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# Er:YAG laser conditioning of enamel and bracket base for bonding orthodontic brackets to primary molars

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**ABSTRACT**

This study aimed to investigate the effect of Er:YAG laser treatment of enamel and bracket base on shear bond strength (SBS) and failure mode of orthodontic brackets to primary molars. Sixty extracted primary molars were collected and randomly assigned into four groups of 15, as follows: Group 1 (Control): conventional acid etching + intact brackets, Group 2: conventional acid etching + laser treated brackets, Group 3: Er.YAG laser etching and conventional acid etching + intact brackets, and Group 4: Er.YAG laser etching and conventional acid etching + laser treated brackets. The Er:YAG laser (2940 nm) was used at settings of 150 mJ, 10 Hz, and 10 seconds for enamel conditioning and 250 mJ, 10 Hz and 10 seconds for bracket treatment. Metal brackets were bonded to teeth with a light-cured composite. After 24 hours' storage in water, SBS was tested in an Instron machine and the adhesive remnant index was determined. There was a significant difference in SBS between the four groups (P=0.001). Tukey test revealed that the bond strength in group 2 was significantly lower than that of group 3 (P=0.004) and group 4 (P=0.003), whereas other comparisons were not significant (P>0.05). No significant difference was found in ARI scores among the groups (P=0.43). Er:YAG laser etching followed by conventional acid etching was a suitable technique to enhance bracket bond strength to primary enamel. However, laser treatment of new orthodontic brackets had a deleterious effect on bond strength and is not recommended.



## 1. INTRODUCTION

The fixed orthodontic treatment is usually performed in the late mixed dentition or early permanent dentition. Sometimes, it is necessary to attach orthodontic appliances in the early mixed dentition stage to align the teeth before inserting removable growth modification devices or to eliminate localized intra-arch misalignments such as ectopic eruption of incisors or anterior cross bites [1]. This has been referred to as the early orthodontic treatment, and aims to prevent a more complicated malocclusion in the future.

Typically, a 2×4 appliance is inserted in such cases with bands on first molars and brackets on 4 permanent incisors. The continuous arch wire placed in a 2×4 appliance causes some problems for the patient, as it has a long span between the bonded lateral incisors and permanent first molars. In these patients, masticatory forces may cause movement of the wire through the dental arch or lead to distortion of the wire. Furthermore, soft tissue irritation may be experienced due to the close contact between the wire and the buccal mucosa [1], [2] Bonding of primary canines and primary molars has been recommended as a way to reduce the free span of wire and prevent such problems [2]. It has been demonstrated that the bond strength of orthodontic brackets to primary teeth is considerably lower than that obtained on permanent teeth [3- 5]. It is assumed that the lower bond strength to primary teeth might result from their enamel texture and the presence of a thicker adhesive layer between the bracket base and the tooth surface [3], [5]. Actually, enamel without prisms is more frequently found on the external surface of primary teeth as compared to permanent teeth [6]. There are numerous studies regarding the shear bond strength, tensile bond strength, and bond failure mode of orthodontic brackets to permanent teeth, but few studies have dealt with methods to enhance bond strength to primary teeth. Since the introduction of lasers into dentistry, different applications have been proposed to benefit from the unique properties of this monochromatic, collimated, coherent and intense light. Some studies employed the erbium family (Er:YAG and Er,Cr:YSGG) lasers for conditioning the enamel surface of permanent teeth [7- 13] or removing composite from the base of detached brackets, [14- 17] but research on the use of laser for enhancing bond strength to primary enamel is limited. Therefore, this study aimed to determine the effect of Er:YAG laser conditioning of enamel and bracket surface on bond strength and failure mode of metal orthodontic brackets to primary molars.

## 2. Methods and materials

### *2.1 Specimens*

Sixty extracted primary molars were collected and stored in saline solution until the time of the experiment. The crowns of the selected teeth were intact without caries, cracks, hypoplastic areas, or restorations. The teeth were then embedded in self-curing acrylic resin in a way that the buccal surface of the tooth was out of the acryl and aligned horizontally. A 4 × 4 mm area was marked at the middle of the enamel surface to represent the bonding site. Afterwards, the surface was cleaned with water slurry of pumice and rubber cup for 10 seconds, rinsed with water and dried with compressed air.

The specimens were randomly assigned into four groups of 15, according to the surface treatment applied on the enamel surface and bracket base, as follows:

Group 1 (Control): etching with 37% phosphoric acid + intact brackets
Group 2: etching with 37% phosphoric acid + laser treated brackets
Group 3: etching with Er.YAG laser and then 37% phosphoric acid + intact brackets
Group 4: etching with Er.YAG laser and then 37% phosphoric acid + laser treated brackets

### *2.2 Enamel conditioning procedure*

The enamel surface in groups 1 and 2 was etched with a 37% phosphoric acid gel for 30 second, then thoroughly rinsed with water and dried with compressed air until the enamel showed a frosty white appearance. In groups 3 and 4, the enamel surface was exposed to laser conditioning prior to the acid etching process. For this purpose, an Er:YAG laser (Smart 2940 D, Deka Laser, Firenze, Italy) was employed. The laser emitted a wavelength of 2940 nm, and the handpiece was held manually at a distance of about 5 mm and perpendicular to the enamel surface. The bonding area was scanned for 10 seconds using pulse energy of 150 mJ and the pulse repetition rate of 10 Hz. After that, acid etching was performed similar to that described in groups 1 and 2.

### *2.3 Laser treatment of the bracket base*

The bracket bases in groups 2 and 4 were irradiated with the Er.YAG laser for 10 seconds using the pulse energy of 250 mJ and pulse repetition rate of 10 HZ. The laser was applied manually and perpendicular to the bracket surface using scanning movements to cover the whole bracket base area.

### *2.4 Bonding procedure*

Stainless steel maxillary premolar brackets (22 Roth prescription; GAC International, Dentsply, New York, USA) were used in this study. After conditioning the enamel surface, a thin layer of Transbond XT primer (3M Unitek, Monrovia, CA, USA) was applied on the enamel, thinned with air spray, and light cured for 10 seconds. Afterwards, the bracket base was covered by a sufficient amount of Transbond XT adhesive and pressed over the enamel surface. The excess adhesive was removed with a sharp explorer and the adhesive was then cured for 40 seconds from the mesial, distal, occlusal and gingival directions using a light-emitting diode (LED) with light intensity of 650 mW/cm2 (Bluephase C8; Ivoclar Vivadent, Schaan, Liechtenstein).

### *2.5 Debonding of brackets and shear bond strength (SBS) testing*

After bonding of brackets, the specimens were stored in distilled water at 37° C for 24 hours. SBS was determined in an Instron Universal Testing Machine (Santam, model STM-20, Iran) with a cross head speed of 1 mm/min. Each tooth was positioned in a way that the buccal surface was parallel to the direction of the debonding force. The force required for fracturing the interface of bracket and tooth was recorded in Newton (N). The SBS value was then calculated in MPa (megapascals; N/mm2) by means of dividing the debonding force by the surface area of the bracket base (10.89 mm2).

### *2.6 Adhesive failure mode*

After the debonding procedure, the debonded surfaces of the teeth were examined under a stereomicroscope at X 10 magnification to score the amount of adhesive remained on the tooth. Scoring was performed according to the adhesive remnant index (ARI) as suggested by Artun and Bergland: [18]

Score 0: no adhesive remained on the enamel surface
Score 1: < 50% of the adhesive remained on the enamel surface
Score 2: > 50% of the adhesive remained on the enamel surface
Score 3: 100% of the adhesive remained on the enamel surface with distinct impression of the bracket base

### *2.7 SEM examination*

One intact and one laser treated bracket was prepared for the observation under scanning electron microscope (SEM; VEGA II LSH, TESCAN, Czech Republic). The specimens were desiccated with alcohol, and coated with a thin layer of gold, and the surface morphology of the bracket base was observed at X 100 magnification.

### *2.8 Statistical analysis*

The SBS data were assessed for normality using the Kolmogorov-Simonov test. After confirming the normal distribution of the data ($P>0.05$), one-way analysis of variance (ANOVA) was run to detect any significant difference in SBS value among the study groups. Pairwise comparisons were made by Tuckey post hock test. The difference in ARI scores between groups was determined by the Fisher exact test. The statistical analysis was performed by the Statistical Package for the Social Sciences (SPSS software; Version 16.0, Chicago, IL, USA) and $P<0.05$ was considered to indicate a statistical difference.

## 3. Results

### *3.1 SBS measurements*

Table 1 presents the descriptive statistics regarding SBS values in the four groups of this study. As demonstrated in Table 1, the lowest SBS was found in group 2 (etching with 37% phosphoric acid + laser treated brackets, 11.4 MPa) and the highest SBS values were observed in group 4 (etching with Er.YAG laser and then 37% phosphoric acid + laser treated brackets; 19.9 MPa) and group 3 (etching with Er.YAG laser and then 37% phosphoric acid + intact brackets; 19.3 MPa). According to ANOVA, there was a significant difference in SBS between the four groups (P=0.001). Pairwise comparisons by Tuckey test revealed that the bond strength in group 2 was significantly lower than that of group 3 (P=0.004) and group 4 (P=0.003), whereas other comparisons were not significant (P>0.05).

### *3.2 ARI scores*

Table 2 presents the ARI scores in different groups of this study. Most specimens in groups 1, 3, and 4 showed ARI score 1. In group 2, the ARI score 0 was more frequent. The Fisher exact test revealed no significant difference in ARI scores among the study groups (P=0.43).

### *3.3 SEM examination*

Figure 1 illustrates SEM images of an intact bracket (A) and a laser treated bracket (B). The intact bracket showed distinct and homogenous microretentive areas at the base (A), whereas the base of laser treated bracket (B) exhibited some damage to the mesh and the formation of accumulated metal particles in some areas.

**Table 1.** The mean (MPa) and standard deviation (SD) and the results of statistical analysis for comparison of SBS values among the study groups

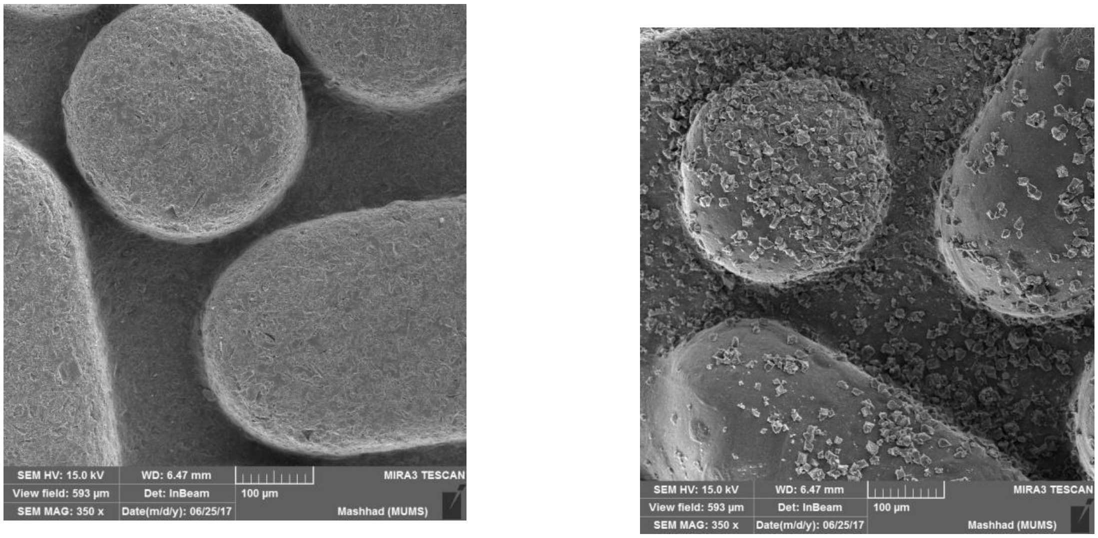
| Group | Description | Mean** | SD |
|---|---|---|---|
| 1 | acid etching + intact brackets | 15.2 [a,b] | 5.2 |
| 2 | acid etching + laser treated brackets | 11.4 [a] | 3.1 |
| 3 | Er.YAG laser etching and acid etching + intact brackets | 19.3 [b] | 6.9 |
| 4 | Er.YAG laser etching and acid etching + laser treated brackets | 19.9 [b] | 6.7 |
| ANOVA* | F=6.18; P=0.001 | | |

*P<0.05 denotes a statistically significant difference at P<0.05.

**Tukey post-hoc test. The groups that have been defined by different letters showed statistical difference at p<0.05; whereas those with the same letters are statistically comparable.

**Table 2.** The distribution (Number and percent) of ARI scores in the study groups

| | 0 | | 1 | | 2 | | 3 | |
|---|---|---|---|---|---|---|---|---|
| Group | N | % | N | % | N | % | N | % |
| 1 | 4 | 27 | 7 | 47 | 2 | 13 | 2 | 13 |
| 2 | 6 | 40 | 2 | 13 | 4 | 27 | 3 | 20 |
| 3 | 5 | 33 | 6 | 40 | 3 | 20 | 1 | 7 |
| 4 | 1 | 7 | 7 | 47 | 5 | 33 | 2 | 13 |




A B

**Figure 1.** Scanning electron microscope (SEM) photographs of an intact bracket (A) and a laser treated bracket (B) under X 100 magnification

## 4. Discussion

The present study investigated the efficacy of Er:YAG laser as a tool to enhance the bond strength of orthodontic brackets to primary teeth. Bond failure is a matter of concern for orthodontists who routinely treat malocclusions in the mixed dentition stage. The outcomes of this study suggest that laser etching followed by conventional acid etching is a suitable technique to enhance bracket bond strength to primary enamel. The erbium family lasers (Er:YAG and Er,Cr:YSGG) are the only laser devices that can be applied on dental hard tissues. These lasers have been used for various purposes in dentistry such as cavity preparation, composite removal, surface conditioning of enamel and restorative materials and bone surgery [19- 24]. The outcomes of the present study exhibited that exposing the base of new orthodontic brackets to Er:YAG laser has a deleterious effect on the bond strength to the enamel surface. In group 2 (acid etching + laser treated brackets), SBS was about 4 MPa lower than that observed in the control group (group 1; acid etching + intact brackets). Although the difference in SBS between groups 1 and 2 was not statistically significant, but in the clinical conditions, the 4 MPa difference in SBS seems important. According to the outcomes of this study, the use of Er:YAG laser for conditioning new orthodontic brackets is not recommended. This technique may distort and damage the bracket base, reduce micromechanical retention, and cause a negative effect on bond strength. In this study, the specimens prepared by the combined conditioning technique (laser etching + acid etching; groups 3 and 4) showed higher SBS values compared to those prepared by acid etching alone (groups 1 and 2). However, the difference in SBS was only significant between group 2 (in which acid etching and laser treated brackets were used) and both groups 3 and 4. Since the combined conditioning technique resulted in higher bond strength in the present study, this technique may be recommended in situations where bonding to primary teeth is required. It should be noted that when the combined technique of enamel conditioning was employed, the mean SBS in group 3 (intact brackets) was close to that observed in group 4 (laser treated brackets). Therefore, the effect of Er:YAG laser etching on enhancing bond strength to primary enamel is strong enough to negate any deleterious effect of laser irradiation on the base of bracket.

There is little information regarding the effect of laser etching on bond strength to primary teeth. Therefore, comparison of the results of this study with previous investigations is limited. The studies on laser etching of permanent enamel also reported controversial findings [10- 12], [25] It appears that laser etching alone is not a suitable alternative to conventional acid etching to prepare the tooth surface before the bonding process [5], [9], [12], [25- 27], but the combination of laser etching and acid etching can provide SBS values that were comparable or even higher than that obtained by the conventional technique [25], [27], [28]. Our results confirm the findings of [27], [25], [28] who indicated that the combination of Er.YAG laser conditioning and phosphoric acid etching lead to a higher bond strength compared to that obtained by each technique alone. In contrast, [10] exhibited that the bond strength of enamel conditioned by the combination of Er:YAG laser and phosphoric acid was significantly lower than that achieved by either laser or phosphoric acid alone. The differences in the results of previous studies might be attributed to the variations in laser settings such as pulse energy, pulse repetition rate, pulse duration, the amount of water and air spray and the duration of treatment, as well as to the differences in dental structure (primary enamel versus permanent enamel or dentine). For example, [10] applied 300 mJ pulse energy in their study which is higher than that employed in the present investigation (150 mJ). This higher pulse energy might provide deeper retention areas at the expense of higher damage to the enamel surface, and thus lower bond strength. It is accepted that the minimum acceptable bond strength of orthodontic brackets to the enamel is about 8 MPa [29], [30]. Therefore, the SBS values of all groups in the present study were remarkably above the threshold strength proposed for successful bonding in the clinical conditions. However, in the present study, the specimens were not exposed to the thermocycling process. Previous studies indicated that several factors such as the duration of storage and thermocycling process influence the bond strength, especially when laser is applied for conditioning [31], [32]. Therefore, future studies should assess the SBS of laser treated primary enamel after exposure to long storage period and thermal cycles. The adhesive remnant index scores did not show a significant difference between the groups of this study. Some studies indicated that ARI is influenced by the adhesive bond strength, so that the greater bond strength leads to higher ARI scores (more adhesive remaining on the enamel surface) [33], [34]. The ARI scores may also be influenced by the method of enamel surface preparation [35]. It is believed that failure at the adhesive-bracket interface is more advantageous as it decreases the probability of enamel fracture [36]. In the present study, the specimens in group 2 showed the lowest SBS and the highest frequency of ARI score 0. In groups 3 and 4 with greater SBS, the frequency of ARI scores 1 and 2 was higher. Although these observations are partly consistent with the assumption that higher SBS leads to greater ARI scores, the difference in the frequency of ARI scores between the groups was small and did not reach statistical significance. The outcomes of this study contradict the results of [12], [26] who found that laser conditioning leads to fracture at the enamel-adhesive interface with less adhesive remained on the enamel surface.

The SEM images of the bracket treated by Er:YAG laser revealed some morphologic alterations at the bracket base and the formation of accumulated metal particles and corrosive areas, which may damage the micromechanical retention. This observation is confirmed by the lower bond strength found in group 2, in which conventional acid etching and laser treated brackets were employed. This research was designed as an in vitro study and the results cannot be directly extrapolated to the clinical setting. However, standardization of measurements and controlling the intervening factors are more easily performed in the laboratory conditions. Further clinical studies are warranted to assess the effect of combined laser and acid conditioning on bond strength of metal brackets to primary molars.

## 5. Conclusions

Under the conditions of this study, Er:YAG laser etching followed by conventional acid etching was a suitable technique to enhance bracket bond strength to primary enamel. However, laser tertament of new orthodontic brackets had a deleterious effect on bond strength to the enamel surface and is not recommended.

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