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Original Article

Effect of 940nm Diode Laser Irradiation on Microtensile Bond Strength of an Etch and Rinse Adhesive (Single Bond 2) to Dentin

Shahin Kasraei [1], Ebrahim Yarmohamadi [2], Pegah Ranjbaran Jahromi [3], Mahdi Akbarzadeh [4]

[1] Dept. of Restorative Dentistry, Dental School, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[2] Dept. of Restorative Dentistry, Dental School, Hamadan University of Medical Sciences, Hamadan, Iran.
[3] Post Graduate Student, Dept. of Restorative Dentistry, Dental School, Hamadan University of Medical Sciences, Hamadan, Iran.
[4] Cellular and Molecular Research Center, Research Institute for Endocrine Science, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

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ABSTRACT

Statement of the Problem: Laser can influence bonding mechanism by increasing the penetration depth of adhesive in smear layer. The effect of 940 nm diode laser on microtensile bond strength of adhesive to dentin has not been investigated in previous studies.

Purpose: The aim of this study was to evaluate the effect of 940 nm diode laser irradiation on microtensile bond strength of Single Bond 2 to dentin.

Materials and Method: Thirty sound premolars extracted for orthodontic reasons were randomly divided into five groups as follows: G1 or control: etching+ Single Bond2 (SB); G2: diode laser (940 nm wavelength, 1W power, continuous mode)+ etching+ SB; G3: etching+ laser irradiation+ SB; G4: etching+ SB+ laser irradiation+ adhesive curing; G5: etching+ laser irradiation+ SB +laser irradiation +adhesive curing. After the bonding procedure, Z250 composite resin was applied on the dentin surface in three layers of 2 mm thickness. After 24 hours of immersion in distilled water at 37°C and thermocycling for 1000 thermal cycles, the teeth were sectioned into 1mm^2 sticks. The microtensile bond strength was measured using a universal testing machine. Bond strength (MPs) was analyzed by one-way ANOVA followed by HSD post hoc Tukey's test (α=0.05).

Results: G4 (38.35±8.99) showed the significant highest bond strength compared to other groups (p= 0.000). G5 (25.16±6.14) showed significantly higher bond-strength than the control group (18.85±4.79) (p= 0.032).Bond strength of G2 (23.39±6.07) and G3 (22.85±5.11) groups was the same and similar to that in the control group (p> 0.05).

Conclusion: Based on the results of this study, it may be concluded that dentin surface irradiation with 940 nm diode laser after adhesive application and prior to curing can significantly increase the bond strength of composite to dentin.

Corresponding Author: Ranjbaran Jahromi P., Dept. of Restorative Dentistry, Dental School, Hamadan University of Medical Sciences, Hamadan, Iran. Email: pegah.ranjbaran@yahoo.com
Tel: +98-8138381894

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Introduction

Dentin bonding agents have greatly improved in terms of formulation and function in recent years. [1] One of the main concerns in using adhesive systems is to obtain an adequate bond between the composite and dentin. [2] Dental tissue preparation prior to the application of adhesive systems for tooth-colored restorations is as an important step in the bonding protocol that determines the success of treatment. [3] Bonding to dentin is more difficult than bonding to enamel because of the tubular pattern of dentin, higher water content, presence of smear layer, and pathophysiological changes such as presence of hyper-mineralized and sclerotic dentin. [4] In recent decades, 5th generation bonding agent as an etch and rinse bonding system was introduced with two-step etch and rinse protocol, which requires mixing of the two components of primer and bonding agent in order to facilitate the bonding procedure. After acid etching of the tooth surface, the adhesive agent fills the porosities created on the surface. [5] Performance of the adhesive system depends on penetration of hydrophilic monomers into the porosities and around the collagen fibrils exposed by acid. Collagen fibrils surrounded by monomers with the remaining hydroxyapatite crystals form the hybrid layer. [6] The efficacy of the adhesive system depends on the formation of hybrid layer interface. [7] Acid etching is an effective strategy to remove the smear layer, demineralize the inter-tubular dentin, and expose the dentinal tubules. [8-9] Studies have shown that commonly used bonding agents cannot fully penetrate into the porosities. [10] Therefore, micron-sized gaps remain between the composite and dentin. [11] Deproteinization of dentin surface can be done to decrease the organic content of dentin. [12] Deproteinization results in better penetration of the adhesive agent into the porosities created by acid etching. [13] Moreover, it improves the bond strength of total-etch adhesive systems. [12] Various methods are available to deproteinize the dentin surface such as chemical methods (application of 10% NaOCl) and laser irradiation. Nd:YAG laser selectively removes the collagen network without affecting the mineralized tissue. [14] Also, Dayem showed that Nd:YAG laser irradiation for deproteinization of dentin results in deeper penetration of resin tags compared to the use of 10% NaOCl due to better removal of collagen network. [13] To enhance the bond of adhesive to dentin, some researchers have suggested that laser irradiation of adhesive before its polymerization may lead to better penetration of bonding agent into the dentinal tubules. [15] A number of studies have shown that irradiation of laser on the surface after the application of adhesive agent causes better penetration and evaporation of solvent and increases the bond strength. [16-20] However, another study showed that laser irradiation before and after the application of adhesive had no effect on bond strength. [21] In this study, we used a 5th generation, two-step adhesive containing acid etchant and primer-bonding agent and assessed the effect of 940 nm diode laser irradiation before etching, after etching and after applying the primer-bonding agent on microtensile bond strength. Due to the potential impact of laser irradiation on increasing the penetration depth of monomers and deproteinization of etched dentin, we assessed the effect of 940-diode laser irradiation on microtensile bond strength of composite to dentin. The null hypothesis stated that there would be no significant difference in microtensile bond strength of composite resin to dentin, with or without 940 nm diode laser irradiation.

Materials and Method

This experimental study was conducted on 30 sound premolar teeth without caries, cracks, wear, structural anomalies, and restorations. The study was approved in the ethics committee of the Vice Chancellor of Research, Hamadan University of Medical Sciences (9509235537) .The teeth had been extracted with the consent of patients for orthodontic purposes. After extraction, the teeth were immediately immersed in 0.2% thymol solution at room temperature (23°C) for one week. Crown and roots were carefully cleaned of any plaque and soft and hard tissue debris using a curette and then polished with pumice paste and stored in distilled water until the experiment. The teeth were mounted in auto-polymerizing acrylic resin (Acropars, Tehran, Iran). All teeth were horizontally sectioned at their occlusal third by a disc (Mashhad Nemov Company, Mashhad, Iran) with 0.3mm diameter and high-speed hand-piece under water coolant to obtain a smooth dentin surface. Then, the exposed dentin surface was ground flat with 600-grit silicon carbide paper to create uniform and standard smear layer. The teeth were randomly divided into five groups. Preparation of samples in each group (n=18) was done as follows.

In the control group (C), dentin surface was acid etched with 35% phosphoric acid (3M Dental Products, St. Paul, MN, USA) for 15 seconds, washed with water for 15 seconds and blotted dry with tissue paper. According to the manufacturer's instructions, by using a micro-brush,two layers of adhesive (Single Bond; 3M

Dental Products, St. Paul, MN, USA) were applied and the surface remained wet for 15 seconds and gently air dried for 5 seconds. Then, it was cured with LED light curing unit (Kerr, Orange, CA, USA) with an output power of 1200 mW/cm^2 for 10 seconds. The A2 shade of composite (Filtek Z250; 3M ESPE, St. Paul, MN, USA) was applied for buildup in three layers on dentin surface such that each layer had 2mm thickness. Each layer was then light cured for 40 seconds with LED light curing unit, while the tip of the device had 1 mm distance from the composite surface.

In the second group, laser+ etching+ bonding (LEB), dentin surface was irradiated with diode laser (Epic 10, Biolase, Irvin, CA, USA) with 940 nm wave length, 1W power, continuous wave mode and 400µm fiber tip size.The diode laser energy was delivered by a hand-piece at a speed of 1mm/second for 10 seconds at 1mm distance from the target point. Irradiation was performed in a circular motion from the center outward and then inward. Etching and bonding steps were performed similar to the control group.

In the third group, etching+ laser irradiation+ bonding (ELB), all steps were similar to the LEB group except that 940 nm diode laser was irradiated after etching and washing of dentin surface.

In the fourth group, etching+ bonding+ laser irradiation (EBL), all steps were similar to the LEB group except that after applying the bonding agent, 940nm diode laser was irradiated and then the adhesive was photo-polymerized for 10 seconds.

Finally , in the fifth group, etching+ laser irradiation+ bonding+ laser irradiation (ELBL), all steps were similar to the ELB group except that after applying the bonding agent, 940 nm diode laser was irradiated again and then the adhesive was photo-polymerized for 10 seconds.

Then, the samples were stored in distilled water for 24 hours at 37°C. All the samples were thermocycled for 1000 Cycles between5°C and 55°C with a dwell time of 60 seconds in distilled water and a transfer time of 5 seconds. The restored teeth were then sectioned in two directions of mesiodistal and buccolingual by a diamond disc (Mashhad Nemov Company, Mashhad, Iran) using a low-speed cutting machine (Mashhad Nemov Company, Mashhad, Iran) operating at 300 rpm under water coolant to obtain dentin-composite dental sticks with a cross-section of approximately 1×1=1mm^2. Three samples were selected from each tooth. For microtensile bond strength testing, the samples were transferred to a universal testing machine (SANTAM, SMT-20, Tehran, Iran).The samples were glued to the device using cyanoacrylate adhesive (Loctite Super Bonder Gel Control, Henkel Ltda, São Paulo, Brazil). The bonding area was positioned vertically relative to the direction of application of tensile load. Tensile load was applied to the resin-dentin interface at a crosshead speed of 0.5 mm/minute (ISO TR 1145) until failure. The data for each group were recorded in Newtons (N) and converted to megapascals (MPa) by dividing the load in Newtons by the surface area in square-millimeters (mm^2).

After the test, each two sections were analyzed under a stereomicroscope (Olympus, Tokyo, Japan) at 40× magnification. The mode of failure was classified as adhesive at the interface, cohesive within the composite, cohesive within dentin, or mixed.

Data were analyzed using SPSS version 23. Comparison of the experimental groups was performed using one-way ANOVA followed by HSD post hoc Tukey's test, for between-group comparisons (α=0.05).

Results

Table 1 shows the mean and standard deviation (SD) of microtensile bond strength of composite to dentin in different groups. One-way ANOVA showed that the

Table 1: Mean values and SD of bond strength (MPa) of composite to dentin in various groups and failure modes of µTBS test

Groups	Surface treatment	Micro-tensile bond strength	95% confidence interval		Failure mode A/ M/ CR/ CD
			Lower	Upper	
Control	No treatment	18.85 (4.79) ^{A}	16.47	21.23	13/2/1/2
LEB	Laser, etch, bond	23.39 (6.07) ^{AB}	20.37	26.41	13/4/0/1
ELB	Etch, laser, bond	22.85 (5.11) ^{AB}	20.31	25.40	12/4/0/2
EBL	Etch, bond, laser	38.35 (8.99) ^{C}	33.88	42.83	9/5/3/1
ELBL	Etch, laser, bond laser	25.16 (6.14) ^{B}	22.11	28.22	10/5/2/1

Abbreviations: SD, Standard deviation; A, Adhesive; M, Mixed; CR, Cohesive in composite; CD, Cohesive in dentin Values with different uppercase letters indicate significant differences according to linear model with HSD post hoc Tukey's test. (p< 0.05) (n=18)

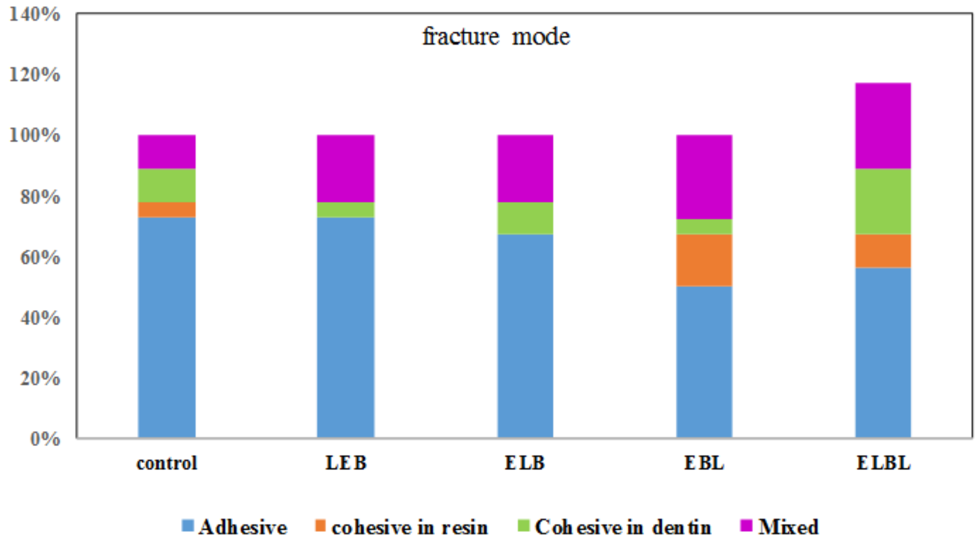

Figure 1: Frequency percentages of the fracture patters of samples in the groups under study

mean bond strength was significantly different among the groups (*p*= 0.000).

According to Tukey's HSD test, the microtensile bond strength of composite to dentin in the EBL group was significantly higher than that in other groups (*p*= 0.001). In addition, the bond strength of the ELBL group was significantly higher than that in the control group (*p*= 0.032). However, there was no statistically significant difference between the LEB and ELB groups (*p*= 0.999) and the control group in terms of failure mode (*p*= 0.338 and *p*= 0.218, respectively). (Figure 1)

Table 1 shows the failure mode in various groups. The results showed that adhesive failure was more common in all groups. Although mixed and cohesive failures were more frequent in EBL and ELBL groups compared to other groups, chi-square test (*p*= 0.71) showed that the failure mode distribution had no significant difference among the groups. (Figure 1)

Discussion

Due to the advances in tooth-colored restorative materials and bonding systems as well as the increasing demand for composite restorations, many studies have been conducted to improve the bond strength and decrease leakage of these restorations. This study aimed at investigating the effect of 940 nm diode laser irradiated at different stages of application of Single Bond 2 on the bond strength of composite resin to dentin. The study results showed a statistically significant difference in the bond strength when laser was irradiated on the dentin surface, after the application of bonding agent and before curing; subsequently, the null hypothesis was rejected. This finding was consistent with the results of some previous studies. [15, 17, 22-23] However, the results of another study were in disagreement with ours. [21]

Franke *et al.* [17] evaluated the effect of Nd:YAG laser irradiation after applying the bonding agent on dentin and before its curing. They concluded that laser irradiation increases the bond strength and observed that laser irradiation increased the number of resin tags and improved the adhesive penetration into dentin; therefore, higher bond strength was achieved. [17] In another study, the same result was obtained when 970nm diode laser was irradiated on dentin surface after application of adhesive agent and before curing. [16] Marimoto *et al.* [24] found similar results after Nd:YAG laser irradiation on 5th generation bonding agent.

Irradiation of laser after the application of adhesive can improve the quality of hybrid layer, which may be the reason for increase in bond strength. Laser irradiation after the application of bonding agent and before curing can cause fusion of adhesive and dentin and may lead to formation of a new substrate. [22, 24] In addition, the increase in the temperature due to laser irradiation can result in enhanced penetration of adhesive, its improved flow on the surface and better evaporation of solvent. [16-17] Similar results were obtained by a study that employed hot air flow on the surface to increase the bond strength. [25] Moreover, it should be noted that high temperature could increase the degree of conversion of adhesive penetrated into dentin. [16]

However, Maleki Pour *et al.* [21] found no difference between the groups that received 808-nm diode laser irradiation after the application of adhesive and the no laser control group. It should be noted that lasers with higher wavelengths such as 980 nm diode laser are more absorbed by water while those with shorter wavelengths such as 810 nm are better absorbed by melanin. Due to less absorption by water, the shorter wavelengths (808 nm) can increase the temperature compared to the higher wavelengths, resulting in morphological changes in dentin. The reason for the difference between the results of their study and the current study can be the difference in laser wavelength. [26-29]

In the process of dentin treatment for adhesive restorations, dentin surface is demineralized by removing the minerals around the collagen fibers. Then, the adhesive is applied to penetrate deep into the demineralized dentin; however, it has been shown that adhesive does not fully penetrate into the created porosities. As the result, the quality of the hybrid layer depends on the penetration depth of adhesive into the etched dentin and decreases in case of incomplete resin penetration. This phenomenon leads to gradual hydrolysis of collagen fibrils, within complete penetration of adhesive; this results in weakening of the collagen-rich areas and their susceptibility to micro- and nano-leakage. [13, 30-31] It has been proposed that removal of collagen fibers with deproteinizing agents can improve access and penetration of adhesives into the etched dentin and create a resin-rich intermediate layer that is more stable and resistant to degradation over time. [12-13]

In the study conducted by Dayem, [13] deepest penetration of adhesive was observed when Nd:YAG laser was irradiated on dentin surface after the etching procedure. The reason is the removal of collagen network enabling better penetration of monomers into the dentinal tubules and the porosities created by etching. [13] Nd:YAG and diode lasers have almost similar wavelengths and are both highly absorbed by melanin and pigments; in higher wavelengths, they are both absorbed by water. [32]

In the current study, 940 nm diode laser was used to evaluate the effect of this type of laser on deproteinization of dentin surface after etching. However, the results did not show a significant increase in bond strength. Laser absorption into the tissue needs an absorbing chromophore containing melanin, hemoglobin, or water in soft tissues and hydroxyapatite and water in hard tissues, which vary depending on the laser wavelength. [33-35] The results of this study may be due to the lack of chromophore and no laser absorption by collagen. Since diode laser is absorbed by the pigments, it is recommended to assess the effect of diode laser after staining of collagen fibers in further studies.

In another study, reduction in bond strength was observed after Nd:YAG laser irradiation before applying the bonding agent. [22, 24] The reason is probably the destruction of organic components by laser due to the generated heat and obstruction of dentinal tubules by recrystallization of dentin. [36-39]

Another finding of this study was that bond strength in diode laser group, which were irradiated before the application of bonding agent, significantly increased compared to the control group. However, the bond strength in this group was less than that in the group of laser irradiated after the application of bonding agent. The reason is probably the partial obstruction of dentinal tubules and morphological changes of dentin surface during laser irradiation before applying the bonding agent. [24] The increase in bond strength may be due to laser irradiation after the application of adhesive and subsequently increased evaporation of solvent and deeper penetration of adhesive resulting from temperature rise in parts of the tubules that were still open.

Laser irradiation before etching of the dentin surface did not have a significant effect on the bond strength of composite to dentin, which is the result of poor absorption of diode laser by the tooth structure. [32]

Conclusion

Despite the limitations of this study, it may be concluded that 940-nm diode laser irradiation after the application of bonding agent on dentin and before its curing, may cause a significant increase in bond strength of composite to dentin. However, diode laser irradiation did not cause a statistically significant difference in bond strength when applied in other steps during the bonding procedure.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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