



Review

Efficacy of phototherapy in the adhesive bonding of different dental posts to root dentin: A systematic review

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ABSTRACT

Background: The aim of the current systematic review was to evaluate the efficacy of phototherapy in the adhesive bonding of different dental posts to root dentin.

Methods: The outline of this systematic review followed the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) guidelines. Searches in both electronic and manual literature were performed in the main databases 'MEDLINE' and 'EMBASE' up to March 2019 using the following terms: (Phototherapy) AND (push out test) AND (bond strength) AND (post) OR (fibre) OR (metal) AND (smear layer).

Results: Six in-vitro studies were included and processed for data extraction. All studies incorporated the use of fiber posts. The mean shear bond strength for test group ranged from 2.23 to 15.17 MPa while mean shear bond strength for control group ranged from 2.93 to 9.38 MPa. The wavelengths of diode lasers ranged from 660 to 2940 nm (nm). Power was reported in 5 studies ranging from 0.075 W to 3 W. All studies compared shear bond strength of phototherapy in the adhesive bonding of different dental posts to root dentin. In all the included studies, greater bond strength achieved by phototherapy compared to nonirradiated group.

Conclusion: Within the limits, this study shows that the dentin to post bond strength was significantly enhanced by phototherapy.

1. Introduction

Severely cavitated teeth require endodontic treatment and its restoration. This restoration brings back the form and function of tooth structure that was lost either due to caries, fracture or restorative procedures [1,2]. There is increasing demand for non-metal restorations and esthetic restorative materials such as prefabricated fibreglass posts which have increasingly replaced the conventional cast-metal cores allowing higher retention of restoration [3].

Posts become necessary where severe cavitation exists. Posts are cemented with the help of resin cement that relies on the bond between the root canal surfaces and posts which is achieved with the help of adhesives [4]. To achieve significant amount of adhesion, suitable modifications of the surfaces (enamel and/or dentin and posts) is needed [4]. Research by Bitter et al. [5], showed superior bond strength scores with the use of Rely-X Unicem when compared with other materials, while other studies demonstrated decreased bond strength [6–8]. There are varying results with regards to the regional differences in bond strength at different levels of root canal [9–11]. Gaston et al. [12] reports that the acceptable conditions of adhesion were found

mainly in the apical and cervical thirds of root canals. These results vary from the outcomes of other research at ultrastructural level, which revealed that the most reliable bond strength was generally observed in the cervical third, due to the comfortable access [13]. Moreover, the bonding procedure in the root canal wall is complex due to the dentin structure and, with this to the chemical constituents regularly used to increase adhesion to dentin structure, such as adhesive systems, other technologies have been investigated for the treatment of root canal dentin to improve bond strength [13,14].

Phototherapy have widely been used in dentistry as an adjunct to treat numerous oral disorders [15–20]. Furthermore, phototherapy has been found to improve bond strength of resin cement to zirconia ceramics and for modifying dentin surface for effective cement adhesion to dentin of the root surface [21,22]. Several studies reports statistically significantly higher bond strength when root surface was irradiated with phototherapy compared with no phototherapy [22–24]. However, to the best of the authors knowledge, there has been no systematic review published that evaluated the efficacy of phototherapy on shear bond strength and thus improving post retention to root dentin. Therefore, the aim of the current systematic review was to

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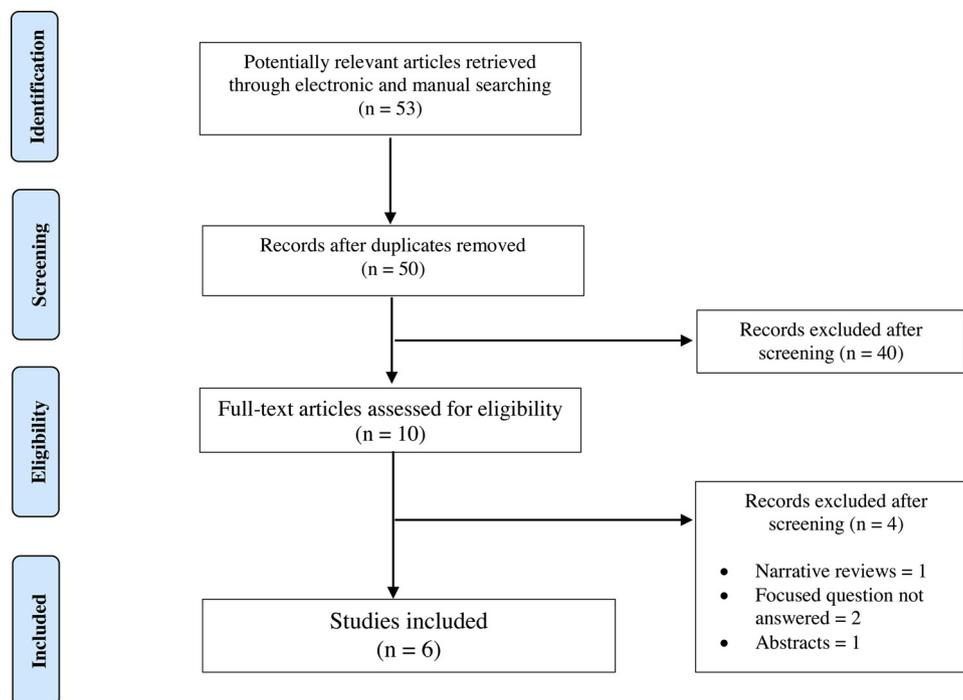


Fig. 1. PRISMA flow diagram for studies retrieved through the searching and selection process.

evaluate the efficacy of phototherapy in the adhesive bonding of different dental posts to root dentin.

2. Materials and methods

2.1. Study protocol

The outline of this systematic review followed the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) guidelines [25].

2.2. Eligibility criteria

Only *in-vitro* studies were considered which included study teeth that have undergone endodontic treatment in correspondence with post application and comparing efficacy of phototherapy with other modalities/no light therapy with push out bond strength as outcome measure. Articles published in other than English language, *ex-vivo* studies, narrative reviews, unpublished data, letters to the editor were not incorporated in the current review.

2.3. Search strategy

Searches in both electronic and manual literature were performed in the main databases 'MEDLINE' and 'EMBASE' up to March 2019 using the following terms: (Phototherapy) AND (push out test) AND (bond strength) AND (post) OR (fibre) OR (metal) AND (smear layer). The authors individually performed the screening of the titles and selection process for eligible articles. If data pertinent to the inclusion criteria was not found in the abstract, or if the abstract was missing, the article was chosen for full-text reading. Subsequently, full-text articles that satisfied the inclusion criteria were recognized and included in the systematic review. Reference lists from original studies were manually hand searched to identify papers that may have missed during the electronic data search. Manual hand searching of the following peer-reviewed journals was performed: Photomedicine and Laser Surgery, Laser Therapy, Acta Odontologica Scandinavica, Photodiagnosis and Photodynamic Therapy and Lasers in Medical Science. Published

studies that satisfied the inclusion criteria were handled for data abstraction.

2.4. Data items and abstractions

The details of the data from the accepted studies were charted according to the research designs, author/country, involved teeth, phototherapy administration, type of post administered, main results and mean shear bond strength outcomes. Data gathered were constructed on the focused question summarized for the current review.

2.5. Quality assessment

Quality assessment of the included *in-vitro* studies was assessed by undergoing risk of bias across studies. The parameters evaluated were: randomization of teeth, caries free teeth, blinding, control groups, similar dimension samples, assessment of the failure mode, description of coefficient of variation, and sample size calculation. Each parameter received a 'Yes' if the details are reported in the paper, otherwise the parameter is reported as 'No'. Studies covering one to three points were regarded as high risk of bias studies, whereas four to five and six to eight were considered as medium and low risk of bias, respectively.

3. Results

3.1. Search results

A total of 53 study titles and abstracts were initially identified. After removal of the duplicates ($n = 3$), initial screening of titles and abstracts was performed, and 40 articles were excluded as irrelevant to the focused question. A total of 10 papers were selected for full-text reading. Of these 10 articles, 4 studies were further excluded (reasons reported in Fig. 1). After the final stage of selection, 6 studies were included and processed for data extraction [22–24,26–28] (Fig. 1).

3.2. General description of included studies

Table 1 describes the general characteristics of the included studies.

Table 1
Descriptive analysis of the included studies.

Author et al., Journal name	Country of study	Teeth involved	Posts used (company name) Type; number; diameter	Shear bond strength test	Main Outcome	Funding
Garcia et al. [22]; <i>Acta Odontologica Scandinavica</i>	Brazil	40 extracted maxillary canines	Fiber glass (NA); 2; 1.3 mm	0.5 mm/min head speed in the universal testing machine (Instron 4411; Instron, Corona, CA)	Greater bond strength achieved by phototherapy compared to nonirradiated group	Not mentioned
Garcia et al. [23]; General Dentistry	Brazil	50 human maxillary canines	Fiber glass (Angelus Dental Industry Products S/A); 2; 1.3 mm	0.5 mm/min head speed in the universal testing machine (Instron 4411, Instron)	Greater bond strength achieved by phototherapy compared to nonirradiated group	Not mentioned
Mohammadi et al. [24]; <i>Lasers in Medical Science</i>	Iran	30 human sound maxillary central incisors	Fiber glass (Endolight Post; RTD, St. Egervre, France); 100; NA	0.5 mm/min head speed in the universal testing machine (HSK-S; Hounsfield Test Equipment, Salfords, UK)	Greater bond strength achieved by phototherapy compared to nonirradiated group	University funded
Tuncdemir et al. [26]; <i>The Journal of Advanced Prosthodontics</i>	Turkey	55 maxillary central incisors	Fiber glass reinforced composite (Snowlight Post, Abrasive technology, OH, USA); 14; 1.4 mm	1 mm/min head speed in the universal testing machine (AGS-X, Schimadzu Co., Kyoto, Japan)	Greater bond strength achieved by phototherapy compared to nonirradiated group	Not mentioned
Ekim & Erdemir [27]; <i>Lasers in Medical Science</i>	Turkey	32 recently extracted maxillary central teeth	Fiber post (White Post DC, FGM); NA; NA	0.5 mm/min head speed in the universal testing machine (Lloyd Instruments, UK)	Greater bond strength achieved by phototherapy compared to nonirradiated group	University funded
Strefezza et al. [28]; <i>Photomedicine and Laser Surgery</i>	Brazil	90 recently extracted single rooted human teeth	Prefabricated fiber post (Ivoclar/Vivadent, Schaan, Lichenstein); NA; NA Metal cast silver-palladium alloy (Pratalloy; Dentsply, R.J, Brazil); NA; NA	0.5 mm/min head speed in the universal testing machine (Instron 5567, Norwood, MA)	Greater bond strength achieved by phototherapy compared to nonirradiated group	Privately funded

NA: not available.

Table 2
Mean shear bond strength values in test and control groups.

Author et al	Randomization of teeth	Carries free teeth	Blinding	Control groups	Similar dimension samples	Assessment of failure mode	Description of coefficient of variation	Sample size calculation	Risk of bias
Garcia et al. [22]	Yes	No	No	Yes	Yes	Yes	No	No	Medium
Garcia et al. [23]	Yes	No	No	Yes	Yes	Yes	No	No	Medium
Mohammadi et al. [24]	Yes	Yes	No	Yes	Yes	Yes	No	No	Medium
Tuncdemir et al. [26]	Yes	No	No	Yes	Yes	Yes	No	No	Medium
Ekim & Erdemir [27]	Yes	No	No	Yes	Yes	Yes	No	No	Medium
Strefezza et al. [28]	Yes	No	No	Yes	Yes	Yes	No	No	Medium

RX/LI – Rely X Unicem/Low irradiation; RX/NI/ – Rely X Unicem/no irradiation; CP/LI – Cement post/low irradiation; CP/NI – Cement post/no irradiation; W -watts; Hz – hertz; CW – continuous wave; * values for cervical areas of root; † values for middle areas of root; € values for apical areas of root; α values for coronal part of the root; β values for apical part of the root, NA: not available.

All studies were categorized as in-vitro studies. Three studies were performed in Brazil [22,23,28], two were performed in Turkey [26,27] and one was performed in Iran [24]. All studies incorporated the use of fiber posts. Mean shear bond strength was tested using 0.5 mm/min head speed in the Universal mechanical testing machine in 5 studies [22–24,27,28], whereas, the remaining one study used head speed of 1 mm/min [26]. Two studies [24,27] had their funding source mentioned as University funding, 1 study had private funding [28], whereas 3 studies did not mention anything about funding source [22,23,26]. The mean shear bond strength for test group ranged from 2.23 to 15.17 MPa while mean shear bond strength for control group ranged from 2.93 to 9.38 MPa in the included studies (Table 2).

3.3. Phototherapy parameters of the included studies

Out of all the studies included, two studies reported the use of gallium-aluminium arsenide (GaAlAs) laser [22,23], 1 study used erbium,chromium:yttrium scandium gallium garnet (Er,Cr:YSGG) [24], 1 study used neodymium:yttrium–aluminum-garnet (Nd:YAG), mid-infrared erbium:yttrium–aluminium garnet (Er:YAG) and photon-induced photoacoustic streaming [27]. The wavelengths of diode lasers ranged from 660 to 2940 nm (nm). Frequency was reported in 3 studies [22,23,27]. Power was reported in 5 studies ranging from 0.075 W (W) to 3 W [22–24,26,27]. One study [27] reported pulse duration and pulse energy each. Only 4 studies reported optic fibre diameter as 200, 200 and 300 μm respectively [22,23,27,28]. None of the included studies reported energy density and number of laser sessions (Table 3).

3.4. Main outcomes of the studies

All studies compared shear bond strength of phototherapy in the adhesive bonding of different dental posts to root dentin. In all the included studies, greater bond strength achieved by phototherapy compared to nonirradiated group.

3.5. Risk of bias across studies

All studies showed medium risk of bias [22–24,26–28]. The sections that did not attain scores were blinding, description of coefficient of variation and sample size calculation. Only 1 study reported about caries free teeth [24]. On the other hand, all studies reported about randomization, control groups, similar dimension samples and assessment of failure modes (Table 4).

4. Discussion

To the authors' knowledge, this is the first systematic review conducted to investigate the effect of phototherapy in the adhesive bonding

of different dental posts to root dentin. The present systematic review hypothesized that phototherapy is effective in significantly increasing bond strength of dental posts to root dentin. Overall, 100% of the included studies indicated that the dentin to post bond strength was significantly enhanced by phototherapy [22–24,26–28].

The premise of root canal irrigation that helps to effectively increase the bond strength may very well be explained by the removal of smear layer and remaining gutta-percha from the root preparation and endodontic sealers from the dentine root canal surface. The smear layer produced by post space preparation should be removed according to some authors owing to the increase of antibacterial effects [29–31] and also adhesive effectiveness [32] as it becomes porous and the authors insisted that the smear layer causes a weak adherent interface between cement and dentin. On the other hand, other authors insist upon retaining smear layer for adaptation of the materials to root surface [33]. In addition, Souza et al. [34] have showed the presence of photosensitizer in the root canal walls after final irrigation protocols. The same authors revealed low bond strength values when the photosensitizer removal is not performed by final irrigants and ultrasonic activation [35,36]. In the study by Tuncdemir et al. [26], it was shown that using the photodynamic diode laser in post space increased the bond strength of resin cement to dentin interface, as compared with other surface treatment methods. It is important to improve the bonding effectiveness of the resin and dentin for post restoration success with removal of the smear layer and formation of the resin-dentin interdiffusion zone [37,38].

Laser devices have been used in root canal treatment since the early 1970s [39], but their acceptance has been very slow. General causes of dissatisfaction have included thermal damage caused by the laser photonic energy [40]. Therefore, the photonic energy should be at its lowest possible level to eliminate thermal damage. The principle of phototherapy or the reason why such treatment modality improve bond strength may be explained by the effects of the heat produced by lasers during thermomechanical processes that appear as liquefaction, recrystallization, changes in the size of mineral particles, carbonization and formation of small cracks. These complex processes may influence the strength of the bond between the dentin matrix and the adhesive system [41]. It has been reported that as the diode-laser treatment ($\lambda=810\text{ nm}$) partially opened dentinal tubules, signs of fusions and temperature increase at the root surfaces were observed [42]. On the other hand, a study conducted by Altundasar et al. [40] after irradiation with a 980-nm diode laser (GaAlAs) (with 2 times more power) had opposite results and two-fold increase in temperature at the root surface was observed. To avoid the temperature rise, lower irradiation power was used for this study ($\lambda=660\text{ nm}$), and it was enough to improve bonding effectiveness at the cement-dentin interface.

The critical factors affecting the bond strength between the post and root dentin are the type of laser and the laser parameters used. There was

Table 3
Phototherapy related parameters of the included studies.

Author et al	Type of laser	Wavelength (nm)	Frequency (Hz)	Pulse duration (μs)	Power (W)	Pulse Energy (mJ)	Optic fibre diameter (μm)	Energy density (J/cm^2)
Garcia et al. [22]	GaAlAs	980	100	NA	1.5	NA	200	NA
Garcia et al. [23]	GaAlAs	980	100	NA	1.5	NA	200	NA
Mohammadi et al. [24]	Er,Cr: YSGG	NA	NA	NA	0.5	NA	NA	NA
Tuncdemir et al. [26]	Diode	660	NA	NA	0.075	NA	NA	NA
Ekim & Erdemir [27]	Diode	810	NA	NA	1.2	NA	300	NA
	Nd:YAG	NA	15	NA	1.5	100	300	NA
	Er:YAG	2940	10	1000	0.5	50	300	NA
	laser-PIPS	2940	15	50	0.3	20	300	NA
Strefezza et al. [28]	Diode	830	NA	NA	NA	NA	300	NA

GaAlAs – gallium aluminium arsenide diode laser; Er,Cr:YSGG – erbium,chromium:yttrium scandium gallium garnet; Nd:YAG - neodymium:yttrium–aluminum-garnet; Er:YAG - mid-infrared erbium:yttrium–aluminum-garnet; PIPS - photon-induced photoacoustic streaming; nm – nanometer; Hz – Hertz; μs – microseconds; W – watts; mJ – microjoules; μm – micrometer; J/cm^2 – joules per square centimetre; NA – not available.

Table 4
Quality assessment of include studies.

Author et al	Randomization of teeth	Caries free teeth	Blinding	Control groups	Similar dimension samples	Assessment of failure mode	Description of coefficient of variation	Sample size calculation	Risk of bias
García et al. [22]	Yes	No	No	Yes	Yes	Yes	No	No	Medium
García et al. [23]	Yes	No	No	Yes	Yes	Yes	No	No	Medium
Mohammadi et al. [24]	Yes	Yes	No	Yes	Yes	Yes	No	No	Medium
Tuncdemir et al. [26]	Yes	No	No	Yes	Yes	Yes	No	No	Medium
Ekim & Erdemir [27]	Yes	No	No	Yes	Yes	Yes	No	No	Medium
Strefezza et al. [28]	Yes	No	No	Yes	Yes	Yes	No	No	Medium

a significant methodological heterogeneity and incomplete information about phototherapy parameters in the included studies. Other factors, for example, fiber diameter could influence power density and energy output in the application of phototherapy and could alter the certain amount of energy released during the process, likely affecting the bonding effect of phototherapy [43]. Since the most important effect of laser is to convert radiant energy to heat (the thermo-mechanical effect), absorption of laser energy by the surface of the material is the most important interaction between the material and phototherapy. Therefore, selection of appropriate laser parameters to change the surface properties of the zirconia surface is of utmost importance.

Effective bond strength is determined by the orientation and the number of dentinal tubules present inside the dentine that relates to the high area of bond strength with higher number tubules. There are approximately 40,000 tubules/mm² dentinal tubules in the cervical and middle thirds of the root that provides a significant area for dentin-bonding adhesives to penetrate, thereby increasing the quantity of mechanical tags that occur between dental cements and root dentin [29]. Not all studies exclusively assessed and compared the bond strength between dental posts and dentin using phototherapy in the cervical and middle thirds of the root dentin. This however, should be studied in future research that compares bond strength in the cervical, middle and apical thirds and relating the effectiveness with the high mechanical interlocking of the cements into the tubules.

With regards to the limitation, it is noteworthy that only 2 authors performed screening and data abstraction without the involvement of the third assessor. The involvement of multiple authors performing independent screening could result in the inclusion of pertinent studies being missed from screening and data extraction by single author alone. Furthermore, the limited number of studies is another important limitation that should be taken into account. More number of included studies with quantitative data assessment would help us to evaluate the actual bond strength necessary for effective bond integrity. Moreover, only 2 databases were considered for paper selection. These methodological shortcomings should be considered when interpreting the findings of the current study.

5. Conclusion

Within the limits, this study shows that the dentin to post bond strength was significantly enhanced by phototherapy.

Conflict of interest

None declared.

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