AJDR
Avicenna Journal of Dental Research
Avicenna J Dent Res, 2023; 15(3):81-86. doi:10.34172/ajdr.487
http://ajdr.umsha.ac.ir
UMSHA Press

Original Article

Effect of Er,Cr:YSGG and Nd:YAG Lasers on Microleakage of Composite Resin Restorations Using Universal Adhesives

Zahra Khamverdi[1], Loghman Rezaei-Soufi[1], Jalil Sobhi Poor[2*], Ali Ahmadi[3], Niloufar Javanrouh[4]

[1]Dental Research Center, Operative Dentistry Department, Dental School, Hamadan University of Medical Sciences, Hamadan, Iran
[2]Operative Dentistry Department, Dental School, Hamadan University of Medical Sciences, Hamedan, Iran
[3]Dentist, Hamadan, Iran
[4]Department of Biostatistics and Epidemiology, Hamadan University of Medical Sciences, Hamadan, Iran

Article history:
Received: July 13, 2021
Accepted: August 12, 2021
ePublished: September 30, 2023

***Corresponding author:**
Jalil Sobhi Poor,
Email: Jalilsobhi@gmail.com

Abstract
Background: Clinical long-term success of bonded restorations relies on reducing marginal microleakage, and the laser application with a combination of new bonding systems may play a positive role in this regard. The aim of this study was the comparative evaluation of the effects of Er,Cr:YSGG and Nd:YAG lasers on the microleakage of class V composite resin restorations using several universal adhesives.
Methods: In this in vitro study, standard class V cavities were prepared on both lingual and buccal surfaces of 72 intact premolar teeth. For the evaluation of microleakage, the cavities were divided into 9 groups according to the conditioning method (n=15), including G1: G-Premio Bond [GP], G2: Scotchbond universal adhesive [SU], G3: All-bond universal [AB], G4: GP+Nd:YAG laser, G5: SU+Nd:YAG laser, G6: AB+Nd:YAG laser, G7: GP+Er,Cr:YSGG laser, G8: SU+Er,Cr:YSGG laser, and G9: AB+Er,Cr:YSGG laser. The cavities were filled with composite resin and then subjected to thermocycling, placed in methylene blue solutions, embedded in resin blocks, and vertically cut in the buccolingual direction. The microleakage in occlusal and gingival margins was defined as the linear penetration of methylene blue and determined with a stereomicroscope to assign microleakage scores using a 4point scale. Data were analyzed by SPSS software and Kruskal-Wallis and Mann-Whitney U tests.
Results: Microleakage scores had statistically significant differences before and after laser irradiation depending on the applied adhesive ($P<0.05$), but there were no significant differences between Nd:YAG and ER,Cr:YSGG lasers, as well as between different universal adhesives (GP, SU, & AB). Based on the results, the total microleakage scores of occlusal margins represented a statistically significant difference in comparison with gingival margins ($P<0.001$).
Conclusions: The results indicated that Nd:YAG and Er,Cr:YSGG laser irradiation had a positive effect on reducing the microleakage of composite Class V restorations after using the investigated universal adhesives. The microleakage rate was shown to be independent of adhesives and laser type used in this study.
Keywords: Lasers, Dental leakage, Adhesives

Please cite this article as follows: Khamverdi Z, Rezaei-Soufi L, Sobhi Poor J, Ahmadi A, Javanrouh N. Effect of Er,Cr:YSGG and Nd:YAG lasers on microleakage of composite resin restorations using universal adhesives. Avicenna J Dent Res. 2023;15(3):81-86. doi: 10.34172/ajdr.487.

Background
Composite resins are widely used for tooth restoration due to their more conservative technique and high aesthetic. However, polymerization shrinkage, which is still their most important problem (1), can lead to debond the composite-tooth interface, thus causing microleakage in the restoration margins (2). If this process continues, it can be the main cause of composite resin restoration failure because of secondary caries, hypersensitivity, and pulp irritation/necrosis (3,4).

The presence of dentin bonding systems can provide sufficient bonding in the composite resin-tooth tissue interface. Nowadays, new types of bonding have been introduced, which are named universal adhesive systems based on the method of application and bonding strategy, which can act as both self-etching and total etching. Moreover, such bonding systems can be applied to enamel, surface and deep dentin, porcelain, amalgam, and metal

(5,6). Regarding the versatility of these adhesives, clinical and laboratory studies on their clinical use and other aspects are increasing (7,8).

In recent years, lasers have found increasing applications in dentistry due to their many capabilities. Nd:YAG (wavelength = 1064 nm) and Er,Cr:YSGG (wavelength = 2780 nm) lasers are among the lasers that are commonly employed in dentistry. Due to the good absorption of these lasers by water and hydroxyapatite, their application on the tooth structure is highly useful because of the presence of water in dental tissues (9).

Several studies have evaluated the microleakage effect and adhesive nature of these lasers due to the change in the dentin surface, and most of them have focused on the bonding resistance of dentin adhesives, while fewer studies have been conducted on the rate of the marginal microleakage of composite materials using laser irradiation (10), reporting contradictory results. In their study, Subramaniam et al observed no significant differences between the microleakage rate of Class III cavities prepared by milling and cavities that were prepared by the Er,Cr:YSGG laser (11). In another study by Kawaguchi et al, laser radiation on the dentin surface did not affect the rate of the marginal microleakage of composite restoration (12). Likewise, Wen et al showed that the use of the Nd:YAG pulsed laser on the dentin surface, before the application of resin bonding, can significantly increase the tensile bond strength and reduce the microleakage (13). Obeidi et al also found that the use of the Nd:YAG laser can reduce composite resin restorations microleakage (14).

Universal bonding systems are versatile and have the ability to be used in different cavity conditions. Working on the best technique for the application of universal adhesives is still in its early stages (15). Due to limited information about the effect of laser application on universal adhesives, the present study sought to evaluate the effect of Nd:YAG and Er,Cr:YSGG lasers on the microleakage of composite resin Class V restorations using several universal bonding systems. The null hypothesis of this study indicated that laser application does not affect the microleakage of composite resin Class V restorations, regardless of the applied universal adhesives.

Materials and Methods

Specimen Preparation

For this *in vitro* study, 72 healthy human premolars that were extracted up to 3 months ago, were collected and kept in 10% formalin solution. The residual of soft tissues was removed with a scaler from the teeth. The teeth were placed into distilled water 24 hours before the test at room temperature. On the buccal and lingual surfaces, standard Class V cavities were prepared with 3 mm of mesiodistal width, 2 mm of height, and 1.5 mm of depth using a cylindrical diamond bur (Teeskavan, Tehran, Iran) and high-speed handpiece (SK, Fukushima, Japan). As a result, the margin of incisal and gingival was 1 mm above and 1 mm below the CEJ, respectively. Finally, the enamel margin of the samples was beveled using a taper diamond bur (Teeskavan, Tehran, Iran) with a 45-degree angle. Each bur was replaced after 5 cavity preparation processes. The dimensions of the prepared cavities were standardized using a periodontal probe. Each lingual or buccal cavity was considered as a specimen.

Adhesive Application and Laser Irradiation

Using True Random Number Service software (www.random.org), the samples were randomly divided into 9 groups (G1-9) based on the adhesive system and used laser (n=15):

G1 [GP]: G-Premio Bond; G2 [SU]: Scotchbond Universal; G3 [AB]: All Bond Universal

In each of these control groups, the adhesive was applied, according to the manufacturer's instructions, to the prepared cavities and light cured for 10 seconds by a light cure LED device (Woodpecker, Guangxi, China) with a power of 850 MW/cm^2.

G4 [GP+Nd:YAG], G5 [SU+Nd:YAG], and G6 [AB+Nd:YAG]

In these groups, after the application of universal adhesives on the specimens, the Nd:YAG laser (Fotona, Ljubljana, Slovenia) was irradiated for 10 seconds on the entire surface of the cavities with a sweeping movement, and then light cured for another 10 seconds. The irradiation was performed in the noncontact mode with an optic fiber of 300 µm diameter tip in a perpendicular position to the target tissue and 5 mm distance from the tooth surface. The characteristics of Nd:YAG were wavelength of 1064 nm, extremely short pulse duration of 100 µs, frequency of 15 Hz, and power of 1 W (16).

G7 [GP+Er,Cr:YSGG], G8 [SU+Er,Cr:YSGG], and G9 [AB+Er,Cr:YSGG]

In these groups, samples were prepared and irradiated as in groups 4-6, except that Er,Cr:YSGG laser (Biolase, San Clemente, CA, USA) was used for these groups. The irradiation parameters of the Er,Cr:YSGG laser included wavelength of 2780 nm, frequency of 10 Hz, "H" Mode, pulse duration of 140 µs, power of 0.1 W, and spot size of 600 µm (17). Water spray was not used during laser irradiations.

Eventually, two layers of Filtek Z250 composite resin were placed in each cavity, and each layer was light cured for 20 seconds. Information on all three types of used adhesives and composite resin is presented in Table 1.

Microleakage Test

After completing the restoration, all groups were placed in a

Table 1. Universal Adhesives and Composite Resin

Materials (Code)	Material Type	Main Components	Instruction for Use
G-Premio Bond (GP) GC Corporation, Tokyo, Japan	Universal adhesive pH: 1.5	4-MET, 10-MDP, water, acetone, filler, and photoinitiators	1. Using a micro brush, apply the adhesive on the surface 2. Leave undisturbed for 10 seconds 3. Thoroughly dry for 5 seconds with air 4. Light cure for 10 seconds
All Bond Universal (AB) Bisco, Schaumburg, IL, USA	Universal adhesive pH: 3.1	bis-GMA, 4-MET, 10-MDP, HEMA, photoinitiators, water, and ethanol	1. Using a micro brush, apply two coats of the adhesive on the surface 2. Scrub for 10-15 seconds 3. Thoroughly dry for 10 seconds with air 4. Light cure for 10 seconds
Scotchbond Universal (SU) 3M; St Paul, MN, USA	Universal adhesive pH: 2.7	HEMA, 10-MDP, 4-MET, Vitrebond copolymer, silane, filler, water, ethanol, and photoinitiators	1. Using a micro brush, apply the adhesive on the surface 2. Rub it for 20 seconds 3. Gently dry for 5 seconds with air 4. Light cure for 10 seconds
Filtek Z250 3M, St. Paul, MN, USA	Composite resin	UDMA, Bis-GMA, Bis-EMA, and Zirconia/silica fillers	1. One layer of 2-mm thickness is applied on the surface 2. Light cure for 20 seconds

Note. HEMA: 2-hydroxyethyl methacrylate; 4-MET: 4-methacryloxyethyl trimellitate; 10-MDP: 10-methacryloyloxydecyl dihydrogen phosphate; Bis-EMA: Bisphenol A diglycidyl methacrylate ethoxylated; Bis-GMA: Bisphenol A diglycidyl methacrylate; UDMA: Urethane dimethacrylate

thermocycler (Nemo, Mashhad, Iran) under 3000 thermal cycles (between 55±2°C and 5± 2°C, 20 seconds), and then the apex of the teeth was covered with adhesive wax. Next, two coats of varnish were used to cover the teeth up to 1 mm beyond the margins of the restoration, and finally, all groups (1-9) were placed in a 2% methylene blue solution for 72 hours (11). Subsequently, the specimens were removed from the solution, rinsed with water, and dried for 2 minutes. Afterward, the teeth were mounted in a self-cured acryl (Kaveh, Tehran, Iran) and buccolingually sectioned by a cutting machine (Nemo, Mashhad, Iran) from the center of each restoration. Each section was observed by a stereo-microscope (Olympus, Tokyo, Japan) with 20x magnification. The rate of microleakage in gingival and occlusal margins was determined based on the following rating:

0 - No dye penetration
1 - Dye penetration to 1/3 of gingival/occlusal wall length
2 - Dye penetration to 2/3 of gingival/occlusal wall length
3 - Dye penetration along the whole gingival/occlusal wall length

Statistical Analysis

The data were statistically analyzed using SPSS software (version 21). Non-parametric Kruskal-Wallis and Mann-Whitney U tests were used for comparing the rates of microleakage. The level of significance was set at $P<0.05$.

Results

In the studied groups, the results related to the rate of microleakage are presented in Table 2. The lowest microleakage rate in the gingival margin was observed in group 6 [AB+Nd:YAG]. However, in the occlusal margin, the lowest microleakage rate was observed in group 8 [SU+Er,Cr:YSGG]. The results of the Kruskal-Wallis test demonstrated a statistically significant difference between the control groups, who received no laser, and the groups that used laser, in the rate of microleakage at both gingival and occlusal margins ($P<0.001$).

Table 2. Comparison of the Microleakage Rates Between the Nd:YAG and Er,Cr:YSGG Laser Groups, and Non-laser Group in Occlusal and Gingival Margins

	Laser Type	Grade				*P* Value[a]
		0	1	2	3	
Gingival	No laser	7	28	2	8	<0.001
	Er,Cr:YSGG laser	20	17	2	6	
	Nd:YAG laser	28	12	2	3	
Occlusal	No laser	17	20	4	4	<0.001
	Er,Cr:YSGG laser	35	8	0	2	
	Nd:YAG laser	31	11	0	3	

[a] Kruskal-Wallis test.

Table 3 provides data on the pairwise comparison of the studied groups. The pairwise comparison of groups in terms of the rate of microleakage revealed a statistically significant difference between the control group and the Nd:YAG and Er,Cr:YSGG laser groups regarding gingival and occlusal margins (Nd: YAG laser at the gingival margin $P<0.019$ and the occlusal margin $P<0.001$ and for the Er,Cr:YSGG laser at the gingival margin $P<0.001$ and the occlusal margin $P=0.004$). However, no significant difference was observed between the Er,Cr:YSGG and Nd:YAG laser groups in terms of the rate of microleakage at gingival and occlusal margins ($P=0.092$ and $P=0.342$, respectively).

Regarding the "bonding" factor, Kruskal-Wallis test results showed that the rate of microleakage using different adhesives was not significantly different at gingival and occlusal margins ($P=0.989$ and $P=0.064$, respectively). Based on the results of the Mann-Whitney test for the pairwise comparison of different groups in terms of the rate of microleakage, the microleakage rates at the gingival margin were statistically significant between G1 and G6, G2 and G6, G3 and G4-9, and G4 and G8 ($P<0.05$). Moreover, the microleakage rates at the occlusal margin

Table 3. Pairwise Comparison Between the Studied Groups in the Gingival and Occlusal Margins

Pairwise Comparison	Gingival Margin		Occlusal Margin	
	Test Statistics	*P* Value[a]	Test Statistics	*P* Value[a]
No laser group vs. Er,Cr:YSGG laser group	545	<0.001	689	0.004
No laser group vs. Nd:YAG laser group	754	0.019	599.5	<0.001
Nd:YAG laser group vs. Er,Cr:YSGG laser group	824	0.092	921.5	0.342

[a]Mann-Whitney U test.

significantly differed between G1 and G8, G3 and G5-9, and G4 and G8 ($P<0.05$). A general comparison between different groups with regard to the microleakage rate at gingival and occlusal margins revealed a statistically significant difference between the two margins ($P < 0.001$).

Discussion

As far as it is known, little information is available on the microleakage of composite restorations using universal adhesives. Accordingly, the present study was conducted to compare the two Nd:YAG and Er,Cr:YSGG lasers in terms of their effect on the microleakage rate of Class V composite resin restorations using universal adhesives.

There are various methods for assessing the rate of microleakage, including chemical detectors, organic tracer dye penetration, thermocycling, color-producing microorganism, radio-active isotopes, air pressure, neutron activation, scanning electron microscopy, and electrical conductivity (18). The dye penetration is the most widely used method for investigating the microleakage of composite restorations and adhesives. This method is economical, convenient, and safe, requires no special tools, and the depth of dye penetration can be easily observed with a stereo-microscope. In this method, colored materials such as methylene blue, Indian ink, purple crystal, eosin, fuchsin, erythrosine, fluorescein, and rhodamine B can be applied to assess the microleakage (19). Accordingly, 2% methylene blue was employed in this study, which has been previously used by Subramaniam et al (11) and Kapoor et al (20).

As high thermal changes occurred in the oral environment, a total of 3000 thermal cycles were utilized (according to ISO TR40 11405: 1994) for the simulation of clinical conditions in experimental situations (21). The effect of the Nd:YAG laser has been evaluated by numerous studies with different irradiation protocols (12-14,22,23). Thus, this laser was used as an available and efficient laser in restorative dentistry. Additionally, the Er,Cr:YSGG laser was employed with regard to its novelty and little information available in this respect. This laser has high absorption by hydroxyapatite and water and is proper for removing hard tooth tissues or preparing cavities on teeth (24).

According to the results of a study by Raskin, approximately 62.5% of microleakage assessment studies used Class V cavities (25). In microleakage studies, these cavities are often applied due to their high C factor and the possibility of the synchronous evaluation of enamel and dentin margins. On the other hand, universal bonding systems take advantage of new technology. These adhesives have facilitated the application process, leading to saving time and reduced errors in various application steps. Thus, universal adhesives (Scotchbond, all-bond, and G-Premio) were employed in the present study according to some previous studies (26,27).

The findings of the study demonstrated that the application of Er,Cr:YSGG and Nd:YAG lasers reduced microleakage in the studied groups. A significant difference was observed between the two laser groups and the group that was not exposed to lasers (control), and both laser groups had the same role in reducing microleakage. Therefore, this finding led to the rejection of the null hypothesis of the study. It seems that the use of laser causes a slight increase in reaction by an enhancement in the temperature of the bonding agent, increasing its penetration. Moreover, it reduces the microleakage by producing chemical and mechanical changes in the tooth structure (28).

These findings are consistent with the results of Wen et al (13), Obeidi et al (14), Navarro, and White, confirming the positive role of the Nd:YAG laser in reducing marginal microleakage (29,30). However, the research conducted by Kawaguchi et al (12), Subramaniam & Pandey (11), Matos et al (31), and Malta et al (16) showed that the irradiation of the Nd:YAG laser on dentin surfaces (before or after adhesive application) does not affect reducing the marginal microleakage of composite restorations.

The findings further indicated that the application of different universal bonding systems (SU, AB, and GP) did not have a significant effect on reducing microleakage. The presence of 10-MDP and 4-MET in the composition of all used universal adhesives may be the possible reason for the obtained result. 10-MDP and 4-MET are acidic functional monomers that can etch the dentin surface and chemically bond to the calcium (32). The pairwise comparison of different groups revealed significant differences between some groups, as previously mentioned in the results, in terms of the microleakage rate reduction at the gingival margin. The significant difference among G4 and G8, both of which received laser, seems to be related to the component of silane in the Scotchbond Universal adhesive composition, whereas the G-Premio bond does not contain it. The silane may cause better absorption when the adhesive is exposed to Er,Cr:YSGG laser radiation compared to radiation with the Nd:YAG laser. The rates of microleakage at the occlusal margin were significantly different between G1 and G8, G3 and G5-9, and G4 and G8. A greater reduction of microleakage is reported in the groups exposed to the laser due to the increase in temperature by the laser.

The comparison between the rates of microleakage at gingival and occlusal margins indicated that the rate of microleakage at the gingival margin is greater compared to the occlusal margin. The dentin structure has a heterogeneous nature with high contents of organic and water compared with enamel. Thus, the bond to dentin is not reliable while enamel creates a stronger bond to composite resin. This may be an explanatory reason for this result. However, beveling, which was performed for enamel margins, can reduce the microleakage (33). In this study, a specific protocol was considered for laser application. Different protocols may show a variety of effects. For future studies, it is recommended to apply different laser irradiation protocols with different powers. In this way, it is possible to extend the results of this study to all adhesives and achieve an optimal combination of laser and adhesive for resin composite restorations with a low rate of microleakage and long-term services.

Conclusion

Considering the limitations of this study, the irradiation of Nd:YAG and Er,Cr:YSGG lasers, after using the studied universal adhesives and before placing the composite resin, had a positive effect on reducing the microleakage of Class V restorations. Different adhesive systems and lasers, used in this study, did not affect the rate of microleakage.

Acknowledgments

The authors thank the Vice-chancellor for Research and Technology of Hamedan University of Medical Sciences for supporting this study.

Author's Contribution

Conceptualization: Zahra Khamverdi.
Data curation: Zahra Khamverdi, Loghman Rezaei-Soufi.
Formal analysis: Niloufar Javanrouh.
Funding acquisition: Zahra Khamverdi.
Investigation: Ali Ahmadi.
Methodology: Zahra Khamverdi, Loghman Rezaei-Soufi.
Project administration: Zahra Khamverdi.
Resources: Ali Ahmadi.
Software: Niloufar Javanrouh.
Supervision: Zahra Khamverdi.
Validation: Zahra Khamverdi.
Visualization: Zahra Khamverdi, Loghman Rezaei-Soufi.
Writing–original draft: Jalil Sobhi Poor
Writing–review & editing: Zahra Khamverdi.

Competing Interests

The authors declare that they have no conflict of interests.

Ethical Approval

The present study was approved by the Medical Ethics Committee of Hamadan University of Medical Sciences, Hamadan, Iran (IR.umsha.REC.1396.128).

References

1. Lin BA, Jaffer F, Duff MD, Tang YW, Santerre JP. Identifying enzyme activities within human saliva which are relevant to dental resin composite biodegradation. Biomaterials. 2005;26(20):4259-64. doi: 10.1016/j.biomaterials.2004.11.001.
2. Al-Boni R, Raja OM. Microleakage evaluation of silorane based composite versus methacrylate based composite. J Conserv Dent. 2010;13(3):152-5. doi: 10.4103/0972-0707.71649.
3. Medić V, Obradović-Djuricić K, Dodić S, Petrović R. In vitro evaluation of microleakage of various types of dental cements. Srp Arh Celok Lek. 2010;138(3-4):143-9. doi: 10.2298/sarh1004143m.
4. Sánchez-Ayala A, Farias-Neto A, Vilanova LS, Gomes JC, Gomes OM. Marginal microleakage of class V resin-based composite restorations bonded with six one-step self-etch systems. Braz Oral Res. 2013;27(3):225-30. doi: 10.1590/s1806-83242013000300003.
5. Khamverdi Z, Kasraei S, Fazelian N, Akbarzadeh M. Effect of tubular orientation on the microtensile bond strength of composite-dentin using universal bonding agents. J Res Med Dent Sci. 2018;6(2):337-44.
6. Danesh Kazemi P, Danesh Kazemi A, Shafiee F, Ghasemi A. Effect of different etching modes on dentin bond strength of two universal adhesives. J Mashhad Dent Sch. 2019;43(2):112-21. doi: 10.22038/jmds.2019.13107. [Persian].
7. Takeda M, Takamizawa T, Imai A, Suzuki T, Tsujimoto A, Barkmeier WW, et al. Immediate enamel bond strength of universal adhesives to unground and ground surfaces in different etching modes. Eur J Oral Sc. 2019;127(4):351-60. doi: 10.1111/eos.12626.
8. Wong J, Tsujimoto A, Fischer NG, Baruth AG, Barkmeier WW, Johnson EA, et al. Enamel etching for universal adhesives: examination of enamel etching protocols for optimization of bonding effectiveness. Oper Dent. 2020;45(1):80-91. doi: 10.2341/18-275-l.
9. Nalcaci R, Cokakoglu S. Lasers in orthodontics. Eur J Dent. 2013;7(Suppl 1):S119-S25. doi: 10.4103/1305-7456.119089.
10. Karaman E, Güler E. Marginal adaptation of class V restorations with a new universal adhesive. Int J Periodontics Restorative Dent. 2016;36(1):125-30. doi: 10.11607/prd.2598.
11. Subramaniam P, Pandey A. Assessment of microleakage of a composite resin restoration in primary teeth following class III cavity preparation using Er, Cr: YSGG laser: an in vitro study. J Lasers Med Sci. 2016;7(3):172-6. doi: 10.15171/jlms.2016.30.
12. Kawaguchi FA, Eduardo CP, Matos AB. Nd:YAG laser influence on microleakage of class V composite restoration. J Clin Laser Med Surg. 2003;21(4):227-9. doi: 10.1089/104454703768247800.
13. Wen X, Liu L, Nie X, Zhang L, Deng M, Chen Y. Effect of pulse Nd:YAG laser on bond strength and microleakage of resin to human dentine. Photomed Laser Surg. 2010;28(6):741-6. doi: 10.1089/pho.2009.2579.
14. Obeidi A, Ghasemi A, Azima A, Ansari G. Effects of pulsed Nd:YAG laser on microleakage of composite restorations in class V cavities. Photomed Laser Surg. 2005;23(1):56-9. doi: 10.1089/pho.2005.23.56.
15. Moritake N, Takamizawa T, Ishii R, Tsujimoto A, Barkmeier WW, Latta MA, et al. Effect of active application on bond durability of universal adhesives. Oper Dent. 2019;44(2):188-99. doi: 10.2341/17-384-l.
16. Malta DA, Costa MM, Pelino JE, de Andrade MF, Lizarelli

RF. Bond strength of an adhesive system irradiated with Nd: YAG laser in dentin treated with Er: YAG laser. Laser Phys Lett. 2008;5(2):144-50. doi: 10.1002/lapl.200710089.
17. Karandish M. The efficiency of laser application on the enamel surface: a systematic review. J Lasers Med Sci. 2014;5(3):108-14.
18. Franke M, Taylor AW, Lago A, Fredel MC. Influence of Nd:YAG laser irradiation on an adhesive restorative procedure. Oper Dent. 2006;31(5):604-9. doi: 10.2341/05-110.
19. Attin T, Hannig C, Wiegand A, Attin R. Effect of bleaching on restorative materials and restorations--a systematic review. Dent Mater. 2004;20(9):852-61. doi: 10.1016/j.dental.2004.04.002.
20. Kapoor N, Bahuguna N, Anand S. Influence of composite insertion technique on gap formation. J Conserv Dent. 2016;19(1):77-81. doi: 10.4103/0972-0707.173205.
21. Castro FL, Andrade MF, Hebling J, Lizarelli RF. Nd:YAG laser irradiation of etched/unetched dentin through an uncured two-step etch-and-rinse adhesive and its effect on microtensile bond strength. J Adhes Dent. 2012;14(2):137-45. doi: 10.3290/j.jad.a21854.
22. Araujo RM, Eduardo CP, Duarte Junior SL, Araujo MA, Loffredo LC. Microleakage and nanoleakage: influence of laser in cavity preparation and dentin pretreatment. J Clin Laser Med Surg. 2001;19(6):325-32. doi: 10.1089/104454701753342785.
23. Maleki-Pour MR, Birang R, Khoshayand M, Naghsh N. Effect of Nd:YAG laser irradiation on the number of open dentinal tubules and their diameter with and without smear of graphite: an in vitro study. J Lasers Med Sci. 2015;6(1):32-9.
24. Schneider LF, Cavalcante LM, Silikas N. Shrinkage stresses generated during resin-composite applications: a review. J Dent Biomech. 2010;2010:131630. doi: 10.4061/2010/131630.
25. Raskin A, D'Hoore W, Gonthier S, Degrange M, Déjou J. Reliability of in vitro microleakage tests: a literature review. J Adhes Dent. 2001;3(4):295-308.
26. Ayar MK, Erdemir F. Bonding performance of universal adhesives to Er, Cr: YSGG laser-irradiated enamel. Microsc Res Tech. 2017;80(4):387-93. doi: 10.1002/jemt.22807.
27. Tekçe N, Tuncer S, Demirci M, Balci S. Do matrix metalloproteinase inhibitors improve the bond durability of universal dental adhesives? Scanning. 2016;38(6):535-44. doi: 10.1002/sca.21293.
28. Maenosono RM, Bim Júnior O, Duarte MA, Palma-Dibb RG, Wang L, Ishikiriama SK. Diode laser irradiation increases microtensile bond strength of dentin. Braz Oral Res. 2015;29:1-5. doi: 10.1590/1807-3107bor-2015.vol29.0004.
29. Navarro RS, Esteves GV, Oliveira WT Jr, et al. Nd:YAG laser effects on the microleakage of composite resin restorations. J Clin Laser Med Surg. 2000;18(2):75-79. doi:10.1089/clm.2000.18.75.
30. White JM, Goodis HE, Setcos JC, Eakle S, Hulscher BE, Rose CL. Effects of pulsed Nd:YAG laser energy on human teeth: a three-year follow-up study. J Am Dent Assoc. 1993;124(7):45-51. doi:10.14219/jada.archive.1993.0273.
31. Matos AB, Oliveira DC, Kuramoto M Jr, Eduardo CP, Matson E. Nd:YAG laser influence on sound dentin bond strength. J Clin Laser Med Surg. 1999;17(4):165-9. doi: 10.1089/clm.1999.17.165.
32. Ugurlu M. Bonding efficacy of a resin-modified glass ionomer with universal adhesives to dentin after radiotherapy. J Adhes Sci Technol. 2020;34(21):2375-86. doi: 10.1080/01694243.2020.1761596.
33. Mahrous AI, Eltiti HA, Ahmed IM, Alagha EI. Effect of different gingival margin restorations of class II cavities on microleakage: an in-vitro study. Electron Physician. 2015;7(7):1435-40. doi: 10.19082/1435.