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Influence of laser pre-treatments of intra-radicular dentin on the bond strength of cemented posts:

A systematic review.

Marion Claudette Cerise Raoux

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

Gandra, 06 de julho de 2021

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Trabalho realizado sob a Orientação de Dr. Valter Raul da Cunha Fernandes e Co-orientador Dr. Luís Manuel de Sousa Caetano

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RESUMO

O objectivo desta revisão sistemática é avaliar os efeitos dos tratamentos laser, utilizados para desinfecção intra-canalar, na força de ligação entre a dentina e o cimento. Um objectivo secundário é avaliar diferentes irrigantes que atuam sobre a dentina radicular, a fim de encontrar aqueles que possam ter um efeito positivo na adesão entre a dentina e o cimento do espigão. Uma pesquisa bibliográfica publicada foi realizada na base de dados PubMed de Janeiro de 2013 a Fevereiro de 2021, utilizando uma combinação dos seguintes termos científicos: : "Laser treatment", "bond strength", "root dentin", "dentin interface", "fiber post". A pesquisa identificou um total de 674 artigos, , dos quais 10 foram considerados relevantes para este estudo. Foram observados diferentes efeitos na força de ligação, dependendo do tipo de tratamento laser, bem como dos seus parâmetros e do irrigante associado. O tratamento com o Er:YAG laser associado ou não ao EDTA mostrou um aumento nos valores de resistência de ligação; o tratamento com o laser Er,Cr:YSGG poderia mostrar um efeito positivo quando combinado com EDTA, e nenhum efeito quando combinado com água destilada ou NaOCl. Os lasers de diodo e Nd:YAG, dependendo das suas combinações, podem não ter efeito ou mesmo piorar a força de adesão. O tratamento laser provou ser eficaz em termos do seu efeito anti-microbiano. O laser mais estudado no tratamento pós-endodôntico é o laser Er:YAG, que demonstrou ter um efeito positivo na força de adesão. Outros tratamentos são promissores mas precisam de ser estudados com outros parâmetros e combinações.

PALAVRAS-CHAVE: "Tratamento laser", "força de ligação", "dentina radicular", "interface dentinar", "espigão".

ABSTRACT

The objective of this systematic review is to evaluate the effects of laser treatments, used for intra canal disinfection, on the bond strength between dentin and cement. A secondary objective is to evaluate different irrigants acting on intracanal dentin in order to find those that could have positive effect on adhesion between dentin and post's cement. A literature search of published was performed through electronic database on PubMed from January 2013 to February 2021 using a combination of the following scientific terms: "laser treatment", "bond strength", "root dentin", "dentin interface", "fiber post". The search identified a total of 674 articles, of which 10 were considered relevant for this study. Different effects on bond strength were observed depending on the type of laser treatment, as well as its parameters and the associated irrigant. Treatment with the Er:YAG laser associated or not with EDTA showed an increase in bond strength values; treatment with the Er,Cr:YSGG laser could show a positive effect when combined with EDTA, and no effect when combined with distilled water or NaOCl. Diode and Nd:YAG lasers, depending on their combinations, could have no effect or even worsen the bond strength. Laser treatment has proven to be effective in terms of its anti-microbial effect. The most widely studied laser in post-endodontic treatment is the Er:YAG laser, which has been shown to have a positive effect on adhesion strength. Other treatments are promising but need to be studied with other parameters and combinations.

KEYWORDS: "Laser treatment", "bond strength", "root dentin", "dentin interface", "fiber post".

General contents

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List of acronyms and abbreviations

CCS	Conventional Cleaning and Shaping
CC	Conventional Cement
CW	Continuous Wave Mode
Er,Cr :YSGG	Erbium Yttrium Scandium Gallium Garnet
EDTA	Ethylenediaminetetraacetic disodium salt
EDTAC	Ethylenediaminetetraacetic disodium salt + Cetavlon
Er :YAG	Erbium-doped Yttrium Aluminium Garnet
FRC	Fiber-Reinforced Composites
LAI	Laser-activated irrigation
PDT	Photodynamic Therapy
PL	Pulsed Mode
PIPS	Photon-Initiated Photoacoustic Streaming
NaOCl	Sodium hypochlorite
Nd:YAG	Neodymium-doped Yttrium Aluminium Garnet
ROS	Reactive Oxygen Species
SAC	Self-Adhesive Cement
SD	Standard Deviation
μSBS	Micro-Shear Bond Testing
$ZnPO_4$	Zinc Phosphate Cement

1. INTRODUCTION

An endodontic post is commonly used for restoring a root-filled tooth that has suffered significant tissue loss, often due to caries, fractures and previous restorations. The post's placement permits to provide sufficient retention of future restoration[1-3]. Ideally, the post should have perfect adhesion to the remaining dental structure to reduce infiltration, restore the endodontic filling and thus avoid bacterial contamination[4,5]. Bacterial infiltration can lead to failure of the restorative treatment and to the collapse of the remaining tooth structure.

To get this near perfect bond between dentin and post, not only is a correct association between the selected resins cement and post material required, but also a suitable dentin surface for a good sealing[6,7]. Rotating instruments during root canal treatment and post-endodontic disobturation will lead to the formation of a layer called the smear layer[8], which could compromise the adhesion between resin cement and dentin in the prosthetic space by obliterating the dentinal tubules[9,10]. The process of adhesion is to replace minerals removed from the hard dental tissue with resin monomers, forming chemical bonds or micromechanical interlocking, called hybrid layer[11]. The interface, and therefore the bond strength, between the cement and the dentin could be compromised by the smear layer and debris created along the canal walls during post space preparation[12].

Several research and studies have been conducted on the use of lasers in restorative dentistry with the aim of maximizing adhesion between the restoration and dentin and optimizing the viability of the prosthetic restoration[13].
Irradiation with a laser system could promote microbial reduction and cleaning root canals, removal of tissue debris, modifying the dentin surface and its permeability and thus improving the interaction between filling material and dentin walls[14-17].
In recent years, phototherapy applications including photodynamic therapy (PDT) and laser irradiation have become common in dentistry, especially in endodontics[18]. The diode, erbium (Er:YAG and Er,Cr:YSGG) and Nd:YAG lasers have been evaluated in the pre-treatment of

post space preparation, using several tests such as push-out test, pull-out test, as well as the micro shear bond test (μSBS).

In addition to the use of laser pre-treatments on dentin, several studies have been conducted using several types of irrigants (NaOCl, EDTA, chlorhexidine (CHX), QMiX which is a combination of EDTA, CHX and detergent) to compare their effectiveness in combination with or without lasers when preparing the post space. Some lasers such as Erbium can activate irrigants when they are in the endodontic canal; these are called Laser-Activated Irrigation (LAI). This technique involving laser and irrigant could help improve adhesion by removing the smear layer as well as the dentin debris still present in the prosthetic space.

The objective of this systematic review is to evaluate the effects of laser treatments, used for intra canal disinfection, on the bond strength between dentin and cement. A secondary objective is to evaluate different irrigants acting on intracanal dentin in order to find those that could have positive effect on adhesion between dentin and post's cement.

2. MATERIALS AND METHODS

2.1 Information sources and search strategy

A bibliographic review was carried out in PUBMED (through the National Library of Medicine) considering that such database includes the main articles in the area of dentistry and biomaterials. The actual search of studies was realized in accordance with previous integrative or systematic review articles.
The strategy used was the combination of free text words and Mesh terms. The following keywords were applied: "fiber post" AND "laser" OR "laser treatment" OR "laser etching" AND "adhesion" OR "bond strength" AND "root dentin" OR "dentin interface" OR "Root canal dentin". 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 criteria used for the selection of articles are as follows:

Inclusion criteria	Exclusion criteria
-Articles published between 2013 and February 2021 -Articles published in English, French, Spanish and Portuguese. -Vitro studies, meta-analyses, randomized controlled trials, prospective cohort studies and cell culture assays. -Treatments laser including the Erbium lasers : Er:YAG, and Er,Cr:YSGG ; the Nd:YAG and diode lasers; and the PDT system. -Treatments performed on intra-canal dentin -Studies analysing the bond strength of the dentin-resin interface	-Abstracts missing -Articles in which human tooth samples are not used. -Animal trials, dissertations, literature reviews and systematic reviews -Laser treatments were performed on the prosthetic post -Studies analysing the bond strength of the resin-post interface -Incomplete and poorly data accessibility

***Table 1**: The eligibility criteria*

2.2 Study selection and data collection process

Once the keywords and filters were entered into the search database, studies were first accepted or rejected according to their title and abstract.

Non-rejected articles were compiled according to their keywords and duplicates were removed using Mendeley software.

In a second step, the non-rejected articles previously selected by their abstracts were evaluated according to the established inclusion and exclusion criteria of the abstract review. Each selected article was fully read and analysed to ensure that it was relevant to the topic and objectives of the present study.

The following variables were collected for the review in the ***Table 2:***: date of publication, author's names, purpose, sample size, study design, type of adhesive resin used, type of laser used for pre-treatment of intra-canal dentin and its properties, push-out and pull-out test results for resin-dentin bond strength (measured in MPa).

3. RESULTS

The literature search in the available database PubMed identified a total of 674 articles of which 148 duplicates were eliminated. After the removal of these duplicates, 526 articles were submitted to the filters and exclusion criteria. Finally, only 30 articles were kept for a full reading, and 11 of them were excluded for not meeting the inclusion criteria and 10 for not containing revealing information in relation to the objectives of this work. *(**Figure 1** – PRISMA flow diagram*). Therefore, 10 articles were selected for this review, and their data were collected in a ***Table 2***.

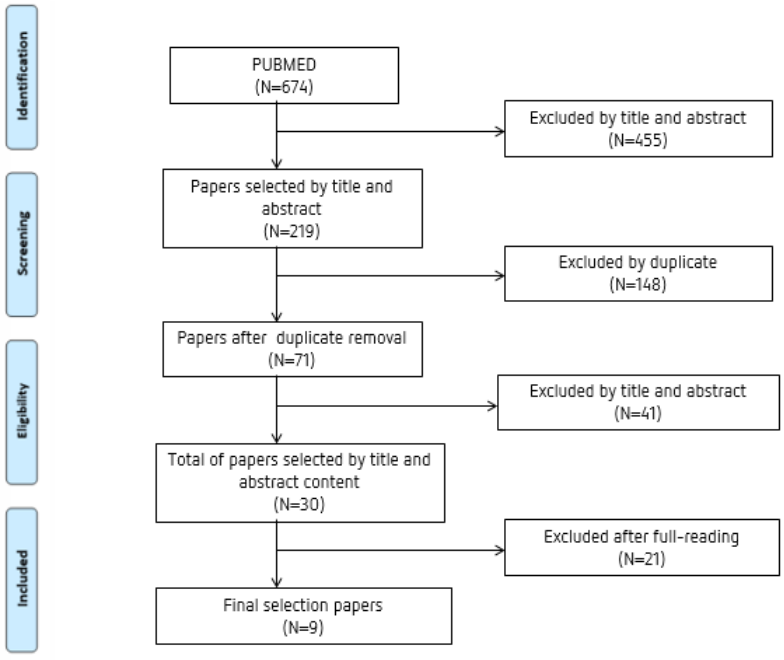

Figure 1. *Flow diagram of the search strategy used in this study*

Of the 10 articles included in this review, all papers (100%) dealt with the laser pre-treatment of root dentin and correspond to in vitro and randomize studies[12,14,19-25]. Nine studies (90%) investigated the bond strength between the root dentin and the cemented post[12,14,19,21-26]; and an in vitro study compared the effect of Er,Cr:YSGG laser treatment with that of EDTA irrigant on the number of adhesions and open dentinal tubules (10%)[14].

For nine articles (50%) Er,Cr:YSGG laser has been used, three (30%) used Er:YAG laser, three (30%) used Nd:YAG laser, two (20%) used PDT treatment which employs diode laser, and two articles (20%) applicated diode laser.

Other studies (30%) seek to compare the effects of laser treatment according to different powers output used[20,23,25] or different powers density applied (10%) (continuous wave mode CW or pulsed mode PL)[19], as well as different durations of irradiation of the dentine (10%)[20].

In order to meet our secondary objective, we also considered the combination of irrigants with the laser treatments studied in our articles (50%) and their effect on the bond strength between dentin and resin[12,14,22,23,26]. Four (40%) used the 17% EDTAC as irrigant, two (20%) used the 1% NaOCl, three (30%) used the saline solution and another one (10%) used the QMiX solution. In addition, 0,005% methylene blue is used in two articles (20%) as a photosensitizer and in one article (10%) a mineral coal is used.

Table 2: Details of relevant previous studies on the effects of laser treatments on the bond strength between root dentin and post adhesive resin.

<table>
<tr><th>Author
Year</th><th>Purpose</th><th>Study design</th><th>Sampl e size</th><th>Type of irrigant</th><th colspan="2">Type of laser</th><th colspan="11">Bond strength (MPa) of dentin to resin cements</th></tr>
<tr><td rowspan="5">C. Strefez-za et al, 2018</td><td rowspan="5">Analyse the effect of root canal irradiation with high-intensity diode laser, emitting at 830 nm and operating in continuous or pulsed mode, on the retention of metal or fiber posts, cemented with self-etching resin cement or zinc phosphate cement.</td><td rowspan="5">Randomized in vitro study</td><td rowspan="5">90</td><td rowspan="5">-</td><td>Pp</td><td>Diode laser</td><td>Cement agent</td><td>Post material</td><td colspan="3">Control</td><td colspan="3">CW laser</td><td colspan="3">PL laser</td></tr>
<tr><td rowspan="4">W
IT
PO
OFD
F
PD
EF</td><td rowspan="4">830
5 cycles of 2mm/sec
-
300
-
1989 (CW) – 994 (PL)
-</td><td colspan="2"></td><td>1/3 C</td><td>1/3 M</td><td>1/3 A</td><td>1/3 C</td><td>1/3 M</td><td>1/3 A</td><td>1/3 C</td><td>1/3 M</td><td>1/3 A</td></tr>
<tr><td>ZnP04</td><td>Metal</td><td>2,6</td><td>4</td><td>2,5</td><td>9</td><td>6,5</td><td>4</td><td>10,5</td><td>7,5</td><td>4</td></tr>
<tr><td>Panavia F</td><td>Metal</td><td>4</td><td>3,5</td><td>1</td><td>16*</td><td>13*</td><td>6,5*</td><td>13,5*</td><td>11,5*</td><td>5*</td></tr>
<tr><td>Panavia F</td><td>Glass fiber</td><td>5</td><td>4</td><td>1,5</td><td>14*</td><td>11*</td><td>5*</td><td>18,5*</td><td>13*</td><td>7*</td></tr>
<tr><td rowspan="2">H. Arslan et al, 2013</td><td rowspan="2">Evaluate the efficacy of different irrigation protocols on the retention of the FRC posts to the root canal dentinal walls using pull-out tests.</td><td rowspan="2">Randomized in vitro study</td><td rowspan="2">60</td><td rowspan="2">- Distilled water
- 5% NaOCl
- 17% EDTA</td><td>Pp</td><td>Er:YAG</td><td colspan="5">Groups</td><td colspan="6">Mean</td></tr>
<tr><td>W
IT
PO
OFD
F
PD
EF</td><td>2940
15
15
400
10
-
-
-</td><td colspan="5">Control
EDTA
Ultrasonic
Er:YAG
Er:YAG + EDTA</td><td colspan="6">2.89
3.12
4.3*
4.39*
4.70*</td></tr>
</table>

V. Lessa C. Araujo et al, 2017	Evaluate in vitro the influence of high-power lasers (Nd:YAG ans diode 980 nm) on bond strength of an epoxy resin-based root canal sealer to root dentin.	Randomized in vitro study	50	-17% EDTAC -Distilled water -5% coal	Pp	Nd:YAG	Diode	Groups	1/3 coronal	1/3 middle	1/3 apical
					W P IT PO OFD F PD EF	1064 Mineral coal 16 1.5 200 100 - -	980 Mineral coal 16 1.5 200 100 - -	Control EDTA + Nd:YAG EDTA + Diode EDTA + coal + Nd:YAG EDTA + coal + Diode	9.81* 4.57 4.65 3.69 6.89	11.47* 8.27 2.99 8.83 3.10	30.34* 23.79* 13.70* 32.25* 16.27*
K. De Almeida Franceschini et al, 2016	Evaluate the Er,Cr:YSGG laser's influence on the bond strength of filling material when associated with different final irrigation protocols.	Randomized in vitro study	96	-17% EDTAC -1% NaOCl -Distilled water	Pp	Er,Cr:YSGG		Groups	Distilled water	1% NaOCl	17% EDTAC
					W IT PO OFD F PD EF	2790 20 2, 3 and 4 275 20 - 23.15; 37.72; 46.3		Non-irradiated 2W 3W 4W	2.36 2.95 2.85 4.27*	2.62 2.86 4.54 3.87*	2.93 4.04* 4.68* 4.40*
L. Tosi Trevelin et al, 2019	Investigate the structural modifications on dentin, following the pre-treatment with Er:YAG laser at different pulse durations.	Randomized in vitro study	60	-	Pp	Er:YAG		Groups	24 hours	12 months	
					W IT PO OFD F PD EF	2940 50 – 300 - 600 1600 – 266 - 133 900 2 80 12.58		Control Laser pulse 50µs Laser pulse 300µs Laser pulse 600 µs	26.17* 22.14 21.25 20.62	24.97* 22.85 22.13 23.01	

F. Abdullah Alonaizan et al, 2019	Evaluate the push-out bond strength and modes of failure of fiber posts among PDT, Er, Cr:YSGG and Nd:YAG laser compared with CCS.	Randomized lin vitro study	80	-	Pp	Diode laser	Er,Cr:YSGG	Nd:YAG	Groups	Mean
					W P IT PO OFD F PD EF	638 Methylene blue 300 1.5 200 - - -	830 - 20 1.25 300 15 1989-1200 -	1064 - 140 1.4 320 10 - 174	PDT Er,Cr:YSGG Nd:YAG CCS	8,16 7.24 7.91 7.42
M. Simundic Munitic et al, 2017	Evaluate the effect of LAI performed by the Er:YAG laser and Er,Cr:YSGG laser and Nd:YAG laser irradiation on the bond strength of self-adhesive cement on intracanal dentine.	Randomized in vitro study	84	-saline solution -QMiX solution	Pp	Er:YAG	Er,Cr:YSGG	Nd:YAG	Groups	Mean
					W IT PO OFD F PD EF	2940 50 - 600 15 20 2.06	2780 140 1.25 250 20 62.5 -	- 100 1.5 - 10 100 140.85	Control Nd:YAG PIPS+QMiX LAI+QMiX PIPS+saline LAI+saline	0.737 0.868 3.401 0.919 1.094 1.111

O. Kirmal-i et al, 2014	Evaluate the effects of dentin surface treatments including Er,Cr:YSGG laser irradiation with different intensities on the push-out bond strength of the glass fiber posts to root dentin.	Randomized in vitro study	40	Distilled water	Pp	Er,Cr:YSGG	Groups	1/3 coronal	1/3 middle	1/3 apical
					W IT PO OFD F PD EF	2780 10 1, 2 and 3 320 20 - -	Control Laser 1W Laser 2W Laser 3W	4.68 4.66 4.66 4.67	4.40 4.43 4.44 4.44	3.24* 3.25* 3.27* 3.22*
A. T. Peroba Rezende Ramos et al, 2017	Evaluate the effects of PDT using 0,005% methylene blue in the intracanal prosthetic space on the bond strength and intradentinal penetrability using conventional or self-adhesive resin cements.	Randomized in vitro study	40	-0,005% Methylene blue -Saline solution	Pp	PDT (diode)	Groups	1/3 coronal	1/3 middle	1/3 apical
					W P IT PO OFD F PD EF	- 0,005% Methylene blue 30 - - - - 30	CC SAC PDT + CC PDT + SAC	4.21 6.09 2.45* 4.55	3.56 4.38 3.27 4.71	3.96 3.51 3.65 4.66

The major findings from the selected articles draw as follow:

- Increased bond strength values could be observed after treatments with Er,Cr:YSGG (2780nm) and Er:YAG (2940nm) lasers combined with saline solution[12]. An increase was also noted with the irradiation of the Er:YAG laser combined with a QMiX solution[12] as well as with 17% EDTAC[22]. In all final irrigation protocols: distilled water, with 1% NaOCl or EDTAC 17%, the Er,Cr:YSGG laser (2790nm) with 4W power showed statistically higher bond strength values when compared to the group control. But in cases where the powers are 2W and 3W, the increase of bond strength values is only significantly higher with 17% EDTAC[23]. In another paper it was observed that irradiation with the diode laser at 830 nm with both modes: pulse and continuous; resulted in statistically higher bond strength values[19].

- In other cases, it was found that there was no effect on the adhesion strength after laser treatment. This is the case for PDT treatment (638nm), with the Er,Cr:YSGG laser (830nm) or with the Nd:YAG laser (1064nm)[21]. In the case of the Er,Cr:YSGG laser irradiating at 2780 nm, there were not effects on adhesion among the groups regardless of the different laser powers: 1W, 2W, or 3W[25]. In the *Auraujo et al* study[14] it could be seen that the control group treated only with the 17% EDTA irrigant had the highest bond strength values. The combination of EDTA with diode (980nm) and Nd:YAG (1064nm) lasers and with/without mineral coal did not increase bond strength. Also, it was found that treatment with 1% NaOCl or 17% EDTAC did not result in a positive effect on bond strength[26].

- Some treatments can have a negative and therefore deleterious effect on adhesion, such as PDT using a photosensitizer: 0.005% methylene blue[24]. In the study by *Trevelin et al* several samples were compared according to the Er:YAG laser (2940nm) irradiation time: 50, 300 and 600 μs. The group untreated presented statistical higher bond strength values in comparison with the groups irradiated regardless of exposure time (24 hours and 12 months)[20].

4. DISCUSSION

To ensure the long-term success of root canal therapy, an optimal adhesion between root canal fillings and canal walls should be as high as possible. Bond strength of the filling material to dentin walls can be influenced by the type of sealer used, as well as the type of treatment that the dentin surface receives, which can be achieved through chemical solutions like irrigants (EDTA, NaOCl, QMiX solution), photosensitizer (methylene blue)[24] or photocatalyser (mineral coal)[26] and laser irradiations as well as the specific properties of the laser used. The parameters of the laser used in the treatment: wavelength, intensity, power, pulse duration, type of irradiation (pulsed or continuous), and also the additional systems used such as optical fibers - which allow the irradiation to be diffused in the root canal - will have a significant influence on the bond strength values obtained during the in-vitro tests.

Dentin surface treatment with the above-mentioned methods causes alterations in the chemical and structural composition of dentin; the permeability and solubility characteristics of dentin may change, and, hence, affect the adhesion of resin cements to dentin surfaces[27].

4.1 Laser treatments

The Photodynamic Therapy (PDT) using at 638 nm is an antimicrobial mode of treatment, which is based on the chemical amalgamation of a low-intensity laser of appropriate wavelength and a photosensitizing agent that is nontoxic in nature. PDT works on the principle that is based on the interaction of the excited photosensitizer with the molecular oxygen from the environment, resulting in the formation of highly reactive oxygen species (ROS), which causes damage to the membrane and its constituent molecules, including the nucleic acids and proteins. Having a strong cationing charge, the photosensitizer binds and penetrates the bacterial cell without causing great damage to the integrity of the host cell. Research suggests that retaining smear layer for adaptation of the materials to root surface may have an impact on the overall efficacy of PDT on bond strength[21].

In our two papers included in the study, *F. Alonaizan et al*[3] and *A. Ramos et al*[24], we could observe a negative effect on the adhesive interface between the root dentin and the fiber post system, resulting in a decrease in the bond strength of the samples. This negative effect would be related to the release of ROS caused by the activation of the photosensitiser[28].

The Nd:YAG (1064 nm) and diode (830 nm) lasers are poorly absorbed by water and hydroxyapatite leading to an increased thermal diffusivity and an increase of dental and adjacent tissue temperature which can melt the dentine, leading to the microbial reduction and apical marginal sealing[1] but which may cause thermal damage. The excessive temperature rise during intracanal irradiation can negatively influence the hardness and dentin[29-31], as it can cause tiny-mergers in dentin which would have a deleterious effect on the bond strength values. This possibility can easily controlled by the use of safe parameters[32,33] and suitable fibers of the procedure afore mentioned[34].

No effect, positive or negative, was observed for the 1064 nm Nd:YAG laser treatment on the bond strength between cement and root canal dentin[14,19]. It was also found that the use of the 980 nm diode laser did not increase the bond strength either[14].

The Er:YAG and Er,Cr:YSGG lasers, considered as high intensity lasers, have the ability to be absorbed by water and hydroxyapatite, which are present in the tooth structure, proiding significant chemical changes in the dentin wall by ablation. Ablation occurs by means of a thermomechanical process of interaction where water molecules become energized and are propelled by the laser light and collide with the molecules of the tissue[35]. Ablation causes micro explosions, which produce irregularities in the tissue and promote an increase in surface temperature, varying with the energy density[23]. These changes provide a better contact and adaptation of the filling material to the dentin walls, since the surface becomes smoother and exposes the collagen structure of the intertubular dentin, thereby increasing the bond strength of the filling material.

The clinical use of Er:YAG lasers at 2940 nm have been well described in the literature. These lasers provide a surface with open dentinal tubules and no smear layer[36,37]; which impact positively the adhesion between dentin and post cement[12,20,23].

In the study of Kirmali et al[25] we can observed a no difference between the different power groups (1W, 2W, 3W) of Er,Cr:YSGG laser treatment and the untreated group. There are several reasons for these results: they aimed to determine the effect of laser treatment only on the dentin surface: only distilled water was used for cleaning. Furthermore the fiber-optic system used had influenced a limitation of laser penetration and contacts with the dentin wall.

4.2 Laser treatments – irrigants combination

The bond strength values significantly varied according to the type of irrigation protocol[12,14,22,23,26]. The sodium hypochlorite and chlorhexidine digluconate have been recommended for prosthetic space irrigation thanks to their antimicrobial action, but presented negative effects on the bond strength between dentin and cement. Moreover the NaOCl may cause undesirable effects. In an attempt to overcome the adverse effects of NaOCl, the study by *A. Ramos et al*[24] sought to combine a new irrigant with antiseptic properties: 0.005% methylene blue with diode laser treatment during PDT. He discovered that this combination leads to the formation of ROS, which could cause a decrease in adhesion between dentin and conventional cement, which explains the negative effect on the bond strength.

The EDTAC acts on the inorganic components of dentin, promoting softening of peri and intertubular dentin, removing smear layer, and increasing dentin permeability and also promoting collagen exposition that gets more susceptible to laser action, allowing more surface contact with the filling material[38].

The effectiveness of the NaOCl-EDTA combination in removing the smear layer from the root canal walls is well documented in endodontics[39,40]. According to the results of the *Arslan et al* study, use of the NaOCl-EDTA resulted in similar pull-out bond strengths as the control group (NaOCl)[22].

It was found in the study of *Arslan et al*[22] that the mean bond strength values increased with the combined use of an Er:YAG laser and EDTA, when compared to the control group only treated with NaOCl.

In the study of *Franceschini et al*[23] it was observed that Er,Cr:YSGG irradiation increased the filling material's bond strength to dentin when associated with different final irrigation protocols. We observed an increase of the bond strength values when Er,Cr:YSGG laser irradiation was associated with the final irrigation with 1% NaOCl associated with 3W and 4W. As well, when 17% EDTAC was used as the final irrigation prior to Er,Cr:YSGG laser irradiation, an increase in bond strength was verified[23].

5. LIMITS

The systematic review has some limitations. Firstly the language may have contributed to the loss of some potentially relevant articles. However, English is undoubtedly the universal scientific language and this systematic review also included articles published in French, Portuguese and Spanish, which allowed the search and selection of many articles. Thus, we consider this parameter the least problematic and conditioning.

Next, the search methodology may have excluded relevant articles because we used a single database: PubMed. This problem was minimized when searching the bibliographic references of the selected studies.

According to the results described in the table 2, it can be noted that there are contradictions in the MPa values obtained in the articles analysed. This observation leads us to reflect on the need to follow rigorous methods for the preparation of root canal dentin after endodontic treatment, the use of an irrigant before the laser irradiation; as well as the use of more homogeneous parameters for laser treatment of dentin. The choice of these parameters should allow emphasis to be placed on those that impact on the dentin-cement bond strength. This can be done by using factors extrinsic to the laser such as temperature control by a cooling air-water system, the diameter of the optical fibre used and the orientation of the laser irradiation, or by using factors specific to the laser such as pulse frequency, energy density, long or short pulses (continuous or pulsed mode) and the irradiation time.

Other factors that have not been addressed in this systematic review may have an effect on the bond strength, such as the type of resin cement used after laser treatment of dentinal surfaces. In this context, it would be interesting to investigate different parameters during laser treatments of dentin, whether or not combined with one or more irrigants with different types of cements.

With regard to the included studies, all published papers are based on in vitro investigations, the data do not give a true prediction of the effect of laser treatment of intra-canal dentin on bond strength under in vivo conditions. Thus, it is now necessary to carry out in-vivo research to assess whether the positive performance of the treated root dentin is similar to the in-vitro performance.

As high intensity lasers have been extensively studied, there is also a need for further research into medium (diode and Nd:YAG) and low intensity (PDT) lasers as well as further studies to define the exact parameters and the right photosensitising agent for PDT, for maximum efficacy and safety.

In addition to these complementary studies, the effectiveness of the laser treatment technique is also to be studied, taking into account:

- The adaptability of this technique to the maximum number of clinical situations (which can be very different)
- The ease and duration of implementation of the technique
- The possibility of using this laser for other purposes (periodontal treatments, surgery) or the versatility of the laser device
- The cost (investment in the device and additional work time required to implement this technique / hourly cost of the practice, as well as the repercussion of this cost on the rates offered to patients) which is a non-negligible aspect in our practice.

6. CONCLUSION

With regard to the bond strength, numerous studies have been carried out but the results of the studies are very variable and even contradictory. This is due to the large number of parameters involved. In many settings, the use of laser as a treatment prior of cementing a prosthetic post has no effect, or even a negative effect on the bond strength.

The risk of heating the surrounding tissue must also be taken into account, especially for high-intensity lasers (Er:YAG and Er,Cr:YSSG). Nevertheless, it appears from the articles reviewed that the Er:YAG laser is the most effective and well-studied for this purpose according to current knowledge.

The medium-wavelength lasers (Nd:YAG and diode), according to the parameters studied, seem to be ineffective for the moment in improving the adhesion strength, even though it was found that with a diode laser treatment at 830 nm there was a slight increase in the bond strength and less risk of heating than with the high intensity lasers.

Low intensity lasers (PDT) associated with a photosensitive agent (in this case methylene blue) show no efficacy on bond strength or even a negative effect due in part to the denaturation of the chemical agent into free radicals and its interaction with the root dentinal tissues.

The results obtained agree that the most effective final irrigation agent is EDTA, whether or not combined with other chemical agents or H_2O.

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