

# Comparison of Shear Bond Strength of Orthodontic Brackets Bonded to Enamel Prepared By Er:YAG Laser and Conventional Acid-Etching

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## Abstract

**Introduction:** The purpose of this study was to compare shear bond strength (SBS) of orthodontic brackets bonded to enamel prepared by Er:YAG laser with two different powers and conventional acid-etching.

**Materials and Methods:** Forty-five human premolars extracted for orthodontic purposes were randomly assigned to three groups based on conditioning method: Group 1- conventional etching with 37% phosphoric acid; Group 2- irradiation with Er:YAG laser at 1 W; and Group 3- irradiation with Er:YAG laser at 1.5 W. Metal brackets were bonded on prepared enamel using a light-cured composite. All groups were subjected to thermocycling process. Then, the specimens mounted in auto-cure acrylic and shear bond strength were measured using a universal testing machine with a crosshead speed of 0.5 mm per second. After debonding, the amount of resin remaining on the teeth was determined using the adhesive remnant index (ARI) scored 1 to 5. One-way analysis of variance was used to compare shear bond strengths and the Kruskal-Wallis test was performed to evaluate differences in the ARI for different etching types.

**Results:** The mean and standard deviation of conventional acid-etch group, 1W laser group and 1.5W laser group was  $3.82 \pm 1.16$ ,  $6.97 \pm 3.64$  and  $6.93 \pm 4.87$ , respectively.

**Conclusion:** The mean SBS obtained with an Er:YAG laser operated at 1W or 1.5W is approximately similar to that of conventional etching. However, the high variability of values in bond strength of irradiated enamel should be considered to find the appropriate parameters for applying Er:YAG laser as a favorable alternative for surface conditioning.

**Key Words:** Er:YAG laser; Shear bond strength; Orthodontic brackets; Enamel surface preparation

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## INTRODUCTION

In fixed orthodontic treatment, brackets were used for transferring orthodontic forces to the teeth. At first, to attach the brackets to the tooth, orthodontic bands were used and after

welding brackets to bands, they were cemented to the tooth [1]. In 1955, Buonocore introduced the acid-etch technique that was gradually used in different dental treatments [2]. In 1965, Newman used direct bonding of

orthodontic brackets that was considered as the first step in application of appliances with the improvement of esthetic presentation [3,4]. This technique was developed rapidly due to its simplicity, efficacy and providing more esthetic qualities [5]. For achieving successful bonding, the bonding agent must penetrate to the enamel surface, have easy clinical use, dimensional stability and enough bond strength [6].

The bond strength of orthodontic brackets should be enough to not cause bonding failure and delay in treatment and it also should have adequate resistance against chewing forces and stresses from archwires [7]. On the other hand, easy debonding of the brackets without any damage to the teeth needs sufficient and safe bond strength [8]. According to few stages for bonding of orthodontic brackets and related problems in the conventional system, other techniques such as application of self-etch primers or laser irradiation was suggested to simplify the bonding procedure [9].

In the acid-etching technique, microporosity was produced on the enamel surface to provide micromechanical bonding. Enamel etching with phosphoric acid results in loss of the superficial layer of the enamel and dissolution of the enamel subsurface [10]. The amount of enamel loss depends on phosphoric acid concentration and the time of application [11].

Laser etching was performed by the erbium family with two different wavelengths (2940 and 2780 nm) [12]. This technique has some advantages such as having no vibration or heat and producing a surface which is acid resistant by altering the calcium to phosphor ratio and formation of less soluble compounds. These characteristics make the erbium family more popular in orthodontics [13].

There are some studies which have evaluated the effect of laser etching on bond strength of orthodontic brackets with controversial results. So, the purpose of this study was to compare shear bond strength (SBS) of orthodontic

brackets bonded to enamel prepared by Er:YAG laser with two different powers and conventional acid-etching.

## MATERIALS AND METHODS

Forty-five human premolars extracted for orthodontic purposes were selected for this study. In transillumination examination, the teeth showed healthy enamel on the buccal surface, without attrition, fracture, restoration, congenital anomalies and structural defects. There was no history of chemical substance application such as hydrogen peroxide for these teeth. After rinsing the teeth, they were placed in 0.5% chloramine T for inhibiting bacterial growth for 2 hours. Then, they were stored in distilled water until use.

The teeth were divided into three groups according to conditioning method:

Group 1: conventional etching with 37% phosphoric acid; group 2: laser irradiation by Er:YAG laser with output power of 1W; and finally group 3: laser irradiation with Er:YAG laser with output power of 1.5W.

In group 1, the samples were etched with 37% phosphoric acid gel (3M, Dental products, St.Poul) for 15 sec, then rinsed for 15 sec with water spray and dried with air spray for 10 sec in a 2 cm distance above the surface of the enamel. Laser irradiation in group 2 and 3 was carried out by Er:YAG laser (US20D, Deka, Italy) with a 2940 nm wavelength. The area was marked before irradiation. In group 2, laser was used with an output power of 1W, energy of 100 mJ and frequency of 10 Hz. These parameters were 1.5 W, 150 mJ and 10 Hz, respectively for group 3. The handpiece of laser was used 5 mm above the surface in non-contact mode and sweeping motion.

Subsequently, the adhesive kit (Transbond XT, 3M, Unitek) was used. The adhesive paste was placed on the bracket base and the brackets were placed on the enamel with a 300 gr compressive force with gauge for 10 sec to produce uniform thickness.

The resin was polymerized by LED (Mectron, starlight pro GAC, Italy) with a 440-480 nm wavelength and 400 mW/Cm<sup>2</sup> intensity for 40 sec. Consequently, the samples were thermocycled for 200 cycles between 5°C and 55°C water baths with 30 sec dwell time for each.

The specimens were mounted in auto-cure acrylic resin and the shear bond strength was measured by using a universal testing machine with a crosshead speed of 0.5 mm per second. After debonding, the amount of resin remaining on the teeth was determined using the adhesive remnant index (ARI) scored 1 to 5 (Table 1) by stereomicroscope (Nikon D-CS, Japan) with 10x magnification.

One-way analysis of variance was used to compare shear bond strengths and the Kruskal-Wallis test was performed to evaluate differences in the ARI for different etching types.

**RESULTS**

The mean and standard deviation of the conventional acid-etch group, laser group (1W) and laser group (1.5W) was 3.82 ± 1.16, 6.97 ± 3.64 and 6.93 ± 4.87, respectively.

One-way ANOVA analysis showed significant difference between the three groups.

**Table 1.** The ARI Scoring for Determination of the Composite Remaining on the Enamel Surface

Score	Degree
Score 1	100% of composite remained on the enamel surface
Score 2	More than 90 % of the composite remained on the enamel surface
Score 3	More than 10% and less than 90% of the composite remained on the enamel surface
Score 4	Less than 10% of the composite remained on the enamel surface
Score 5	No composite remained on the enamel surface

There was no significant difference between laser group (1.5W) and laser group (1W) (p=1.000) and conventional group (p=0.085), but there was a significant difference between laser group (1W) and conventional group (p=0.016).

According to graph 1, the variances of values of the laser samples' bond strengths was higher than the acid-etch group.

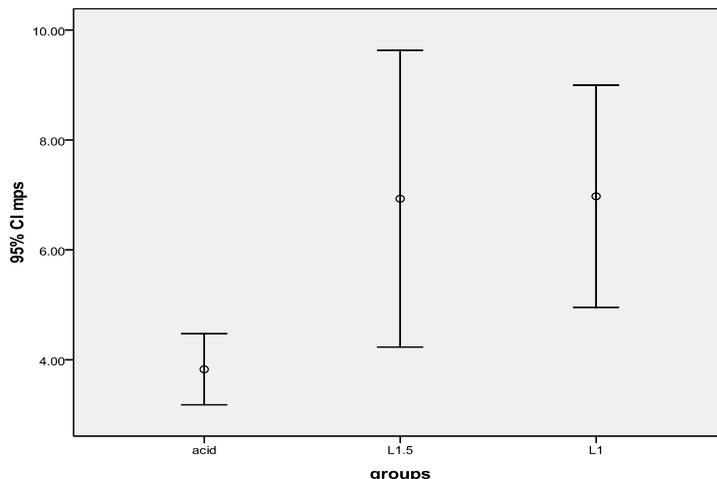
Table 2 shows the frequency distribution of ARI degrees in the three groups. According to the Kruskal-Wallis test, there was no significant difference between the three groups (p=0.918).

**DISCUSSION**

There are some studies which evaluate the enamel preparation by laser irradiation for orthodontic brackets. The aim of this study was to assess the shear bond strength of orthodontic brackets bonded to enamel prepared by Er:YAG laser or acid-etch.

The bond strength of light curing composites may be influenced by thermal changes of the oral cavity and the quality of polymerization [14]. Thermocycling is a common method for stimulating this condition; therefore, we used this technique in this research.

The result of this study showed that both laser groups had higher bond strengths than the acid-etch group. Although this difference was significant between the laser group with an output power of 1W and the acid-etch group, the laser group with an output power of 1.5W showed no significant difference with the acid-etch group. According to Usumez's study, laser irradiation with a power of 2W in comparison with the acid-etch technique showed similar shear bond strengths, but application of laser with a power of 1W showed a lower bond strength [15]. On the other hand, Gokcelik et al.'s study which assessed the shear bond strength of samples prepared by Er:YAG laser and acid-etch found no significant difference between these two groups [16].



**Graph 1.** Error bar showing 95% confidence interval of the mean for the three group's shear bond strengths

Controversial results were obtained from different studies which evaluated the effect of laser irradiation compared to conventional methods due to different study designs and various parameters used in these studies. Morphological changes of enamel produced after laser irradiation depends on the energy density of the laser, the time of exposure, the distance of the laser handpiece from the surface and percentage of water irrigation [17]. Samples irradiated with 1.5W power showed no significant difference compared to laser group with 1W power which is in agreement with the results obtained from Basaran's study [18]. In the present study, the laser groups showed higher bond strengths with higher standard deviations compared to the acid-etch group.

This finding reduced the credibility of laser application for enamel preparation, considered as an unfavorable characteristic.

In similarity, Usumez et al. reported higher distribution coefficient for shear bond strength of orthodontic brackets in laser prepared surfaces [15]. The reason may be related to the irregular etching pattern of surfaces irradiated by laser. Sasaki et al. found that preparation of enamel surfaces by Er:YAG laser can not be done homogeneously.

Surfaces irradiated by laser showed some areas which were similar to unlased enamel surfaces but surface preparation by acid etch technique showed more homogeneous patterns which was like honey comb pattern that is favorable structure for adhesion process [19].

**Table 2.** Frequency Distribution of ARI Degrees in the Three Groups

Groups	Score 1	Score 2	Score 3	Score 4	Score 5
Acid-etch group	1	2	2	6	4
Laser group (1W)	0	0	4	10	1
Laser group (1.5W)	0	0	8	5	2

Higher standard deviations in the laser groups may be associated with intrinsic nature differences of the teeth collected from different people, time of storage and environmental effects on the tooth after extraction. In order to control these problems, animal teeth can be used because numerous tooth samples can be provided from an animal.

Among different animals, bovine teeth are preferred due to similar microscopic structures to human teeth [20]. Maijer and Smith stated that bond strength of 8 MPa is essential for orthodontic treatment [21]. In this study, the mean of shear bond strength in the three groups was below the suggested value. Lower values can be related to the aging process resulted from thermocycling of samples. Cerekja and Cakirer showed that that thermocycling process reduced the shear bond strength of orthodontic brackets [2]. In addition, Daub confirmed that this condition was due to differences in thermal expansion coefficients of the adhesive, brackets and enamel [22]. Two thirds of the samples showed an ARI degree of 4 or 5 which showed that the highest debonding happened in resin to teeth contact surface which needs less cleaning of debonded enamel leading to reduction of abrasion risk to the enamel, but it is better to have debonding in resin-bracket contact or inside the resin [23] because the less adhesive remaining on the tooth, the more stress affecting the enamel surface [24]

In clinical condition, this kind of debonding is rare because providing favorable etching in enamel surface is difficult due to lack of controlling humidity, time and cooperation of patients in preparing the surfaces [5].

In addition, the structural pattern of the bracket base makes debonding in the resin bracket contact surface uncommon [25]. In contrast to these results, Lee in the evaluation of bonded brackets observed that samples prepared by acid-etch technique or Er:YAG laser irradiation showed more fracture pattern in resin-bracket contact surface [26].

These different results may be contributed to the debonding test procedure, which was tensile bond strength in Lee's study. Valletta reported that debonding happened in bracket resin surface in tensile bond strength and in resin tooth contact surface in shear bond strength [27]. Kermanshah et al. in assessing Nd:YAG laser with an output power of 2 W and frequency of 2 Hz showed no significant increase in shear bond strength compared to the control group [28].

In the present study, ARI degree among the two laser groups and between laser groups and the acid-etch group showed no significant difference. In contrast, Gokcelik showed higher ARI degrees in Er:YAG laser compared to the acid-etch group [16].

In laboratory conditions, loading forces to brackets were different from clinical conditions. In clinical conditions, brackets are influenced by a combination of tensile, shear and rotational forces. Besides, in the oral cavity, there are different kinds of stresses such as thermal changes, humidity and microbial plaque that make the simulation condition in laboratory difficult [5]. Although bond strength tests are still far from ideal, attempts should be made to standardize these tests to make comparisons easier [29].

## CONCLUSION

The shear bond strength of bracket to laser-prepared enamel with two different powers of 1 and 1.5 W was similar and laser groups showed higher bond strengths than the acid etch group. However, high variances of values in bond strength of irradiated enamel should be considered to find the appropriate parameters for applying Er:YAG laser as a favorable alternative for surface conditioning.

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