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ORIGINAL ARTICLE

Effect of laser-assisted bleaching with Nd:YAG and diode lasers on shear bond strength of orthodontic brackets

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Abstract The aim of the present study was to assess the effect of laser-assisted bleaching with neodymium:yttrium–-aluminum–garnet (Nd:YAG) and diode lasers on shear bond strength (SBS) of orthodontic brackets. One hundred and four extracted human premolars were randomly divided into four groups: group 1: No bleaching applied (control group); group 2: Teeth bleached with 40 % hydrogen peroxide; group 3: Teeth treated with 30 % hydrogen peroxide activated with Nd:YAG laser (1064 nm, 2.5 W, 25 Hz, pulse duration of 100 μs, 6 mm distance); and group 4: Teeth treated with 30 % hydrogen peroxide activated with diode laser (810 nm, 1 W, CW, 6 mm distance). Equal numbers of teeth in groups 2, 3, and 4 were bonded at start, 1 h, 24 h, and 1 week after bleaching. A universal testing machine measured the SBS of the samples 24 h after bonding. After bracket debonding, the amount of residual adhesive on the enamel surface was observed under a stereomicroscope to determine the adhesive remnant index (ARI) scores. The SBS in the unbleached group was significantly higher than that in the bleached groups bonded immediately and 1 h after laser-assisted bleaching ($P<0.05$). In groups 3 and 4 at start and group 2 at start and 1 h after laser-assisted bleaching, the SBS was found to be significantly lower than that in the control group. Significant differences in the ARI scores existed among groups as well. The SBS of brackets seems to increase quickly within an hour after laser-assisted bleaching and 24 h after conventional bleaching. Thus, this protocol can be recommended if it is necessary to bond the brackets on the same day of bleaching.

Keywords Bleaching · Laser · Nd:YAG · Diode · Shear bond strength

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Introduction

The increasing awareness of a beautiful smile line among patients has made tooth bleaching quite popular; also, it can increase self-confidence. A large number of orthodontic patients demand tooth bleaching at the time of orthodontic treatment. In-office bleaching and at-home bleaching are done using various bleaching agents. The most commonly used bleaching agent for tooth bleaching is hydrogen peroxide, which releases free oxygen radicals to induce structural changes and lighten the tooth color.

To accelerate tooth whitening, bleaching agents may be activated by light, heat, or laser [1]. The history of power bleaching goes back to Abbots, who used high-intensity light to raise the temperature of hydrogen peroxide and consequently accelerate the chemical process of bleaching [2]. Various lasers such as Nd:YAG laser (1064 nm), diode laser (810 and 980 nm), Kalium-Titanyl-Phosphate laser (KTP, 532 nm), and Erbium: Yttrium Aluminum Garnet laser (Er:YAG, 2940 nm) have been used to improve the effect of bleaching gel [3–7].

The quality of bracket bonding is one of the most important factors contributing to the success of orthodontic treatment.

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Rebonding of brackets during orthodontic treatment is a time-consuming and costly procedure. Moreover, it adversely affects treatment. It may also cause enamel damage in the debonding process or during removal of residual resin. Although progress in bonding of brackets has been considerable in the recent years, bonding failure still remains an important side effect, especially after procedures such as bleaching.

Various studies have investigated the effect of enamel bleaching on bond strength of orthodontic brackets as well as alteration of enamel structure and surface morphology; much controversy exists in this regard. Many studies have reported significant decrease in bond strength after bleaching [8–15]. On the other hand, some authors have found no significant difference in bond strength of bleached and unbleached teeth [16].

Several studies have evaluated the effect of bleaching on the bond strength of orthodontic brackets with the in-office and at-home bleaching techniques. However, to the best of our knowledge, no study has compared the effects of laser-assisted and conventional bleaching on shear bond strength (SBS) of metallic brackets.

The present study aimed to investigate the effect of laser-assisted bleaching and conventional bleaching at four time intervals on SBS of metallic brackets to enamel and the adhesive remnant index (ARI) scores.

Materials and methods

Specimen preparation

A total of 104 non-carious premolar teeth without visible enamel imperfections, cracks, restorations, and structural defects extracted for orthodontic purposes were selected for this study. No pretreatment history with such chemical agents as hydrogen peroxide existed in patient records. All residual soft tissues were removed via a periodontal scaler and then the teeth were polished with pumice paste and rubber cups for 15 s and washed with water. The teeth were stored in 0.02 % (weight/volume) chloramine-T solution for 1 week and then in distilled water at room temperature for 1 month prior to bleaching.

Bleaching and bonding

All teeth were randomly assigned by simple randomization to four groups namely:

Group1: No bleaching (control group); group 2: Teeth bleached with 40 % hydrogen peroxide (Ultradent Opalescence Boost 40 %; Ultradent Products Inc., South Jordan, UT, USA); group 3: The teeth were treated with 30 % hydrogen peroxide (Heydent JW power, Farafan Diagnostics Co., Tehran, Iran, under license of Heydent, Germany) activated by Nd:YAG laser (1064 nm, 2.5 W, 25Hz, 6 mm distance) according to the manufacturer's instructions; and GROUP 4: The teeth were treated with 30 % hydrogen peroxide (Farafan Diagnostics Co., Tehran, Iran, under license of Heydent, Germany) activated by diode laser (810 nm, 1 W, CW, 6 mm distance) according to the manufacturer's instructions.

The teeth were bonded at the start, 1 h, 24 h, and 1 week after the bleaching procedure. All information about the study groups is shown in Table 1. All enamel surfaces of the teeth were dried. The bonding area of the teeth in group 2 was coated with a 1.5-mm-thick layer of bleaching gel (Ultradent Opalescence Boost 40 %). After 20 min, the gel was washed by air/water spray for 10 s and the teeth were dried by compressed air without contaminants. The procedure was repeated three times with 1.5-min intervals.

A 1.5-mm-thick layer of power bleaching gel (Heydent JW) was applied on the bonding area of the teeth in groups 3 and 4; then, they were activated by diode laser (810 nm, 1 W, CW, 6 mm distance) and Nd:YAG laser (1064 nm, 2.5 W, 25Hz, pulse duration of 100 μs, 6 mm distance) for 30 s. The procedure was repeated two more times with 1-min interval. The gel was left on the tooth surface for 3 min and was then washed out and dried in the same way as in group 2 (according to the manufacturer's instructions). The beam diameter for both lasers was 5 mm. The power density was 5.09 W/cm^2 for diode laser and 12.73 W/cm^2 for Nd:YAG laser.

All the teeth, except the ones that had to be bonded immediately after bleaching, were kept in fresh distilled water in a sealed container at room temperature.

Table 1 Information about the study groups

Group	Treatment regimen	Subgroup	Time delay before bonding
Control	Not bleached		
Experimental	Conventional bleaching by 40 % HP	1	Immediate
		2	1 h
		3	1 day
		4	1 week
	Laser-assisted bleaching with Nd:YAG (1064 nm)	1	Immediate
		2	1 h
		3	1 day
		4	1 week
	Laser-assisted bleaching with diode (810 nm)	1	Immediate
		2	1 h
		3	1 day
		4	1 week

Before debonding, the teeth were individually mounted in auto-polymerizing acrylic resin. After buccal surface preparation, the teeth were etched with 37 % phosphoric acid for 30 s. Then, the teeth surfaces were rinsed using a water syringe for 30 s and dried until achieving a chalky white appearance. Transbond sealant (3 M Unitek, Monrovia, USA) was applied on the etched area and cured for 20 s.

We bonded 104 Ultra-Minitrimedgewise metal premolar brackets with 10 mm^2 surface area using light-cure Transbond XT (3 M Unitek, Monrovia, USA) according to the manufacturer's instructions. The paste was applied on the bracket base, and the bracket was then positioned on the bonding area and pressed lightly in the correct position. Excess bonding resin was removed with a sharp scaler. Each specimen was cured with LED light curing unit (Elipar Free light 2, 3 M ESPE, USA) first for 20 s, and then for an extra 10 s. The procedure was performed for all specimens. All the teeth were immersed in distilled water until debonding.

Debonding

In order to assess the SBS, each sample was loaded in a Universal Testing Machine (Roell-Z050, Zwick/Roell, Germany) in such a way that the bracket base was parallel to the direction of shear load application. The chisel edge plunger was positioned at the upper surface of the bracket to produce a shear force at the adhesive-enamel interface. Shear loads were applied at a crosshead speed of 0.5 mm per minute until debonding occurred. The maximum load required to debond was recorded in Newtons and was then converted to Megapascals (MPa).

After bond failure, the same operator examined all enamel surfaces and bracket bases under a stereomicroscope (×10 magnification) to assess the residual adhesive on enamel surfaces. Scoring was done according to the modified ARI [13, 15]. The scoring criteria were as follow:

1. The entire composite with an impression of the bracket base remained on the tooth.
2. More than 90 % of the composite remained on the tooth.
3. Less than 90 % but more than 10 % of the composite remained on the tooth.
4. Less than 10 % of the composite remained on the tooth.
5. No composite remained on the tooth.

Statistical analysis

The SPSS version 20 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. 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. To determine significant differences in ARI scores among the groups, the Kruskal-Wallis test was used.

Results

The descriptive statistics for the SBS of all groups tested are shown in Table 2. ANOVA indicated significant differences among the groups ($P<0.05$). The results of Tukey's HSD test comparing SBS (in MPa) of all study groups are shown in Table 3. The SBS values of brackets bonded to bleached enamel in laser-assisted groups immediately after bleaching and in the conventional group immediately and 1 h after bleaching were significantly lower than those of brackets bonded to unbleached enamel in the control group. The lowest SBS belonged to brackets bonded to bleached enamel in the conventional group in subgroups 1 and 2.

No significant difference existed among groups after 1 day.

Table 4 shows ARI scores of all groups. The Kruskal-Wallis test showed significant differences among all groups ($P<0.05$). The Dunn's test showed that the Nd:YAG laser group was significantly different from other groups.

Discussion

The aim of the present study was to investigate the effect of various bleaching protocols with various time delays before bonding on the SBS of metallic brackets bonded to the enamel surfaces. According to the results of the current study, laser-

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

Method	Time	Number	Min	Max	Mean	SD
Control		8	15.00	33.85	26.13	5.72
Ultradent	Immediate	8	4.12	12.26	8.62	3.01
	1 h	8	5.89	15.08	10.04	2.73
	1 day	8	11.75	27.81	20.45	5.63
	1 week	8	9.81	37.29	21.48	9.56
Nd:YAG (1064 nm)	Immediate	8	8.26	16.41	13.23	2.88
	1 h	8	9.45	28.25	20.53	6.34
	1 day	8	15.45	27.04	20.71	4.44
	1 week	8	16.54	27.76	21.87	3.85
Diode (810 nm)	Immediate	8	10.60	14.86	12.08	1.63
	1 h	7	17.34	26.21	21.35	3.27
	1 day	8	12.97	36.60	25.20	7.21
	1 week	8	12.69	30.39	20.53	6.05

Significant differences existed among groups ($P<0.05$)

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

Method	Time	Immediate	1 h	1 day	1 week
Ultradent	Immediate	–	0.972	0.005	0.002
	1 h	0.972	–	0.014	0.006
	1 day	0.005	0.014	–	0.986
	1 week	0.002	0.006	0.986	–
Nd:YAG (1064 nm)	Immediate	–	0.017	0.014	0.004
	1 h	0.017	–	1.00	0.936
	1 day	0.014	1.00	–	0.957
	1 week	0.004	0.936	0.957	–
Diode (810 nm)	Immediate	–	0.008	<0.001	0.013
	1 h	0.008	–	0.476	0.990
	1 day	<0.001	0.476	–	0.282
	1 week	0.013	0.990	0.282	–

assisted and conventional bleaching with hydrogen peroxide reduced SBS when brackets were bonded immediately after bleaching. However, 1 h delay after laser-assisted bleaching (30 % hydrogen peroxide) and 1 day after conventional bleaching (40 % hydrogen peroxide) restored the SBS. The maximum SBS values were found in the control group.

Several studies have been performed to determine the effect of bleaching on SBS of brackets [8–13, 15] using variable types and concentrations of bleaching agents, bleaching protocols, types of brackets and adhesives, disinfection, and storage media of teeth before bonding and time allotted between bleaching and bonding. The variety of the studied factors has led to differences in the findings of these studies. However, previous studies have generally shown that bleaching agents decrease the bond strength of brackets.

Some authors believe that exposure of teeth to the bleaching agents changes the enamel surface structure. These changes include loss of prismatic form and minerals especially calcium, alterations in the organic substance, decrease in microhardness, and increase in porosity leading to over-etched appearance of the enamel surface [17–19]. Peroxide and residual oxygen on the enamel surface interfere with resin infiltration into the bleached enamel and inhibit resin polymerization [16, 19]. These changes have been blamed for reduction in SBS. In our study, teeth bonded immediately after bleaching had lower SBS values than others. This reduction could be related to high concentration of residual oxygen released from the bleaching agents that inhibits resin polymerization and infiltration into the bleached enamel. Laser-assisted bleaching may accelerate oxygen release and hydrogen peroxide decomposition and yield acceptable SBS 1 h after bleaching.

We observed rapid increase in the SBS in the conventional bleaching groups after 24 h, which is in agreement with previous studies [8, 20]. In contrast, some studies have shown significant reduction in SBS of brackets bonded 24 h after dental bleaching with hydrogen peroxide [10–12]. Cacciafesta et al. reported a significant reduction in SBS of orthodontic brackets when bonded immediately after bleaching with 35 % hydrogen peroxide [13]. The result of the present study supports this finding.

Goharkhay et al. showed little effect of Nd:YAG laser-assisted bleaching on the enamel surface morphology [14]. The results of our study support their findings. In contrast, Akin et al. found lower SBS values for the groups that underwent Nd:YAG laser-activated bleaching or conventional bleaching after 2 weeks [15].

To give an account of how laser-assisted bleaching decreased the required time delay before bonding in comparison with conventional bleaching, we can note that it probably accelerated oxygen release and caused less changes in the enamel surface morphology.

Table 4 Distribution of adhesive remnant index (ARI) scores among the study groups

Groups	Subgroups	Number	1	2	3	4	5
Control		8	1 (12.5 %)	1 (12.5 %)	3 (37.5 %)	3 (37.5 %)	0
Conventional (Ultradent)	1	8	6 (75.0 %)	2 (25.0 %)	0	0	0
	2	8	0	6 (75.0 %)	2 (25.0 %)	0	0
	3	8	0	3 (37.5 %)	4 (50.0 %)	1 (12.5 %)	0
	4	8	3 (37.5 %)	3 (37.5 %)	1 (12.5 %)	1 (12.5 %)	0
Nd:YAG laser-assisted (1064 nm)	1	8	0	2 (25.0 %)	6 (75.0 %)	0	0
	2	8	1 (12.5 %)	4 (50.0 %)	2 (25.0 %)	1 (12.5 %)	0
	3	8	0	3 (37.5 %)	3 (37.5 %)	2 (25.0 %)	0
	4	8	0	2 (25.0 %)	3 (37.5 %)	2 (25.0 %)	1 (12.5 %)
Diode laser-assisted (810 nm)	1	8	0	5 (62.5 %)	3 (37.5 %)	0	0
	2	8	0	2 (25.5)%	4 (50.0 %)	2 (25.5)%	0
	3	8	0	2 (25.5)%	2 (25.5)%	4 (50.0 %)	0
	4	8	0	5 (62.5 %)	2 (25.0 %)	1 (12.5 %)	0

Reynolds suggested that bond strength of 5.8–7.8 MPa is adequate for most clinical orthodontic treatments [21]. In the current study, all experimental groups showed SBS values above this threshold. According to this threshold, all experimental groups in our study exhibited sufficient SBS values for clinical use. Nevertheless, many factors affect SBS of brackets in the clinical setting, which cannot be simulated in vitro. It also should be noted that Reynolds investigated tensile bond strength, while the current study was based on SBS. The ARI scores were significantly different among groups. ARI scores of 2 and 3 were frequently observed. This shows that failures mostly happen at the bracket-adhesive interface. This is in agreement with previous studies [15, 20]. Failure in this interface leaves enamel surface intact and decreases the risk of enamel surface damage.

Conclusion

Despite the limitations of this in vitro study, we can conclude that laser-assisted bleaching (immediately) and conventional bleaching (1 day before bonding) seem to significantly reduce the SBS. The SBS of brackets seems to increase quickly within 1 h after laser-assisted bleaching. Thus, this protocol can be suggested if it is necessary to bond the brackets on the same day of bleaching.

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