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Evaluation of the Effect of Phosphoric Acid or Er: YAG Laser on the Shear Bond Strength of Orthodontic Brackets to Enamel Surfaces Followed by 980-Laser Assisted Bleaching: An In Vitro Study

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Abstract

Introduction: The residual oxygen remained on tooth surface after bleaching may interfere with adhesion of brackets to enamel surface. This study aimed to evaluate the influence of phosphoric acid and Er: YAG laser as an etching technique on the shear bond strength (SBS) of orthodontic brackets to enamel surfaces after 980-laser-assisted bleaching.

Method: A total of 84 human premolars were recruited in the present study. Samples were divided into 6 groups including conventional bleaching with conventional etching, conventional bleaching with Er: YAG laser etching, laser-assisted bleaching with conventional etching, and Laser-assisted bleaching with Er: YAG laser etching, without bleaching with traditional etching, and without bleaching+Er: YAG laser etching. Following thermocycling, the debonding of brackets was conducted using a universal testing machine. Scanning electron microscope (SEM) microscope evaluation and adhesive remnant index (ARI) scores were assessed. The comparison of SBS values between groups was carried out by means of a one-way analysis of variance, followed by post-hoc tests.

Results: The non-bleaching with conventional etching group showed the highest SBS mean value (23.45±5.16 MPa), whereas the conventional bleaching with conventional etching group represented the lowest SBS mean value (8.8±3.83 MPa). In all groups, the most common type of failure was classified as either score 1 or score 2. No significant difference was observed in terms of SBS mean between the groups ($P=0.165$); however, the average SBS of bleached teeth was significantly lower, compared to the non-bleached group ($P=0.000$). Honeycomb structure and porosity were observed following Er: YAG laser etching on the tooth surface.

Conclusion: Increased bond strength of brackets was observed in bleached teeth following Er: YAG laser etching. Therefore, if necessary, bond the brackets on the same day of bleaching will be done, the application of Er:YAG laser as etching technique will can be recommended.

Keywords: Bleaching; Diode; Er:YAG; Laser; Laser etching; Shear bond strength.

Introduction

Compared to resin composites, porcelain veneers and dental veneers, bleaching offers the best protection against tooth discoloration.[1] Because of this, dentists and patients alike are increasingly using vital and non-vital bleaching comprising a variety of bleachers for whitening teeth.[2]

Bleaching may be accomplished at home or in the workplace. Higher amounts of carbamide peroxide (35%) and hydrogen peroxide (35-40%) are found in commercial products, whereas lower concentrations are found in home bleaching materials.[3]

Free radicals generated throughout bleaching serve as reactants for the bleaching chemical; however, not all of the radicals created are utilized. The tubular arrangement of the enamel traps unreacted free radicals, preventing the resin from entering entirely and generating a resin tag.[4] It may also impede thorough polymerization of the composite whenever resin is employed on the tooth surface following bleaching. Polypeptides and minerals apart from these bleaching chemicals also affect the surface areas of the enamel, all of which lower the bonding strength of the adhesive.[5-7]

Lasers have been suggested as a possible solution to this issue. Enhancing the temperature of stiff tissues and removing free radicals may create morphological

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alterations and improve bond strength with the help of the laser.[8] On the other side, laser irradiation generates temperature fluctuations on the enamel layer, which results in etching-like imperfections on the surface. With a penetrating profundity of roughly 10-20 microns, lasers are well-suited for bonding applications. Dental decay resistance is increased by altering the proportion of calcium to phosphorus and by decreasing the proportion of carbonate to phosphate owing to laser treatment to the enamel layer and decreasing the water and organic substances. As a consequence, the shortcomings of the acid etching method may be avoided with this method.[9]

The integration of both procedures was tested in this research because of the advantages of laser treatment in decreasing the complications of bleaching and its favorable effects whenever performed in the orientation of the etching of tooth enamel. The purpose of the current study was to evaluate the influence of phosphoric acid and Er: YAG laser as an etching technique on the shear bond strength (SBS) of orthodontic brackets to enamel surfaces after 980-laser-assisted bleaching or conventional bleaching.

Materials and Methods

This study was approved by the Institutional Review Board, Faculty of Dentistry, Tehran University, Iran (IR.TUMS.DENTISTRY.REC.1400.045), and complied with the principles of the Declaration of Helsinki. The premolars used in this study were collected from specialized clinics and specialized offices in Tehran.

A total of 84 human premolar teeth were utilized in the experimental investigation, and they were separated into six categories:

1. Conventional bleaching, followed by conventional etching.
2. Conventional bleaching, followed by etching with an Er: YAG laser.
3. Laser-assisted bleaching with a 980 nm diode, followed by conventional etching.
4. Laser-assisted bleaching with a 980 nm diode, followed by etching with an Er: YAG laser.
5. Non-bleaching teeth, followed by conventional etching.
6. Non-bleaching teeth, followed by Er: YAG laser etching.

Sample Preparation

Bleaching with 35% hydrogen peroxide occurred in the first and second groups (DoctorSmile, Italy). It was necessary to apply bleaching gel having a thickness of 1.5-2 mm within a 5 mL syringe containing a mixing tip on the buccal surface of enamel over 20 minutes.

With 35% hydrogen peroxide, bleaching was used in the third and fourth categories (DoctorSmile, Italy). The buccal surface of the enamel was treated with bleaching gel, which was applied with a mixing tip in a 5 mL syringe having a thickness of 1.5-2 mm. It was subsequently treated with a 980 nm diode laser over 30 seconds at an interval range between 1 to 2 mm from the tooth surfaces using a specific bleaching head. This procedure was done two more times on the teeth once it had been completed for one minute. Bleaching gel was applied to teeth for seven minutes and subsequently rinsed following the third radiation.

Bonding Process

After using 37% phosphoric acid (3M Dental Products, St Paul, Minn) for 30 seconds, the first, third, and fifth groups were etched. To get a frosty appearance on the tooth surface, they were thereafter washed over 30 seconds and dried for 10 seconds.

Er: YAG (Pluser, DoctorSmile, Italy) laser irradiation having a frequency of 40 Hz, 1 W output strength, and 25mj energy in 10 seconds was used to etch the second, fourth, and sixth categories (tip diameter was 600 microns, and the interval between the laser and the enamel membrane was 1 mm).

First, a layer of bonding was applied and cured with a light cure device. After that, a light cure composite (Transbond XT from 3M Unitek in Monrovia, Calif) was carefully placed on the base of the metal brackets of American Orthodontics and then gently placed on the surface of the tooth. Before curing with a light-emitting diode (LED) device, any excess composite had to be removed. The LED device used was the Elipar Free Light 2 from 3M ESPE in the USA, which was applied for a total of 40 seconds, with 10 seconds coming from each side.

Assessing the Shear Bond Strength

Following the attachment of the brackets and aligning them based on their slots, they were incubated in distilled water at 37 ˚C for 24 hours (Kavoosh Mega incubator device, Iran). Next, the teeth samples were subjected to a thermocycler machine (Vafaei Industrial, Iran) that cycled 3000 times with each cycle lasting for 20 seconds and an interval of 10 seconds between temperatures ranging from 5-55 ˚C.

After mounting them in the autopolymerization acrylic (Acropas, Iran, Tehran), they were transferred by a Universal Testing Machine (Zwich, Germany). The force was applied occlusogingivally with a speed of 0.5 mm/min. The force at the fracture time was recorded, and the pressure was calculated by dividing the force by the cross-sectional diameter of the bracket (10.28 mm^2) in MPa, which is the amount of SBS.

Measurement of the Adhesive Remnant Index

In the study, the samples that were close to the average SBS were included and assessed by using a microscope (Nikon, Japan) with a 10x magnification. The researchers

recorded the adhesive remnant index (ARI) score for each sample under the microscope. A score of 0 indicated that there was no adhesive left on the tooth, while a score of 1 meant that less than half of the adhesive remained. A score of 2 meant that more than half of the adhesive remained, and a score of 3 indicated that all of the adhesives remained on the tooth.[9]

Scanning Electron Microscope Examination

The surface of tooth enamel was examined for structural and surface changes, such as porosity or irregularity, using an electronic microscope called the scanning electron microscope (SEM, HITACHIS4160, Japan). Two samples from each group were selected for SEM analysis, one of which was treated with acid phosphoric gel while the other was not. These samples were cleaned with ethanol and then dried before being observed at magnifications of x500, x1000, and x1500.

Statistical Analysis

All statistical analyses were performed using SPSS 25 (IBM, Armonk, NY, USA). Descriptive statistics were obtained for each group, including the mean, standard deviation, standard error, and minimum and maximum values. To compare the SBS values, a one-way analysis of variance (ANOVA) with a post-hoc test was conducted. The level of significance was set at $P < 0.05$.

Results

This study investigated the effect of 980 nm diode laser bleaching on the SBS of orthodontic brackets to phosphoric acid and Er: Y laser etched enamel surfaces by assessing 84 samples in 6 groups (14 samples were in each group).

Shear Bond Strength

The group that used conventional etching without bleaching had the highest average SBS, with a value of 23.45 ± 5.16 MPa. On the other hand, the group that used conventional bleaching with conventional etching had the lowest average SBS, with a value of 8.8 ± 3.83 MPa. The ANOVA test with a 95% confidence interval (CI) did not show any significant differences in the average SBS between the groups ($P < 0.05$). However, the average SBS of the teeth that were bleached was significantly lower than the non-bleached group. Table 1 provides detailed information about the SBS for each of the study groups, while Figure 1 displays the average SBS and 95% CI for each group.

Adhesive Remnant Index

The ARI was selected as the next factor to study in terms of the amount of remaining adhesion. The frequency distribution of the ARI scores for each group is summarized in Table 2. The results showed that the majority of groups had ARI scores of either 1 or 2.

Scanning Electron Microscope

In the SEM view of the laser etched specimens, the honeycomb structure was observed. In bleached groups, conventional etching failed to form the honeycomb structure and also produced fewer porosities and less depth than etched lasers (Figures 2 and 3). In the bleaching groups, the laser created a honeycomb etching pattern with a greater number and depth of porosity (Figures 4 and 5). In the control group, the etching surface created the following normal etching, and laser etching had a nearly similar appearance (Figures 6 and 7).

Discussion:

This study aimed to evaluate the effect of different bleaching protocols (laser-assisted and conventional bleaching) and different etching methods (laser etching and conventional etching) on the SBS of enamel-bound metal brackets.

According to the results, conventional etching reduced SBS in the bleached teeth, particularly in conventional bleaching. However, SBS was improved by laser-assisted bleaching and laser etching.

Compared to resin composites, porcelain veneers, and veneers, bleaching is the most protecting method for stained (discolored) teeth.

Hydrogen peroxide (H2O2) is commonly used to bleach teeth, but bleaching with H2O2 reduces the SBS of brackets in patients undergoing orthodontic treatment, in particular when there is a short interval between bleaching and bracket bound and using a high concentration of H2O2.[10,11] Methods have been proposed

Table 1. Descriptive Statistics of SBS Values

Bleaching	Etching	Number	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
Conventional bleaching	Conventional etch	14	12.422	2.92053	0.78054	9.419	15.424
	Laser etch	14	15.175	3.71146	0.99193	12.172	18.177
Laser assisted bleaching	Conventional etch	14	8.805	3.83891	1.02599	5.802	11.807
	Laser etch	14	12.928	2.72801	0.72909	9.926	15.931
Non-bleaching	Conventional etch	14	23.458	5.16166	1.37951	20.456	26.461
	Laser etch	14	22.028	4.23304	1.13133	19.025	25.030

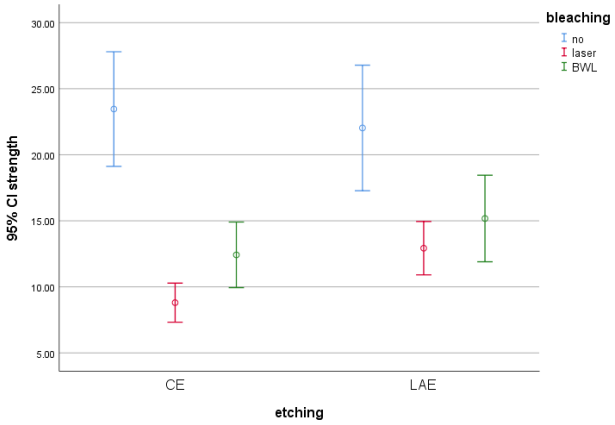


Figure 1. Displaying Mean SBS Values in Different Groups. CE, conventional etching; LAE, laser assisted etching

to overcome this problem. Increasing the time interval between bleaching and bonding is one of the methods that Mullins et al. (2009) stated that if patients have a history of bleaching in the office with 38% hydrogen peroxide, the orthodontic bonding should be delayed for 2-3 weeks.[12] Feiz et al reviewed the use of antioxidants as another proposed method. They evaluated the effect of antioxidant agents (e.g. sodium ascorbate) on the SBS of repair materials after bleaching. Their review indicated that antioxidants, regardless of their type, form, concentration, and duration of use, could enhance SBS after bleaching by reversing the action of bleaching agents such as H2O2.[13] This was in line with the findings of Kunt et al who evaluated the effects of antioxidants (e.g. ascorbic acid) on the improvement of SBS in bleached teeth.[14]

Another suggested technique is the application of a laser for the etching process. A comparison between the Er:YAG Laser (with 1 W and 1.5 W powers) and conventional etching revealed a higher SBS in Er:YAG Laser etching groups (6.97 ± 3.64 and 6.93 ± 4.87, respectively) than that of conventional etching (3.82 ± 1.16), with a significant difference between the 1W Er:YAG Laser and conventional etching.[15] However, there are limited studies with contrasting results in this regard. Similarly, our study demonstrated that SBS was improved by the Er:YAG Laser in bleaching groups, particularly in the conventional bleaching group.

According to SEM results, laser etching created honeycomb structures on the surface of bleached enamel, while conventional etching did not. However, some studies have shown that laser etching of teeth changes the ratio of calcium to phosphorus, decreases the ratio of carbonate to phosphate, and creates resistant compounds, and lasers are not able to create a standard and reliable etching pattern.[16] Gorucu-Coskunner et al assessed the effect of different bleaching and etching techniques on orthodontic bracket bond strength; the results of their study showed that Er, Cr: YSGG laser etching did not

Table 2. Distribution of ARI Scores Among the Study Groups

Bleaching	Etching	Number	0	1	2	3
Conventional bleaching	Conventional etch	14	2 14.3%	9 64.3%	2 14.3%	1 7.1%
	Laser etch	14	0 0.0%	4 28.6%	9 64.3%	1 7.1%
Laser assisted bleaching	Conventional etch	14	2 14.3%	9 64.3%	3 21.4%	0 0.0%
	Laser etch	14	3 21.4%	8 57.1%	3 21.4%	0 0.0%
Non-bleaching	Conventional etch	14	0 0.0%	4 28.6%	6 42.9%	4 28.6%
	Laser etch	14	1 7.1%	6 42.9%	7 50.0%	0 0.0%

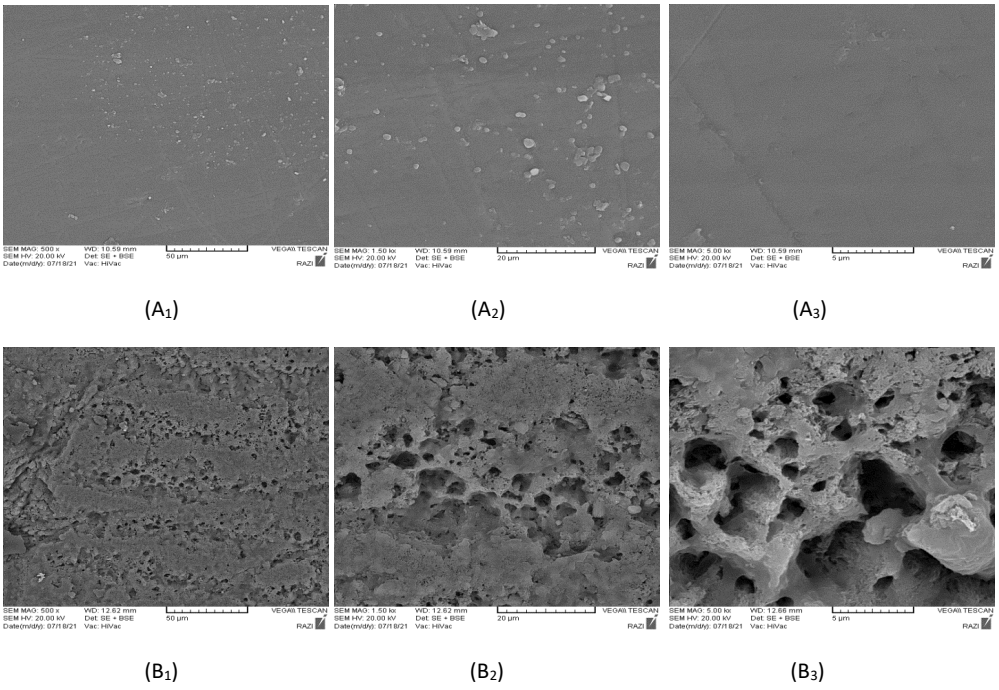
improve bond strength, which differed from the present study; their researchers attributed the difference to the distance from the laser to the tooth surface.[17] While in the study of Başaran et al it was shown that there was no significant difference between the conventional etching group was not from the Er: YAG laser etching group with a radiation distance of 1 mm, in terms of SBS ($P > 0.05$). However, according to their study, the bond strength decreases with increasing the laser distance to the tooth surface during laser etching.[18]

Another method of improving bond strength in bleached teeth is laser assisted bleaching, which has conflicting results depending on the applied laser and its wavelength. In the present study, although the average bond strength of conventional bleaching was higher, compared to the average of laser assisted bleaching group, there was no significant difference.

Some studies have suggested that peroxide and oxygen radicals remaining on the surface are a reason for the reduction of SBS after bleaching because they interfere with the penetration of the adhesive and prevent the polymerization of the resin.[19] The study by Mirhashemi et al showed that SBS was generally lower in the bleach groups than in the non-bleach groups. In their study, the bond strength in the laser assisted bleaching groups was higher than the conventional bleaching group. They attributed this to the accelerated radical release of oxygen and the low morphological changes of the enamel surface following the use of Nd: YAG (1064 nm) and diode (810 nm) lasers.[20]

In contrast, in the study by Akın et al who investigated the SBS of resin composites to teeth bleached with 35% hydrogen peroxide with or without immediate activation with the Nd: YAG laser, the measurement of SBS after two weeks of bonding showed that the SBS decreased with or without the Nd: YAG laser, and they recommended the use of antioxidants to counteract this effect and prevent this reduction.[21] In the present study, the bond strength in the laser-assisted bleaching with diode (980 nm) group was lower than in the conventional bleaching groups.

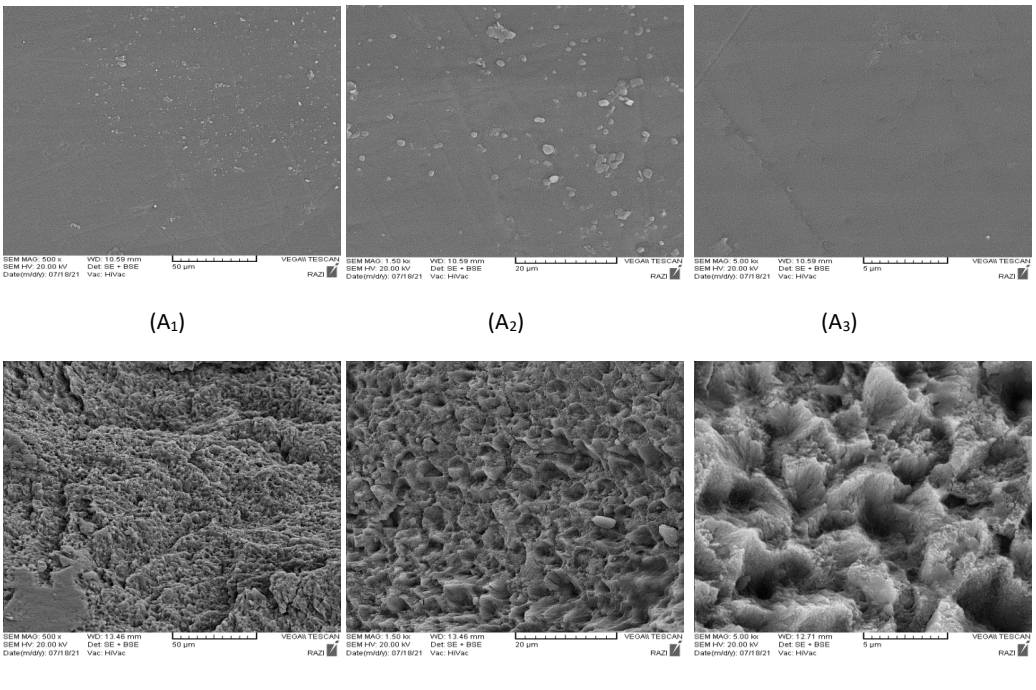
The type of laser device used for laser-assisted bleaching can be important. In a study, Mirhashemi et al evaluated



(A_1) (A_2) (A_3)

(B_1) (B_2) (B_3)

Figure 2. Group 1, SEM Images of the Enamel Surface in the Bleaching Without Laser Group Before (A1, A2, A3) and After Conventional Etching (B1, B2, B3) at Magnifications of × 500, × 1500 and × 5000



(A_1) (A_2) (A_3)

(B_1) (B_2) (B_3)

Figure 3. Group 3, SEM Images of the Enamel Surface in the Laser Assisted Bleaching Group Before (A1, A2, A3) and After Conventional Etching (B1, B2, B3) at Magnifications of × 500, × 1500 and × 5000

the effect of bleaching with different lasers (Nd: YAG, Er: YAG and CO2) as well as the effect of antioxidants after bleaching on the SBS of orthodontic brackets, and their results showed that bleaching Er: YAG and CO2 lasers further improved SBS than Nd: YAG lasers and antioxidants.[22]

Some studies have attributed this to structural changes in the enamel surface by bleaching factors. These studies showed that changes after teeth bleaching include decreased minerals (especially calcium), changes in organic matter, decreased microhardness, increased porosity, and loss of enamel prism.[22-25]

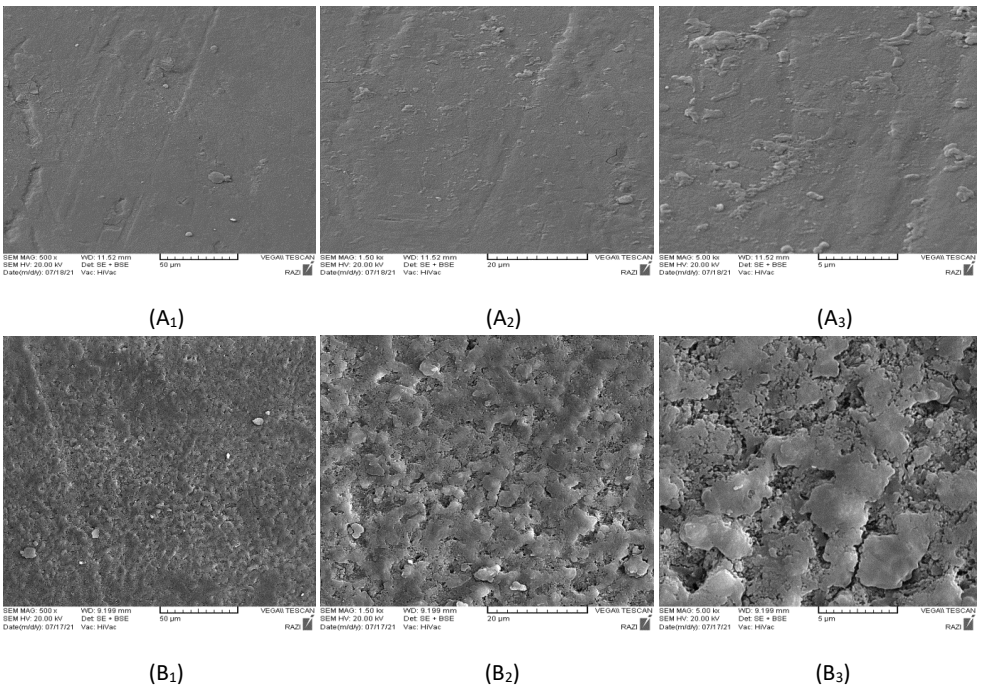


Figure 4. Group 2, SEM Images of the Enamel Surface in the Bleaching Without Laser Group Before (A1, A2, A3) and After Laser Etching (B1, B2, B3) at Magnifications of × 500, × 1500 and × 5000

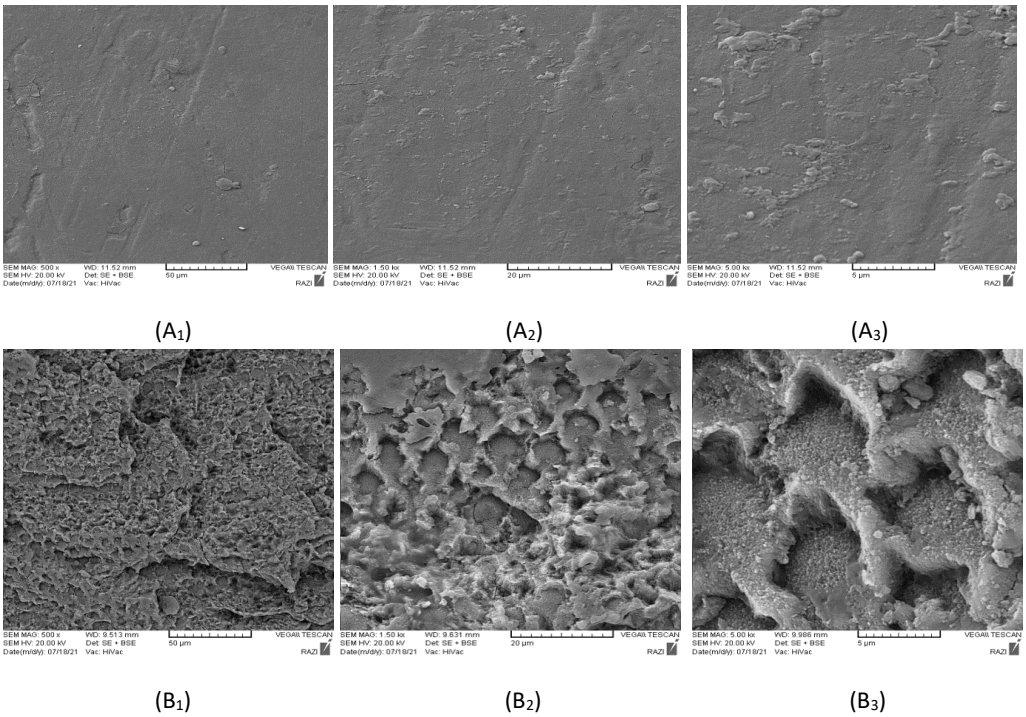
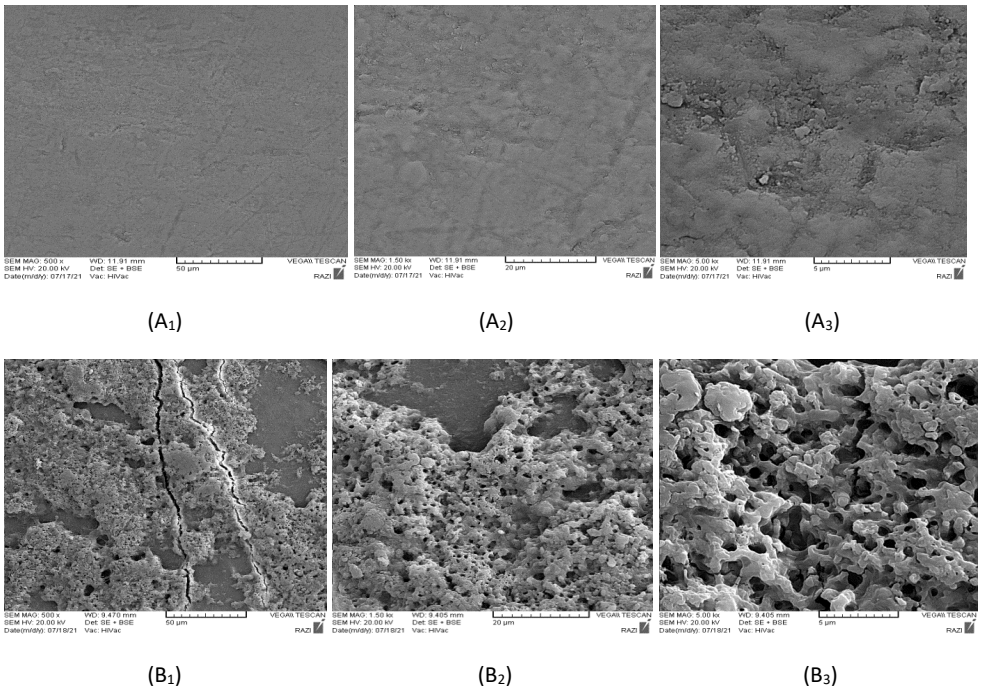


Figure 5. Group 4, SEM Images of the Enamel Surface in the Laser Assisted Bleaching Group Before (A1, A2, A3) and After Laser Etching (B1, B2, B3) at Magnifications of × 500, × 1500 and × 5000

In this study, SEM was performed to examine the surface changes of enamel; after bleaching and before etching in the bleaching groups (laser assisted bleaching-conventional bleaching), porosities that were not seen in the view of the teeth of the control group were created on the enamel surface following bleaching. Of course, these superficial changes were not significantly different between the control group and other groups. The results of Goharkhay and colleagues' study showed that Nd: YAG Laser assisted bleaching had little effect on the surface structure of enamel.[26]

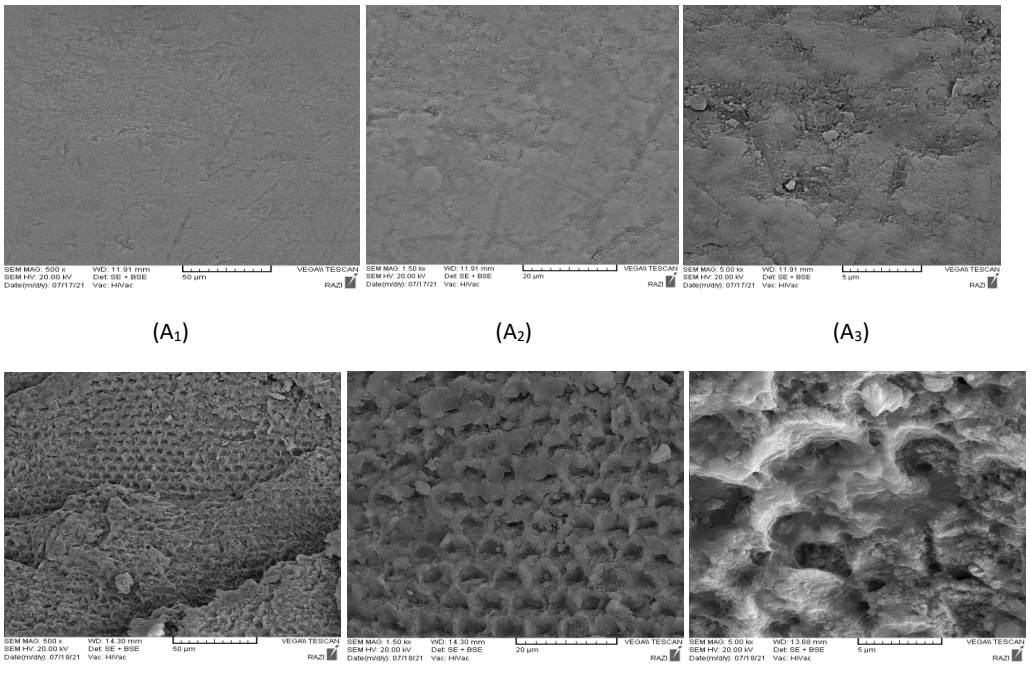
A score of 1 and 2 was recorded for the ARI. Most of



(A_1) (A_2) (A_3)

(B_1) (B_2) (B_3)

Figure 6. Group 5, SEM Images of the Enamel Surface in the Control Group Before (A1, A2, A3) and After Conventional Etching (B1, B2, B3) at Magnifications of × 500, × 1500 and × 5000



(A_1) (A_2) (A_3)

(B_1) (B_2) (B_3)

Figure 7. Group 6, SEM Images of the Enamel Surface in the Control Group Before (A1, A2, A3) and After Laser Etching (B1, B2, B3) at Magnifications of × 500, × 1500 and × 5000

the failures were cohesive failure types, suggesting that the failure occurred inside the composite and prevented the transfer of high force to the enamel. Hence, this would cause less stress to the enamel during bonding. In the study by Akın et al, the ARI score was often 1, but the majority of fractures in bleached teeth were adhesive failures.[21] In the study by Gorucu-Coskuner et al, the amount of adhesive remaining on the enamel surface was significantly different between laser etching and conventional etching; most failures in the laser etching group occurred at the teeth-adhesive interface, and the ARI score was 0.[17] In the study by Mirhashemi et al, the

ARI was often 2 and 3, and most of the failures were in the bracket-adhesive interface.[20]

Conclusion

A brief summary of the findings of the current study would be as follows:

1. The SBS of brackets to bleached teeth was significantly lower, in comparison to the control group.
2. SBS in teeth treated with conventional bleaching was higher than laser assisted bleaching, but their difference was not significant.
3. Laser etching by the erbium laser in different bleaching protocols (laser assisted bleaching-conventional bleaching) caused honeycomb structure and consequently increased the SBS of orthodontic brackets.

Therefore, it can be said that if the bracket bond to the tooth is needed after bleaching, laser etching is recommended; Of course, we need more studies in this field, especially in vivo studies.

Authors' Contribution

Conceptualization: Nasim Chiniforush, Amirhossein Mirhashemi.
Data curation: Rashin Bahrami.
Formal analysis: Mohammad Oladzad.
Funding acquisition: Amirhossein Mirhashemi.
Investigation: Nasim Chiniforush.
Methodology: Nasim Chiniforush, Mohammad Oladzad.
Project administration: Amirhossein Mirhashemi.
Resources: Amirhossein Mirhashemi, Mohammad Oladzad.
Software: Mohammad Oladzad.
Supervision: Nasim Chiniforush.
Validation: Nasim Chiniforush, Amirhossein Mirhashemi.
Visualization: Mohammad Oladzad.
Writing–original draft: Nasim Chiniforush, Mohammad Oladzad.
Writing–review & editing: Nasim Chiniforush, Mohammad Oladzad.

Competing Interests

The authors declare that they have no competing interests.

Consent for Publication

Not applicable.

Data Availability Statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethical Approval

The study was approved by the Institutional Review Board, Faculty of Dentistry, Tehran University, Iran (IR.TUMS.DENTISTRY.REC.1400.045).

As the study used human extracted teeth in such a manner that subjects cannot be identified from the beginning by any code (unidentifiable data), the need for informed consent was waived by the Institutional Review Board, Faculty of Dentistry, Tehran University, Iran (IR.TUMS.DENTISTRY.REC.1400.045).

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