



Examining the Effect of Laser Radiation on the Repair of Dental Composite Restorations: A Systematic Review

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Abstract

Background: This study aimed to determine the impact of laser radiation on the repair bond strength of dental composite restorations by gathering, assessing, and systematically reviewing previous articles referring to this issue.

Methods: Several previous studies relevant to the objectives of this research were found in PubMed, Scopus, and Web of Science databases. All prior articles indexed in these databases according to the selected keywords until 2018 were gathered and assessed. Some article abstracts showed the necessary basic conditions for inclusion in the study. Therefore, the full texts of these relevant articles were further evaluated in terms of the study objectives.

Results: A total of 300 relevant articles were obtained by searching the databases. Eight studies remained highly relevant after performing a title review, eliminating the duplicate articles, and implementing the selection criteria. The latest study was conducted in 2018. A statistically significant difference was observed between the impacts of laser and other methods in the seven of these final relevant studies. Of these articles, five indicated a better impact in the case of other methods, particularly the dental milling technique, and one study was related to the impacts of the laser method. Additionally, the Er,Cr: YSGG laser was considered the most adequate laser in these studies.

Conclusions: According to the review of prior studies on the impact of laser radiation on the repair bond strength of composite restorations, Er: YAG and Er,Cr: YSGG lasers are advised for surface preparation of composites. However, surface preparation by adopting the milling technique remains the adequate choice for repairing composites.

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Background

The demand for cosmetic restorations, the emergence of novel adhesives and curing systems alongside the progress made in material properties have rendered dental composites as the most prevalent direct restoration materials (1). Resin-based composites are materials selected for the restoration of anterior and posterior teeth. The annual failure rate for anterior and posterior composite restorations ranges approximately between 1% and 4% (2,3). Shrinkage resulting from polymerization, also known as polymerization shrinkage, is still regarded among the most critical consequences of conventional methacrylate-based composites (4). Shrinkage may cause microleakage, edge discoloration, and gap formation, further acting as one of the primary determinants in the occurrence of secondary caries (5). In most cases, intra-oral repair of restorations is preferred to total replacement (6).

However, defective restorations should be examined thoroughly for repair. Moreover, according to the

Highlights

- ▶ The use of milling is still the best choice for repairing composite
- ▶ The use of Er,c: YSGG and Er:YAG laser is recommended for composite surface preparation

concept of minimally invasive restorative dentistry, total replacement should be avoided, except in cases where a fracture in the composite, discoloration of the resin contact surface with the tooth, and secondary caries are observed (7). This method helps to preserve healthy dental tissues (8).

The dentist has three main methods to deal with defective restorations in the composite restoration failure cases, namely restoration, repair, and replacement. Restoration implies that no extra material or dental structure will be removed; however, additional restorative material will be applied to fix the defective structure (9,10). Meanwhile, the repair is a process that involves the relative removal of a defective repair, which is then repaired with brand new materials (10). Replacement involves complete removal of

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the defective composite (even clinically acceptable parts) to replace it with new material. Practically, the removal of a healthy tooth is inevitable in this method (11). Studies have shown that composite repair procedures may prolong the life of dental restorations (12,13).

Brosh et al indicated that devising a single bond between the old and the new composite during the repair process is attainable through three respective mechanisms, namely (a) chemical bond to the organic matrix, (b) chemical bond to the exposed fillers, and (c) micromechanical trap (8). Preceding studies have determined the efficacy of micromechanical traps created by diamond milling, sandblasting, or acid etching in the bond strength of repaired composites (14).

The use of lasers is another technique for generating surface abrasion. According to studies, Erbium group lasers, namely Nd: YAG and CO₂ Cr: YSGG, have been employed in this process. It has been confirmed that Er: YSGG laser can be employed in dentistry for the removal of tooth decay and conditioning of dental surfaces, enamel, and dentin purposes. Özel Bektas et al examined the impact of Er: YAG laser, milling, and thermal cycle on the shear bond strength of repaired composite resins. The laser and milling procedure samples were confirmed to display similar results following the shear bond strength test. Aging with 10000 thermocycles significantly affected the restoration bond strength of composite resins (13).

Nevertheless, the results are not consistent in all cases. Accordingly, we tried to gather several articles in this field and review their results as an approach to examine the impact of laser application on the repair process of composite restorations given the extended use of lasers in modern dentistry and considering numerous prior studies that have produced diverse results. Furthermore, this study aimed to demonstrate the importance of restoring dental composites rather than replacement.

Materials and Methods

Protocol, Registration, Search, and Study Selection

The previous studies were searched in three international databases: Web of Science, PubMed, and Scopus. The selection procedure was conducted up to the publication date (2018). The adopted search strategy was Laser AND Composite repair AND Surface treatment. Additionally, reference and source lists, along with the related articles, were similarly reviewed to increase the search sensitivity (Figure 1).

Inclusion Criteria

- All types of composites employed for dental composite repair studies
- All types of lasers employed in dental composite repair studies
- All surface preparation methods employed for the composite repair process
- All types of aged or non-aged dental composites

- All types of dental or composite samples for dental composite repair studies

Data Collection

We devised a data extraction form to gather the data, which included research information such as the corresponding author's name, year of publication, country, journal name, sample size, mean, and standard deviation. Following the extraction, the retrieved articles from various databases were imported into the Endnote software and duplicate articles were eliminated. The respective titles and abstracts of the remaining relevant articles were then examined. At this point, articles that had examined the impact of laser application on the repair process of composite restorations were incorporated into the study.

Risk of Bias Across Studies

Two faculty members assessed each article at three levels of low, average, and adequate.

Results

A total of 300 relevant articles were obtained from three respective databases, namely Web of Science, PubMed, and Scopus. Eight studies remained relevant (4,15-21) after reviewing the title, eliminating duplicate articles, and evaluating the study selection criteria. The majority of these eight selected studies have been conducted in Iran, and the most recent study belonged to 2018 (20). The obtained studies indicated that three types of lasers including Er, Cr: YSGG, CO₂, and Nd: YAG were studied and compared with the aid of methods including air abrasion, milling, silane, hydrofluoric acid, aluminum oxide, and sandblast. The highest bond strength (30.44) was reported by Dinç Ata et al (20) using the Er, Cr:

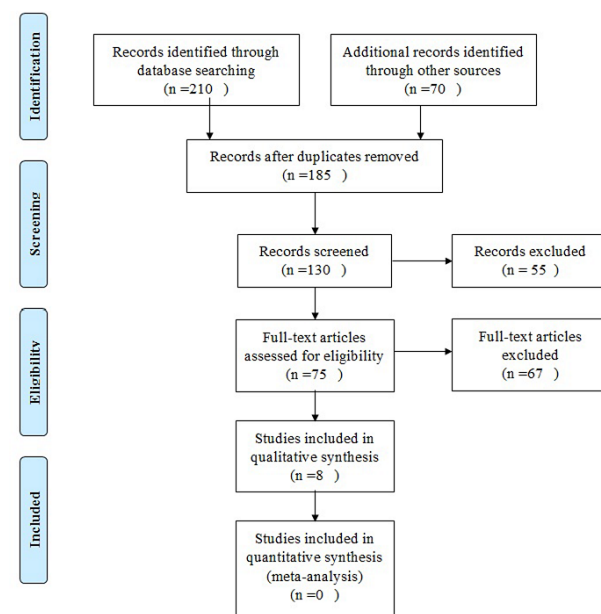


Figure 1. Flowchart of the systematic review

YSGG laser. The lowest bond strength (4.75) pertained to a study done by Kiomarsi et al in 2017 (17). Moreover, the highest average bond strength of other methods (33.85) was also employed by Dinç Ata et al (20) using the milling method. On the other hand, the lowest average bond strength (2.60) was reported by Barcellos et al using silane and hydrofluoric acid (15). A statistically significant difference was observed between the impacts of laser and other methods in the seven of these final relevant studies, of which five studies indicated a better impact in the case of other methods, particularly dental milling technique, and one study dealt with the impacts of the laser method. Additionally, the Er, Cr: YSGG laser was deemed the most adequate laser in these studies (see Table 1).

Discussion

In this study, an attempt was made to compare the impact of laser radiation on the bond strength of the composite repair process and the other methods. The results obtained from prior studies reveal that the laser radiation method

has an inadequate impact on bond strength compared to the other surface preparation methods. On the contrary, the laser displayed a more remarkable impact compared to the other methods used in a study by Alizadeh Oskoe et al, although this difference was not statistically significant (16). Dinç Ata et al (20) further showed that the highest bond strength obtained belonged to the milling method. Rodriguez et al and Costa et al in scanning electron microscope (SEM) evaluations of sandblasted composite surfaces revealed that slight surface roughness expands the surface area available for the bond, and thus reinforces the bond strength by implementing this preparation method (22,23). Denehy et al suggest that the success of composite resin repair depends on two measures, namely surface preparation and proper application of the adhesive system (24). According to Brosh et al, a solid bond can be formed between the new and old composites during the repair process through three respective mechanisms 1) chemical bonding to the organic matrix, 2) chemical bonding to the exposed fillers, and 3) micromechanical

Table 1. Descriptive Characteristics of the Studies Entered the Systematic Stage of the Review

Author	Study Place	Year	Volume Sample	Method	Average (Bond Strength)	Standard Deviation (Bond Strength)	Highest Average Bond Strength In Each Study	Reference	Quality
Barcellos et al	Brazil	2015	84	Laser	7.50	3.50	Scotchbond	15	Adequate
				Scotchbond	9.50	4.60			
				Sandblast	18.70	4.60			
				Aluminum oxide	18.80	4.70			
				Silane	2.60	2.30			
				Hydrofluoric acid	2.60	3.80			
Alizadeh Oskoe et al	Iran	2017	76	Er,Cr:YSGG laser	8.99	1.16	Er,Cr:YSGG laser	16	Adequate
				CO ₂ laser	7.20	1.27			
				Nd;YAG Laser	7.33	1.16			
				No treatment	6.69	1.68			
Kiomarsi et al	Iran	2017	120	Laser	4.75	1.73	Milling	17	Average
				Milling	13.85	2.50			
Duran et al	Turkey	2015	60	Laser	19.65	0.72	Sandblast	18	Adequate
				Sandblast	33.41	1.16			
Cho et al	USA	2013	60	Laser	14.20	1.40	Air abrasive	19	Adequate
				Air abrasive	18.8	1.3			
				Tribochemical	17.4	1.4			
Dinç Ata et al	Turkey	2018	60	Er,Cr:YSGG laser	30.44	7.30	Milling	20	Adequate
				Nd;YAG laser	19.96	4.68			
				Milling	33.85	11.30			
Rossato et al	Brazil	2009	60	Aluminum oxide	8.91	2.53	Aluminum oxide	21	Adequate
				Er,Cr:YSGG Laser	7.67	1.66			
				Milling	8.47	0.75			
Malekipour et al	Iran	2016	32	Sandblast	19.51	1.56	Sandblast	4	Average
				Silane	10.05	2.70			
				Er,Cr:YSGG Laser	16.46	1.65			

trapping (14). The same type of chemical bond between new and old monomers is suggested similarly in the process of repairing methacrylate bases with composites. However, relying on this type of bond without any surface preparation has not presented satisfactory results given the inadequate number of free radicals remaining during artificial or natural aging (22,23,25). Consequently, it is necessary to utilize valid surface preparation methods to attain convenient contact levels. However, a chemical bond between the two matrices is not conceivable in the case of methacrylate to silane-based bonds, given the distinct types of monomers and their unique polymerization methods. As a result, the other two previously discussed mechanisms are relevant in building an adequate bond (26). Several surface preparation methods have been proposed to increase micromechanical adhesion and the wettability of older composites, such as acid etching, milling, sandblasting, and laser radiation methods, respectively (27). Immediate repair of composite bond strength such as the cohesive strength repair brings forth the presence of an oxygen inhibitory layer. Nevertheless, further determinants such as the decrease concerning the number of active monomers, polishing, and structural change alter the composite bond strength, repair procedure, and post-aging process (28).

Differences observed in the matrix polymer structure and fillers can lead to consequent differences in bond strength (24,29). Beyer et al showed that the optimal clinical bond strength is equal to 60%-70% of the cohesive strength (23). An enamel composite strength that ranges between 15 and 30 MPa under clinical conditions is deemed adequate in this regard (30-32). Some authors maintain that the resulting interface bond must amount to higher than 18 MPa, or may range between 20 and 25 MPa, to be considered valid and perform adequately under clinical conditions (33,34). With the above explanations in mind, it is resolved that sandblasting with alumina or Erbium laser methods should be utilized in the composite repair processes (both methacrylate-based and silane-based), and disregarding the surface preparation process or silane use are not sufficient to obtain the adequate bond strength (5). The present study indicates that the highest bond strength obtained belonged to the milling method, followed by the laser preparation method, and then the sandblasting method. The use of Erbium laser in the removal of dental cement, as well as the associated selective ablation in the composite restoration procedures, has been further evaluated (35). Composite ablation with Er: YAG laser is performed through explosive evaporation, followed by hydrodynamic launching. Strong expansion forces are generated during this process of rapid melting and volume change is observed in the material. Protrusions emerge on the surface, and the molten material is subsequently withdrawn from the surface in the form of droplets due to the interaction of the generated forces and the structure of the composite (26,36,37). Accordingly, it

appears that laser irradiation is not convenient for surface preparation of aged silane-based composites (38). The morphological properties of the surface resulting from laser ablation depend on the features of the radiated laser beam and the composite structure it impacts (13). Alizadeh Oskoe et al assessed the impact of various surface preparation methods, including sandblasting, Er: YAG laser, and diamond milling, on the bond strength of repaired silane-based composites. The results showed that both laser and diamond milling methods had performed effectively in repairing silane-based composite, indicating that the results of these two methods were superior to the sandblasting method. However, the laser bond strength was observed to be higher than the sandblast bond strength in a study by Alizadeh Oskoe et al, which is contrary to the results obtained from the present study. This disparity may be due to the differences in laser parameters of the two studies. Nevertheless, more SEM studies are required to compare the laser-irradiated and sandblasted surfaces (39). The findings of recent studies suggested that although the bond strength repair procedure by laser has been more prevalent compared to the other methods, this difference is not statistically significant ($P > 0.05$). A recent study has detailed the efficacy of the composite repair method using the Er, Cr: YSGG laser (40). The blue laser cuts the hard tissue with the aid of particles and high energy. Water molecules with surface energy wear the composite to maintain the surface temperatures low, leading to a decrease in the probability of the formation of subsurface microcracks that function as stress enhancers in the future. Water molecules with surface energy also generate a clean surface by eliminating composite debris during the abrasion process. This situation may provide a better composite strength repair outcome than the Nd: YAG application adopted in this study. Nevertheless, further studies are required to illustrate the advantages of employing Er, Cr: YSGG lasers in composite repair processes (41,42).

Limitations of the Study

1. The number of relevant articles or prior studies was limited and thus more studies are suggested to be conducted in this regard.
2. We could not conduct a meta-analysis due to the major disparities observed between studies, including differences between lasers, comparison groups, composite types, etc.

Conclusions

Er: YAG and Er,Cr: YSGG lasers are advised for surface preparation of composites according to the review of prior studies on the impact of laser radiation on the repair bond strength of composite restorations. However, surface preparation by adopting the milling technique remains the adequate choice for repairing composites.

Authors' Contribution

FM as the responsible author - LR as the supervisor - YM as the statistical consultant participated in this study.

Ethical Statement

Not applicable.

Conflict of Interest Disclosures

The authors declare that they have no conflict of interests.

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