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Effect of Diode Laser (810 nm) Irradiation on Marginal Microleakage of Multi-mode Adhesive Resins in Class V Composite Restorations

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Abstract

Introduction: Some studies have shown that laser irradiation on unpolymerized adhesives can improve composite-dentin adhesion. The aim of the present study was to evaluate the effect of the diode laser (810 nm) on the microleakage of multi-mode adhesive systems at enamel and dentin margins of composite restorations.

Methods: Classic class V boxes were prepared on 48 sound premolar teeth and randomly divided into 6 groups (n=16). In the control groups, Scotchbond Universal (SBC), G-Premio (GBC), and Ambar U (AMC) were used by a self-etch mode. In the test groups (SBL, GBL, ABL), the 810 nm diode laser was irradiated (1 W) for 10 seconds before the polymerization of the adhesive. The boxes were restored by the resin composite. After finishing and polishing, the samples were thermocycled (5°C to 55°C) for 1000 cycles and then immersed in 0.1% methylene blue dye (48 hours). Dye penetration through the gingival and occlusal margins was measured by Stereomicroscope. The data were analyzed at the 5% significance level using Kruskal-Wallis and Mann-Whitney U tests.

Results: Significant differences were found between the control and test groups ($P<0.05$). The occlusal margins of the SBL and GBL groups and the cervical margin of the SBL group exhibited the lowest microleakage ($P<0.05$). The AM control group showed maximum microleakage at cervical and occlusal margins.

Conclusion: The irradiation of the 810 nm diode laser on the unpolymerized universal adhesive systems in a self-etch mode caused a significant reduction in enamel and dentin marginal microleakage of composite restorations.

Keywords: Adhesive; Lasers; Dental leakage; Dentin bonding agent; Diode Lasers.

Introduction

The demand for esthetic care and further maintenance of the dental structure has led to the further development of adhesive materials in contemporary dentistry. Multimode adhesive systems have been considered for adhesion to enamel, dentin, composites and porcelain.[1,2] According to the previous studies, these bonding systems can be used as etch and rinse, self-etch, and selective etch modes.[1-3] In fact, the universal dentin bonding systems have a clear ability to simplify and expedite their clinical application.[4] It has been reported that one of the main challenges in adhesive dentistry when using multimode bonding agents is the creation of a durable and reliable adhesion between the composite and the tooth structure.[5-8] The presence of water in these kinds of one-bottle adhesives is essential due to acid ionization.[9,10] Due to the similarity of water content in the multi-mode bonding system and the seventh generation(one-step self-etch) dentin adhesives, the destruction of the adhesive layer can also occur in the universal bonding systems. Controversial results on microleakage, bond strength, and the degree of polymerization of multimode adhesives have been reported.[7]

Marginal microleakage, which is the most effective factor in the durability of restoration,[11] can lead to such complications as dental sensitivity, color change, caries recurrence, and pulpal inflammation.[11,12] Different methods have been proposed for increasing the penetration of bonding resin to the tooth structure and the formation of an improved hybrid layer in order to reduce the marginal microleakage. Some of these methods include increased surface temperature, adhesive and composite heating, the use of electrical current and laser irradiation.[13-17]

Some researchers have suggested the use of laser irradiation for improving the bonding efficacy of dentin

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bonding systems.[17] The laser used in dental practice is part of nonionizing radiation of the electromagnetic spectrum. Its photochemical and photothermal effects can be used in order to assist the restorative procedures, according to the laser parameters.[18]

It is reported that the irradiation of the near infra-red lasers such as the diode and neodymium-doped yttrium aluminum garnet (Nd: YAG) lasers on unpolymerized adhesive can increase bond strength and decrease marginal microleakage of composite restorations.[19] Using laser beam irradiation through increasing the primer penetration and improving hybrid layer quality can improve restoration durability and also decrease recurrent caries and postoperative sensitivity.[18,20-22] However, in some studies, it has been shown that laser irradiation on unpolymerized conventional dentin bonding could have a negative influence on the bond strength.[19,23] On the other hand, there is not much information on the confrontation of the laser and universal adhesives.

Considering that laser application is a new topic in restorative dentistry and it can be used in any stage of bonding application, the aim of this study was to evaluate the effect of diode laser (810 nm) irradiation on microleakage of enamel and dentin margins of class V composite resin restorations. Our null hypothesis was that laser beam application to unpolymerized universal adhesives has no effect on marginal microleakage of composite resin restorations.

Methods

In this in-vitro study, 52 extracted, caries-free and sound human premolar teeth were selected. The teeth were extracted because of orthodontic purposes. The teeth were disinfected in chloramine 1% for a maximum of 3 months. Periodontal fibers and debris were cleaned with a periodontal scaler. Before the initiation of this study, they were kept in distilled water for 1 week. 48 teeth were randomly divided into 6 groups, each containing 8 samples for measuring marginal microleakage of restorations. In addition, 4 extra teeth were used for the evaluation of the temperature change of bonding resin after applying the composite and laser beam irradiation. Classic class V boxes were prepared on the buccal and lingual surfaces of each tooth (3 mm mesiodistally, 2 mm occlusogingivally, 1.5 mm depth) in a way that its occlusal margin was located 1 mm upper than CEJ (enamel) with a 0.5 mm bevel and its apical margin located 1mm below the CEJ (n=16). Each bur was used for the preparation of only 5 boxes and cavities were measured using a periodontal probe. In this study, 3 multimode adhesives were used: Scotch bond universal (3M ESPE, St. Paul, MN, USA) [SB], G-Premio (GP, GC Corp., Tokyo, Japan) [GB], and Ambar (FGM Prod Odont; Joinville, SC, Brazil) [AB].

In the control group of Scotchbond Universal (SBC) after preparing the box-shaped cavity on the buccal surface, the adhesive agent was applied in the self-etch mode according to the manufacturer instruction (Table 1). The cavity surfaces were dried with a piece of absorbent paper and then the bonding agent was scrubbed into the cavity by a micro brush. After air-thinning the adhesive layer, the bonding system was light-cured for 10 seconds with the Dr's Light AT (Good Doctors Co. Ltd, Incheon, Germany) curing unit. The intensity of the light-curing unit was measured with a radiometer (output intensity 470 mW/cm^2). In order to restore the class V cavity, the first layer of the composite Z250 (3M ESPE, St. Paul, MN, USA) was applied on the gingival floor of the cavity (D=1 mm) and then light-cured for 20 seconds. After that, the whole cavity was filled in with a single layer of the composite and then light-cured for 40 seconds. In the GBC and ABC control groups, the bonding process was similar to the SBC group.

In the test groups (SBL, GBL, ABL), the 810nm diode laser beam (Doctor Smile, LAMBDA Spa, Italy) was irradiated before curing the adhesive. The continuous diode laser was irradiated with the power of 1 W with a fiber tip (400 microns) in a non-contact mode (1 mm from the surface) for 10 seconds on the whole cavity surface. The fiber tip was adjusted by hand at an approximate distance of 0.5 mm, perpendicular to the cavity surface, and the entire surface of the cavity was irradiated at a rate of 2 mm/s for 10 seconds. After light-curing the adhesive agent, the restorations were completed with the composite in the same way as the control groups.

The restored class V cavities were finished with a Medium-grit bur (D+Z, Kalletal, Germany) and polished

Table 1. Adhesive Systems and the Instruction of Use in This Study

Bonding Type	Bonding Application
Scotch bond universal (3M, USA)	1. Apply the adhesive to the entire preparation with a micro-brush and rub it for 20 s; if necessary, rewet the disposable applicator during treatment 2. Direct a gentle stream of air over the liquid for about 5 s until it no longer moves and the solvent is evaporated completely 3. light-cure for 10 s
G-Permio (GC, Japan)	1. Apply the adhesive to the air-dried tooth surface with a micro-brush for 10 seconds 2. Apply a maximum air pressure over the liquid for about 5 s 3. Light-cure for 10 s
Ambar (FGM, Brazil)	1. Apply 2 coats vigorously by rubbing the adhesive for 20 s (10 each) 2. Gently air-dry for 10 s to evaporate the solvent 3. Light-cure for 10 s

with polishing disks from fine to superfine grades (Soft-Lex, 3M ESPE, St. Paul, MN, USA). Afterward, the samples were stored in distilled water and then incubated at 37°C for 48 hours. For simulating the temperature changes of the oral environment, all samples were thermocycled (5-55°C for 30 seconds each thermal bath for 1000 cycles). The whole surface of teeth was covered with 2 layers of nail polish 1 mm short of restoration's margins and the apical region of the roots was sealed with adhesive wax. All samples were submerged in methylene-blue 0.1% for 48 hours. After rinsing the samples and drying them, the teeth were cut bucccolingualy at the middle of the composite restoration with a water-cooled diamond disk (KG Sorensen, SP, Brazil). Finally, Dye penetration was assessed twice by a trained observer using a Stereomicroscope (Olympus SZX16, Japan) at a magnification of 40× based on the following criteria:

0: No dye penetration

1: Dye penetration at the tooth–restoration interface up to the half of the cavity depth

2: Dye penetration to the whole cavity depth without the involvement of the axial wall

3: Dye penetration along the axial wall

The scores were tabulated and the data were compiled from each scoring using the worst rank for each specimen.

The data were recorded and statistical analysis was done using Kruskal-Wallis and Mann-Whitney U tests. The level of significance was set at $P < 0.05$.

For evaluating the dentinal temperature rise during tooth restoration, 3 samples in each group were fabricated in a cylindrical hole with a height of 3mm and a diameter of 0.6 mm. The holes were prepared from the mesial surface of the teeth for placing a thermocouple sensor so that the remained dentin at the bottom of the class V cavity was about 1 mm. A K-type Thermocouple (TES electronics; Taipei, Taiwan) with a diameter of 0.6 mm was put into the prepared hole and the other one was placed in the environment next to the teeth. For better transferring the heat through the Thermocouple, the hole was filled with a thermally conductive paste. The amount of thermal change during diode laser irradiation on bonding agent, light-curing the adhesive, and composite polymerization was measured and recorded in each second with the use of the data logger (TES electronics; Taipei, Taiwan).

In order to investigate the temperature rise at the surface and one millimeter subsurface of dentin, another tooth was prepared. The occlusal surface of the tooth sample was ground with an orthodontic trimmer to expose about 5 mm diameter of superficial dentin. A slice of dentin (thickness = 1 mm) was cut by using a water-cooled diamond disk (KG Sorensen, SP, Brazil). The dentin slice was stuck to a glass slide using cyanoacrylate adhesive and the slice was positioned on the focal point of the infra-red non-contact thermometer lens (CS Laser LT, OPTIRS, Germany). The non-contact infra-red thermometer had 2 convergent laser beams for focal point determination (Figure 1). The thermometer was calibrated considering the dentin emissivity to be 0.91 within the temperature range of 20 to 100°C[24] and the dentinal surface and subsurface maximum temperature rises were measured. The data acquisition was done at 2 Hz. The room humidity was 30% and the temperature was stabilized at 31± 0.5°C for 2 hours during the measurements. The data obtained from the temperature increase were recorded every 0.5 seconds during Diode laser (810 nm) beam irradiation on the surface and subsurface of primed dentin, the curing adhesive and the polymerization of the composite.

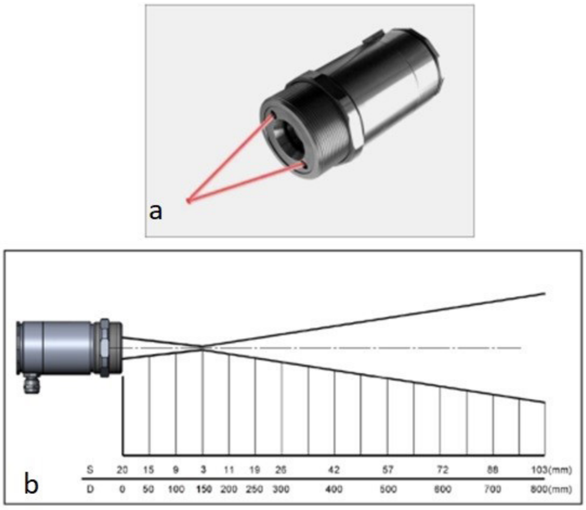

Figure 1. Infra-Red sensor (OPTIRS) (a) Focal measurement accuracy (b).

Results

As it is seen in Table 2, the comparison of occlusal microleakage with the Kruskal-Wallis test showed a significant difference between the studied groups ($P = 0.32$). The pairwise comparison of the studied groups with the Mann-Whitney U tests showed that the highest occlusal microleakage score was in the ABC group and the least amount of occlusal microleakage was in the SBL and GBL groups ($P < 0.05$).

The Kruskal-Wallis test revealed a significant difference between the cervical margin microleakage of the studied groups ($P = 0.47$). According to post-hoc tests, the highest microleakage of cervical margin was in the ABC group and the lowest cervical microleakage was in the SBL group ($P < 0.05$).

The comparison of microleakage at the total occlusal and cervical margins of the restorations in the laser test groups with the control groups using Mann-Whitney U tests showed lower microleakage in the test groups ($P = 0.001$ and $P = 0.004$ respectively).

According to the Mann-Whitney U test, the occlusal marginal microleakage was less than the cervical marginal microleakage in all composite class V restorations ($P < 0.05$).

The maximum temperature rises in the studied

Table 2. Comparison of Marginal Microleakage Scores of Class V Composite Restorations in the Study Groups

Margin	Groups	Laser Application	Adhesive Agent	Microleakage Score (%)				*P* Value*
				0	1	2	3	
Occlusal	GBC	No	G-Premio	0 (0%)	13 (81.3%)	3 (18.3%)	0 (0%)	0.032
	GBL ^{b}	YES ^{b}		7 (43.8%)	9 (56.3%)	0 (0%)	0 (0%)	
	SBC ^{a}	No ^{a}	Scotch	1 (6.3%)	10 (62.5%)	3 (18.3%)	2 (12.5%)	
	SBL ^{b}	YES ^{b}		7 (43.8%)	9 (56.3%)	0 (0%)	0 (0%)	
	ABC ^{a}	No ^{a}	Ambar	1 (6.3%)	10 (62.5%)	4 (25%)	1 (6.3%)	
	ABL ^{b}	YES ^{b}		7 (43.8%)	7 (43.8%)	2 (12.5%)	0 (0%)	
Cervical	GBC ^{cfgi}	No ^{cfgi}	G-Premio	2 (12.5%)	9 (56.3%)	2 (12.5%)	3 (18.3%)	0.047
	GBL ^{eghi}	YES ^{eghi}		2 (12.5%)	7 (43.8%)	6 (37.5%)	1 (6.3%)	
	SBC ^{ch}	No ^{ch}	Scotch	0 (0%)	7 (43.8%)	5 (31.3%)	4 (25%)	
	SBL ^{e}	YES ^{e}		5 (31.3%)	9 (56.3%)	1 (6.3%)	1 (6.3%)	
	ABC ^{c}	No ^{c}	Ambar	1 (6.3%)	4 (25%)	8 (50%)	3 (18.3%)	
	ABL ^{ef}	YES ^{ef}		3 (18.3%)	9 (56.3%)	2 (12.5%)	2 (12.5%)	

* The Kruskal-Wallis test; Letters with the same lowercase letters do not have a significant difference with the Mann-Whitney U test ($P>0.05$).

Table 3. Average Thermal Changes of 3 Samples at a Distance of 1 mm from the Floor of the Cavity Using the Thermocouple

Groups	Max Temperature Rise (°C)
10 s light-curing	2.3
10 s light-curing adhesive	3.7
10 s Laser irradiation of the unpolymerized adhesive	2.3
20 s light-curing of 2 mm composite	6

Table 4. The Increase of Surface and Subsurface Temperature Within Dentin-Shaped Disks of 1 mm Thickness with the Use of an Infrared Thermometer

Groups	Max Temperature Rise (°C)
10 s light-curing adhesive (subsurface)	14.4
10 s Laser irradiation on unpolymerized adhesive (surface)	11.4
10 s Laser irradiation on the unpolymerized adhesive (subsurface)	8.1
40 s light-curing composite (subsurface)	20

specimens are presented in Tables 3 and 4, and the temperature changes per second relative to the initial temperature are shown in Figures 2 and 3.

Discussion

As polymerization shrinkage is associated with composite resin restorations, microleakage of ions and water molecules takes place at the margins of restorations.[25] It is reported that rising temperature of the adhesive agent with a warm air stream,[16] the use of an electric current,[26] and also laser irradiation improves bonding resin infiltration into the tooth structure.[19,27,28] In this study, the effect of the 810 nm diode laser irradiation on marginal microleakage of universal bonding systems in class V composite restorations was evaluated. The results showed that the 810 nm diode laser irradiation on the unpolymerized universal adhesive, which was applied in a self-etch mode, significantly reduced the marginal microleakage of the composite restorations ($P<0.05$). Therefore, the null hypothesis was rejected. Although some previous studies confirmed the results of the present study,[22,29-31] there are a few studies reporting that laser irradiation on unpolymerized adhesive has adverse or no effect on marginal microleakage of composite resin restorations.[22,32-34]

Due to the presence of acidic functional monomers, water and solvent in the universal bonding systems, laser irradiation on the unpolymerized adhesive agent can be effective in the formation of the hybrid layer mechanism. Diode laser radiation increases the temperature of the solvent-resin components and the cavity surface.[35] Most previous studies focused on the influence of laser radiation on the solvent evaporation from the adhesive agents, without considering the role of the functional monomer of the applied adhesives.[20,22,35] However, In the current study, the universal bonding systems containing

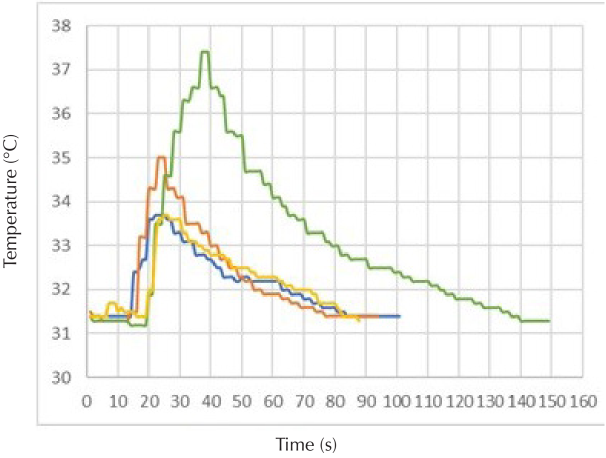

Figure 2. Measurement of the temperature increase per second relative to the initial temperature in samples with a cavity at a distance of 1 mm from the floor of the cavity by the thermocouple. Blue (10 s light-curing), Orange (light-curing adhesive for 10 s), green (light-curing composite resin for 20 s), yellow (laser irradiation on adhesive for 10 s).

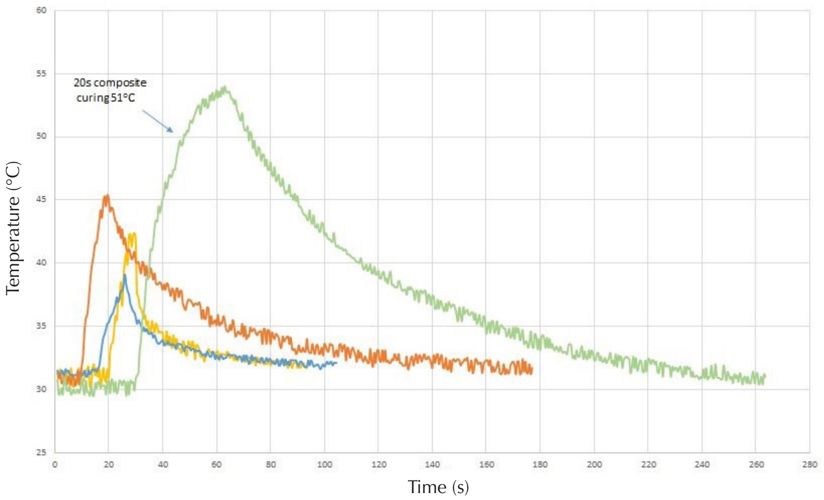

Figure 3. Measurement of surface and subsurface temperature of a disk-shaped sample of 1 mm thickness using an Infra-Red thermometer. Yellow (surface; laser irradiation of unpolymerized adhesive), Blue (subsurface; laser irradiation of unpolymerized adhesive), Orange (subsurface; light-curing adhesive for 10 s), Green (subsurface; light-curing composite resin for 40 s).

especially functional monomers which have chemical interaction ability with dental hydroxyapatite.

The 810 nm diode laser has a greater absorption in water and resin bonding than hydroxyapatite.[33] Hence, with laser irradiation on a cavity in which the bonding system is applied, the increase in heat occurs following absorbing laser energy in the unpolymerized adhesive agent.[18,36] Increasing the temperature of the adhesive system causes more evaporation of the adhesive solvents and results in less porosity at the interface of bonding due to less solvent residual. This can ultimately lead to an increase in the degree of polymerization and quality improvement in the hybrid layer.[35,37,38]

Batista et al in 2015 reported that ND: YAG laser irradiation on unpolymerised adhesive causes the temperature rise in the bonding agent and subsequently improves the physical-mechanical properties of the adhesive agent.[20] Brianezzi et al revealed that the irradiation of the 970 nm diode laser could increase the degree of conversion of simplified adhesives due to the increase in the movement of free radicals.[35] The increased degree of conversion increases the bond strength of enamel and dentin to composite resin.[39]

Despite the fact that there is no linear relationship between increased bond strength and microleakage reduction,[40] it has been reported that increasing bond strength to tooth structure influences marginal microleakage and marginal adaptation of composite restorations.[41] In a research study about the effect of the laser beam on bond strength of dentin bonding, Maenoso et al showed that the irradiation of the 970 nm diode laser with a power of 0.8 W for 30 seconds can boost the microtensile bond strength. They explained that the probable reason points to the effect of laser heat on the evaporation of the solvent and the increase in the degree of conversion.[18]

As solvent evaporation can result in lower marginal microleakage and a higher degree of polymerization, it should be noted that if solvent evaporation does not occur at the right time, the viscosity of the adhesive will increase and have a negative effect on the results. Therefore, in different adhesive systems, solvent evaporation using lasers can be material dependent.[32,33,42-44] Following the temperature rise of the adhesive and the use of the warm adhesive, the viscosity reduces and the monomer penetration velocity into the dentin increases so it can penetrate better, which can improve the formation of the hybrid layer.[37,45,46] Also, there will be an increase in ionic reactions and functional monomer infiltration into dentin structure and collagen networks, thus resulting in more adhesive-tooth structure interactions and adhesion procedure.[35,36,47]

Although laser radiation may increase bond strength and decrease marginal microleakage, the temperature changes were also measured in the present study due to the concerns about thermal necrosis of the pulp. It is reported that a 5.5°C increase in pulpal temperature causes a 15% chance of pulpal necrosis.[48] As it was seen in the results of the present study, the increase in temperature during the radiation of the 810 nm diode with the power of 1 W for 10 seconds was less than the temperature rises during curing adhesive and composite resin (Tables 3 and 4; Figure 2 and 3). Suleiman et al in 2006 reported that the laser radiation of the 830 nm diode with the power of 1-2 W for 30 seconds produced acceptable temperature changes in the pulp.[48]

Most previous researches, who have studied temperature changes in deep dentin and a pulp chamber, have used thermocouples. Basically, thermocouples are designed to measure the temperature variations of fluids, and their installation to measure the temperature of solids is always associated with some problems.[49] On the other hand, since the contact surface of the thermocouple and the object is not ideal, the error of the contact resistance between the object and the thermocouple interfere with results. Therefore, the high conductive paste is needed in order to limit this error; however, in this condition, the error is not completely eliminated.

In the current study, an infra-red thermometer was used for evaluating transient temperature changes of dentin (thickness=1 mm) within 10 seconds of the diode laser irradiation. It has been reported that measurement error for the thermocouple is estimated at about 1 degree, while for the infra-red thermometer is 0.1°C. Therefore, the infra-red thermometer does not cause the mentioned problems and can be useful for detecting a temperature rise in solid materials.[50]

Most of the universal adhesives have a functional monomer such as 10-MDP, which is a monomer for chemical bonding to mineral apatite of the substrate.[17] It is shown that while MDP forms calcium salt with less solubility on the surface of hydroxyapatite, it can provide an effective chemical bond between carboxylic groups and their phosphate groups with dentin hydroxyapatite crystals.[51,52] An increase in the adhesive temperature and reactivity of the functional monomer with dentin leads to the formation of more calcium organophosphate nano-layer and a lower marginal gap of restorations in the lased groups (Table 1).

It has been reported that the one-step self-etch adhesives cause lower bond strength and more microleakage on enamel margins of restorations.[52] Based on the results of our study, diode laser irradiation on unpolymerized universal adhesive systems using a self-etch mode reduces microleakage of enamel margins of the composite restoration (Table 1).

Malekipour et al showed that the 808 nm diode laser radiation on the unpolymerized fifth generation adhesive system could not increase the shear bond strength of the composite to dentin. In that study, they irradiated the 0.5, 1, 1.5-W diode laser before and after bonding application for 20 seconds with a 600 µ fiber.[43] Oskoee et al in 2013 reported that the 810 nm diode laser irradiation did not significantly affect microleakage in class V cavities. In their study, the wavelength of the diode laser 810 with the power of 1 W in a continuous mode was used to condition the dentin surface before the implementation of a sixth generation adhesive system, which differs from the current study.[32]

Laser radiation before applying the adhesive, depending on the laser parameters used, can lead to the destruction of dentin organic components, the reduction of calcium and phosphate of dentinal structure and change in the composition of hydroxyapatite. This, in turn, may lead to reduced bond strength and an increased marginal gap.[44,53]

It seems that, with introducing new universal adhesive systems in recent years, further studies should be performed on the effect of laser irradiation on improving bond strength and marginal microleakage of composite restorations. More investigation is recommended to observe the effect of long-term storage specifically, for enamel margins when using laser irradiation on a self-etch universal adhesives with before the polymerization of the bonding agent.

Conclusion

The Irradiation of the 810 nm diode laser on unpolymerized universal adhesive systems applied in a self-etch mode to class V cavities reduces the enamel and dentin marginal microleakage of composite restorations.

Ethical Considerations

The research protocol was approved by the ethics committee of the Dental Research Center of Shahid Beheshti University of Medical Sciences (Ethics No. IR.SBMU.RIDS.REC.1396.464).

Conflict of Interests

The authors declare no conflict of interest.

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