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Effect of enamel surface pretreatment with different laser types and antioxidizing agents office-bleaching on the shear bond strength of orthodontic brackets

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Abstract

The aim of this study was to investigate orthodontics brackets shear bond strength (SBS) after pretreatment of bleached enamel surface with different laser types in comparison with antioxidants agent. A total of 150 sound human premolars were randomly assigned to into a control group which was experimental group (Group A) as bleached with 40% HP bleaching agent and not bleached (Group B). Then, both control and experimental groups were divided into five subgroups.

Subgroup 1: no surface treatment
Subgroup 2: treated by Nd:YAG laser (1 W, 100 μs, 10 Hz) for 30 s.
Subgroup 3: treated by Er: YAG laser (0.5 W, 230 μs, 10 Hz, 5 mm distance) for 30 s.
Subgroup 4: treated by CO_2 laser (0.5 W, 10 Hz, pulse width of 1 ms) for 30 s.
Subgroup 5: conditioned by 10% sodium ascorbate solution for 10 min.

Then, the metal premolar brackets were bonded to conditioned enamel surface. All the specimens were debonded using the Universal Testing Machine. The data were analyzed by One-way analysis of variance and the Tukey's HSD. The SBS values of brackets bonded to bleached enamel in subgroup 1(no surface pretreatment) and 2(surface pretreatment with Nd:YAG laser) were significantly lower than subgroup 3(surface pretreatment with Er: YAG laser) and subgroup 4 (surface pretreatment with CO_2 laser). The lowest SBS belonged to brackets bonded to bleached enamel in the subgroups 1 and 2, also the SBS values in subgroup 2 and subgroup 3 were significantly higher than subgroup 5. Pretreatment with Er: YAG and CO_2 laser will improve SBS on bleached enamel surface more efficiently than surface pretreatment with Nd:YAG laser or antioxidant agent.

Keywords: ascorbate, Er: YAG laser, Nd:YAG, CO_2, shear bond strength, orthodontic bracket

1. Introduction

Nowadays, with increasing awareness of the patients, their aesthetics demands have been increased and clinicians dealing with patients at their office who want to have more beautiful teeth and smile. Among different techniques for improving tooth color and shape such as composite fillings, laminates, crowning, or the placement of veneers, bleaching becomes more popular and user-friendly because is a more conservative and simple method [1]. The most commonly used bleaching agent for tooth bleaching is hydrogen peroxide, which induces structural changes and lightens the tooth color by releasing free oxygen radicals. Based on recent reviews enamel bleaching with hydrogen peroxide (HP) bleaching gel reduces the shear bond strength (SBS) of orthodontic brackets and bonding procedure should be delayed to restore the decreased bond strength values [2–4]. Although there is no consensus on how much time should pass after enamel bleaching before bonding, most studies report 3 weeks after bleaching treatment, bond strength values increase to normal value as residual bleaching radical release [3–7]. Most clinicians suggest bleaching when orthodontics treatment finished as a supplementary procedure to improve treatment result and patient satisfaction, however as a challenge clinician may deal with orthodontic patients who seek tooth bleaching before or at the time of orthodontic treatment. Delaying the bonding process to recover bond strength will increase treatment time and also increase the common orthodontics treatment side effects. Orthodontic treatment and precise tooth positioning highly depend on the quality of bracket bonding. Decreased bond strength after bleaching results in brackets bonding failure. Bracket rebonding during treatment is a time-consuming and costly process, also enamel damage risk will be increased during debonding and removal of residual resin. Although bonding material and methods have been improved in recent years, bonding failure still remains a common side effect especially after procedures such as bleaching.

Several preventative techniques have been suggested to enhance the shear bond strength of brackets immediately after bleaching, included: bleached enamel surface conditioning with alcohol, removal of the superficial layer of enamel, adhesives containing organic solvents use, or the application of biocompatible and neutral antioxidants [8–10]. The history of power bleaching goes back to Abbots, who used high-intensity light for increasing the hydrogen peroxide temperature and accelerate the chemical process of bleaching [11]. Light, heat, or laser can be used to accelerate the oxidation-reduction reaction and activation of the chemical agents involved in the bleaching process [12]. Various lasers such as Nd:YAG laser (1064 nm), diode laser (810 and 980 nm), Potassium- Titanyl-Phosphate laser (KTP, 532 nm), and Erbium: Yttrium Aluminum Garnet laser (Er: YAG, 2940 nm) have been used to accelerate bleaching gel [13–17]. By reviewing the papers published in this area, no study was done before on the effect of the laser immediately after the office-bleaching process on recovering the shear bond strength of the orthodontic brackets.

The null hypothesis is that laser energy can be used to accelerate releasing residual oxygen radical that remain from an office-bleaching process and also change enamel surface post office-bleaching, so will restore orthodontics brackets SBS and it can be used instead of antioxidants agent, so brackets bonding can be done faster, without any delay.

The aim of this study was to investigate orthodontics brackets SBS after pretreatment of bleached enamel surface with different laser types and compare it with orthodontics brackets SBS to bleached enamel surface that pretreated with antioxidants agent.

2. Material and methods

2.1. Samples preparation

One hundred and fifty healthy, noncarious, sound human premolars, without previous repair, evolutionary anomalies, hypoplastic areas and cracks which were extracted for orthodontic treatment, were collected. The teeth were examined under a stereomicroscope to not have any hypoplastic lesions and cracks. The teeth were not treated with a chemical agent such as hydrogen peroxide before. Residual tissue tags were cleaned from the tooth surface by periodontal scaler and then disinfected by storing in 0.02% (weight/volume) chloramine-T solution for 1 week and then stored in distilled water at 4 °C temperature for 1 month prior to bleaching.

2.2. Bleaching and surface pretreatment with laser and antioxidant agent

All teeth were mounted vertically in self-cure orthodontic acrylic somehow that two-thirds of the root was embedded. The labial surfaces of the teeth were cleaned and polished with oil and fluoride free pumice and rubber cups then rinsed with a water spray for 20 s dried with oil-free compressed air for 10 s. The specimens were divided randomly into a control group which was not bleached (Group B) and experimental group (Group A) which was bleached with 40% HP Office-bleaching agent (Ultradent Opalescence Boost 40%; Ultradent Products Inc. South Jordan, UT, USA) as follows: 2 mm thick layer of bleaching gel was applied to the enamel surfaces of the teeth for 20 min without photoactivation at room temperature of 25 °C. After the reaction time, the bleaching gel was washed with air/water spray for 10 s and the teeth were dried by compressed air. The procedure was repeated three times per tooth with a 1.5 min interval, based on manufacturer instructions.

2.3. Both control and experimental groups were divided into five subgroups

Subgroup 1: samples were not treated with antioxidant and laser before bonding.

Subgroup 2: samples surfaces treated by Nd:YAG laser (1 W, frequency of 10 Hz, pulse width of 100 μs, beam diameter: 320 μm, 1 mm distance) for 30 s.

Subgroup 3: samples surfaces treated by Er: YAG laser (0.5 W, frequency of 10 Hz, pulse width of 230 μs, beam diameter: 1 mm, 5 mm distance) for 30 s.

Subgroup 4: samples surfaces treated by CO_2 laser (0.5 W, frequency of 10 Hz, pulse width of 1 ms, beam diameter: 1 mm, 12.5 mm distance) the laser have a clamp that causes laser exposed from 12.5 mm distance for 30 s.

Subgroup 5: samples surface conditioned by 10% sodium ascorbate solution for 10 min and then washed with distilled water.

3. Bonding procedure

The buccal enamel surface of the teeth was etched with 37% phosphoric acid for 30 S, then the teeth surfaces were rinsed with water syringe for 30 s to remove the etching liquid and demineralized tooth particles and then dried with oil-free compressed air until achieving a chalky white appearance. After surface preparation, Transbond sealant (3 M Unitek, Monrovia, USA) was applied and cured for 20 s. One hundred and four Ultra-Minitrimedgewise metal premolar brackets were bonded with 10 mm^2 surface area using light-cure Transbond XT (3 M Unitek, Monrovia, USA) according to the manufacturer's instructions. The bonding resin was applied on the bracket base, and the bracket was then placed on the bonding area and arranged in the correct position and pressed lightly, then excess bonding resin was removed with a sharp explorer. At last each specimen was cured with the LED light curing unit (Elipar Free light 2, M ESPE, USA) for 20 s. The same procedure was done for all specimens. All the teeth were submerged in distilled water until debonding.

3.1. Debonding and the SBS test

Each specimen was positioned in a Universal Testing Machine (Roell-Z050, Zwick/Roell, Germany) with a crosshead speed of 0.5 mm per min, in such a way that the bracket base was parallel to the direction of shear load application and the knife-edge-shaped plunger was placed at the upper surface of the bracket between the joint of enamel surface and the resin material to produce a shear force. The maximum load required debonding was recorded in Newtons then converted to the ratio of the fracture load to the bonding area and expressed in megapascals (1 MPa = 1 N mm^{-2}).

3.2. Statistical analysis

All statistics were performed using SPSS version 20 (SPSS Inc. Chicago, IL, USA). The data were normally distributed and there was the homogeneity of variance among the groups based on the Shapiro–Wilk test and Levene's variance homogeneity test. Descriptive statistics, including the mean, standard deviation, standard error, and minimum and maximum values were calculated for the groups. One-way analysis of variance (ANOVA) and the Tukey's HSD multiple comparisons test at $P < 0.05$ level of significance were used to compare SBS values among the groups.

Table 1. Information about the study groups.

Groups	Subgroup	Treatment regime
(A) Bleaching (Experimental)	1	Control
	2	Nd:YAG
	3	Er: YAG
	4	CO_2
	5	Ascorbate
(B) Not bleached (Control)	1	Control
	2	Nd:YAG
	3	Er: YAG
	4	CO2
	5	Ascorbate

Table 2. Descriptive statistics and the results of ANOVA on shear bond strength (in MPa) in all groups and subgroups.

		Number	Min	Max	Mean	SD
(A) bleaching	(1) Control	15	3.23	13.17	8.51	3.46
	(2) Nd: YAG	15	2.96	13.73	7.65	3.71
	(3) Er: YAG	15	18.10	28.89	23.40	3.30
	(4) CO_2	15	5.53	23.28	15.49	5.88
	(5) Ascorbate	15	3.83	50.98	15.53	11.34
(B) Control	(1) Control	15	2.96	22.09	11.69	5.47
	(2) Nd:YAG	15	6.92	15.57	12.25	2.37
	(3) Er: YAG	15	8.25	34.72	20.47	6.93
	(4) CO_2	15	10.29	32.44	21.75	6.77
	(5) Ascorbate	15	4.48	16.99	9.35	3.27

4. Results

The descriptive statistics for the SBS (in MPa) of all groups and subgroups are shown in table 2. The result of one way ANOVA indicated that differences between the groups and the subgroups were significant ($P < 0.05$). The results of Tukey's HSD test of all study groups and subgroups are shown in table 3, comparing SBS (in MPa).

The SBS values of brackets bonded to bleached enamel in subgroup 1 (no surface pretreatment) and 2 (surface pretreatment with Nd:YAG laser) were significantly lower than subgroup 3 (surface pretreatment with Er: YAG laser) and subgroup 4 (surface pretreatment with CO_2 laser). The lowest SBS belonged to brackets bonded to bleached enamel in the subgroups 1 and 2, also the SBS values in subgroup 2 and subgroup 3 were significantly higher than subgroup 5 that means Er: YAG laser and CO_2 laser will more effective than the neutral antioxidant agent (Ascorbic acid) at recovering SBS.

5. Discussion

The aim of this study was to compare the effects of Er: YAG, CO_2, Nd:YAG laser and antioxidant agent (sodium ascorbate) on the orthodontics brackets shear bond strength recovery post enamel office-bleaching.

Among three types of lasers that were used, Nd:YAG laser were caused bleached enamel surface structure melting and recrystallization. Our study showed this laser type will

Table 3. The results of Tukey's test comparing shear bond strength (in MPa) of all study groups and subgroups.

		1) Control	2) Nd:YAG	3) Er: YAG	4) CO_2	5) Ascorbate
Bleaching	1) Control	_	0.996	0.000	0.028	0.027
	2) Nd:YAG	0.996	_	0.000	0.010	0.009
	3) Er: YAG	0.000	0.000	_	0.009	0.009
	4) CO_2	0.028	0.010	0.009	_	1.000
	5) Ascorbate	0.027	0.009	0.09	1.000	_
Control	1) Control	_	0.999	0.000	0.000	0.746
	2) Nd:YAG	0.999	_	0.001	0.000	0.570
	3) Er: YAG	0.000	0.001	_	0.964	0.000
	4) CO_2	0.000	0.000	0.964	_	0.000
	5) Ascorbate	0.746	0.570	0.000	0.000	_

decrease SBS values; so will not suitable for improving orthodontics brackets SBS to bleached enamel [18, 19].

Bleaching technique is popular and user-friendly aesthetic dental procedure among orthodontics patients and will improve patient's satisfaction from treatment results. Many studies have been investigated the effect of bleaching agents on orthodontic brackets SBS and most of these studies conclude that 24 h to 4 weeks interval between bleaching procedure and bonding will reduce the bleaching agents effects and recover SBS to normal values. HP 35% application did not reduce metal brackets bond strength, but a 2 to 3 week interval between bleaching and bonding procedure will be beneficial [20].

Cavalla et al. reported that a 3 week delay post office-bleaching will recover SBS to normal values [21].

In another study, Banding failure occurred more in the mandibular arch and within 24 h after bleaching due to more functional forces in the mandibular arch and a 2–3 week interval suggested between office-bleaching by 38% hydrogen peroxide and bonding procedure [22].

Many studies reported that bleaching agents especially hydrogen peroxide will change enamel surface properties and will decrease bond strength to enamel [23–25].

In another study claim that long-term conditioning enamel surface by 10% carbamide peroxide will create sediment on enamel surface that will decrease bond strength [26].

However, ceramic brackets SBS post office-bleaching was acceptable after 72 h delay [27].

In another study, it was reported that HP 25% gel and CP 10% do not have any effect on bond strength after a 7 to 14 day delay, so Bonding was proposed to be done after 2 weeks. It has been reported that CP 45% does not reduce ceramic brackets bond strength to enamel [28].

Among factors that affecting bracket bonding strength such as duration of the light cure has been investigated. In a study, the use of light cure for 40 s in light intensity of 500 mw cm^{-2} improved bracket bond strength to enamel that was bleached by HP 38%, also it was reported that 24 h delay post office bleaching by HP 38% and CP 10% will improve bond strength significantly [29].

The carbon dioxide laser is well absorbed by water and hydroxyapatite and will create micro-cavity on enamel surface and increases the bracket bond strength to bleached enamel. This laser type is more effective in improving bracket bond strength to bleached enamel in comparison to Nd:YAG laser.

Erbium group lasers increase band strength with different mechanisms. Erbium laser radiation will increase the temperature and evaporate the water present in the enamel surface and this process causes micronic explosions and micro-cavity that promote bracket bonding strength to enamel [19, 30].

Laser beam reduces the calcium to phosphorus ratio and also reduce and evaporate water in surface enamel composition, thereby increasing enamel resistance to acid or any others enamel solvents [31].

In a study by Mirhashemi *et al*, laser-assisted bleaching by Nd:YAG and Diode laser significantly reduce the SBS, same as conventional bleaching procedure but the brackets SBS seems to increase quickly within 1 h after laser-assisted bleaching in comparison to conventional bleaching method. Thus, this protocol can be suggested if it is necessary to bond the brackets on the same day of bleaching [2].

Goharkhay *et al* showed little effect of Nd:YAG laser-assisted bleaching on the enamel surface morphology [32].

Bleaching agents change enamel surface structure and cause loss of prismatic form, minerals especially calcium, organic substance alternation, decreasing microhardness and increasing porosity that cause an over-etched appearance of the enamel [33, 34].

Peroxide and residual oxygen on the enamel surface interfere with resin infiltration into the bleached enamel and inhibit resin polymerization [35]. These changes have been considered for SBS reduction. In our study, teeth that were bonded without any enamel surface conditioning, had lower SBS values than others groups. This reduction could be related to a high concentration of residual oxygen released from the bleaching agents that inhibits resin polymerization and infiltration into the bleached enamel.

Enamel surface conditioning with a laser after bleaching may accelerate oxygen release and also change enamel surface morphology that yields acceptable SBS after bleaching [2].

Antioxidants agents can also be used to overcome this problem as mentioned before in many research. In our study, sodium ascorbate 10% was applied for 10 min on bleached enamel surface and the results showed that this antioxidant agent can improve SBS, but it is less effective than the Er: YAG and CO_2 laser. Among factors that cause this difference and less effectiveness of antioxidant agent than a surface condition with laser may be that we apply antioxidant agent in minimal duration on the tooth surface. In a study by Kimyai S *et al* S. ASC 10% application for 3 h on enamel surface that was bleached by CP 10% improved bond strength values more than ASC 10% application for 10 min. However, there is no difference in the applied antioxidant agents form gel or solution both improve the bond strength same as each other [36].

According to some studies, ASC should remain at least one-third of the bleaching time to achieve the best result and the highest bond strength post office bleaching [37].

In another study, ASC application on the bleached enamel surface, improved orthodontics bracket bond strength, although the exposure time and concentration of the substance should be taken into account to get optimum results [38].

In a review study which evaluated the effect of different antioxidants on the orthodontic brackets bond strength after enamel bleaching, it was concluded that all of these materials, regardless of type, form, concentration and application period improved bond strength. Also different adhesive systems are effective and improve bond strength after application of anti-oxidant agents [39].

According to studies, it has been reported that alcohol which is present in some adhesives composition, react with residual oxygen radicals at the surface of the enamel and cause better rein polymerization and increases bond strength [40].

In this study, enamel surface treatment by Er: YAG laser was effective and improve SBS in both non-bleached and bleached enamel. The highest improvement in SBS was seen in the groups that treated by this laser type. However, the different results about this laser type effect have been reported in other studies as various factors such as laser parameters and the type of bleaching material may cause these differences.

Enamel surface treatment with CO_2 laser results in acceptable bond strength in both bleached and none-bleached groups. However, for the bleached group, its effectiveness was less than the Er: YAG laser, which is actually possible due to the different mechanism that each laser works.

Another interesting result was that Er: YAG and CO_2 laser improve SBS values in none-bleached enamel approximately equal.

In a study that enamel was bleached with HP 38%, then Er: YAG and the usual method were used. The bond strength was less than acceptable, and even these values remained unacceptable after 3 weeks delay for banding procedure. In this study, in cases where HP 38% was used for bleaching, they suggested a phosphoric acid for etching and Er: YAG Laser with 300 mJ/pulse, 1 mm distance, 10 pulse per second for 10 s was used [41].

In study Er: YAG laser at a distance of 12 mm and a power output of 80 mJ and 4 Hz and an energy density of 250 mJ cm^{-2} was used for enamel conditioning post office bleaching with HP, it was reported that after a 24 hour delay, etching by laser will improve bond strength more than etching by phosphoric acid.

Etching enamel surface by laser causes surface irregularity that provides required bonding surface [42].

Mohammadi used CO_2 laser (0.5 W, 10 Hz) after bleaching with CP 38%, HP 30%, which was activated by 1 W diode laser in continuous mode, as well as Er: YAG (0.5 W, 10 Hz) and Nd:YAG laser (1 W, 10 Hz, 60 s) and reported that post office bleaching with HP 38%, Nd:YAG laser, sodium ascorbate, and CO_2 laser, and post office bleaching with HP 30% Er: YAG laser will increase bond strength [40].

Also CO_2 laser with the output power of 0.4 W and 5 Hz increases the microhardness and increases the bond strength to this demineralized enamel [43].

At last, the effect of these lasers will vary according to laser parameters such as dosage, energy intensity

6. Conclusion

In spite of this *in vitro* study, the following conclusions were drawn:

(a) Orthodontics brackets SBS will reduce immediately post office-bleaching procedure and bleached enamel surface pretreatment with Er: YAG and CO_2 laser will improve SBS.
(b) Bleached enamel surface pretreatment with Er: YAG and CO_2 laser will improve SBS more efficiently than surface pretreatment with Nd:YAG laser or antioxidant agent.

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Conflict of interest statement

The authors declare no conflict of interest.

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None.

Ethical approval

This study has been approved by ethical committee of Tehran University of Medical Sciences.

Informed consent

This study was invitro.

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