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Effect of Er: YAG Laser on Microtensile Bond Strength of Bleached Dentin to Composite

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Abstract

Introduction: In non-vital tooth bleaching, dentin is in direct contact with the bleaching agent, 1 to 3-week delay is needed to eliminate free radicals from tooth structure. The present study aimed to evaluate the effect of irradiation of Er: YAG laser on immediate microtensile bond strength of bleached dentin to composite.

Methods: Sixty sounds human teeth were collected and randomly divided into 4 groups (n = 15): no bleaching (NB), opalescence endo hydrogen peroxide (HP) gel bleaching, sodium perborate (SP) bleaching and laser bleaching with heydent gel (LB). The groups were divided into 3 subgroups (n = 5): no surface treatment, Er: YAG laser irradiation and 10% sodium ascorbate (SA). All samples were restored and underwent microtensile bond strength testing. Statistical analysis was carried out using one-way and two-way ANOVA.

Results: Bond strength in NB-SA group had a significant difference with the NB group ($P < 0.05$) while no significant difference was noted between NB and NB-Er groups ($P = 0.55$). Application of SA and Er: YAG laser after bleaching with SP did not enhance the bond strength ($P = 0.07$).

Conclusion: Application of SA and Er: YAG laser after HP gel bleaching significantly enhanced the bond strength. Application of Er: YAG laser after internal bleaching with HP gel could enhance the bond strength.

Keywords: Bleaching; Er: YAG laser; Bond strength

Introduction

Tooth bleaching and tooth-colored restorative materials are among the most common dental procedures.[1] Evidence shows that adhesions of restorations decrease to freshly bleached enamel and dentin.[2-4] Several studies have assessed the impact of different bleaching agents on mechanical and morphological properties of the bonding interface.[5-10] The results of most studies have indicated decreased bond strength of restorative materials to bleached dentin.[7,11,12] Residual free oxygen radicals in the dentinal tubules and in the collagen matrix have been proposed as possible reasons for this reduction in bond strength[7,11,12] since they prevent adequate polymerization of adhesives and composite resin. Bleaching of non-vital teeth is commonly performed to treat internal staining and discoloration of teeth. During the process of bleaching, enamel and dentin undergo morphological changes such as a change in superficial enamel crystals, loss of calcium and phosphate, destruction of the organic matrix of the enamel and accumulation of oxygen radicals in dentin.[6]

Since in this method dentin is directly bleached, 1 to 3-week time-lapse has been recommended between bleaching and adhesive restorations to obtain sufficient bond strength between the restorative material and bleached tooth structure.[13,14] However, this time lapse not only causes a delay in treatment but also increases the chance of coronal fracture, microleakage, and relapse of discoloration of endodontically treated teeth, which are all unfavorable for the patients and dentists.[15]

Sodium ascorbate (10%) and catalase have been suggested to overcome this problem, which is not commonly used in the clinical setting.[15] Sodium ascorbate salt is a potent antioxidant capable of suppressing reactive free radicals in biological systems.[16]

Parallel to the advances in bonding agents, new technologies have been employed such as the use of laser radiation to enhance the bond strength. The effects of lasers on hard dental tissues have been assessed by several researchers since the 1960s. As laser application changes the dental structure, it was necessary to investigate the

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consequences of these alterations. Various studies have shown contradictory results regarding the use of different lasers for increasing the bond strength of restorative materials to human dentin.[17-21]

Low energy Er: YAG laser changes the dentin surface and creates a surface free from the smear layer with open dentinal tubules. After tooth bleaching, dentin is saturated with the residual whitening agents such as free radicals, which are highly unstable. It seems that the heat created by low-level Er: YAG laser can eliminate free radicals and alter dentin to provide a more suitable substrate for bonding.[22-24] The present study sought to evaluate the effect of Er: YAG laser on microtensile bond strength of composite to freshly bleached dentin.

Methods

This experimental study was conducted on 60 extracted molar teeth due to periodontal or orthodontic reasons, collected within four months. Organic debris was eliminated using a periodontal scaler, and prophylaxis was performed using a mixture of pumice paste and water (pumice slurry) and a rubber cup. The samples were evaluated by a stereomicroscope (Nikon, Tokyo, Japan) at × 50 magnifications to exclude samples with hypoplastic defects or cracks. After cleaning, the samples were stored in 0.5% chloramine T (Merck, Germany) for 1 week and were then transferred to 4°C distilled water until the experiments (ISO/TS11405).[25] The materials used are presented in Table 1.

For the preparation of dentin, the occlusal surfaces were ground to the mid-coronal level by a low-speed diamond saw under water irrigation to reach a smooth dentin surface. A 600-grit silicon carbide abrasive disc was also used for 60 seconds to remove the residual enamel and create a smooth surface and a standard smear layer. The teeth were randomly assigned to 4 groups. It should be noted that the classification of groups was based on the type of bleaching, and the control group did not receive any bleaching treatment.

The four main groups in this study were as follows (n=15) (Table 2):

1. Dentin surfaces, which were not bleached (NB)
2. Dentin surfaces, which were bleached using 35% hydrogen peroxide gel (OP)
3. Dentin surfaces, which were bleached using sodium perborate (sp) solution (SP)
4. Dentin surfaces, which were bleached using Heydent gel and laser (LB).

Study Groups

The control group (NB, n=15): Bleaching was not performed for samples. The samples were transferred to artificial saliva 1week prior to testing.

Opalescence bleach group (OP, n=15): Bleaching was performed with 35% hydrogen peroxide (HP) gel (35% Opalescence Endo, Ultradent, USA). The teeth were surrounded by a wax rim with 3 mm height using sticky wax. Care was taken not to allow wax residues contact the dentin surfaces. The gel was then applied in 2 mm thickness on the exposed dentin for 3 days. The thickness of the gel was measured by a periodontal probe. A transparent shell was placed over the wax rim to provide a closed chamber to keep gel on the exposed dentin surface in such a way that no air bubble was noticed at the interface of the wax, tooth and the transparent shell. The samples were stored in a Petri dish containing artificial saliva and incubated at 37°C for 3 days. The teeth were then washed under running water for 1 minute and this process was repeated 3 times.

Laser bleaching group (LB, n=15): Bleaching was performed with Heydant JW Power gel (Farafan Co., Iran) and included 2 phases. Each phase included 3

Table 1. Materials Used in the Study

Material	Main Composition	Manufacturer
Artificial Saliva	1.5 mmol/L Ca^{+2}, 50 mmol/L KCL, 0.9 mmol/L $(PO4)^{-3}$, 20 mmol/L Trihydroxymethyl-aminomethane, pH: 7	-
Abrasive Aluminium Oxide Disks	Particle size:600 grit (fine grit)	3M ESPE, USA
Opalescence Endo 35%	Hydrogen peroxide 35%, potassium nitrate, fluoride	Ultradent, USA
Heydent Office Bleach Gel	Liquid: hydrogen peroxide 30% Powder: JW powder with TiO_2 particles	Farafan Co, Iran
Sodium Perborate	Sodium perborate monohydrate, TAED, sodium carbonate	Sultan Chemist Co, Iran
10% Sodium Ascorbate Solution	Liquid: distilled water Powder: 98% ascorbic acid sodium	Merck, Germany
Single Bond2	Bis GMA, HEMA, Ethanol, Water,10% by weight spherical silica, copolymer poly acrylic & poly itaconic acid	3M ESPE, USA
Filtek Z250	UDMA, Bis-GMA, Bis EMA, TEGDMA, Zirconia/Silica fillers	3M ESPE, USA

Abbreviations: Bis-GMA: sisphenol A glycidyl methacrylate; UDMA: urethane dimethacrylate; TEGDMA: triethylene glycol dimethacrylate; Bis-EMA, bisphenol A polyethylene glycol diether dimethacrylate; HEMA,hydroxyethyl methacrylic acid.
Each group was then randomly divided into 3 subgroups (n=5) based on the type of surface treatment after bleaching:
Subgroup 1: The teeth did not receive any surface treatment and were subjected to bonding process immediately after bleaching.
Subgroup 2: The teeth were treated with 10% sodium ascorbate solution and were then subjected to bonding process (SA).
Subgroup 3: The teeth were subjected to Er: YAG laser irradiation and were then subjected to bonding process (Er).

Table 2. The Study Groups

No.	Group	Number	Group	Type of Surface Treatment
1	Group 1-1	5	NB	No bleaching+ Single Bond 2
2	Group 1-2	5	NB- SA	No bleaching+ sodium ascorbate+ Single Bond 2
3	Group 1-3	5	NB- Er	No bleaching+ Er:YAG laser+ Single Bond 2
4	Group 2-1	5	Op	Bleaching with 35% hydrogen peroxide+ Single Bond 2
5	Group 2-2	5	Op- SA	Bleaching with 35% hydrogen peroxide+ Sodium ascorbate+ Single Bond 2
6	Group 2-3	5	Op- Er	Bleaching with 35% hydrogen peroxide+ Er:YAG laser+ Single Bond 2
7	Group 3-1	5	Sp	Bleaching with sodium perborate+ Single Bond 2
8	Group 3-2	5	Sp-SA	Bleaching with sodium perborate+ sodium ascorbate+ Single Bond 2
9	Group 3-3	5	Sp-Er	Bleaching with sodium perborate+ Er:YAG laser+ Single Bond 2
10	Group 4-1	5	LB	Laser bleaching with Heydent gel+ Single Bond 2
11	Group 4-2	5	LB-SA	Laser bleaching with Heydent gel+ sodium ascorbate+ Single Bond 2
12	Group 4-3	5	LB-Er	Laser bleaching with Heydent gel+ Er: YAG laser+ Single Bond 2

Abbreviations: SA, sodium ascorbate; LB, laser bleach; Sp, sodium perborate bleach; Op, opalescence; NB, no bleach.

applications of gel. The powder was mixed with 30% HP. The mixture was applied on the dentin surfaces in 1.5 mm thickness and activated by diode laser irradiation (Cheese TM, Wuhan Gigaa, China) with 810 nm wavelength, 1 W power, and continuous wave mode for 30 seconds at 6 mm distance from the gel surface. The gel remained on dentin for 1 minute and was then wiped off. This process was repeated in triplicate. After rinsing and applying the wax rim, the clear shell was placed and the teeth were immersed in artificial saliva and incubated at 37°C. The artificial saliva was refreshed daily. Three days later, the same process was repeated.

Sodium perborate bleach group (SP, n=15): First, 5 g of SP powder (Sultan Chemist Co., Iran) was mixed with 1 mL of distilled water to obtain a suspension. The periphery of the tooth was covered with utility wax and an adequate amount of the suspension with 2 mm thickness was placed on the exposed dentin for 3 days. Dentin was covered by a plastic shell and the teeth were immersed in artificial saliva and incubated at 37°C for 3 days. The suspension was then rinsed and these processes were repeated in triplicate.

Experimental Groups

Subgroups 1, 4, 7 and 10

Subgroup 1 (NB): No bleaching was performed. Bonding agent and composite resin were applied.

Subgroup 4 (OP): Bleaching was performed using 35% HP gel followed by the application of bonding agent and composite resin.

Subgroup 7 (PS): Bleaching was performed using SP solution followed by the application of bonding agent and composite resin.

Subgroup 10 (LB): Bleaching was performed using Heydant laser bleach gel followed by the application of bonding agent and composite resin.

Subgroups 2, 5, 8 and 11

Subgroup 2 (NB-SA): No bleaching was performed. Surfaces were treated with SA, and bonding agent and composite resin were then applied.

Subgroup 5 (OP-SA): Bleaching was performed using 35% HP gel followed by SA surface treatment, a bonding agent application, and composite restoration.

Subgroup 8 (SA-SP): Bleaching was performed using SP solution followed by SA surface treatment, bonding agent application, and composite restoration.

Subgroup 11 (SA-LB): Bleaching was performed using Heydant laser bleach gel followed by SA surface treatment, bonding agent application, and composite restoration.

Surface treatment with SA was performed as follows: 10 mL of 10% SA solution was applied on the specimen surfaces at 1 mL/min speed. This solution remained on dentin surfaces for 10 minutes; during this time period, the surfaces were constantly agitated by a microbrush and after 10 minutes, they were washed with distilled water and dried.

Subgroups 3, 6, 9 and 12

Subgroup 3 (NB-Er): No bleaching was performed. Surfaces were treated by Er: YAG laser irradiation. The bonding agent was then applied and followed by composite restoration.

Subgroup 6 (OP-Er): Bleaching was performed using 35% HP gel. Surfaces were treated by Er: YAG laser irradiation. The bonding agent was then applied and followed by composite restoration.

Subgroup 9 (SP-Er): Bleaching was performed with SP solution. Surfaces were treated by Er: YAG laser irradiation. Bonding agent was then applied and followed by composite restoration.

Subgroup 12 (LB-Er): Bleaching was performed with Haydon laser bleach gel. Surfaces were treated by Er: YAG laser irradiation. The bonding agent was then applied and followed by composite restoration.

Er: YAG laser (USD20, DEKA Dental laser systems, Florence, Italy) was irradiated with 50 mJ energy, 10 Hz frequency, 0.5 W power, 230 µs pulse width and non-contact mode for 4 seconds from 4 mm distance by using a grid. It was manually performed by an operator. To standardize the 4mm distance from laser handpiece to the surface, an endodontic K-file attached to the handpiece was used.

In all the aforementioned groups, the bonding agent was applied according to the manufacturer's instructions. First, the samples were etched with 35% phosphoric acid for 15 seconds, rinsed for 10 seconds and dried, leaving a moist dentin surface. Two layers of Adper Single Bond 2 were applied on dentin surfaces and air-dried for 5 seconds by air spray to evaporate the solvent. Next, light curing was performed for 10 seconds (LED Demi, Kerr, CA, USA) and Z250 composite resin (3M ESPE, St. Paul, MN, USA) was applied in two layers, each with the 1.5 mm thickness on the entire surface of exposed dentin. Each layer was light-polymerized for 20 seconds. Eventually, the entire composite restoration was light-cured for 20 seconds from each direction.

Microtensile Bond Strength Testing

After preparation and restoration of all samples, they were immersed in artificial saliva at 37°C for 24 hours. The teeth were then mounted in auto-polymerizing acrylic resin (Meliodent, Heraeus Kulzer, Germany). The teeth were sectioned in X and Y-axis directions by a low-speed diamond saw (CNC, France) under air and water coolant to obtain rectangular microbars of resin-dentin with a mean cross-sectional area of 1 mm^2. A digital caliper (Mitutoyo, Tokyo, Japan) was used for measurement of the rectangular-shaped samples. A total of 120 microbars in 12 subgroups (10 microbars in each subgroup) were fabricated. The samples were fixed to the clasps of the microtensile tester (Bisco, USA) at the 2 sides by cyanoacrylate glue (Mitreaple, Turkey) and underwent microtensile load application at a crosshead speed of 1 mm/min. The microtensile bond strength was calculated in megapascals (MPa) by dividing the load at fracture in Newtons by the cross-sectional area of the resin-dentin interface in square-millimeters (measured before fracture).

Mode of Failure

The samples were inspected under a stereomicroscope at ×50 magnification to determine the mode of failure. The mode of failure was reported as:

Adhesive: Failure at the adhesive-tooth or adhesive-composite interface in over 75% of the areas.

Cohesive in resin: Failure mainly in the composite mass such that over 75% of the tooth bonding area was covered with composite.

Cohesive in the tooth: Failure mainly within the tooth structure.

Mixed: A combination of the above-mentioned modes of fracture.

Raw data were analyzed using one-way ANOVA. Tukey's HSD test was used for paired comparisons of normally distributed data. Level of significance was set at 0.05.

Results

ANOVA revealed a significant difference between NB-SA and NB groups ($P<0.05$). No other significant differences were noted ($P=0.55$ for NB-Er and NB-SA and $P=0.55$ for NB-ER and NB). In other words, bond strength improved with the use of SA while Er: YAG laser did not improve the bond strength compared to the control group and did not decrease it either. The application of SA and Er: YAG laser after bleaching with SP did not improve the bond strength either ($P=0.07$). Application of SA and Er: YAG laser after bleaching with 35% HP (OP) significantly increased the bond strength ($P<0.05$). Application of SA compared to Er: YAG laser caused greater improvement in bond strength. Application of SA and Er: YAG laser after laser bleaching with Heydent gel did not enhance the bond strength.

Comparison of the groups based on the method of surface preparation by Tukey's HSD test revealed the followings:

Application of 35% HP gel (OP) significantly decreased the bond strength ($P<0.05$). Application of SP did not significantly decrease the bond strength. Application of laser bleaching compared to the control group (NB) did not reduce the bond strength either. Comparison of the four groups revealed that the lowest bond strength belonged to the OP group and the highest to LB group ($P=0.082$ for the comparison of LB and NB groups).

Surface treatment with SA significantly increased the bond strength to dentin bleached with OP gel ($P=0.14$ for the comparison of NB-SA and OP-SA). After bleaching with SP, preparation with ascorbate could not significantly improve the microtensile bond strength ($P<0.05$ for the comparison of NB-SA and SP-SA).

Application of Er: YAG laser after bleaching with SP, Heydent laser bleach gel and 35% HP gel (OP) yielded a bond strength similar to that in the control group ($P>0.083$).

Mode of Failure

Fracture surfaces were evaluated using a stereomicroscope at ×50 magnification.

Adhesive failure: A total of 80 microbars out of 120 (74%) showed adhesive failure.

Cohesive failure in the composite: Three microbars out of 120 (2.5%) showed cohesive failure in composite.

Cohesive failure in tooth structure: A total of 13 microbars out of 120 (11%) showed cohesive failure in the tooth.

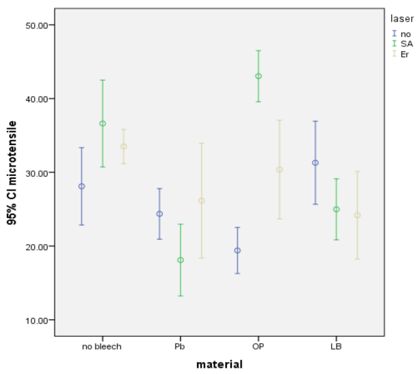

Figure 1. Comparison of Microtensile Bond Strength of Composite to Bleached Dentin in Megapascals.

Mixed failure: A total of 15 microbars (12.5%) showed mixed failure.

Discussion

Techniques and materials used for tooth bleaching have greatly advanced. Internal bleaching is an effective, affordable, simple and noninvasive technique compared to prosthetic treatments. Hydrogen peroxide with different concentrations can be used for internal bleaching. By increasing the concentration of peroxide, whitening efficacy is enhanced to a certain point.[26] It seems that 30% HP gel acts faster than SP with regard to bleaching; this is important considering the susceptibility to fracture of endodontically treated teeth. Materials with a lower pH can cause greater surface changes in dental tissues.[26]

After completion of treatment, bonded restorations must be delayed for 1-3 weeks to decrease the adverse effects of peroxide on the bonding procedure.[14] If such adverse effects are eliminated, coronal restoration can be performed immediately after completion of bleaching treatment.

In this study, Heydent JW power gel was used for dentin bleaching. This gel contains titanium dioxide particles and is activated by the diode laser. Although the high concentration of HP (30%) is also used in this method, the shorter application time of this gel has advantages such as lower risk of external resorption. Evidence shows that the safest compound for internal tooth bleaching is SP mixed with water or 10% carbamide peroxide after applying a barrier in the cervical area of root canals.[27]

In the current study, SA and Er: YAG laser surface treatments were used to eliminate the adverse effects of bleaching agents. To compensate for the decrease in bond strength of resin-based materials to bleached dentin, several methods have been proposed such as the use of 10% SA and catalase. The antioxidant properties of SA help neutralize and reverse the oxidizing effects of bleaching agents.[28-31]

Low-level Er: YAG laser can alter the dentin surface. In this situation, a surface free from smear layer with open dentinal tubules is created. Since the surface is full of unstable free radicals after direct contact with the bleaching agent, it seems that the generated heat makes dentin surface a better substrate for bonding.[23] For the composite bond to tooth structure, Single Bond 2 fifth generation bonding system was used, which is a light-cure, ethanol-based, two-step etch and rinse adhesive. Some studies have shown that use of ethanol-based adhesives may be able to neutralize the negative effects of bleaching on bonding to enamel.[32,33]

Inspection of the fracture surfaces determines the mode of failure. Determination of the mode of failure along with analyzing the mechanical parameters of failure is important to assess the reliability of bond and decrease misinterpretations.[34] Thus, samples were evaluated under a stereomicroscope at ×50 magnifications to evaluate the mode of failure in the current study. In this study, application of SA compared to the control group (NB) improved the bond strength. It seems that application of antioxidant agents enhances the bond strength even in absence of bleaching (by eliminating oxygen). In other words, the absence of oxygen in the area may improve resin polymerization. Cohesive tooth fracture was noted in 3 samples in this group in our study, which indicates a strong bond to dentin.

In our study, application of Er: YAG laser had no significant effect on microtensile bond strength of composite to bleached dentin. In other words, application of laser alone had no positive effect on microtensile bond strength of composite to bleached dentin. The results of previous studies in this respect are controversial. Ramos et al evaluated the microtensile bond strength of dentin adhesive systems irradiated with Er: YAG and Er, Cr: YSGG lasers and showed that irradiation of both lasers decreased the bond strength.[35]

Goncalves et al studied the effect of Er: YAG laser irradiation on bond strength of resin to dentin and concluded that Er: YAG laser pretreatment improved the tensile bond strength of adhesive to dentin.[36]

Katsumi et al noticed cracks in dentin following Er: YAG laser irradiation.[37] Such a structural flaw was not limited to superficial dentin, and laser irradiation caused weakness in dentin as deep as 3-5 microns, which eventually decreased the bond strength. Goncalves et al showed that elimination of the laser-modified layer by etching returned the bond strength back to normal.[36] Based on these findings, it seems that application of etching and rinse adhesive system after Er: YAG laser irradiation yielded bond strength values as high as that of the control (NB) group. In the current study, the use of SP did not significantly decrease the bond strength compared to the control (NB) group. Maleknejad et al evaluated the changes in dentin microstructure and reported that although application of a combination of SP and 30% HP resulted in the widening of dentinal tubules, the combination of SP and water had no effect on the diameter of dentinal tubules.[38] It seems that no drop in bond strength after the application of SP was due to the low concentration of oxygen in this material. Also, the current study showed that SA and Er: YAG laser after the application of SP did not significantly improve the bond strength. This finding is not far from expectation considering no reduction of bond strength after the application of SP. Yoon et al also reported that SP bleaching did not affect the microtensile bond strength of dentin.[39]

In the current study, the application of 35% HP compared to SP causes a significant reduction in bond strength, which is in line with the findings of Ferrari et al. They demonstrated that bond strength after the application of 35% HP was much lower than that after the use of SP mixed with water; they attributed this finding to the fact that HP gel is stronger than SP.[40] After the application of OP compared to NB, a significant decrease in bond strength was noted. The decrease in bond strength following the application of high concentrations of HP was not far from expectation. This finding is similar to the results of Vieira et al. They showed that bleaching dentin with HP decreased dentin bond strength to the resin. By an increase in the concentration of HP, bond strength decreased.[12] Application of SA after bleaching with OP gel significantly enhanced bond strength. This finding was comparable to that of Lai et al showed that the process of infusion of peroxide ions into the tooth structure was reversible by using an antioxidant agent such as SA.[41,42]

Application of SA on dentin of teeth, which have undergone internal bleaching, enables immediate bonding of composite to tooth structure.[43] In the current study, SA remained on the surface for 10 minutes and was constantly agitated by a microbrush. There is no consensus on the duration of application of SA on the tooth structure to enhance bond strength.[44] On the other hand, SA well reacts with hydroxy-peroxy apatite crystals created by bleaching and significantly increases the bond strength of bleached samples and those under treatment with SA.

In the current study, use of Er: YAG laser as a surface treatment after bleaching with 35% HP gel significantly enhanced the microtensile bond strength of dentin to composite ($P<0.05$). Er: YAG laser irradiation, via the thermo-mechanical process of ablation, causes micro-explosions in tooth structure. It appears that these micro-explosions and the generated heat at the site eventually result in extrusion of free radicals from the tooth structure.[45]

In the current study, when HP gel was used for bleaching, application of SA for surface treatment caused a greater increase in bond strength compared to Er: YAG laser irradiation. It should be noted that no previous study was found comparing surface treatment with SA and Er: YAG laser.

Maleknejad et al showed that application of internal bleaching agents such as 35% HP and 45% carbamide peroxide increased the diameter of dentinal tubules and decreased the calcium to phosphorus ratio. These elements are present in the structure of hydroxyapatite crystals and a reduction in their weight percentage means demineralization.[36]

The results of the aforementioned studies explain the reduction in bond strength to dentin after bleaching with 35% HP. Application of Heydent bleaching gel compared to NB did not significantly decrease the bond strength. Moreover, application of SA and Er: YAG laser did not enhance the bond strength either. After bleaching a significant drop in bond strength was not seen, it is concluded that application of SA and Er: YAG laser did not significantly enhance the bond strength either. Application of OP compared to Heydent gel along with laser irradiation significantly decreased the bond strength; this finding may be due to the shorter application time of HP gel in laser-bleaching. Considering the shorter application time of bleaching agent in laser-bleaching method and absence of an adverse effect on bond strength to dentin in this technique, the efficacy of this system should be evaluated for the elimination of intrinsic discolorations and in case of clinical success, routine use of laser bleaching can be recommended in dental offices.

Conclusion

The following conclusions were drawn in this study:

1. Application of 35% HP (OP) significantly decreased the bond strength ($P<0.05$). But the application of SP and laser bleaching (Heydent) had no significant effect on bond strength ($P=0.07$).
2. Application of SA after bleaching with 35% HP (OP) enhanced the bond strength ($P<0.05$) but did not influence the bond strength after bleaching with SP and laser bleaching ($P=0.09$).
3. Irradiation of Er: YAG laser after bleaching with 35% HP (OP) significantly enhanced the bond strength ($P<0.05$) but did not affect the bond strength after bleaching with SP and laser bleaching.
4. After bleaching with 35% HP gel, application of SA compared to Er: YAG laser resulted in greater improvement in bond strength ($P<0.05$).

Ethical Considerations

Not applicable.

Conflict of Interests

The authors declare no conflict of interest.

References

1. Gurgan S, Alpaslan T, Kiremitci A, Cakir FY, Yazici E, Gorucu J. Effect of different adhesive systems and laser treatment on the shear bond strength of bleached enamel. *J Dent.* 2009;37(7):527-534. doi:10.1016/j.jdent.2009.03.012
2. Titley KC, Torneck CD, Smith DC, Chernecky R, Adibfar

A. Scanning electron microscopy observations on the penetration and structure of resin tags in bleached and unbleached bovine enamel. *J Endod.* 1991;17(2):72-75. doi:10.1016/s0099-2399(06)81611-0
3. Oz FD, Kutuk ZB. Effect of various bleaching treatments on shear bond strength of different universal adhesives and application modes. *Restor Dent Endod.* 2018;43(2):e20. doi:10.5395/rde.2018.43.e20
4. Garcia-Godoy F, Dodge WW, Donohue M, O'Quinn JA. Composite resin bond strength after enamel bleaching. *Oper Dent.* 1993;18(4):144-147.
5. Barbosa CM, Sasaki RT, Florio FM, Basting RT. Influence of in situ post-bleaching times on resin composite shear bond strength to enamel and dentin. *Am J Dent.* 2009;22(6):387-392.
6. Barcellos DC, Benetti P, Fernandes VV Jr, Valera MC. Effect of carbamide peroxide bleaching gel concentration on the bond strength of dental substrates and resin composite. *Oper Dent.* 2010;35(4):463-469. doi:10.2341/09-242-l
7. Ferreira EA, Souza-Gabriel AE, Silva-Sousa YT, Sousa-Neto MD, Silva RG. Shear bond strength and ultrastructural interface analysis of different adhesive systems to bleached dentin. *Microsc Res Tech*. 2011;74(3):244-250. doi:10.1002/jemt.20895
8. Shinohara MS, Peris AR, Rodrigues JA, Pimenta LA, Ambrosano GM. The effect of nonvital bleaching on the shear bond strength of composite resin using three adhesive systems. *J Adhes Dent.* 2004;6(3):205-209.
9. Shinohara MS, Peris AR, Pimenta LA, Ambrosano GM. Shear bond strength evaluation of composite resin on enamel and dentin after nonvital bleaching. *J Esthet Restor Dent.* 2005;17(1):22-29; discussion 29.
10. Uysal T, Er O, Sagsen B, Ustdal A, Akdogan G. Can intracoronally bleached teeth be bonded safely? Am *J Orthod Dentofacial Orthop.* 2009;136(5):689-694. doi:10.1016/j.ajodo.2007.11.033
11. Plotino G, Buono L, Grande NM, Pameijer CH, Somma F. Nonvital tooth bleaching: a review of the literature and clinical procedures. *J Endod*. 2008;34(4):394-407. doi:10.1016/j.joen.2007.12.020
12. Vieira C, Silva-Sousa YT, Pessarello NM, Rached-Junior FA, Souza-Gabriel AE. Effect of high-concentrated bleaching agents on the bond strength at dentin/resin interface and flexural strength of dentin. *Braz Dent J.* 2012;23(1):28-35.
13. Heymann HO, Swift EJ Jr, Ritter AV. *Sturdevant's Art and science of operative dentistry.* 6th ed. Canada: Elsevier Mosby; 2013:7-13.
14. Summitt JB, Robbins JW, Hilton TJ, Schwartz RS, Santos JD Jr. *Fundamentals of Operative Dentistry: A Contemporary Approach.* 4th ed. China: Quintessence Pub Co; 2013.
15. Jung KH, Seon EM, Choi AN, Kwon YH, Son SA, Park JK. Time of Application of Sodium Ascorbate on Bonding to Bleached Dentin. *Scanning*. 2017;2017:6074253. doi:10.1155/2017/6074253
16. Kunt GE, Yilmaz N, Sen S, Dede DO. Effect of antioxidant treatment on the shear bond strength of composite resin to bleached enamel. *Acta Odontol Scand.* 2011;69(5):287-291. doi:10.3109/00016357.2011.568958
17. Rocha Gomes Torres C, Caneppele TM, Del Moral de Lazari R, Ribeiro CF, Borges AB. Effect of dental surface treatment with Nd:YAG and Er:YAG lasers on bond strength of resin composite to recently bleached enamel. *Lasers Med Sci.* 2012;27(4):755-760. doi:10.1007/s10103-011-0946-6
18. De Munck J, Van Meerbeek B, Yudhira R, Lambrechts P, Vanherle G. Micro-tensile bond strength of two adhesives to Erbium:YAG-lased vs. bur-cut enamel and dentin. *Eur J Oral Sci.* 2002;110(4):322-329.
19. Pahlavan A, Mehmanchi M, Ranjbar Omrani L, Chiniforush N. Effect of Air Abrasion and Erbium-Doped Yttrium Aluminum Garnet (Er: YAG) laser preparation on Shear Bond Strength of Composite to Dentin. *J Lasers Med Sci.* 2013;4(3):127-130.
20. Alkhudhairy F, AlKheraif A, Bin-Shuwaish M, Al-Johany S, Naseem M, Vohra F. Effect of Er,Cr:YSGG Laser and Ascorbic Acid on the Bond Strength and Microleakage of Bleached Enamel Surface. *Photomed Laser Surg.* 2018;36(8):431-438. doi:10.1089/pho.2018.4437
21. Chousterman M, Heysselaer D, Dridi SM, et al. Effect of acid etching duration on tensile bond strength of composite resin bonded to erbium:yttrium-aluminium-garnet laser-prepared dentine. Preliminary study. *Lasers Med Sci.* 2010;25(6):855-859. doi:10.1007/s10103-009-0719-7
22. Soares LE, Brugnera Junior A, Zanin F, Pacheco MT, Martin AA. Molecular analysis of Er:YAG laser irradiation on dentin. *Braz Dent J.* 2006;17(1):15-19. doi:/S0103-64402006000100004
23. Leonetti Edos S, Rodrigues JA, Reis AF, Navarro RS, Aranha AC, Cassoni A. Microtensile bond strength of resin composite to dentin treated with Er:YAG laser of bleached teeth. *Lasers Med Sci.* 2012;27(1):31-38. doi:10.1007/s10103-010-0838-1
24. Basir MM, Rezvani MB, Chiniforush N, Moradi Z. Effect of CO2, Nd:YAG and Er:YAG Lasers on Microtensile Bond Strength of Composite to Bleached-Enamel. *Open Dent J.* 2016;10:148-157. doi:10.2174/1874210601610010148
25. International Organization for Standardization (ISO). Technical specification ISO/TS 11405. *Dental materials-Testing of adhesion to tooth structure*. 2nd ed. Switzerland: ISO; 2003.
26. Haywood VB, Berry TG. Natural tooth bleaching In: Summitt JB, Robbins JW, Hilton T, Schwarts RS, eds. *Fundamentals of Operative Dentistry*. 3rd ed. China: Quintessence Pub Co; 2006:437-462.
27. de Oliveira LD, Carvalho CA, Hilgert E, Bondioli IR, de Araujo MA, Valera MC. Sealing evaluation of the cervical base in intracoronal bleaching. *Dent Traumatol.* 2003;19(6):309-313.
28. Khoroushi M, Aghelinejad S. Effect of postbleaching application of an antioxidant on enamel bond strength of three different adhesives. *Med Oral Patol Oral Cir Bucal.* 2011;16(7):e990-996.
29. Danesh-Sani SA, Esmaili M. Effect of 10% sodium ascorbate hydrogel and delayed bonding on shear bond strength of composite resin and resin-modified glass ionomer to bleached enamel. *J Conserv Dent*. 2011;14(3):241-246. doi:10.4103/0972-0707.85799
30. Mazaheri H, Khoroushi M, Shafiei E, Ghorbanipour R, Majdzade F. Bond strength of composite-resin and resin-modified glass ionomer to bleached enamel: delay bonding versus an antioxidant agent. *Indian J Dent Res.*

2011;22(3):432-435. doi:10.4103/0970-9290.87066
31. Dabas D, Patil AC, Uppin VM. Evaluation of the effect of concentration and duration of application of sodium ascorbate hydrogel on the bond strength of composite resin to bleached enamel. *J Conserv Dent*. 2011;14(4):356-360. doi:10.4103/0972-0707.87197
32. Spyrides GM, Perdigao J, Pagani C, Araujo MA, Spyrides SM. Effect of whitening agents on dentin bonding. *J Esthet Dent*. 2000;12(5):264-270.
33. Sung EC, Chan SM, Mito R, Caputo AA. Effect of carbamide peroxide bleaching on the shear bond strength of composite to dental bonding agent enhanced enamel. *J Prosthet Dent*. 1999;82(5):595-599.
34. Escribano NI, Del-Nero MO, de la Macorra JC. Inverse relationship between tensile bond strength and dimensions of bonded area. *J Biomed Mater Res B Appl Biomater*. 2003;66(1):419-424. doi:10.1002/jbm.b.10033
35. Ramos TM, Ramos-Oliveira TM, Moretto SG, de Freitas PM, Esteves-Oliveira M, de Paula Eduardo C. Microtensile bond strength analysis of adhesive systems to Er:YAG and Er,Cr:YSGG laser-treated dentin. *Lasers Med Sci*. 2014;29(2):565-573. doi:10.1007/s10103-012-1261-6
36. Goncalves M, Corona SA, Borsatto MC, Silva PC, Pecora JD. Tensile bond strength of dentin-resinous system interfaces conditioned with Er:YAG laser irradiation. J Clin Laser Med Surg. 2002;20(2):89-93. doi:10.1089/104454702753768070
37. Goncalves SE, de Araujo MA, Damiao AJ. Dentin bond strength: influence of laser irradiation, acid etching, and hypermineralization. *J Clin Laser Med Surg*. 1999;17(2):77-85.
38. Maleknejad F, Ameri H, Kianfar I. Effect of intracoronal bleaching agents on ultrastructure and mineral content of dentin. *J Conserv Dent*. 2012;15(2):174-177. doi:10.4103/0972-0707.94586
39. Yoon M, Burrow MF, Wong R, Parashos P. Effect of sodium ascorbate on resin bonding to sodium perborate-bleached dentin. *Oper Dent*. 2014;39(1):98-106. doi:10.2341/12-516-l
40. Ferrari R, Attin T, Wegehaupt FJ, Stawarczyk B, Taubock TT. The effects of internal tooth bleaching regimens on composite-to-composite bond strength. *J Am Dent Assoc*. 2012;143(12):1324-1331.
41. Lai SC, Mak YF, Cheung GS, et al. Reversal of compromised bonding to oxidized etched dentin. *J Dent Res*. 2001;80(10):1919-1924. doi:10.1177/00220345010800101101
42. Lai SC, Tay FR, Cheung GS, et al. Reversal of compromised bonding in bleached enamel. *J Dent Res*. 2002;81(7):477-481.
43. Briso AL, Rahal V, Sundfeld RH, dos Santos PH, Alexandre RS. Effect of sodium ascorbate on dentin bonding after two bleaching techniques. *Oper Dent*. 2014;39(2):195-203. doi:10.2341/12-054-l
44. Turkun M, Turkun LS. Effect of nonvital bleaching with 10% carbamide peroxide on sealing ability of resin composite restorations. *Int Endod J*. 2004;37(1):52-60.
45. Staninec M, Gardner AK, Le CQ, Sarma AV, Fried D. Adhesion of composite to enamel and dentin surfaces irradiated by IR laser pulses of 0.5-35 micros duration. *J Biomed Mater Res B Appl Biomater*. 2006;79(1):193-201. doi:10.1002/jbm.b.30530