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# A scoping review on the laser irradiation of Glass Fiber-Reinforced Composite posts for endodontic rehabilitation

Alice Éléanore Lanthiez

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

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Trabalho realizado sob a Orientação de Doutor Valter Fernandes e Coorientação de Professor Doutor Júlio C.M. Souza.

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# Declaração de Integridade

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

# AGRADECIMENTOS

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# RESUMO

O principal objetivo deste estudo foi realizar uma revisão integrativa sobre a modificação de superfície de espigões de compósito reforçado com fibra de vidro (GFRC) usando a irradiação laser. Uma revisão bibliográfica foi realizada na PUBMED utilizando uma combinação dos seguintes termos científicos: "laser irradiation" OR "laser treatment" OR "laser-treated" OR "laser" AND "surface" AND "endodontic post" OR intracanal post" OR "intraradicular post" OR "fiber post" AND "adhesion" AND "bond strength".

A pesquisa identificou 186 estudos, dos quais 14 foram relevantes e selecionados para esta revisão. O procedimento restaurador dos dentes tratados endodonticamente deve garantir a estabilidade coronal do elemento restaurador direto ou indireto, sendo os espigões GFRC são uma boa opção pelas suas características mecânicas e óticas. Porém acontecem muitos acidentes por descimentação deste tipo espigões. Tratamentos de superfície químicos e micromecânicos são indicados para criar rugosidade da superfície dos espigões e expor as fibras de vidro aumentado capacidade de adesão. A irradiação laser amplamente usada na medicina dentaria nos últimos anos, com diferentes aplicações, revelou-se eficaz nas alterações de diferentes tipos de superfícies. O efeito do laser Er:YAG, Nd:YAG e Er,Cr:YSGG (modo de impulsão) na superfície de dois tipos de espigões intracanal, espigões  de fibra de vidro e fibra de quartzo, foram investigados nesta revisão.

A irradiação com laser Er:YAG a 2940nm aumenta a Força de Ligação de ambos os tipos de espigões, mas alguns estudos mostram que o jateamento e o ácido fluorídrico às vezes têm melhores resultados. Por outro lado, o uso de Nd:YAG a 1064nm na superfície dos espigões de fibra de vidro e quartzo não melhorou a ligação entre os espigões  e o cimento de resina. Para o laser Er,Cr:YSGG a 2780nm, sua irradiação mostrou sua eficácia na superfície de ambos os tipos de espigões, mas com uma limitação acima de 1,5W de potência.

**Palavras-Chaves:**

Laser, superfície, espigão endodôntica, adesão, força de ligação.

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# ABSTRACT

The main aim of this study was to accomplish an integrative review on the surface modification of Glass Fiber-Reinforced Composite (GFRC) posts by using laser irradiation. A bibliographic review was performed on PUBMED using a combination of the following scientific terms: "laser irradiation" OR "laser treatment" OR "laser-treated" OR "laser" AND "surface" AND "endodontic post" OR "intracanal post" OR "intraradicular post" OR "fiber post" AND "adhesion" AND "bond strength".

The research identified 186 studies, of which 14 were relevant and selected for this review. The restorative procedure of endodontically treated teeth must guarantee the coronal stability of the direct or indirect restorative element, being the GFRC posts are selected as a good are a good choice for their mechanical and optical characteristics. However, there are many accidents due to the decementation of this type of post. Chemical and micromechanical surface treatments have been suggested to create roughness of surface posts and expose glass fibers increasing adhesion capacity. Laser irradiation widely indicated in dentistry these past few years has become an alternative to conventional treatments of posts surface. The effect of laser Er:YAG, Nd:YAG and Er,Cr:YSGG (impulsion mode) on the surface of two types of intracanal posts, Glass and Quartz fiber posts, were investigated in this review.

The irradiation with laser Er:YAG at 2940nm increases the Bond Strength of both types of posts but some studies show that the sandblasting and Hydrofluoric acid at times have better results. On the other hand, the use of Nd:YAG at 1064nm on the surface of Glass and Quartz fiber posts did not improve the bonding between the fiber posts and the resin cement. For the laser Er,Cr:YSGG at 2780nm, its irradiation showed its effectiveness on the surface of both types of posts but with a limitation above 1.5W of power.

KEYWORDS:

Laser, surface, endodontic post, adhesion, bond strength.

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Geral Index :

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**Lista de abreviaturas, siglas e acrónimos:**

- GFRC: Glass Fiber Reinforced Composite
- BS: Bond Strength
- SB: Sandblasting
- HF: Hydrofluoric Acid
- SC: Silica Coated (Co-Jet system)
- CFR: Carbon Fiber-Reinforced posts

# 1. INTRODUCTION

Posts have been used for several years to restore endodontically treated teeth that have insufficient crown structure. Glass fiber-reinforced composite (GFRC) posts are selected as an alternative technique for casting metal post and core systems because they reduce the risk of fracture and eliminates corrosion problems associated with metal posts. The success of post-core restorations depends on a strong bond between resin-post and resin-dentin interface and debonding is the most important problem that causes failure at the post-retained restorations (1) (2). The rigidity and homogenous structure of metal posts can defy the lateral forces without deformation but have a low modulus of elasticity and can causes root fractures according to the stress distribution (3). The post placed in the root canal must reinforce the remaining dental tissue and have mechanical properties, such as the flexural strength and elastic modulus similar to the properties of dentin. The mechanical properties are also determined by the bond between filler and matrix which differs according to each post manufacturer, by the shape (Weibull modulus), and the orientation (4)(5). The restorative procedure of endodontically treated teeth must be also provided retention and stability for indirect and direct restorations(4).

Fibers reinforced composite posts are composed of glass, quartz, carbon, or silica fibers embedded by a polymer matrix usually an epoxy or methacrylate resin with a high degree of monomers conversion and a highly cross-linked structure. Fibers occupy 30-50% of the area in a transverse section of the post, they are oriented parallel to the post longitudinal axis and have a diameter between 6 and 15μm. The fiber/matrix resin ratio depending on each manufacturer but commonly the posts are made to 60% of fiber and 40% of the matrix resin. GFRC posts have an elastic modulus similar to dentin (±20GPa), favorable optical properties, an ability to conduct light and facilitate the goal of esthetic (2). A homogenous structure is created between fiber post, dentin, resin cement, and resin core material known as "mono-block" (6). An appropriate bonding of these interfaces improves stress distribution generated by the occlusal loads (3). The polymer matrix resin of GFRC post is almost unable to react with the monomers of resin cement and depends on the previous silanization of fibers (1)(7). Debonding between GFRC post and resin elements is the most common failure in these restorations.

To enhance the Bond Strength (BS) of fiber posts, both chemical and micromechanical surface treatments have been suggested to create the rough surface post and expose glass fibers. The chemical bonding is achieved by a silane-coupling agent or hydrogen peroxide applications which improve the surface wettability and produce a bridge between methacrylate groups of the resin and hydroxyl groups of glass fiber (8). On the other hand, the micromechanical retention can be provided by air-abrasion with Aluminum Oxide ($Al_2O_3$) particles (Sandblasting (SB)) or etching with Hydrofluoric acid (HF). Microporosities are created on the surface of the post therefore resin can penetrate, forms micromechanical interlocking, and improve the retention of the core build-up material (9). The Co-Jet system (SC) is a modification of Aluminum Oxide particles ($Al_2O_3$) with silica, the process referred to as "tribo-chemical coating" and provides ultrafine mechanical retention (10).

Recently, laser irradiation has been used in dentistry and has shown effectiveness in removing caries, treating hypersensitivity, or disinfecting the root canals (2)(7)(11)(12)(13). Besides, the laser allows a better shear Bond Strength of zirconia to veneer porcelain as compared to conventional sandblasting treatment (14). The different types of lasers with various wavelengths become an alternative to chemical and mechanical techniques for surface treatment methods. Laser irradiation created porosities and roughness on the surface of materials, which enhance retention between the post and resin (11). However, there is a lack of information about laser treatment of GFRC post surface.

## 2. OBJECTIVE AND HYPOTHESIS

The main aim of this study was to accomplish an integrative review of the surface modification of glass fiber-reinforced composite (GFRC) posts by using laser irradiation.

It was hypothesized that the laser treatment on the surface of the fiber posts, composed either of glass or quartz fibers, increases the Bond Strength (BS) of the posts in a post-core restoration. Also, the type of laser used must be considered because their wavelengths, Energy, Frequency, repetition rate, pulse irradiation, time irradiation, Power, and the distance between the laser and the surface are not the same for each laser.

## 3. MATERIALS AND METHODS

### 3.1. Information sources and search strategy:

A bibliographic review was performed on PUBMED (via National Library of Medicine) considering such database includes the major articles in the field of dentistry and biomaterials. The present search of studies was carried out in accordance with previous integrative or systematic review articles. The following search terms were applied: "laser irradiation" OR "laser treatment" OR "laser-treated" OR "laser" AND "surface" AND "endodontic post" OR "intracanal post" OR "intraradicular post" OR "fiber post" AND "adhesion" AND "bond strength". Also, a hand search was performed on the reference lists of all primary sources and eligible studies of this systematic review for additional relevant publications. The inclusion criteria encompassed articles published in the English language, within the last 20 years, focusing on the surface modification of glass fiber-reinforced composite posts for endodontic rehabilitation. The eligibility inclusion criteria used for article searches also involved: *in vitro* studies; mechanical assays; surface analyses; meta-analyses; randomized controlled trials; animal assays; and prospective cohort studies. The exclusion criteria were the following: papers without abstract; case report with short follow-up period; articles dealing with laser irradiation of the tooth root canal dentin for further adhesion tests with endodontic posts. Studies based on publication date were not restricted during the search process.

### 3.2. Study selection and data collection process:

Studies were primarily scanned for relevance by title, and the abstracts of those that were not excluded at this stage were assessed. Three of the authors (J.C.M.S.; V.F.; A.L.) independently analyzed the titles and abstracts of the retrieved, potentially relevant articles meeting the inclusion criteria. The total of articles was compiled for each combination of key terms and therefore the duplicates were removed using Mendeley citation manager. The second step comprised the evaluation of the abstracts and non-excluded articles, according to the eligibility criteria on the abstract review. Selected articles were individually read and analyzed concerning the purpose of this study. At last, the eligible articles received a study nomenclature label, combining first author names and year of publication. The following variables were collected for this review: authors' names and publication year, purpose, GFRC post details (chemical composition, surface, microstructure), surface modification roughness (μm), and push-out bond strength (MPa). PICO question was adjusted to the issue where "P" was related to the patients, animal, or specimens while "I" referred to the methods of analyses. Data of the reports were harvested directly into a specific data-collection form to avoid multiple data recordings regarding multiple reports within the same study (e.g., reports with different set-ups). This evaluation was individually carried out by two researchers, followed by a joint discussion to select the relevant studies.

## 4. RESULTS

The literature search on PUBMED identified a total of 186 articles although 105 duplicates were removed, as seen in Figure 1. Of the remaining 81 articles, after a preliminary evaluation of the titles and abstracts with the inclusion criteria of the present study, 63 articles were excluded. This evaluation revealed 18 potential studies that were selected for a full reading. However, 4 of these were excluded because they did not provide comprehensive data considering the purpose of the present study. Therefore, 14 studies were included in this review.

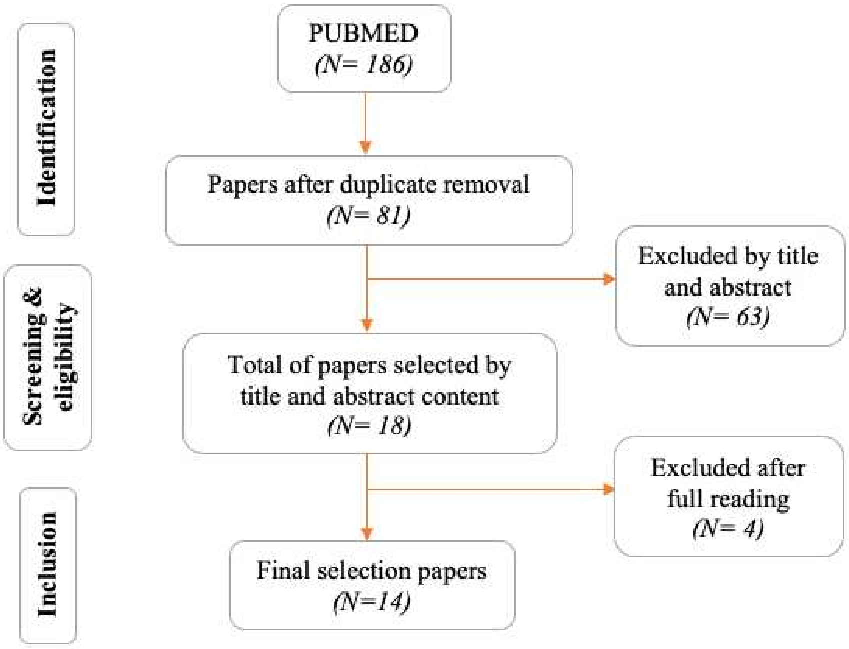


**Figure 1.** Flow diagram of the search strategy used in this study

Of the 14 selected articles, all of these correspond to *in vitro* studies, of which ten (71.4%) evaluated the push-out bond strength of Glass Fiber posts. Among these articles, seven investigated glass fiber posts with an epoxy resin matrix, two articles with TEGDMA matrix, and two articles with DMA matrix and fillers. At last, five articles (35.7%) evaluated the push-out bond strength of Quartz Fiber posts. Each study of this review investigated the influence of laser irradiation on fiber posts with a different type of laser and powers. For nine articles (64.3%) Er: YAG laser has been used, six (42.9%) used Er,Cr:YSGG laser, three (21.4%) used Nd:YAG laser, and two articles (14.3%) applicated diode laser.

Surface modification roughness has been also analyzed in four studies (28.6%) between control and fiber posts groups. The major findings from the selected articles are shown in Table 1 and draw as follow:

- Irradiation of Er:YAG laser with 4.5W of powers on the surface of glass fiber posts improved the bond strength in comparison with the group control, Er:YAG at 1.5W, and 3W groups (3)(10). Furthermore, it was shown that the use of laser Er:YAG at 1.5W on the surface of quartz fiber posts and also of glass fiber posts did not improve the BS (12)(7)(15). In comparison, other studies revealed that laser Er:YAG at 1.5W applicated on the surface for both types of fiber posts increases the bonding (16)(8)(1). This type of laser Er:YAG at a high power of 500W decrease significantly the BS between the glass fiber and the resin cement (17).

- In other studies, it has been observed that the use of laser Nd:YAG with 1W, and 2W on the surface of quartz fiber posts got the lowest values, and did not affect the BS (16)(2). This same type of laser at 1W of power applicated on the surface of glass fiber posts, also show the lowest values of bonding with no statistical difference with the control group (8).

- The third type of laser that has been evaluated in this review is the laser Er,Cr:YSGG, and some studies have shown that irradiation with this laser at 1W on the surface of glass fiber posts improve significantly the BS between the post and the resin cement (6) (9). However, laser Er,Cr:YSGG treatment with a power of 1.5W on the surface of glass fiber posts is controversial. In a few studies, the results prove that there an effect positive on the bonding (6)(15), but in another study, there is no difference with the control group (9). Moreover, the use of higher powers of laser Er,Cr:YSGG do not improve or, decrease significant the bond strength (6)(9)(4). In comparison, the irradiation of Er,Cr:YSGG laser on the surface of quartz fiber posts with 0.5W, 1W, and, 1.5W shown better results than the control group, and consequently increase the BS (6)(11); but with a power of 2W, there is no effect on the bonding (6).

- In four studies, the roughness of the surface was evaluated after laser irradiation and is expressed in μm. The results of the laser Er:YAG treatment with 1.5W of powers on the surface of quartz fiber posts (1.3μm) show that there is no statistically significant difference with the control group (1.1μm) (16). The same laser irradiation with the same power on the surface of glass fiber posts has a better result (3.62μm) than the control group (0.98μm) (8). Furthermore, the laser Er:YAG with higher power (500W) also applied to the surface of glass fiber posts (FRC Postec) shows good results, 2.985μm compared to 0.525μm for the control group (17). The laser Nd:YAG treatment with 1W of power on the surface of both groups of posts, quartz and glass fiber, shows superior results to the control group (16) (8). And the use of the laser Er,Cr:YSGG at 1.5W on glass fiber posts revealed high values of roughness, 9.70μm compared to 2.56μm for the control group (7).

- In all these studies it has been proven that the laser affects the surface of the GFRC posts, but no correlation was found between bond strength and surface roughness (16) (8).

**Table 1**. Details gathered to form the selected studies

| Author (year) | Purpose | Study design | GFRC post details | Surface modification Roughness (µm) | Push out bond strength (MPa) ($p < 0.05$) |
|---|---|---|---|---|---|
| (10) | *Push-Out Bond Strength Between Composite Core Buildup and Fiber-Reinforced Posts After Different Surface Treatments* | *In vitro*<br>The effect of Co-Jet system and Er:YAG laser irradiation (using different powers) on the push-out bond strengths of fiber-reinforced posts. | **Glass fiber posts** (*Cytec Blanco, Hahnenkratt, Germany*): 60% of Glass fiber and 40% of the Epoxy resin matrix. | - | *Control:* **15.006**<br>*Co-Jet (30 µm, $Al_2O_3$):* **19.184**<br>*Er:YAG 150 mJ, 10Hz, 1.5 W:* **4.949**<br>*Er:YAG 300 mJ, 10Hz, 3 W:* **16.895**<br>*Er:YAG 450 mJ, 10Hz, 4.5W:* **23.879** |
| (12) | *The effect of post surface treatments on the bond strength of fiber posts to root surfaces* | *In vitro*<br>Compare the effect of laser (150 mJ) etching as an FRC post surface treatment with other surface treatments. | **Quartz fiber posts** (*DT-Light posts, RTD/France*): 60% of Quartz fiber and 40% of the Epoxy resin matrix. | - | **Control**: *Coronal* **5.69** *Middle* **3.09** *Apical* **1.79**<br>**$Al_2O_3$** *(50 µm)*: *Coronal* **4.61** *Middle* **2.70** *Apical* **2.17**<br>**Er:YAG** *(10Hz, 150 mJ)*: *Coronal* **4.68** *Middle* **3.14** *Apical* **2.84** |
| (3) | *Effects of post surface treatments including Er:YAG laser with different parameters on the pull-out bond* | *In vitro*<br>Evaluated the effects of air abrasion and Er:YAG laser irradiation under different power settings on the pull-out bond strengths of | **Fiber-reinforced composite (FRC)** (*Rebilda Post, Voco, Cuxhaven, Germany*): 70% Glass fiber, 20% Dimethacrylate | - | *Control:* **5.26**<br>*SB (50µm, $Al_2O_3$):* **6.46**<br>*Er:YAG (150 mJ, 10 Hz, 1.5W):* **6.21**<br>*Er:YAG (300mJ, 10Hz, 3W):* **5.42** |

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|---|---|---|---|---|---|---|
| | *strength of the fiber posts.* | FRC posts and resin cement. | (UDMA), and 10% fillers. | | *Er:YAG (450mJ, 10Hz, 4.5W):* **6.76** | |
| (6) | *The Effect of Er,Cr:YSGG Laser Application on the Micropush-Out Bond Strength of Fiber Posts to Resin Core Materia* | *In vitro*<br>Compare the effects of Er,Cr:YSGG laser application to different surface treatments on the micro push-out bond strengths between glass and quartz fiber posts and composite resin core material. | - **Translucent quartz fiber posts** (*DT-Light post/Bisco, USA*): 62% of Quartz and 38% of the Epoxy resin matrix.<br>- **Glass fiber posts** (*Cytec Blanco, Hahnenkratt, Germany*): 60% of Glass fiber and 40% of the Epoxy resin matrix. | - | **Quartz fiber post**<br><br>*Control:* **9.40**<br>*SB ($Al_2O_3$, 50µm):* **13.22**<br>*HF:* **12.94**<br>*$H_2O_2$:* **12.53**<br>*$CH_2Cl_2$:* **14.48**<br>*Er,Cr:YSGG (1W,20Hz):* **13.60**<br>*Er,Cr:YSGG (1.5W,20Hz):* **12.55**<br>*Er,Cr:YSGG (2W,20Hz):* **10.12** | **Glass fiber post**<br><br>*Control:* **9.07**<br>*SB ($Al_2O_3$,50µm):* **13.51**<br>*HF:* **7.28**<br>*$H_2O_2$:* **13.25**<br>*$CH_2Cl_2$:* **12.59**<br>*Er,Cr:YSGG (1W, 20Hz):* **13.19**<br>*Er,Cr:YSGG (1.5W, 20Hz):* **13.38**<br>*Er,Cr:YSGG (2W, 20Hz):* **9.90** |
| (16) | *Evaluation of surface roughness and bond strength of quartz fiber posts after various pre-treatments* | *In vitro*<br>investigate effects of different surface treatments including sandblasting, HF, silica coating, Nd: YAG, and Er: YAG laser treatments on the strength of the bond between quartz fiber posts and resin cement. | **Translucent quartz fiber posts** *(DT-light post/Bisco, USA):* 62% of Quartz fiber and 38% of the Epoxy resin matrix. | *Control:* **1.1**<br><br>*SB (110µm, $Al_2O_3$):* **4.5**<br><br>*SC:* **2.2**<br><br>*HF:* **2.4**<br><br>*Nd:YAG (100mJ, 10Hz, 1W):* **2.7**<br><br>*Er:YAG (150mJ, 10Hz, 1.5W):* **1.3** | **Tensile bond strength (N):**<br><br>*Control:* **318.4**<br><br>*SB (110µm, $Al_2O_3$):* **444.4**<br><br>*SC:* **320.0**<br><br>*HF:* **309.4**<br><br>*Nd:YAG (100mJ, 10Hz, 1W):* **298.2**<br><br>*Er:YAG (150mJ, 10Hz, 1.5W):* **419.1** | |

<table>
<tr>
<td>(8)</td>
<td>Adhesion between glass fiber posts and resin cement: evaluation of bond strength after various pre-treatments</td>
<td>In vitro<br>Evaluate surface roughness and bond strength of glass fiber posts to a resin cement after various surface treatments.</td>
<td>Unidirectional E-glass (Everstick post, StickTech, Turku, Finland): 48% glass fiber, 52% semi-IPN of PMMA, Bis-GMA, TEGDMA.</td>
<td colspan="2">Control: 0.98<br>SB (110μm, $Al_2O_3$): 4.24<br>SC: 2.27<br>HF: 1.14<br>Nd:YAG(100mJ, 10Hz, 1W): 4.15<br>Er:YAG (150mJ, 10Hz, 1.5W): 3.62</td>
<td colspan="2">Tensile bond strength (N):<br><br>Control: 546.6<br>SB (110μm, $Al_2O_3$): 619.2<br>SC: 655.2<br>HF: 691.6<br>Nd:YAG (100mJ, 10Hz, 1W): 537<br>Er:YAG (150mJ, 10Hz, 1.5W): 627.1</td>
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<td rowspan="2">(17)</td>
<td rowspan="2">Effect of Er:YAG laser pretreatment on bond strength of a composite core build-up material to fiber posts</td>
<td rowspan="2">In vitro<br>Evaluate the micro push-out bond strength of resin material (Multicore Flow) to two types of fiber posts (FP), namely fiber-reinforced composite (FRC) Postec and Radix Fiber posts using Er:YAG laser pretreatment.</td>
<td rowspan="2">- FRC Postec posts (Ivoclar-Vivadent, Liechenstein) :<br>70% Glass fiber, 9% silicon dioxide, 21% TEGDMA, UDMA.<br>- Radix Fiber posts (Dentsply Maillefer, Switzerland): Zirconium-enriched Glass fibers 60% and 40% Epoxy resin matrix.</td>
<td>FRC Postec posts</td>
<td>Radix Fiber posts</td>
<td>FRC Postec posts</td>
<td>Radix Fiber posts</td>
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<td>Control:<br>0.525<br><br>Er:YAG (500W, 20Hz):<br>2.985</td>
<td>Control:<br>0.715<br><br>Er:YAG (500W, 20Hz):<br>2.925</td>
<td>Control:<br>15.0<br><br>Er:YAG (500W, 20Hz):<br>8.0</td>
<td>Control:<br>11.6<br><br>Er:YAG (500W, 20Hz):<br>11.4</td>
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| (7) | *Evaluation of Mechanical Properties of Glass Fiber Posts Subjected to Laser Surface Treatments* | *In vitro*<br>Evaluate the influence of different laser irradiations (Er:YAG, Er,Cr:YSGG, and 980 nm diode) on flexural strength, elastic modulus and surface roughness, and morphology of GFPs. | **Translucent Glass fiber posts** *(Exacto, Angelus, Londrina, PR, Brazil)*: 80% of Glass fiber and 20% of Epoxy resin matrix. | **Before laser**<br>*Control:* **2.79**<br>*Er:YAG (150 mJ, 10Hz, 1.5W):* **2.73**<br>*Er,Cr:YSGG (150mJ, 10Hz, 1.5W):* **2.95**<br>*Diode laser (1.5W):* **3.00** | **After laser**<br>*Control:* **2.56**<br>*Er:YAG (150 mJ, 10Hz, 1.5W):* **3.21**<br>*Er,Cr:YSGG (150mJ, 10Hz, 1.5W):* **9.70**<br>*Diode laser (1.5W):* **4.43** | **Flexural strength** ***(MPa):***<br>*Control:* **980.48**<br>*Er:YAG (150mJ, 10Hz, 1.5W):* **995.22**<br>*Er,Cr:YSGG (150 mJ, 10Hz, 1.5W):* **746.83**<br>*Diode laser (1.5W):* **691.34** |
| (1) | *Influence of different surface treatments on push-out bond strengths of fiber-reinforced posts luted with dual-cure resin cement* | *In vitro*<br>Investigate the effects of air abrasion and Er:YAG laser irradiation on the push-out bond strengths of FRC posts and resin cement. | **Translucent glass FRC composite Posts** (*Rebilda Post, Voco, Cuxhaven, Germany*): 70% glass fiber, 20% DMA matrix and 10% fillers. | - | | *Control:* **15.28**<br>*Air abrasion (50µm, $Al_2O_3$):* **19.73**<br>*Er:YAG (150 mJ, 10 Hz, 1.5W):* **17.84** |

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| (2) | *Evaluation of Various Pretreatments to Fiber Post on the Push-out Bond Strength of Root Canal Dentin* | *In vitro*<br>Evaluate the effects of various pretreatments, such as Nd:YAG lasers with different pulse durations, sandblasting, and 9.7% hydrofluoric acid etching, on the push-out bond strength (PBS) of fiber posts applied to laser-activated root dentin with an Er,Cr:YSGG laser. | **Quartz fiber posts:**<br>60% of quartz fiber and 40% of Epoxy resin. | - | **Coronal**<br>*Control:* **5.02**<br>*HF:* **4.62**<br>*SB (120μm $Al_2O_3$):* **4.96**<br>*Nd:YAG (200mJ, 10Hz, 180ms):* **5.18**<br>*Nd:YAG (200mJ, 10Hz, 320 μs):* **5.09** | **Middle**<br>*Control:* **5.38**<br>*HF:* **5.12**<br>*SB (120μm $Al_2O_3$):* **5.48**<br>*Nd:YAG (200mJ, 10Hz, 180ms):* **5.00**<br>*Nd:YAG (200mJ, 10Hz, 320 μs):* **5.26** | **Apical**<br>*Control:* **4.03**<br>*HF:* **4.11**<br>*SB (120μm $Al_2O_3$):* **4.04**<br>*Nd:YAG (200mJ, 10Hz, 180ms):* **4.39**<br>*Nd:YAG (200mJ, 10Hz, 320 μs):* **4.14** |
| (9) | *Bond Strength of Fiber Posts to Composite Core: Effect of Surface Treatment With Er,Cr:YSGG Laser and Thermocycling* | *In vitro*<br>Assess the effect of Er,Cr:YSGG laser irradiation on push-out bond strength of fiber post to the composite core with/without thermocycling, in comparison with sandblasting and no surface treatment. | **Glass fiber posts**<br>*(Glassix #3, Nordin, Switzerland):*<br>60% Glass fiber and 40% Epoxy resin. | - | **Termocycling**<br>*Control:* **12.59**<br>*SB (50μm, $Al_2O_3$):* **15.76**<br>*Er,Cr:YSGG (1W, 20Hz):* **17.02**<br>*Er,Cr:YSGG (1.5W, 20Hz):* **14.19**<br>*Er,Cr:YSGG (2W, 20Hz):* **14.83** | **No Termocycling**<br>*Control:* **14.68**<br>*SB (50μm, $Al_2O_3$):* **16.56**<br>*Er,Cr:YSGG (1W, 20Hz):* **18.30**<br>*Er,Cr:YSGG (1.5W, 20Hz):* **15.18**<br>*Er,Cr:YSGG (2W, 20Hz):* **15.11** | |

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| (15) | *Influence of laser irradiation on the push-out bond strength between a glass fiber post and root dentin* | *In vitro*<br>Evaluate the influence of various laser irradiation types (Er:YAG, Er,Cr:YSGG, and diode laser) on the bond strength of glass fiber posts along the root. | **Glass fiber posts** *(Exacto, Angelus, Londrina, PR, Brazil):*<br>80% Glass fiber and 20% Epoxy resin matrix. | - | **Cervical** | **Middle** | **Apical** |
| | | | | | *Control:* **4.028**<br>*Er:YAG (150 mJ, 10Hz, 1.5 W):* **2.192**<br>*Er,Cr:YSGG (150mJ, 10 Hz, 1.5 W):* **3.793**<br>*Diode laser (1.5 W):* **2.140** | *Control:* **2.626**<br>*Er:YAG (150 mJ, 10Hz, 1.5 W):* **1.358**<br>*Er,Cr:YSGG (150mJ, 10 Hz, 1.5 W):* **4.683**<br>*Diode laser (1.5 W):* **2.525** | *Control:* **1.616**<br>*Er:YAG (150 mJ, 10Hz, 1.5 W):* **1.381**<br>*Er,Cr:YSGG (150mJ, 10 Hz, 1.5 W):* **4.963**<br>*Diode laser (1.5 W):* **1.737** |
| (11) | *Effects of motion direction and power of Er,Cr:YSGG laser on pull-out bond strength of fiber post to root dentin in endodontically-treated single-canal premolar teeth* | *In vitro*<br>Assess the effect of surface treatment of quartz fiber posts with Er,Cr: YSGG laser with different powers and motion direction on their pull-out bond strength to root dentin in single-rooted,<br>single canal endodontically treated premolars. | **Quartz fiber posts** *(DT Light Post/ Bisco, USA):*<br>62% quartz fiber and 38% epoxy resin matrix. | | *Control:* **218.3267 (N)**<br>*Longitudinal Er,Cr: YSGG 0.5W:* **221.2067 (N)**<br>*Circumferential Er,Cr: YSGG 0.5W:* **222.9133 (N)**<br>*Longitudinal Er,Cr: YSGG 1W:* **238.5933 (N)**<br>*Circumferential Er,Cr: YSGG 1W:* **240.9467 (N)**<br>*Longitudinal Er,Cr: YSGG 1.5W:* **242.3867 (N)**<br>*Circumferential Er,Cr: YSGG 1.5W:* **241.5733 (N)** | | |

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| (4) | *Mechanical properties of glass-fiber-reinforced composite posts after laser irradiation with different energy densities* | *In vitro*<br>Define the mechanical properties of Glass-fiber-reinforced composite (GFRC) posts treated with different surface treatments and to evaluate their structural features using scanning electron microscopy (SEM) | **Glass-fiber-reinforced composite posts** *(Rebilda Post 12, VOCO, GmbH, Cuxhaven, Germany)*: 70% glass fiber, 20% DMA matrix and 10% fillers. | | **Flexural strength (MPa):**<br><br>*Control:* **1142.66**<br><br>*SB (120 μm, $Al_2O_3$):* **1009.88**<br><br>*HF acid:* **934.54**<br><br>*Er,Cr:YSGG 150 mJ, 20Hz, 1W:* **908.84**<br><br>*Er,Cr:YSGG 150 mJ, 20Hz, 2W:* **855.32**<br><br>*Er,Cr:YSGG 150 mJ, 20Hz, 3W:* **787.56**<br><br>*Er,Cr:YSGG 150 mJ, 20Hz, 4W:* **844.8**<br><br>*Er,Cr:YSGG 150 mJ, 20Hz, 5W:* **739.81**<br><br>*Er,Cr:YSGG 150 mJ, 20Hz, 6W:* **712.23** |

# 5. DISCUSSION

The present integrative review reported the major results of relevant previous studies considering the effect of the laser on the surface of Glass Fiber Reinforced Composite posts by evaluating the push-out bond strength in MPa. The composition of each fibers posts depending on the manufacturer, the type of laser (Er:YAG ; Nd:YAG ; Er,Cr:YAG), and the laser parameters affect the bonding between the posts and the resin cement. Thereby, the finding validates the hypothesis of this study. A detailed discussion on the main factors affecting the bond strength such as the different type of laser is provided as follow.

## 5.1. The posts and the cementation:

In the endodontically treated teeth, sometimes there is an important missing tooth structure caused by caries, existing restorations, fracture/trauma, or decreased moisture (18). The solution that has been proposed, to create more retention to the coronal structure is to use a post intraradicular. However, the preparation of space for the posts can introduce a certain degree of risk to a restorative procedure, increasing the chances of root fracture and, treatment failure. So, the posts should only be used when there is a lack of coronal structure and when other treatments or options are not available to retain the core. Ideally, posts should be bonded to the root, and they must withstand functional and parafunctional forces, with a minimal enlargement of the post space for their placement (19).

Historically the most commonly used post was the prefabricated metal posts, they can be in stainless steel, platinum-gold-palladium, pure titanium, titanium alloys, and chromium alloys. The root fractures that occur due to their excessive stiffness (elastic modulus) and post corrosion problems metal posts have thrown into doubt their utilization (20). Another major problem of metal posts was the esthetics, because they are visible through the ceramic restorations, commonly in the region anterior (21).

The nonmetallic prefabricated posts have been developed as an alternative, including Ceramic (white Zirconium Oxide) and fiber-reinforced resin posts. The Zirconium posts cannot be etched, then making core retention become a problem, and also it is impossible to cut intraorally with a diamond bur (19)(20). Ceramic and Zirconium posts have been replaced by fiber-reinforced resin posts. In the 1990s, Duret and Renaud developed the Carbon fiber-reinforced (CFR) posts with unidirectional carbon fibers parallels to the long axis of the posts, embedded in an epoxy resin matrix that comprises 64% of the post by weight (22). The CFR also presented some limitations, such as radiolucency and difficulties under all-ceramic or composites esthetics restorations (23).

Later, glass and quartz fibers reinforced composite posts were introduced as a substitute to metal and CFR posts. They are made of pre-stretched silanized glass or quartz fibers bounded by methacrylate or epoxy polymer resin matrix with a high degree of conversion and a highly cross-linked structure that binds the fibers (18). In a transverse section of the posts, fibers occupied 30-50% of the area with a diameter between 0.6 and 1.5 mm selected according to preparation intracanal on each tooth (figure 2), and they are oriented in parallel to the post longitudinal axis such as the CFR. Ideally, the post should have an apical seal with a minimum length of 4mm, his diameter should be less than one-third the diameter of the root at the cementoenamel junction, and 1 mm or more of the dentin should remain around the coronal part of the post, this is the ferrule effect (18).

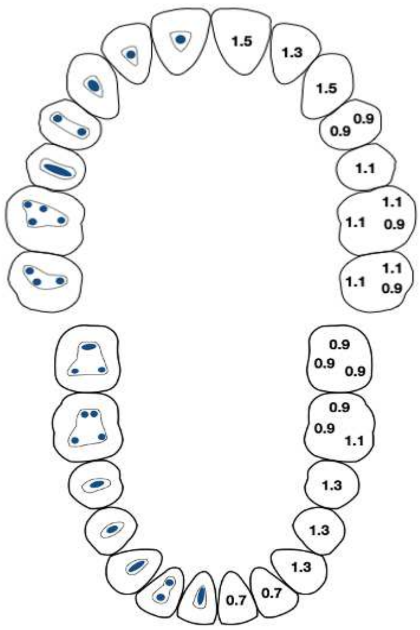


**Figure 2.** Recommended diameter of posts on each tooth.

Commonly the posts are made to 60% of fibers and 40% of the matrix resin but depending on each manufacturer. The posts are available in different shapes: cylindrical (parallel), tapered (conical), cylindrical-tapered, or double tapered. Some studies show that the cylindrical posts are more retentive than tapered posts, but on the other hand, the tapered posts required less dentin removal because they have a better adaptation to the shape of the endodontically treated canals (19)(24). The posts are passively retained into the root canal, therefore the effectiveness of the adhesive cement and luting agent plays a major role in the clinical performances of the restoration (25).

There is a multitude of luting agents that have been used for several years, they each have their properties and they must be chosen according to future restoration. One of the oldest and conventional luting agent is Zinc Phosphate, which is used for all-metal crowns/Onlays and prefabricated metal posts. In the 1960s was developed the Zinc Polycarboxylate, the first dental cement to adhere to the tooth structure and it was recommended for metal-ceramic restorations (26). Later, in 1990 the Glass Ionomer become the most frequently used definitive adhesive luting agent and was indicated for all-metal, or metal-ceramic restorations, but also in all-ceramic crowns. Since the fiber posts are passively retained into the root canal, the effectiveness of the adhesive cement and luting procedure are the major roles of clinical performance of the restorations (25). The use of resin cement has increased, and some studies reported higher retention values and resistance to fatigue compared to the Zinc Phosphate, or Glass Ionomer (18). The resin luting agents are made of Methacrylate and Dimethacrylate monomers (Bis-GMA, UDMA, TEGMA), filler particles (quartz, silica, aluminosilicate), and an initiator activated chemically or by the light. These resin cements are categorized by the curing mechanism and bonding mechanism (table 2):

| The curing mechanism | The bonding mechanism |
|---|---|
| • *Light-cured*: require an external source of light to be activated.<br>• *Self-cured*: auto polymerization occurs once all the constituents are mixed.<br>• *Dual-cured*: light-activated paste mixed with a chemical catalyst for resin polymerization. | • *Total-etch (etch & rinse) 3steps*: (1) conditioner, (2) primer, (3) adhesive.<br>• *Total-etch (etch & rinse) 2 steps:* (1) conditioner, (2) primer + adhesive.<br>• *Self-etch:* (1) primer, (2) adhesive.<br>• *Self-adhesive:* (1) adhesive resin cement |

**Table 2.** The different categories of resin cement and adhesive systems.

The posts should be cemented with self-cured or dual-cured resin cement because of the limited light penetration into the root canal, even with a translucent post (19). Also, it was shown that use a total-etch, or self-etch adhesive system combined with resin cement is a good option and has high bonding values with the Glass fiber posts (27). The fiber-reinforced composite posts luted in the root canal with a self-adhesive resin cement improve significantly the bond strength (28)(29).

### 5.2. Laser irradiation:

Lasers have become popular since Maiman introduce them in 1960, and very quickly laser technology developed for several uses in different fields of dentistry. The laser principle ("Light Amplification by Stimulated Emission of Radiation") is based on the stimulated emission of an incident photon which will create an identical photon with the same properties and so on. There are two types of laser emission: continuous, and impulse. All the laser studies in this review are pulse lasers. For the medical applications, some characteristics can be distinguished: the wavelength (nm), Energy (J), Repetition rate (Frequency, Hz), pulse irradiation (μs), Time irradiation (s), Power (W), and the distance laser-surface (mm). These parameters demonstrated how the laser radiates on the tissues and the time between the pulses and whether or not water is applied. In this review, all the articles investigated the effect of laser irradiation on the surface of glass or quartz fiber posts to show if it increases or not the bond strength.

The laser Er:YAG (Erbium: Yttrium, Aluminum, Garnet) widely used in dentistry, is part of solid-state lasers, with a wavelength emission of 2940 nm well absorbed by the water and the hydroxyapatite (10). It was proposed for the treatment of hard tissues as an alternative to the rotating instruments, such as removing caries or composite, cavities preparation, but also for enhancing the bond strength of the dental materials (8)(12)(30).

Six articles use the laser Er:YAG with the same properties: Optical fiber diameter of 400µm, Frequency of 10Hz, Pulse duration of 100µs for 60s, and Distance with the spot of 1mm. The only parameter that changes is the Power expressed in W (Watts) and depends on Energy:

$$Power\ (W) = \frac{Energy\ per\ pulse\ (J)}{Pulse\ per\ seconds\ (s)}$$

Among them, two different manufacturers were put into evidence, three studies use the laser Er:YAG at 2940nm made by Doctor Smile Erbium and Diode laser, Lambda Scientifica S.r.l, Vicenza, Italy, with an incidence angle of 45° under water cooling (10)(3)(1). For these investigations, the surface irradiation of the Glass Fiber posts with a power of 4.5W, and 1.5W show effectiveness on the bonding and increase the adhesion between the posts and the resin cement.

The three others studies investigated with the laser Er:YAG at 2940nm made by Fotona, Fidelis, or Fidelis Plus III, Ljubljana, Slovenia, with an RO2-C (Fidelis) or R14 (Fidelis Plus III) angled handpiece (12)(7)(15). Nevertheless, the application of the laser with a power of 1.5W on the surface of Glass and Quartz Fiber posts did not increase the Bond Strength.

Moreover, two articles study with laser Er:YAG made by Smart 2940D Plus, Deka Laser, Firenze, Italy, with 2940nm, Frequency of 10Hz, the Energy density of 119.42 $J/cm^2$, Pulse duration of 700µs for 20s, and a Distance application of 10mm. The irradiation with this type of laser Er:YAG on the surface of Glass and Quartz Fiber posts at 1.5W of Power improve significantly the Bond Strength for both groups (8)(16).

The last study that analyzes the laser Er:YAG at 2940nm use a Fidelis Plus II system, Fotona, Ljubljana, Slovenia, with different parameters compared to other studies: 90° angled handpiece (R13-C) with water, Frequency of 20Hz, Pulse Duration of 300µs for 20s (two times of 10s), the Energy density of 78.9mJ/mm$^2$, 150mJ/pulse, distance application of 1 cm, and peak power of 500W. The laser irradiation on the surface of Glass Fiber posts with these properties highly decreases the Bond Strength between the posts and resin cement (17).

The most used laser in endodontics is the laser Nd:YAG (Neodymium:Yttrium-Aluminum, Garnet) with a wavelength of 1064nm, in the infrared, and is also part of solid-state laser like the laser Er:YAG. It can be used for intraoral soft tissues surgeries, such as maxillary vestibular and lingual frenectomies, but also pulpotomy and disinfection because the laser Nd:YAG yields a bactericidal effect on root canals surfaces, and this wavelength well absorbed by pigmented tissues, can act effectively on deeper dentin layer and curved roots (13)(30).

In this review, three studies use the laser Nd:YAG (Smart A10, Deka Laser, Florence, Italy) with contact, no distance, and delivered by pulse mode with the following parameters: optical fiber diameter of 300µm, Frequency of 10Hz, the Energy density of 141.54 mJ/cm$^2$, Pulse Duration between 180 and 320µs for 20s (Time irradiation), and with water/airflow cooling. There is only the Pulse Energy that changes, 100mJ (1W of Power) or 200mJ (2W of Power), but each group on each study showed that the laser irradiation with Nd:YAG on the surface of Glass and Quartz fiber posts, no matter the Pulse Duration or the Power, that there is no difference with the control groups and therefore did not increase the Bond Strength (2)(8)(16).

A new generation of laser appeared, the laser Er,Cr:YSGG (Erbium, Chromium: Yttrium, Scandium, Gallium, and Garnet) with a wavelength of 2780nm and such as the laser Er:YAG, exhibit highest absorption by water and hydroxyapatite. It is also a solid-state laser and its light emitted in the infrared proven to be effective for the removal of tooth decay and cavity preparation but also in endodontic to eliminate materials infected, debris, or necrotic tissues in the root canals even in the apical region (31).

The application of laser Er,Cr:YSGG made by Waterlase iPlus MD, Biolase, USA, on the surface of Glass and Quartz Fiber posts show different results for almost every study. The laser emitted on the Glass fiber posts at 2780nm with 10Hz or 20Hz of Frequency (depending on the study), non-contacting mode (Sapphire tip MG6), 0.6mm spot size, Pulse duration between 60μs and 140μs for 60s or 80s, and a cooling 60% of water and 40% of air, indicates that with a Power of 1W the bond strength has been increased. But with a Power of 1.5W, the results are inconsistent, because one study (Frequency at 20Hz) shows that the bonding is better after this laser irradiation and the other one (Frequency at 10Hz) demonstrates that it is not significantly different from the control group. However, all the studies prove that the use of laser Er,Cr:YSGG at 2W of Power on the surface of Glass Fiber posts does not affect the Bond Strength (7)(9)(15).

On the other hand, the same laser Er,Cr:YSGG (Waterlase iPlus MD, Biolase, USA) applicated on the surface of Quartz Fiber posts at 2780nm, 20Hz of Frequency, Pulse duration of 150μs for 30s, non-contacting mode, an optical fiber diameter of 600μm and with water and air cooling is shown efficiency when the Power is 0.5W, 1W, and 1.5W. In these cases, the Bond Strength is improved between the Quartz Fiber posts and resin cement (6)(11)

Another group of Glass Fiber posts irradiated with laser Er,Cr:YSGG (Millennium, Biolase, Technology, Inc., San Clemente, CA) with the same properties but different Pulse duration form 140 to 200μs for 20s, and 55% of water/65% of airflow demonstrated that in all group (1W, 2W, 3W, 4W, 5W, 6W of Power) the values of bond strength was lowest than the control group. It was concluded that when the Power increased the Bond Strength decrease (4).

## 6. LIMITS

This systematic integrative review has some limitations. Firstly, the search methodology was carried out using a single database, PubMed. Therefore, some revealing articles could be excluded and minimized the bibliographic references of the selected studies.

According to table 1, it has been highlighted the results of the Push-out bond strength test (in MPa) for each article of this review. All those data were measured *in vitro* so they cannot give an exact prediction of the results if this was done *in vivo*. It can be noted that the preparation of the posts before using the universal test machine, is different depending on the study. Some use extracted teeth and prepared the canal with a rotary or manual system before cementing the posts through the canal, and others use a plastic tube (in general with 10mm of thickness) to represent the natural canal of the teeth.

Moreover, each study realized the push-out test with a universal testing machine but from a different manufacturer and more precisely with different speeds, 0.5mm/min, 1mm/min, or 2mm/min.

These differences can affect the results of the bonding test of our study. For futures studies, it would be preferable to use the same preparation method for each GFRC post.

Further, different resin cements were used in these studies, most of them use dual-cured resin but others cemented the posts with light or self-curing system. Table 2 shows the different categories of resin cement and adhesive system, it was concluded that the choice of the resin cement can play a major role in the adhesion between the posts and the dentin, and different results might be obtained.

## 7. CONCLUSION

In this integrative systemic review, relevant results were evidenced by previous studies concerning the effect of laser irradiation on the surface of Glass Fiber-Reinforced Composite (GFRC) posts. Two types of posts were investigated, Glass and Quartz fibers posts, and three different types of laser were used, laser Er:YAG, Nd:YAG, and Er,Cr:YSGG. The main conclusions of the selected studies can be drawn as follows:

- The effect of laser Er:YAG on the surface of Glass and Quartz fiber posts is debatable, in a few studies the laser improves the Bond Strength, but to others, the control groups have higher values, and the Sandblasting, or Hydrofluoric acid (HF), show better results than the laser Er:YAG. Moreover, its application to too high power significantly decreases the Bond Strength between the fiber posts and the resin cement.

- Irradiation with the laser Nd:YAG on the surface of both types of fiber posts has not shown its effectiveness through these different studies compared to other types of laser.

- The laser Er,Cr:YSGG applicated on the surface of posts provide to increase significantly the Bond Strength of Glass, and also Quartz fiber posts, but its use beyond 1.5W gradually decreased the bonding between the posts and resin cement.

- Relative to the roughness, the laser Er:YAG, laser Nd:YAG, and laser Er,Cr:YSGG influenced the mechanical properties of Glass and Quartz fiber posts but no correlation was found with the Bond Strength.

- Within the limitations of this integrative systemic review, it can be concluded that the type and the power of the laser choose for the irradiation of the surface of the fiber posts has major importance on the effect of the Bond Strength, and also that must take into consideration the composition of each Glass or Quartz fiber posts.

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