.: 50 μm aluminum oxide particles + a single layer of the silane coupling agent</td><td>Adhesive composite resin cement (Panavia F2.0, Kuraray Medical Inc., Japan)
root canal dentin walls were conditioned with an auto polymerizing primer (ED primer, Kuraray Medical Inc., Tokyo, Japan)</td><td>Apparatus:
A universal testing machine (Walt + Bai AG Testing Machines Industriestrass 4, Löhningen, switzerland)
Speed: 1mm/min
Slice: 3mm</td><td>Push -out results:(MPa):

<table><tr><th>Group</th><th>Cervical</th><th>Middle</th><th>Apical</th></tr><tr><td>1</td><td>21.54</td><td>19.09</td><td>9.12</td></tr><tr><td>2</td><td>18.45</td><td>10.17</td><td>6.55</td></tr><tr><td>3</td><td>20.53</td><td>14.57</td><td>6.30</td></tr><tr><td>CONTROL</td><td>9.76</td><td>9.08</td><td>5.58</td></tr></table>
Different surface treatments and root canal dentin regions had significant effects on Tensile Bond Strength (TBS), but interaction between surface</td></tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>(Ultradent Porcelain Etch and Silane)
GROUP 3: Silane.: only a single layer of the silane coupling agent (Ultradent Porcelain Etch and Silane)</td>
<td></td>
<td></td>
<td>treatments and root canal regions had no significant effects on TBS.
The H_2O_2 + Silane Group had the highest TBS mean value especially in the coronal region. The lowest TBS mean value was seen in the control group and in the apical region.</td>
</tr>
<tr>
<td>Šimundić Munitić M, Bago I, Glockner K, Kqiku L, Gabrić D, Anić I.

2017</td>
<td>Evaluate the influence of laser activated irrigation by Er: YAG and Er: YSGG (LAI) protocols and Nd: YAG laser irradiation on the bond strength of self adhesively cemented fiber posts to root canal dentin</td>
<td>Type: Fiber-reinforced composite post.
Surface: Silanized (Monobond plus, Ivoclar Vivadent)</td>
<td>Self-adhesive resin cement (Speed CEM)
Polimerized by 60 sec.</td>
<td>Apparatus: Universal testing machine (AGS-10knd; shimadzu Co., Kyoto, Japan)
Speed: 0,5 mm/min
Slice: 1mm
Stereomicroscope (Olympus SZX10; DF PL1.5, Hamburg, Germany) at 20x magnification
Failure predominance:
1°: adhesive between dentin/cement
2°: adhesive between post/cement</td>
<td>Push -out Mean results:(MPa):
<table>
<tr><th>GROUP</th><th>MEAN</th></tr>
<tr><td>Needle+saline</td><td>0.737</td></tr>
<tr><td>Nd: YAG</td><td>0.868</td></tr>
<tr><td>PIPS+QMix</td><td>3.401</td></tr>
<tr><td>Er: YSGG+Qmix:</td><td>0.919</td></tr>
<tr><td>PIPS+saline</td><td>1.094</td></tr>
<tr><td>Er,Cr: YSGG+saline</td><td>1.111</td></tr>
</table>
Highest bond strength photon-initiated photoacoustic streaming (PIPS) +QMix, followed by laser activated irrigation (LAI) Er, cr:YSGG and PIPS + saline solution, which did not differ significantly .</td>
</tr>
<tr>
<td>Tuncdemir AR, Buyukerkmen EB, Celebi H, Terlemez A, Sener Y.

2018</td>
<td>Evaluate the effect of different Post Surface treatment techniques on the push-out bond strength of the quartz fiber posts</td>
<td>Type: quartz fiber posts (D. T. LIGHT-POST,
Bisco, USA). radiopaque translucent fiber post with unidirectional 60% glass fibers embedded
in an epoxy resin matrix
Surface:
• Group 2: A 50-μm aluminum-oxide (Al_2O_3) airborne-particle</td>
<td>Self-curing adhesive cement (Multilink Automix, Ivoclar, Vivadent, Liechtenstein)</td>
<td>Apparatus:
A universal testing machine (AGS-X, Schimadzu Corp., Kyoto, Japan)

Speed: 1.0 mm/min

Slice: 1mm

Scanning electron microscope X200</td>
<td>Push-out Mean results(MPa):
<table>
<tr><th>GROUP</th><th>MEAN</th></tr>
<tr><td>SANDBLASTING</td><td>4.14</td></tr>
<tr><td>CONTROL</td><td>3.36</td></tr>
<tr><td>LASER</td><td>3.16</td></tr>
</table>
Push-out test values differed significantly according to the post surface treatment system. Al_2O_3 airborne-particle abrasion group showed higher and</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>• Group 3: FS laser. FS laser pulses from an amplifier (Integra-C3.5;
Quantronix, New York, USA)</td>
<td></td>
<td>Failure predominance:
1°: adhesive between post/cement
2°: mix</td>
<td>FS laser group showed lower bond strength values for quartz fiber posts
Push-out bond strength values of the root segments were the same in all groups.
A 500 mW/pulse and maching speed 30, skip speed 1250, and a 10 kHz repetition rate FS irradiation applied on quartz fiber posts negative affect on push-out bond strengths of the root surfaces.</td>
</tr>
<tr>
<td>Amiri EM, Balouch F, Atri F.

2017</td>
<td>Compare the effect of self-adhesive and separate etch adhesive dual cure resin cements on the bond strength of fiber post to dentin at different parts of the root</td>
<td>Type: fiber glass post
Surface: Z primer plus (Bisco Dental)</td>
<td>Group 1: self-adhesive cement (rely X Unicem, 3M).
Group 2: separate etch adhesive cement (Duo-Link cement, Bisco dental). 37% phosphoric acid for 15 sec.+All Bond 2 (Bisco Dental, Schaumburg</td>
<td>Apparatus:
Zwick Roell, Uim, Germany
Speed: 1mm/min
Slice:4mm</td>
<td>Push -out Mean results:(MPa):
<table><tr><td>Group</td><td>Cervical</td><td>Middle</td><td>Apical</td></tr><tr><td>1</td><td>5.7</td><td>7.2</td><td>9.6</td></tr><tr><td>2</td><td>14.0</td><td>10.9</td><td>7.0</td></tr></table>
Bond strength highest in coronal and middle section at group 1
Bond strength highest in apical section at group 2</td>
</tr>
<tr>
<td>Druck CC eoli., Bergoli CD almoli., Pereira GK ali. R, Valandro LF elip.

2015</td>
<td>To evaluate the effect of fiber post surface treatments on push-out bond strength between fiber post and root dentin.</td>
<td>Type: Fiber post (White Post DC, FGM, Joinvile, SC, Brazil)
Surface:
1) silane (Prosil, FGM, Brazil)
2) air-abraded with 30 μm aluminum oxide particles modified with silica (Cojet Sand, 3M
ESPE, St Paul, MN, USA) and the silane coupling agent (ProSil, FGM, Brazil)</td>
<td>Three step 'etch & rinse' adhesive system (Scotchbond multi-purpose plus, 3M ESPE, St Paul, USA).
Composition:
<u>RelyX ARC Etchant</u>: 35% H3PO4
Adhesive: Bis-GMA, HEMA, UDMA, dimethacrylates, ethanol, water, canphorquinone, photoinitiators, polyalkenoic acid copolymer, 5-nm silica
Particles Cement:Bis-GMA, TEGDMA polymer, zirconia/silica filler, AllCem Bis-GMA, BIS-EMA,</td>
<td>Apparatus:
A universal testing machine (DL 2000, Emic, São Jose dos Pinhais, Brazil)

Speed: 1 mm/min

Slices 2mm
optical microscope (Olympus, BX60M, Japan) with 200x magnification scanning electron microscopy</td>
<td>Push -out Mean results:(MPa):
<table><tr><td>GROUP</td><td>MEAN</td></tr><tr><td>AllCem + Sil</td><td>9.5</td></tr><tr><td>ARC + Sil</td><td>8.3</td></tr><tr><td>AllCem + TBS</td><td>6.9</td></tr><tr><td>ARC + TBS</td><td>6.6</td></tr><tr><td>ARC + untreated</td><td>7.5</td></tr><tr><td>AllCem+untreated</td><td>6.0</td></tr></table>
Post surface conditioning had a significant influence on bond strength values , but that the resin cement did not In teeth restored with fiber posts, the cement/</td>
</tr>
</table>

<table>
<tr><td></td><td></td><td></td><td>TEGDMA, photoinitiators (canphorquinone e dibenzoyl peroxide), barium-aluminum-silica glass particles, and SiO2 nano-particles Prosil (FMG): 3methacryloxypropyltrimethoxysilane, ethanol, water
Cojet (3M ESPE): aluminum oxide particles coated by siliceous dioxides</td><td>(JEOL-JSM-5400, Jeol Ltd, Tokyo, Japan)
Scanning electron microscopy (JEOL-JSM-5400, Jeol Ltd, Tokyo, Japan)

Failure predominance:
1°: adhesive between dentin/cement
2° adhesive between post/cement</td><td>dentin interface appears to be the most susceptible to failure,
while different post surface treatments appear to have little influence on bond behavior.
The tested fiber posts surface treatment appears do not influence the fiber post bond behavior.</td></tr>
<tr><td>Kivanç BH, Arisu HD, Üçtaşli MB, Okay TC.

2013</td><td>Assess the post retentive potential of a self-adhesive resin cement using different adhesive systems to compare the push-out bond strengths of fiber posts</td><td>**Type**: glass fiber post (RelyX Fiber Post).</td><td>G2: total-etch adhesive resin (Adper Single Bond 2
G3: A two-step self-etch adhesive resin (Clearfil SE Bond
G4: A one-step self-etch adhesive resin (Clearfil S3 Bond)
In all groups, self-adhesive resin cement (RelyX Unicem) was used for luting the posts.</td><td>**Apparatus:**
universal testing machine (Autograph AG-10kNIS, Shimadzu Co., Kyoto, Japan)
Speed: 0,5mm/min−1
Slice: 1,5 mm
Stereomicroscope (Olympus S 240, Tokyo, Japan) at ×40 magnification

Failure predominance:
Mix</td><td>Push -out Mean results:(MPa):
<table><tr><td>GROUP</td><td>MEAN
1 WEEK</td><td>MEAN
3 MONTHS</td></tr><tr><td>RelyXUnicem</td><td>3.78</td><td>5.16</td></tr><tr><td>Single Bond</td><td>6.78</td><td>6.50</td></tr><tr><td>Clearfil SE</td><td>5.38</td><td>9.63</td></tr><tr><td>Clearfil S3</td><td>7.21</td><td>5.12</td></tr></table>
Dentin bond strength of the total-etch adhesive resin Single Bond, the one-step self-etch adhesive resin Clearfil S3 Bond, the self-adhesive resin cement RelyX Unicem remained stable and the bond strengths of the two-step self-etch adhesive resin Clearfil SE Bond increased with time.</td></tr>
<tr><td>Machado FW, Bossardi M, Ramos TDS, Valente LL,</td><td>Evaluate the effect of different post surface treatments on the</td><td>**Type:** glass fiber–reinforced
Surface:
Group S/A: Silane (Silane coupling agent; Dentsply) + Adhesive (Scotchbond</td><td>Adhesive system (Scotchbond Multipurpose Plus System) + The resin cement (RelyX ARC; 3M ESPE)</td><td>**Apparatus:**
A universal testing machine (DL500; EMIC, S~ao Jos_e dos Pinhais, PR, Brazil)
Speed: 1mm/min</td><td>Push -out results:(MPa):
<table><tr><td>Group</td><td>Cervical</td><td>Middle</td><td>Apical</td></tr><tr><td>S/A</td><td>8.6</td><td>8.1</td><td>3.2</td></tr><tr><td>S</td><td>5.6</td><td>4.1</td><td>5.1</td></tr></table></td></tr>
</table>

<table>
<tr>
<td>Münchow EA, Piva E.

2015</td>
<td>retention of glass fiber–reinforced post to root dentin.</td>
<td>Multipurpose Plus Adhesive; 3M ESPE)
<u>Group S</u>: Silane (Silane coupling agent; Dentsply)
<u>Group A</u>: Adhesive (Scotchbond Multipurpose Plus Adhesive; 3M ESPE)</td>
<td></td>
<td>Slice: 1,0 mm
Stereomicroscope and digital micrometer (Mitutoyo, Santo Amaro, SP, Brazil) with 0.01-mm accuracy atX40 magnification
Failure predominance:
Adhesive between post/cement</td>
<td><table><tr><td>A</td><td>4.4</td><td>4.4</td><td>5.5</td></tr></table>
Whereas silanization as the only post surface treatment did not improve retention, the combination of silane plus resin adhesive enhanced post retention to dentin in the middle and coronal root regions.</td>
</tr>
<tr>
<td>Freitas TL de, Vitti RP, Miranda ME, Brandt WC.

2019</td>
<td>Evaluate the effect of different glass fiber posts (GFPs) diameters on the push-out bond strength to dentin</td>
<td>Type: Translucent Glass fiber post (White Post DC, FGM),
PC – customized post number 0.5 with composite resin (Tetric Ceram A2, Ivoclair Vivadent).
Surface:
37% phosphoric acid (Condac 37, FGM) Then, a Silane (Prosil, FGM)+ The catalyst of the adhesive system (Adper Scotchbond Multipurpose Plus, 3M ESPE</td>
<td>Dual-curing luting composite (Variolink II, Ivoclair Vivadent)
The adhesive system (Adper Scotchbond Multipurpose Plus, 3M ESPE) was applied (adhesive system plus actor .</td>
<td>Apparatus:
A universal testing machine (DL 2000, EMIC, Sao Jose dos Pinhais, PR, Brazil)
Speed: 0.5 mm/min.
Slice: 2mm and 1,7mm

Stereomicroscope (EK3ST, Eikonal Equipamentos Opticos e Analiticos, Sao Paulo, SP, Brazil) at 40x magnification
Failure predominance:
1°: adhesive between dentin/cement
2° adhesive between post/cement</td>
<td>Push -out results:(MPa):
<table><tr><th>Group</th><th>Cervical</th><th>Middle</th><th>Apical</th></tr><tr><td>1</td><td>6.2</td><td>4.9</td><td>5.1</td></tr><tr><td>2</td><td>10.7</td><td>7.9</td><td>8.6</td></tr><tr><td>5</td><td>6.0</td><td>4.4</td><td>5.9</td></tr><tr><td>C</td><td>8.8</td><td>10.5</td><td>7.7</td></tr></table>
P2 and PC showed the highest bond strength values, which were not statistically different from each other. P5 and P1 were not statistically different and showed the lowest bond strength values.
A predominance of ACD failure was observed for P2, P5, and PC. On other hand, the predominant failure mode in P1 was APC</td>
</tr>
<tr>
<td>Samimi P, Mortazavi V, Salamat F.

2014</td>
<td>Compare two pretreatment methods of a fiber post and to</td>
<td>Type: conical shape glass fiber posts
Surface:
<u>Group HF+S</u> =</td>
<td>self-etch resin cement (Panavia F2.0, Kuraray, Japan).</td>
<td>Apparatus:
a Universal Testing Machine (Zwick Roell Z020, Zwick, Germany).</td>
<td>Push -out Mean results:(MPa):
<table><tr><th>Group</th><th>Cervical</th><th>Middle</th><th>Apical</th></tr><tr><td>HF+S</td><td>9.34</td><td>8.43</td><td>6.94</td></tr><tr><td>HF+S+WP</td><td>12.8</td><td>10.96</td><td>14.64</td></tr></table></td>
</tr>
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<tr>
<td></td>
<td>evaluate the effect of heat treatment to applied silane on the push-out bond strength for different levels of root.</td>
<td>hydrofluoric acid (HF) etching and silane (S)
Group HF+S+WP = HF etching and heat-treated silane application and warmed posts (WP); Group H_2O_2 +S = hydrogen peroxide etching and silane application;
Group H_2O_2+S+WP = hydrogen peroxide and heat treated-silane application and warmed post;</td>
<td></td>
<td>Speed: 0,5mm/min
Slice: 2 mm
Stereomicroscope (Lomo SF-100, MBC-10, Moscow, Russia) (363)
Scanning electron microscope (SEM, Philips XL30, Philips Eindhoven, etherlands).
Statistical
Failure predominance:
1°: mix
2°: adhesive between pin/cement and dentin/cement</td>
<td><table>
<tr><td>H_2O_2+S</td><td>14.38</td><td>9.69</td><td>6.76</td></tr>
<tr><td>H_2O_2+S+WP</td><td>6.96</td><td>10.53</td><td>9.13</td></tr>
</table>
Bond strength was not statistically influenced by the kind of etching material used, but was significantly affected by heat treatment of applied silane. The interaction between these two factors was not statistically significant. Group HF+S+WP showed the highest bond strength.</td>
</tr>
<tr>
<td>Gomes KGF, Faria NS, Neto WR, Colucci V, Gomes EA.

2017</td>
<td>Evaluate the influence of laser irradiation on the push-out bond strength of glass fiber posts to radicular dentin.</td>
<td>Type: Glass fiber post (Exacto; Angelus)

Surface: silane control (GC); Er:YAG laser irradiation (GYAG); Er;Cr:YSGG laser irradiation (GCR); and diode laser irradiation (GDI).
Silane-coupling agent (Ceramic Primer; 3M ESPE)</td>
<td>Dual-polymerizing cement (RelyX ARC; 3M ESPE)

The adhesive system (Adper Single Bond 2; 3M ESPE)
A dual-polymerizing resin cement (RelyX ARC; 3M ESPE</td>
<td>Apparatus:
A universal testing machine (3345; Instron Corp)
Speed: 0,5mm/min
Slice: 2mm

Stereomicroscopy (Leica DFC295 attached to a Leica S8 APO; Leica Microsystems) at ×40 m magnification
Failure predominance:
1°:adhesive between post/cement
2°:adhesive between dentin/cement</td>
<td>Push -out Mean results:(MPa)
<table>
<tr><td>Group</td><td>Cervical</td><td>Middle</td><td>Apical</td></tr>
<tr><td>GC</td><td>4.028</td><td>2.626</td><td>1.616</td></tr>
<tr><td>GYAR</td><td>2.192</td><td>1.358</td><td>1.381</td></tr>
<tr><td>GCR</td><td>3.793</td><td>4.683</td><td>4.963</td></tr>
<tr><td>GDI</td><td>2.140</td><td>2.525</td><td>1.737</td></tr>
</table>
Cervical third GC and GCI showed higher bond strength.
Middle and apical thirds GCR showed higher bond strength.
Er;Cr:YSSG laser radiation improved the pushout bond strength of the cement-post-dentin in all regions of the root: cervical, middle, and apical thirds.</td>
</tr>
</table>

<table>
<tr>
<td>Liu C, Liu H, Qian YT, Zhu S, Zhao SQ

2014</td>
<td>Evaluate the influence of post surface pre-treatments on the bond strength of four different cements to glass fiber posts.</td>
<td>Type: radiopaque, translucent Glassix glass fiber composite posts (Harald Nordin SA, Chailly/ Montreux, Switzerland)
Surface:
SA: sandblasting,
SI: silanization
SS: sandblasting followed by silanization</td>
<td><u>Four dual-cure resin cements</u>
<u>DMG LuxaCore</u> Smartmix Dual DMG,(Acrylic resin, glass powder, silica, urethane dimethacrylate, aliphatic dimethacrylate, aromatic dimethacrylate) (No primer available)
<u>Multilink Automix Ivoclar-Vivadent</u>, (HEMA, dimethacrylate, barium glass, ytterbium) (primer comp.: Water, HEMA, phosphoric acid acrylate, polyacrylic acid-modified methacrylate resin)
<u>Panavia F2.0</u> (Kuraray) (MDP, dimethacrylate, barium glass powder, sodium fluoride, silica, amine, benzoyl peroxide, sodium aromatic sulfinate)(primer comp.: HEMA, 10-MDP, N-methacryl, odium benzene sulfinate, 5-aminosalicylic, N,N-diethanol ptoluidine, water)
<u>RelyX Unicem</u> (3M ESPE, St Paul, USA) (Silica, calcium hydroxide, methacrylated phosphoric ester, glass, dimethacrylate, acetate)
(No primer available)</td>
<td>Apparatus:
A universal testing machine (1121; Instron, Danvers, MA,USA).

Speed: 0,5mm/min

Slice: 1,00 mm

Stereo microscope XTL-33 Stereomicroscope (340) (Shanghai Pudan Optical Instrument, Shanghai, China)
Failure predominance:
1°: adhesive between post/cement
2°: cohesive of dentin</td>
<td>Push -out Mean results:(MPa):
<table>
<tr><th>GROUP</th><th>MEAN</th></tr>
<tr><td>NS/ DMG LuxaCore</td><td>8.44</td></tr>
<tr><td>NS/ Multilink Automix</td><td>8.79</td></tr>
<tr><td>NS/ Panavia F2.0</td><td>11.77</td></tr>
<tr><td>NS/ RelyX Unicem</td><td>14.77</td></tr>
<tr><td>SA/DMG LuxaCore</td><td>13.97</td></tr>
<tr><td>SA/Multilink Automix</td><td>9.37</td></tr>
<tr><td>SA/Panavia F2.0</td><td>14.34</td></tr>
<tr><td>SA/ RelyX Unicem</td><td>16.89</td></tr>
<tr><td>SI/DMG LuxaCore</td><td>9.46</td></tr>
<tr><td>SI/ Multilink Automix</td><td>9.83</td></tr>
<tr><td>SI/Panavia F2.0</td><td>16.40</td></tr>
<tr><td>SI/ RelyX Unicem</td><td>15.29</td></tr>
<tr><td>SS/DMG LuxaCore</td><td>13.23</td></tr>
<tr><td>SS/Multilink Automix</td><td>8.95</td></tr>
<tr><td>SS/Panavia F2.0</td><td>12.63</td></tr>
<tr><td>SS/ RelyX Unicem</td><td>15.33</td></tr>
</table>

When DMG LUXACORE Smartmix Dual is used, air abrasion of glass fiber posts has a significantly helpful effect on the micro push-out bond strength. Silanization of the post surface has no significant effect on the interfacial bond strength between the post and the resin cement. There was no significant difference in bond strength between the silanization group and the control group. Comparing the pooled data of the four cements, Panavia F2.0 and RelyX Unicem proved to have significantly higher mean micro push-out bond strength values than DMG LUXACORE Smartmix Dual and Multilink Automix.</td>
</tr>
</table>

<table>
<tr>
<td>Dimitrouli M, Geurtsen W, Lührs AK.

2012</td>
<td>Compare the push-out strength of glass fiber posts dependent on the resin cement.</td>
<td>Type: Two glass fiber post systems (DT Light SL (DTSL). The DT Light SL posts (quartz fibers). The DT Light SL post has a double taper design, The DT Light SL posts possess an industrial-coated surface. This coating is made of silane and silicate and RelyX Fiber Post (RF)) were used. RelyX Fiber posts consist of glass fibers (zirconia based, 80–90% by weight). the RelyX Fiber posts do not possess a coating</td>
<td>DT Light posts were cement with 3 self-adhesive resin cements:
Maxcem Elite (MC) Kerr, Bioggio, Switzerland
iCem (IC) Heraeus, Hanau, Germany)
BifixSE (BF) VOVO, Cuxhaven, Germany
RelyX Fiber Posts were cemented using:
RelyX Unicem (RLX) 3M ESPE,Seefeld,Germany
The control group, also using DT Light Post were cemented with an etch & rinse cement:
Variolink II/Exite DSC (VL) Ivoclar Vivadent, Ellwagen, Germany</td>
<td>Apparatus:
(Type 20K, UTS, Ulm)
Speed: 1mm/min
Slice: 2mm
Microscope, Wild M3Z Type-S, Heerbrugg, Switzerland) at ×25 and ×40 magnification
Failure predominance:
1°:Adhesive between cement/post
2° mix</td>
<td>Push -out Mean results:(MPa):
<table>
<tr><th>GROUP</th><th>BEFORE TC</th><th>AFTER TC</th></tr>
<tr><td>VL</td><td>16.5</td><td>13.5</td></tr>
<tr><td>RLX</td><td>8.0</td><td>11.3</td></tr>
<tr><td>MC</td><td>10.0</td><td>9.4</td></tr>
<tr><td>IC</td><td>14.2</td><td>13.1</td></tr>
<tr><td>BF</td><td>22.5</td><td>9.5</td></tr>
</table>
The highest push-out strength among all cements was measured for BF without TC, which was significantly different to RLX and MC. No significant differences between groups could be detected after TC. Group VL, the only “etch & rinse” system tested, revealed the second highest push-out strength before TC, which dropped after TC , but without statistically significant difference compared to the self-adhesive resin cements. The lowest values were found for RLX without TC which increased slightly after thermocycling.
The bond strength of adhesively cemented glass fiber posts are not dependent on the type of resin cement. A self-adhesive resin cement system can result in bond strength values that are comparable to a conventional “etch & rinse” adhesive system.</td>
</tr>
<tr>
<td>Shiratori FK, Valle AL Do, Pegoraro TA, Carvalho RM, Pereira JR

2013</td>
<td>The purpose of this study was to evaluate the bond strength of 3 self-adhesive cements used to cement</td>
<td>Type: glass fiber</td>
<td><u>Group BIS: Biscem</u> cement (Bisco Inc); (comp.: : Bis-GMA, Unpolymerized dimethacrylate monomer, Glass Filler, Phosphate acidic monomer)
<u>Group BRE:</u> Breeze cement (Pentron Clinical Technologies,</td>
<td>Apparatus:
A universal testing machine (DL500; EMIC,
Pinhais, Brazil)
Speed: 1mm/min
Slice: 1mm</td>
<td>Push -out Mean results:(MPa)
<table>
<tr><th>GROUP</th><th>Sub- A</th><th>Sub-L</th><th>Sub- C</th></tr>
<tr><td>BIS</td><td>7.25</td><td>13.37</td><td>9.48</td></tr>
<tr><td>BRE</td><td>12.27</td><td>13.65</td><td>13.64</td></tr>
<tr><td>MAX</td><td>7.87</td><td>7.21</td><td>9.89</td></tr>
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<td></td>
<td>intraradicular glass fiber posts. The cements all required different application and handling techniques.</td>
<td></td>
<td>wallingford, Conn); (comp.: Breeze Mixture of BISGMA, UDMA, TEGDMA, HEMA, & 4-MET resins, silane-treated barium borosilicate glasses, silica with initiators, stabilizers, and UV absorber, organic and/or inorganic pigments, opacifiers).
<u>Group MAX</u>: Maxcem Elite cement (Kerr, Orange, Calif) (comp.: Unpolymerized methacrylate ester monomers, mineral fillers, ytterbium fluoride, activators, stabilizers, and colorants.).
Cement insertion techniques
A: Auto mixture syringe + Application tip
L: Spatulation for 20 sec + Lentulo for 5 sec
C: Spatulation for 20 sec + Centrix Syringe</td>
<td>Optical microscopy (Carl-Zeiss, Oberkochen, Germany) at ×40 magnification

Failure predominance:
Adhesive between dentin/cement in all samples</td>
<td>Application and handling techniques may influence the bond strength of Biscem cements when used for intraradicular post cementation Compared with the other techniques Biscem cement presents the lowest mean bond strength values when used with a self-mixing syringe and application tip.
Breeze cement and Maxcem cement do not differ significantly with different application and handling techniques.</td>
</tr>
<tr>
<td>Laith Konstantinos B.

2017</td>
<td>Compare the traditional cement systems with those of the latest generation, to assess if indeed these could represent of viable substitutes in the</td>
<td>Type: Fiber post (LuxaPost-DMG)</td>
<td><u>Group A</u>: 37% orthophosphoric acid (Superlux-Thixoetch- DMG) + a dual-curing adhesive system (LuxaBond-Total Etch-DMG), dual-cured resin-composite cement (LuxaCore-DMG)
<u>Group B</u>: self-adhesive resin cement (Breeze-Pentron Clinical)
<u>Group C:</u> 3 steps light-curing, self-etching self-conditioning</td>
<td>Apparatus:
A universal testing machine Galdabini-Sun 500
speed: 0,5 mm/min
slice: 1 mm

optical microscope (Zeiss laser scan).50x</td>
<td>Push -out Mean results:(MPa):
<table><tr><th>GROUP</th><th>MEAN</th></tr><tr><td>A</td><td>12.58</td></tr><tr><td>B</td><td>6.58</td></tr><tr><td>C</td><td>5.7</td></tr></table>
The adhesion force is greater for the group A, Lowest bond strength values were obtained where the etching step wasn't performed.</td>
</tr>
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<td></td>
<td>cementation of indirect restorations, and in the specific case of endodontic posts.</td>
<td></td>
<td>bonding agent (Contax- Total-etch-DMG), dual-cured resin-composite cement (LuxaCore-DMG)</td>
<td></td>
<td>Etching with orthophosphoric acid combined with a dual-curing adhesive system and a dual-cured resin-composite cement is the technique that guarantees a satisfying bond strength.</td>
</tr>
<tr>
<td>Tuncdemir AR, Yıldırım C, Güller F, Özcan E, Usumez A.

2013</td>
<td>Evaluate the influence of post surface treatment methods on the push-out bond strength of adhesively luted quartz fiber posts</td>
<td>Type:
quartz fiber posts.
Surface:
Group 2: 50-μm aluminum-oxide (Al_2O_3)
airborne-particle abrasion
Group 3: Er:YAG laser (10 Hz,150 mJ) irradiation.</td>
<td>Self-curing adhesive cement (MultilinkAutomix, Ivoclar, Vivadent, Liechtenstein),</td>
<td>Apparatus:
A universal testing machine (AGS-X, Schimadzu Corp., Kyoto, Japan)
Speed: 1 mm/min
Slice: 1 mm
Failure predominance:
Mix in all samples</td>
<td>Push -out results:(MPa)
<table>
<tr><th>Group</th><th>Cervical</th><th>Middle</th><th>Apical</th></tr>
<tr><td>CONTROL</td><td>5.69</td><td>3.09</td><td>1.79</td></tr>
<tr><td>Al_2O_3</td><td>4.61</td><td>2.70</td><td>2.17</td></tr>
<tr><td>Er:YAG</td><td>4.68</td><td>3.14</td><td>2.84</td></tr>
</table>
The airborne particle abrasion or Er:YAG laser irradiation applied on quartz fiber posts did not affect the push-out bond strengths relative to the root surfaces.
The highest bond strength was observed in the coronal root section in all groups.</td>
</tr>
<tr>
<td>Durski MT, Metz MJ, Thompson JY, Mascarenhas AK, Crim GA, Vieira S, et al.

2015</td>
<td>Evaluate the push-out strength of two different adhesive cements (total etch and self-adhesive) for glass fiber post (GFP) cementation using two different techniques (microbrush and elongation</td>
<td>Type: glass fiber post
Application:
1)RelyX ARC +microbrush
2)Relyx ARC + elongation tip;
3)RelyX Unicem + microbrush
4) RelyX Unicem +elongation tip;
5) RelyX Unicem + 37% phosphoric acid + microbrush,
6)RUE + elongation tip (all 3M ESPE).</td>
<td><u>RelyX ARC</u> (ARC) HEMA, (bisGMA, dimethacrylate resins, methacrylate modified polycarboxylic acid copolymer, photoinitiator/ water, ethanol)
<u>RelyX Unicem</u> (RU) AND <u>RelyX Unicem</u> <u>þ etching</u> (RUE):
(Methacrylated phosphoric esters, dimethacrylates, acetate, initiators, stabilizers, glass fillers,</td>
<td>Apparatus:
A Universal Testing Machine
Instron, Canton, MA, USA)

Speed:0.5 mm/min.

Slice: 1,0 mm</td>
<td>Push -out results:(MPa)
<table>
<tr><th>Group</th><th>Cervical</th><th>Middle</th><th>Apical</th></tr>
<tr><td>1</td><td>10.44</td><td>7.09</td><td>3.95</td></tr>
<tr><td>2</td><td>11.13</td><td>8.24</td><td>5.85</td></tr>
<tr><td>3</td><td>14.81</td><td>11.32</td><td>7.3</td></tr>
<tr><td>4</td><td>18.68</td><td>14.97</td><td>9.42</td></tr>
<tr><td>5</td><td>21.57</td><td>17.19</td><td>9.34</td></tr>
<tr><td>6</td><td>22.17</td><td>18.61</td><td>14.72</td></tr>
</table>
Self-adhesive cement has a higher push-out strength values when compared to total-etch cement in all thirds of the root canal dentin.</td>
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<tr>
<td></td>
<td>tip) of cement application.</td>
<td></td>
<td>silica, calcium hydroxide).</td>
<td></td>
<td>The cervical third region of the root canal dentin displayed the highest push-out strength values, while the apical third had the lowest results.
The cement application technique utilizing the elongation tip had higher push-out strength values when compared with the microbrush technique.
The optional conditioning step before self-adhesive cementation obtained the highest push-out strength values regardless of application technique or root area.</td>
</tr>
<tr>
<td>Arslan H, Ayranci LB, Kurklu D, Topçuoglu HS, Barutcigil C.

2016</td>
<td>Evaluate whether fiber post surface conditioning with air abrasion or (Er:YAG) laser would influence the bond strength of dual-cure resin cement to the (FRC) posts.</td>
<td>Type: fiber-reinforced (FRC) posts.
Surface: G2: air abrasion with Al_2O_3 (50μm/20seg.).
G3: Er:YAG laser (150 mJ, 10 Hz, 1.5 W), 60 seg.</td>
<td>Dual -polymerizing resin (Variolink II; Ivoclar Vivadent AG)</td>
<td>Apparatus: (MicroTester, Instron, Norwood, MA).
Speed: 0.5 mm/min
Slice: 2mm
Stereomicroscope (Novex, Arnhem, Holland) at ×20 magnification
Scanning electron microscope (EVO LS10, Zeiss, Oberkochen, Germany) at ×3000 magnification.</td>
<td>Push -out Mean results:(MPa):
<table>
<tr><th>GROUP</th><th>MEAN</th></tr>
<tr><td>Control</td><td>15.25</td></tr>
<tr><td>Air abrasion</td><td>19.73</td></tr>
<tr><td>Er:YAG 150mJ</td><td>17.84</td></tr>
</table>
The highest push-out bond strength was observed in the air abrasion group, and there was a significant difference when the group was compared to the untreated group. In the Er:YAG laser group, a higher bond strength value was observed than in the control group, but statistical analysis did not reveal any significant differences .
After air abrasion, the surface topography of the FRC posts appeared to be significantly more micro-retentive</td>
</tr>
</table>

The major findings are shown in Table 1 and described as follow.

- The highest push-out strength values between teeth root intracanal posts and resin-matrix cements were recorded at 17.5 and 22.5 MPa (2,3,15). Statistic differences (P=.001) were noticed to others resins-matrix cements regarding the push-out strength values ranging from 4.65 to 13.6 MPa(2);
- The high push-out test bond strength value of 22.5 MPa were measured over a factory pré-treated surface post by physical vapor deposition process of silane and silicate, cemented by a self-adhesive cement
- Another high push-out bond strength values of 21.54 MPa were measured on intracanal post surfaces modified with a combination of silane and hydrogen peroxide treatment (4). The solely application of silane had a significant influence on the post surface modification since the bond strength values were recorded around 20.5 MPa (4);
- High push-out bond strength mean values of 19.73 ±2.72 MPa were also recorded on teeth root intracanal posts modified by grit-blasting with 50µm Al_2O_3 particles for 20 s (20). There were significant differences when comparing to a untreated group (15.28 ± 3.39 MPa) (P=.005) (20). Microscopic analyses revealed rough surface aspects after grit-basting that increase the mechanical interlocking of the resin-matrix cement (20);
- Within the regions of the root canal (cervical, middle, and apical thirds), twelve studies revealed differences in bond strength values regarding the thickness, polymerization, and adhesive type of the resin-matrix cements. On self-adhesive cements, a decrease in bonding strength values was noticed from apical (9.9 MPa) towards to middle (7.2 MPa), and cervical (5.7 MPa) (7). They correlate the decrease in bond strength in cervical regions due to decreased density of dentin tubules(7);
- Teeth root intracanal post surfaces treated with hidrofluoric acid, silane, and heat treatment showed a decrease in bond strength values from the middle (10.96 MPa) to cervical (12.08 MPa) or apical (14.64 MPa) third (11);
- The modification of the teeth root intracanal post surfaces by laser-irradiation also promoted an increase in the push-out bond strength values of posts to the resin-matrix

cements in all regions of the root canal (13,20). Mean values of push-out bond strength were recorded at 17.8 ±3.42 MPa for Er:YAG at 150 mJ, 10 Hz, 1.5 W, 100μm for 60 seg irradiation (20) followed by 4.963 ±0.65 MPa for Er;Cr:YSGG at150 mJ, 10 Hz, 1.5 W, 140μm for 60 seg (13).

- Fracture Analysis evaluations were performed in almost all the pushed-out specimens under a microscopic analyses. The dominant failure patterns were noted at the resin cement to dentin, resin cement to post, and mixed fractures. Five studies reported adhesive fracture between the dentin and resin-matrix cement (3,5,8,11,16); while 5 studies pointed out adhesive fracture between resin-matrix cement and post (6,10,13–15) and 4 studies pointed out mixed fractures (dentin, cement and post) (1,9,12,18). Only 1 study reported a cohesive failure at the dentin interface (14).

4. DISCUSSION:

4.1. Teeth root intracanal posts

Different types of standard and custom-made teeth root intracanal posts are used to restore the remnant teeth structure compromised by injuries or caries. In the last years, standard metal-free posts have intensely been used for endodontically-treated teeth reconstruction, as seen in Figure 2 (6,10,15–17,20).

Figure 2: in the left side: conical and cilindrical posts, serrated posts and double tapered. In the right side a custom made post.
http://angelus.ind.br/assets/uploads/2019/12/medias_1708161112_Caso-Clinico-025-PORT.pdf

Considering design, conical-like posts are the most available post, although double tapered, cylinder, conical or parallel walled posts with tapered or straight ends can also be found (15,19). Their cross-sections are often circular, due to the root intracanal preparation by drilling tools. However, posts with an oval cross-section can be found, in that case, an ultrasonic tip maintains the root intracanal design with an oval shape leading to a proper fit of the post and decreasing the resin-cement layer thickness (1,15,18,19). Metal-free teeth root intracanal posts are mainly composed of composite materials involving short glass fibers embedded by an organic epoxy matrix. That strategy intends to form a single body with the remaining teeth structure when cemented with a resin-matrix cement (6,10,15–17,20). The risks of teeth fracture are reduced regarding the properties of the composite posts and resin cement. However, the relationship among the root intracanal preparation, post design, and materials' properties determine the mechanical behavior of the endodontically restored teeth.

Regarding materials, metallic or zirconia-based posts show quite dissimilar properties when compared to dentin and enamel leading to a mismatch in stress distribution. The elastic modulus of zirconia of around 240 GPa is significantly higher when compared to that of dentin (~20-40 GPa) and enamel (~60-80 GPa), as seen in Table1 (1,18). The dissimilar elastic modulus induces the concentration of stress at the post-to-teeth interfaces leading to risks of fractures at the resin-cement layer (2,3,7,12). In this way, the epoxy-matrix reinforced with glass fibers show a quite closer elastic modulus (30-60 GPa) when compared to the teeth structures (12,14). The content, shape, dimensions, and dispersion of the fibers are mainly responsible for the mechanical properties of the composite post as stiffness and strength (6,15,18). The fibers have short length which are aligned to the long axis of the post. The matrix/fiber ratio can vary from 35/65 up to 20/80 (Table 1) (10,15,16,18,20). Thus, the mechanical properties of the composite post are also similar to that of the resin-matrix cements that allows transmission the occlusal forces throughout the entire post/cement/teeth structures (6,11,16,18). Composite posts provide optimal mechanical behavior with a dentin-like flexural modulus avoiding stiffness mismatches and fractures (2–4,10,12,14,19,20). Furthermore, the corrosion resistance and biocompatibility of composite posts are higher than those reported by metallic post. The optical properties of glass fiber-reinforced composite (GFRC) posts are proper to mimic the optical properties of the dentin. These posts are also translucent, that gives then an esthetic advantage when compared the metallic posts (5,6). GFRC posts are also capable of light transmission light to ensure the light-curing process of resin-matrix cements inside the root canal (11,18–20). Therefore, radiopaque compounds are added in their chemical composition for fitting examination by radiographic analyses.

4.2. Resin-matrix cements for endodontic post retention:

Resin-matrix cements are usually composed of a resinous matrix including methacrylate monomers such as Bis-GMA, Bis-EMA, UDMA, TEGDMA, HEMA, 4-META (8)(16). The viscosity is balanced by the combination Bis-GMA, UDMA or Bis-EMA with TEDGMA, HEMA and 4-META which also provide hydrophilic capabilities (3,11). A photoinitiator such as camphorquinone is required to start the polymerization under light irradiation in association with a co-initiation, mainly a tertiary amine. Additionally, the polymerization by chemical activation is initiated by the presence of the benzoyl peroxide in the case of dual- and self-cured resin cements (3,14). Water, ethanol, organic and inorganic pigments and opacifiers will also be present in the resinous matrix (3,14,16) . Self-etching cements also contain an acidic component in their formula such as 10-MDP (methacryloyloxydecyl dihydrogen phosphate). That compound is a phosphorylated methacrylate used for interaction with GFRC or ceramic posts and the dentin hydroxyapatite leading to a chemical bonding (3,14,19).

Concerning the limitations with the teeth root intracanal narrow region and clinical visibility, dual- and chemically cured resin cements are recommended for the retention of endodontic posts (5,9). Thus, the chemical activation become crucial to guarantee the polymerization of the resin cement mainly in the apical region of the teeth root canal. The physical properties and handling of the resin cement are also important to allow the flowing throughout the endodontic post and intracanal space (2,16). Paste-to-paste or self-mixing syringe are commercially available to the use of resin cements for retention of endodontic posts. However, paste-to-paste materials are dependent on the individual handling sensitivity that can lead to inclusion of bubbles into the cement and heterogenic chemical composition (10,12). Self-mixing resin cements by using specific syringes have the advantage of avoiding the bubbles which can form pores in the resin cement microstructures (17,19). Regarding the material application, the following clinical protocols can be used: coating the post with resin cement; placement of the post with a paste carrier drill or microbrush; syringe application into the intracanal paste; or combining the mentioned methods (13,16,19). Thus, resin-matrix cements must reveal physical properties such as: viscosity, flowability, elastic modulus close to the teeth tissues, low shrinkage, sealing, chemical stability after polymerization, biocompatibility, optical versatility, and proper mechanical properties (2,5,9,11,16,17,19).

The intrinsic features of the root canal anatomy such as conicity and roundness determine the shape of the intracanal region (2,19). Moreover, the preparation of the intracanal space by using drills can provide the space required for a standard and custom-made posts (7,11,13). The fitting of the endodontic post will result in a minimum resin cement thickness for retention of the post into the root canal. Nevertheless, the resin cement layer thickness tends to increase from apical to coronal regions (1). Previous findings reported that bond strength of the endodontic post to the teeth root canal is inversely proportional to the resin cement layer thickness, as seen in Table 1. As a thick resin cement layer showed a higher risk of defects such as: voids, pores, and cracks from polymerization shrinkage (3,12). Thicker layers of resin cements also increase the concentration of stresses at the interface as seen in Table 1 (7,13).

4.3. Adhesion of fiber-reinforced composite posts

Different surface treatments have been assessed to increase the bond strength of fiber posts to resin cement (Table 1). Such surface modification includes the following methods: (i) chemical modification by using silane, acidic etching, and adhesives; (ii) physical modification by air-abrasion (grit-blasting); laser irradiation; and machining processes (8).

The silane-based coating can promote the chemical bonding between the post surface and the resin cement since the silane compounds (8). The air-abrasion with abrasive aluminum oxide (Al_2O_3) particles increases the roughness of the endodontic post and surface contact area. That allows the flowing of the resin-matrix cement and mechanical interlocking under light-curing (13,14). The roughness can be controlled by selecting the size of abrasive particles and the air-abrasion parameters (distance, pressure, and time) (20). The light amplification by stimulated emission of radiation, known as LASER, has become increasingly popular in different fields including dentistry. Different lasers have been used to modify surfaces as follow: Neodymium-doped Yttrium Aluminium Garnet (Nd:YAG) laser, copper vapor laser, and excimer laser, Er:YAG, Er:YSGG, Diode laser. Although several benefits, undesired thermal side effects and mechanical drawbacks were reported as the disadvantages of laser procedures. Failures such as microcracks and fissures have been reported as a result of the laser thermal effects (6). Physical modification of surfaces tend to expose the fibers underneath the post outer layer that can be functionalized by further physicochemical methods (8).

Most of the selected studies have validated the effect of physical and chemical methods as seen in Table 1. A previous study compared the push-out strength (Figure 3) of GFRC posts from teeth root canal as dependent on five different resin matrix cements: group VL: etch-and-rinse system (Variolink II)group RLX: Rely X Unicem, Group MC: Maxcem Elite, Group IC: iCem; Group BF: Bifix SE (15). The highest push-out strength values were recorded at around 22.5 MPa (BF group) followed by 16.5 MPa (VL group). Fracture analysis showed mainly adhesive failure modes between post and resin cement for the etch-and-rinse surface modification groups while the self-adhesive resin cements groups revealed mainly mixed fracture modes between tooth and resin cement or between post and resin cement (15). Another study compared the effect of eight different resin-matrix cements on the shear bond strength of post to teeth root canals(2): resin modified glass ionomer cement (Rely X Luthing Plus), convencional glass ionomer cement(Luthing and Lining, Ketac Cem), dual-polymerized resin cement (Rely X Arc, duo-Link), dual-polymerized self-adhesive resin cement (Biscem, Rely X U 100, Variolink II). A conventional ionomer cement displayed the highest bond strength values at around 18 MPa followed by the dual-curing self-adhesive resin cement (Biscem) with SBS values at 17.5 MPa(2).

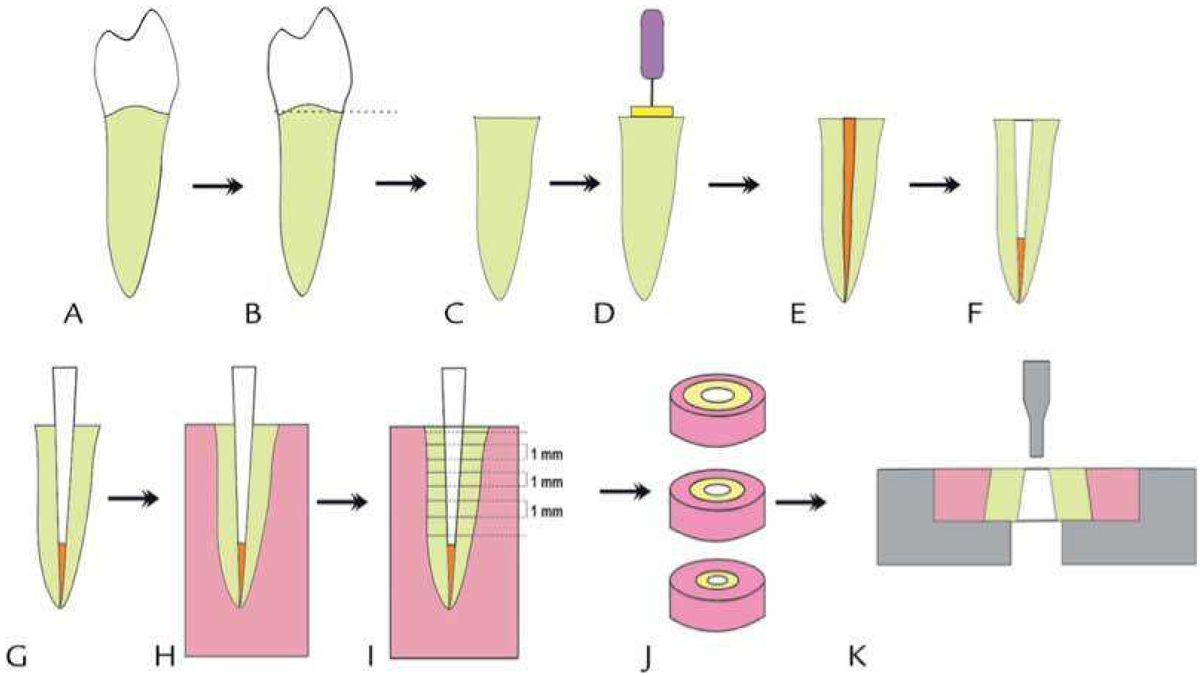

Figure 3. The micro push-out schematics: (a,b,c,d,e) specimen endodontic preparation, (f,g,h,i) preparation and cementation of the fiber glass pin; (j) tooth slices (k) diagram of micro push-out test device.
https://www.researchgate.net/figure/Specimen-preparation-and-testing-apparatus-for-push-out-test-A-Mandibular-premolar_fig1_289569342

The effect of using silane or air-abrasion with Al_2O_3 particles has been compared on the bond strength of endodontic posts to teeth root canals (8). Silane coating showed to increase the bond strength values in push-out test (9.5 MPa) of endodontic posts to teeth root canals(8). A previous study evaluated the effect of grit-blasting (aluminum oxide particle), silanization and the association of grit-blasting followed by silanization(14). The findings showed that a pre-treatment has resulted in significantly higher push out bond strength values when compared to a control (free of surface pre-treatment). The highest mean values were recorded for the grit-blasting group (13.65 MPa), followed by the silanization group (12.75 MPa) (Table 1). Another study revealed the highest push-out bond strength values for the surfaces modified with a combination of H_2O_2 and silane (16.582 MPa) followed by surfaces solely modified with silane (13.799 MPa) or a combination of grit-blasting and silane (11.726 MPa)(4).

Regarding the laser irradiation effect on the push-out bond strength of endodontic posts to teeth root canals, the following groups were assessed in a previous study: silane as control; Er:YAG laser irradiation; Er;Cr: YSGG laser irradiation; and light emission diode (LED) irradiation(13). The surfaces modified with silane (4.02 MPa) and Er;Cr: YSGG (3.78 MPa) showed the highest bond strength values(13). Analysis of the post surfaces by laser microscopy revealed a slight removal and fusion of the outmost layer composed of epoxy matrix, thereby exposing the fibers without loss of material and/or ablation of glass fibers in the Er:YAG laser irradiation group. The glass fiber post treated with the LED irradiation showed excessive material loss, ablation of glass fibers and epoxy matrix(13). Another study also revealed the highest push-out bond strength values (3.4 MPa) on the surfaces treated with Er:YAG when compared to surfaces irradiated with Er,Cr:YSGG or Nd: YAG laser (0.737 to 1.111 MPa)(5).

On the effect of cementation techniques, a statistically significant difference was noted within self-adhesive cements(16). Three techniques were assessed: (i) automix/point tip applicator; (ii) handmix/lentulo; and (iii) handmix/centrix. The handmix/lentulo (13.65 MPa) combination yielded the highest mean bond strength values (13.65 MPa) followed by handmix/centrix (13.64 MPa)(16). Another study also reported differences when applying the etch-and-rinse or self-etch resin cements with microbrush or enlongation tip techniques(4). The elongation tip technique revealed the highest mean values on push-out strength test.

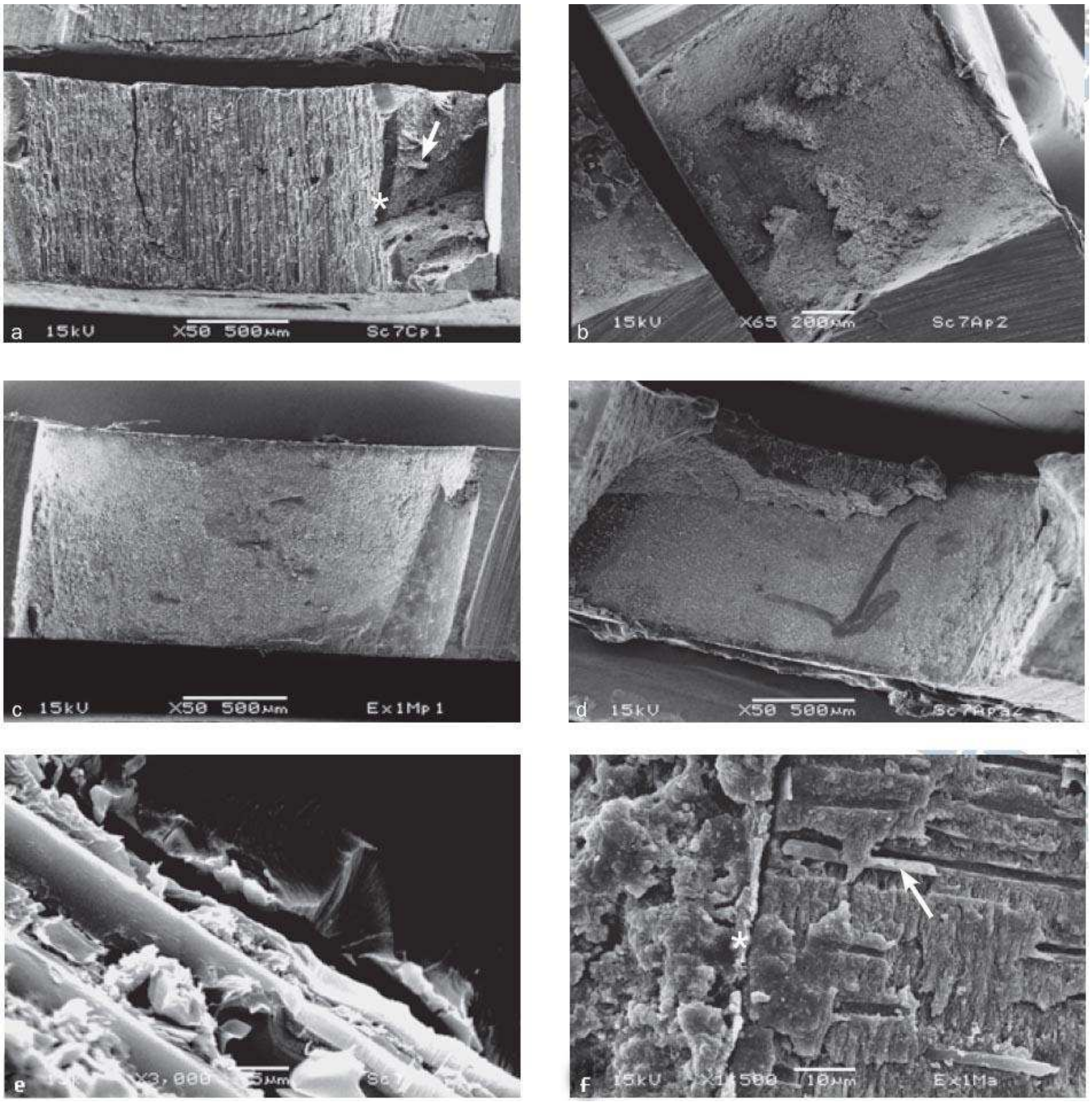

Figure 4. A study to evaluate the effects of different glass-fiber post surface treatments on the bond strength to root dentin that shows SEM images of the fracture modes . (a): failure at the resin cement/glass-fiber post adhesive interface. Note the thick adhesive layer(*) and the occurrence of voids in the resin cement layer (arrow); (b): failure at the resin cement/dentin bond interface; (c) cohesive failure in the resin cement; (d): mixed failure; (e) SEM images of the adhesive interfaces between the glass-fiber post and adhesive; and (f) between the resin cement and the root dentin. No hybrid layer was produced by the self-adhesive resin cement (*) and endodontic sealer remained inside the dentinal tubule (arrow). (3)

5. Conclusion

In the present review, was evalueted the bond strength of endodontic post to resin cements using a push-out test. Through the analysis of relevant articles some conclusions can be drawn as follow:

• The chances of success are not only influenced by a huge array a variables, but also the way each variable interacts among themselves can have a big impact in the outcome of the treatment;

• Root canal anatomy, thickness of the cement line, the diffusion of light throughout the body of the tooth/cement/post, the surface treatment of the post, the surface treatment of the tooth, the polymerization system of the resinous cement and the way it is applied to the root canal/post are the main variables to be considerate when performing the kind of treatment.

• The anatomy of the root canal with its different conicities and curvatures can even disallow the use of prefabricated posts and has a major role in the thickness of the cement line.

• There are several kinds of post treatment surface, such as sandblasting, laser irradiation, acid etching and silanizing, and they all increase the cement/post retention.

• Acid etching is the main process to treat the root canal system surface, can be performed through the use of phosphoric acid and rinsed prior to the adhesive application, of with the acid incorporated in the formulation of the cement (self-etch cements). Other treatments can be used in conjunction to help or to increase adhesion. Use of EDTA, laser irradiation and ultrasound are used to help remove the smear layer.

• Since the diffusion of light is low to non-existent in the more apical region of the root, dualcure or self-cure cements are preferred over exclusively photoactivated cements.

• The cement/post insertion protocol can greatly influence the outcome of the treatment. Automix syringes allows mixture and insertion in a simplified single step, are less prone to include air bubbles in the cement body and forms less gaps due to incomplete root channel filling. Other methods of material insertion can be used.

No cementation protocol is fail proof. The specificities of the clinical case in conjunction with the experience and judgment of the professional will dictate the suitable technique and materials to solve each clinical case needs.

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