Adhesion in Dentin Prepared with Er,Cr:YSGG Laser: Systematic Review

Abstract

Background: In dentistry, cavities prepared with Erbium lasers present more advantages, compared to traditional methods, but there is still a lack of investigation about the adhesion in dentin surfaces prepared with Erbium lasers, especially with Erbium, chromium:yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser. **Aim:** The purpose of this systematic review was to find out which might be "The most adequate adhesive and laser parameters for adhesion in dentin prepared with Er,Cr:YSGG laser." **Methods:** An electronic search was performed in the PubMed database. The search was limited to studies between 2009 and 2016. **Results:** Ten articles were selected to the systematic review according to TRANSPARENT REPORTING of Systematic Reviews and Meta-ANALYSES checklist. **Conclusions:** The adhesive that showed the best bond strength results in dentin prepared with Er,Cr:YSGG laser was the self-adhesive Clearfil™ SE (Kuraray), with preconditioning with 40% phosphoric acid. The settings 2 W, 75% water, 60% air, 140 µs pulse duration, and 20 Hz showed the best adhesion outcome.

Keywords: *Adhesion, bond strength, dentin, erbium, chromium:yttrium-scandium-gallium-garnet, laser*

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Introduction

Over the years, there have been many attempts to understand and improve the adhesion of dental materials to dentin. The first attempts to condition the dentin resulted in poor micromechanical adherence, due to preferential conditioning of peritubular dentin. The hydrophobic characteristics of the composite resins do not allow its penetration in peritubular walls due to their inability to move the dentinal fluid, which resulted in dentinal tags away from the walls of the tubules along with polymerization shrinkage.[1]

Dentin is a hard tissue, consisting of 70% mineral component, 20% organic matrix, and 10% fluid. The organic matrix consists of 90% fibrillar collagen type I, and the remaining 10% is noncollagen proteins, proteoglycans, in particular phosphoproteins. The three-dimensional structure is formed by intratubular and peritubular dentin and tubules that extend from the pulp to the dentin–enamel junction.[2]

Dentin is a complex biological and hydrated structure, and therefore the interactions with other structures and materials are limited.[1]

The formation of the hybrid layer with impregnation of resin monomers in partially demineralized dentin and its polymerization is the currently accepted and more successfully method to achieve adhesion to dentin.[3,4]

The Erbium laser cavity preparation in dentistry is more advantageous compared to traditional methods using handpiece, since it prevents microcracks, decreases the vibration, and has a bactericidal effect. With this method, there is no need of anesthesia, the patient also feels less uncomfortable regarding the noise and pressure.[5,6]

The Erbium, chromium:yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser has a wavelength of 2.79 µm, and the ablation occurs by the absorption of the incident energy by water molecules, resulting in microburst in the surface of the dentin. The dentin ablation threshold is 2.69–3.66 J/cm^2.[7]

The cavity preparation using Erbium laser results in the absence of smear layer, open dentinal tubules, and microirregularities due to the removal of intertubular dentine. The laser effect on collagen network is still not completely clear, but it is accepted that the

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laser irradiation may cause changes and microruptures in collagen fibers.[8]

The studies on adhesion to dentin prepared with Er,Cr:YSGG show contradictory results, yet there is no consensus on what are the best laser parameters and the best adhesive material to use.[9]

A systematic review on adhesion in dentin prepared with Er,Cr:YSGG laser might lead to a better understanding, giving some answers regarding this question.

Review

Objective

The aim of this study is to do a systematic review that could identify what are the most adequate adhesive and laser parameters to be used in dentin prepared with Er,Cr:YSGG laser.

Methods

The search was limited to studies *in vitro* conducted in healthy human dentin, written in English between 2009 and 2016; a combination of the following terms was used: Adhesion, laser, Er,Cr:YSGG, and dentin bond strength. In total, 44 articles have been found. The titles and abstracts of potential references were manually examined to exclude irrelevant publications, and those with no full-text version available were also excluded. In total, 10 articles were selected [Table 1].

An electronic search was performed in the PubMed database, through the Virtual private network (VPN) of the Faculty of Dental Medicine, University of Porto.

There was a risk of a potential bias in this review related to the language, since the selection was reduced to articles written in English only.

Selection criteria

The following selection criteria were used: (1) original articles, (2) articles in English, (3) articles available with full text, (4) use of human and healthy teeth, (5) articles with *in vitro* tests performed in dentin, (6) dentin preparations with Er,Cr:YSGG laser [Table 1].

Study selection

The titles and abstracts of all studies were examined, and the full-text articles relevant for the review in accordance with the methods of inclusion and exclusion were analyzed. The articles were identified, analyzed, selected, and included in the systematic review according to TRANSPARENT REPORTING of Systematic Reviews and Meta-ANALYSES checklist [Table 2].

Table 1: Systematic search strategy

Question	**What are the most adequate adhesive and laser parameters to use in dentin prepared with Er,Cr:YSGG laser?**
Search strategy	
Samples	Healthy human dentin
Treatment	Er,Cr:YSGG laser
Comparison	Strength bonding of adhesive
Results	Adhesion strength
Keywords	Adhesion, laser, Er,Cr:YSGG, dentin bond strength
Database	
Electronics	PubMed
Selection criteria	
Inclusion criteria	Original articles Articles in English Available articles with full text Use of human and healthy teeth Articles with *in vitro* adhesion tests on dentin Preparations in dentin performed with Er,Cr:YSGG laser The material tested is an adhesive
Exclusion criteria	Articles in languages other than English Articles without access to full text Tests on carious dentin or sclerotic Tests on dentin treated with another laser beyond the Er,Cr:YSGG laser Articles that do not offer adhesion tests Studies in primary dentition

Er,Cr:YSGG: Erbium, chromium:yttrium-scandium-gallium-garnet

Results

Using the foregoing screening method, 44 articles were found. After analyzing the titles and abstracts, 6 articles were excluded because of the lack of access to the full text [Table 2].

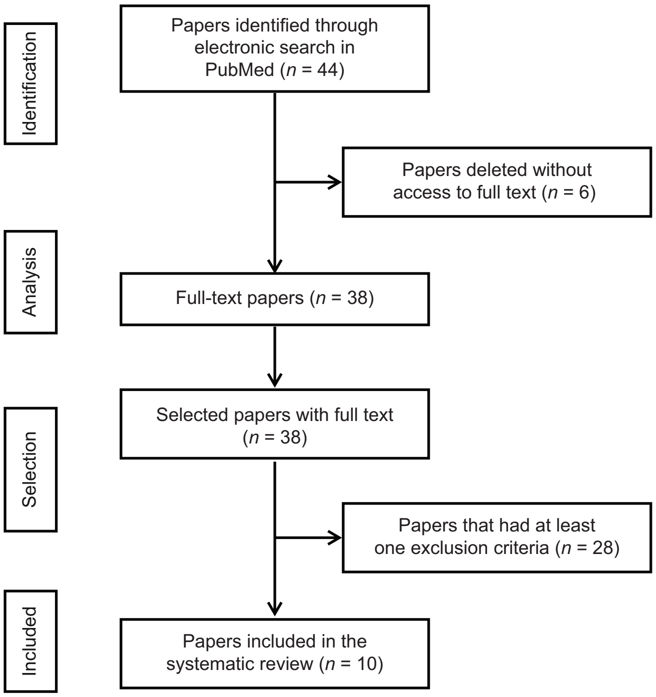
The remaining 38 articles were analyzed, and those selected were the ones who did not have any exclusion criteria, as articles in language other than English, containing tests on carious or sclerotic dentin and studies in primary dentition [Table 2].

At the end, 10 articles met all the requirements for this systematic review and were selected.

Tables 3 and 4 show the analysis of the bond strength considering the adhesive, the laser settings, and the type of surface conditioning, and the selected articles are described below.

In the article by Takada *et al.,* two self-etch adhesives were used: one consisting of primer and adhesive, the Clearfil™ SE Bond (Kuraray, New York, USA) and the other was one step, Clearfil™ Tri-S Bond (Kuraray, New York, USA). In this study, there were two more groups where the adhesives were also tested with additional treatment with 40% of phosphoric acid and 10% sodium hypochlorite gel. The Er,Cr:YSGG laser parameters used were the following: 2 W, 75% water, 60% air, 140 µs pulse duration, and 20 Hz. The best bond strength results (average about 41 MPa) was

Table 2: Flowchart according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses



obtained by using laser in dentin, followed by phosphoric acid etching at 40% for 30 s, and applying the adhesive Clearfil™ SE bond [Table 3]. The group treated only with laser and Clearfil™ SE Bond was the one with the lowest bond strength.[10]

In the study by Ramos *et al.,* they tested the Single Bond™ adhesive (3M ESPE, Minneapolis, USA) (etch-and-rinse) and the Clearfil™ SE bond in laser-treated dentin with Er,Cr:YSGG laser, using the following settings: 1.5 W, 70% water, 65% air, 140 µs pulse duration, and frequency 30 Hz. The results of the bond strengths were higher for Clearfil™ SE Bond (38.7 ± 16.5 MPa) [Table 4] than for Single Bond™ group (33.4 ± 6.1 MPa) [Table 4], but without significant statistical difference.[11]

The authors Shahabi *et al.* used the Er,Cr:YSGG laser with the following parameters 3.5 W, 65% water, 55% air, 140 µs pulse duration, and 20 Hz in dentin, with Adper™ Single Bond (3M ESPE, Minneapolis, USA) after acid etching with 37% phosphoric acid for 20 s, getting a bond strength of 4.85 ± 0.93 MPa [Table 3].[12]

By testing three different adhesives, Excite® (Ivoclar Vivadent, Schaan, Liechtenstein), Scotchbond™ Multipurpose (3M ESPE, Minneapolis, USA), and Syntac® Classic (Ivoclar Vivadent, Schaan, Liechtenstein), in dentin prepared with the same laser parameters, 2 W with 65% water, 55% air, with and without 37% phosphoric acid etching, Beer *et al.* achieved the best results (average 14.07 MPa) with the use of Syntac® without etching.[13]

Adebayo *et al.* tested the adhesives Clearfil™ SE Bond, Xeno® IV (Dentsply, York, Pennsylvania, USA) and Tokuyma Bond Force® (Tokuyma Dental, Japan) in laser-treated dentin with Er,Cr:YSSG laser with 3.5 W, 60% water, and 65% air, and an energy density of 109.4 J/cm^2, obtaining the best result with IV Xeno® adhesive (average of 10.4 MPa).[14]

In the study by Jaberi Ansari *et al*., the conditioning of the dentin with 1 W, 55% water and 65% air, and application of Single Bond™ adhesive (3M™) resulted in adhesion strength of 22.44 ± 5.41 MPa[15] [Table 4].

The use of different etching durations in the paper by Ferreira *et al*., and Single Bond™ in dentin prepared with 4 W, 75% water, and 65% air, resulted in a better adhesion strength (12.38 ± 2 47 MPa) in the group where conditioning was performed for 15 s with phosphoric acid at 35%[16] [Table 3].

The authors Obeidi *et al*. performed a similar study to the one of Ferreira *et al*., using the parameters 3 W, 70% water, and 60% air, with application of the adhesive Adper™ Single Bond Plus and conditioning with 37% phosphoric acid, with different durations, getting the best result of adhesion, with a duration of 15 s conditioning (13.62 ± 7.28 MPa)[17] [Table 3].

In 2009, Obeidi *et al.* tested the use of an excavator after application of Er,Cr:YSGG laser with 3 W, 70% water and 60% air, and acid etching with 37% phosphoric acid, using the Single Bond™ Plus, having the best adhesion strength (±14 MPa) using the excavator and etching for 15 s.[18]

In the paper by Botta *et al*., the adhesives Adper™ Single Bond, Clearfil ™ SE Bond, and One Up® F were tested in dentin prepared with the parameters 0.25 W, 50% air and with 20% water and without any water, resulting in better adhesion strength in the group which was used water during cavity preparation with Clearfil™ SE Bond (16.28 ± 2.93 MPa) [Table 4].[19]

The best result on bond strength (average about 41MPa) resulted from the use of self-etch adhesive Clearfil™ SE conditioned with 40% phosphoric acid for 30 s, as shown in Table 3. The second best result (average of approximately 39 MPa) was obtained with additional conditioning of 90% sodium hypochlorite gel for 90 s.[10]

The best results achieved with Er,Cr:YSGG and no additional conditioning of dentin was with the settings of 1.5 W, 140 µs of pulse duration, 30 Hz of frequency, 70% water, and 65% air, with the adhesive Clearfil™ SE [Table 4].

Discussion

In recent years, there has been a large development in technologies regarding the preparation of tooth surfaces,

Table 3: Shear bond strength of adhesives in dentin prepared with erbium, chromium:yttrium-scandium-gallium-garnet laser, conditioning type and laser settings

Adhesive	Paper	Conditioning	Etching time (s)	SBS (MPa)	Power (W)	Pulse duration (μs)	Frequency (Hz)	Water (%)	Air (%)
Adper™ single bond	Shahabi *et al*.[12]	Etching with 37% phosphoric acid	20	4.85 MPa	3.5W	140 μs	20 Hz	65	55
Single bond™	Ferreira *et al*.[16]	Etching with 35% phosphoric acid	60	8.80 MPa	4 W	140 μs	20 Hz	75	65
			30	10.69 MPa	4 W	140 μs	20 Hz	75	65
			15	12.38 MPa	4 W	140 μs	20 Hz	75	65
Adper™ single bond	Obeidi *et al*.[17]	Etching with 37% phosphoric acid	30	13.15 MPa	3 W	140 μs	20 Hz	70	60
			15	13.62 MPa	3 W	140 μs	20 Hz	70	60
Clearfil™ SE	Takada *et al*.[10]	Etching with 40% phosphoric acid	30	±41 MPa	2 W	140 μs	20 Hz	75	60

SBS: Shear bond strength; SE: Self-etch

such as the use of Er,Cr:YSGG laser.[20] In this sense, there has been a growing need to test, study, and understand how dental materials, which are designed to work in cavities prepared with conventional methods, would result in cavities prepared with laser.

In the case of adhesion to dentine, there are several factors that can influence adhesion including: the substrate, the type of treatment, and conditioning of the dentin.[21,22] In fact, adhesion to dentin was always a bigger challenge than adhesion to enamel because of its water content and collagen.[19]

There is a consensus, shown in several studies, that the dentin prepared with Er,Cr:YSGG laser presents a rough and uneven surface, with open dentinal tubules and no smear layer. The intertubular dentin undergoes greater ablation than the peritubular dentin, since it has a higher amount of water, resulting in dentin tubules protruded.[8]

All the features mentioned above should provide, in theory, good conditions for adhesion, if not better than the ones resulting from the preparation with handpiece.[19]

However, in many studies, it is seen that the bond strength in dentin prepared with Er,Cr:YSGG laser is still lower than the one achieved with handpiece preparation,[8,19,23,24] and the most suitable adhesive for use in this type of surfaces is still a controversial issue with no consensus.[25,26]

In the self-etch adhesive systems, the acids are weak, achieving adhesion to dentin through the conditioning and simultaneous infiltration of adhesive monomers, in the surface of the dentin.[13]

The self-etch adhesive systems theoretically would be most appropriate for use in laser-prepared dentine, and should obtain the best adhesion results.

Due to the heterogeneity of the laser parameters, the adhesive procedures and the adhesive materials used, it was not possible to carry out a meta-analysis, so it was performed an analysis of selected items from a descriptive point of view. There was also a risk of a potential bias in this review related to the language, since the selection was reduced to articles written in English only.

From the analyzed articles, it was found that the best results were obtained with the self-etch adhesive Clearfil™ SE with the settings 2 W, 75% water, 60% air, 140 μs pulse duration and 20 Hz and conditioning with 40% phosphoric acid;[10] and with the etch and rinse Single Bond™ (3M™), using 1.5 W, 70% water, 65% air, 140 μs pulse duration, and frequency of 30 Hz.[15,27]

On the other hand, in the study by Ramos *et al*., it was possible to compare the adhesion strength of Clearfil™ SE and Single Bond™ adhesives without acid etching, and despite having an adhesion strength (38.7 ± 16.5 MPa) slightly lower than the previous study, Clearfil™ SE continued to show the best result. In the same article, the adhesives Clearfil™ SE and Single Bond™ presented better results when tested in dentin surfaces prepared with diamond bur (47.9 ± 16.5 MPa and 41.0 ± 10.7 MPa, respectively).[11]

Also, Adebayo *et al.* tested the shear bond strength Clearfil™ SE in dentin prepared with diamond bur, getting better results than when using laser (13.0 ± 5.05 MPa vs. 9.0 ± 3.35 MPa).[14]

The worst bond strength results were recorded with the use of Scotchbond™ Multipurpose adhesive (average 3.5 MPa), Excite® (average 5.2 MPa) with the settings 2 W with 65% water, 55% air[13] and with Adper™ Single Bond (mean 4.85 ± 0.93 MPa) with 3.5 W, 65% water, 55% air, 140 μs pulse duration, and 20 Hz in dentin.[12] In all cases, etching was carried out with 37% phosphoric acid before application of the adhesive.

The adhesive Excite® and Adper Single Bond™ are both two-step adhesives, while Scotchbond™ Multipurpose is divided into three steps: etching, primer, and bonding.

Scotchbond™ Multipurpose and Excite® showed better shear bond strength with no acid etching prior to application of the adhesive, with average of 9.65 MPa and average of 9.02 MPa, respectively.[13]

Table 4: Shear bond strength of adhesives in dentin prepared with erbium, chromium:yttrium-scandium-gallium-garnet laser and laser settings

Adhesive	Paper	SBS (MPa)	Power (W)	Pulse duration (µs)	Frequency (Hz)	Water (%)	Air (%)
Adper™ single bond	Botta *et al*.[19]	5.59 MPa	0.25 W	140 µs	20 Hz	0	50
Clearfil™ SE	Adebayo *et al*.[14]	9.0 Mpa	3.5 W	140 µs	20 Hz	60	65
Adper™ single bond	Botta *et al*.[19]	11.90 MPa	0.25 W	140 µs	20 Hz	20	50
Clearfil™ SE	Botta *et al*.[19]	14.55 MPa	0.25 W	140 µs	20 Hz	0	50
Clearfil™ SE	Botta *et al*.[19]	16.28 MPa	0.25 W	140 µs	20 Hz	20	50
Clearfil™ SE	Takada *et al*.[10]	±21 MPa	2 W	140 µs	20 Hz	75	60
Single Bond™	Al-Ansari *et al*.[31]	22.44 MPa	1 W	140 µs	20 Hz	55	65
Single Bond™	Ramos *et al*.[27]	33.40 MPa	2 W	140 µs	20 Hz	75	60
Clearfil™ SE	Ramos *et al*.[27]	38.7 Mpa	1.5 W	140 µs	30 Hz	70	65

SBS: Shear bond strength; SE: self-etch

The use of phosphoric acid in dental surfaces prepared by laser dissolves the intertubular dentin causing a change in surface produced by the laser, leading to demineralization of the dentine to a depth unpredictable, which may interfere with the diffusion of the monomers.[28-30]

The laser parameters such as power, frequency, pulse duration, the percentage of water and air, and consequently the energy density, used in a given treatment, interfere with ablation and the type of final surface. Examples of that are the different bond strength results obtained with the same adhesive, Clearfil™ SE Bond, with the same application procedure, but different parameters. The settings of 1.5 W, 70% water, 65% air, 140 µs pulse duration and frequency 30 Hz, energy density of 4.5 J/cm^2 resulted in a bond strength of 38.7 ± 16.5 MPa, while the settings of 3.5 W, 60% water and 65% air, and an energy density of 109.4 J/cm^2 resulted in 9.0 ± 3.35 MPa.[11,14] This means that the settings of the laser device might play an important role in the bond strength of the adhesives.

The Clearfil™ SE Bond has in its composition the MDP monomer (10-Metacriloiloxidecil dihydrogen phosphate), and a molecule, according to the manufacturer, with better capacity for chemical adhesion to the structure of tooth, enamel, and dentin. This might be the reason why it showed better results.

According to Takada *et al.,* the application of phosphoric acid after laser preparation of dentin resulted in widely open dentin tubules and intertubular dentin protruded. These findings might explain why there were better adhesion results with application of phosphoric acid in lased dentin.[10]

All dental products on the market are designed to operate on tooth surfaces prepared with handpiece, thus all studies conducted end up testing these products. However, the results should be used to develop new products, taking into account the characteristics of the prepared tooth surfaces with a laser.

Conclusions

The adhesive that showed the best shear bond strength results was the two steps self-etch adhesive, Clearfil™ SE after conditioning with 40% phosphoric acid, with the settings 2 W, 75% water, 60% air, 140 µs pulse duration, and 20 Hz (energy density 50.96 J/cm^2). The laser parameters used in a particular treatment seem to interfere with the type of final surface and bond strength of the adhesive.

The results of this systematic review show a kind of adhesive and specific laser settings that might be useful to develop new investigation that could lead to new products and to the best preparation of tooth surfaces with a laser device.

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Conflicts of interest

There are no conflicts of interest.

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