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Evaluation of shear bond strength of orthodontic brackets bonded with Er-YAG laser etching

S. Hamid Raji[1,2], Reza Birang[1,3], Fateme Majdzade[2], Reza Ghorbanipour[2]

[1]Torabinejad Dental Research Center, [2]Departments of Orthodontics, [3]Periodontics, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

ABSTRACT

Background: Based on contradictory findings concerning the use of lasers for enamel etching, the purpose of this study was to investigate the shear bond strength of teeth prepared for bonding with Er-YAG laser etching and compare them with phosphoric acid etching.

Materials and Methods: In this *in vitro* study forty – eight premolars, extracted for orthodontic purposes were randomly divided in to three groups. Thirty-two teeth were exposed to laser energy for 25 s: 16 teeth at 100 mj setting and 16 teeth at 150 mj setting. Sixteen teeth were etched with 37% phosphoric acid. The shear bond strength of bonded brackets with the Transbond XT adhesive system was measured with the Zwick testing machine. Descriptive statistics, Kolmogorov–Smirnov test, of homogeneity of variances, one- way analysis of variances and Tukey's test and Kruskal Wallis were used to analyze the data.

Results: The mean shear bond strength of the teeth lased with 150 mj was 12.26 ± 4.76 MPa, which was not significantly different from the group with acid etching (15.26 ± 4.16 MPa). Irradiation with 100 mj resulted in mean bond strengths of 9.05 ± 3.16 MPa, which was significantly different from that of acid etching ($P < 0.001$).

Conclusions: laser etching at 150 and 100 mj was adequate for bond strength but the failure pattern of brackets bonded with laser etching is dominantly at adhesive – enamel interface and is not safe for enamel during debonding.

Key Words: Acid etching, bond strength, Er-YAG laser, orthodontic brackets

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Address for correspondence:
Dr. Fateme Majdzade, Department of Orthodontics, Isfahan School of Dentistry, Isfahan University of Medical Sciences, Hezar- Jerib Ave., Isfahan, Iran.
E-mail: fmajdzade@yahoo.com

INTRODUCTION

Since the publishing of the report by Buonocore in 1955,[1] the standard protocol to eliminate the smear layer for successful bonding has been acid etching. Phosphoric acid etching is a good technique of preparing tooth enamel for bonding resins and orthodontic attachments.[1,2]

Despite the fact that the acid etching method is a useful procedure in orthodontics, a potential disadvantage is the possibility of decalcification, which increases the predisposition of enamel to dental caries critically under orthodontic brackets.[3,4] Additionally, the acid etch technique involves several steps and is technique sensitive.[5]

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Recently, alternative methods for preparing dental hard tissues, such as laser irradiation, have been developed.[3]

Since 1960, numerous types of laser have been used in dentistry.[3] In dental practice, the first generation of lasers was used only for soft tissues.[4] The serious problem applying them on teeth was the immediate increase in temperature, resulting in inflammation of the dental pulp.[6] With the invention discovery of two types of lasers, Er: YAG and Er, Cr: YSGG, which were approved by US Food and FDA, Dental hard tissues can now be removed without causing damage.[7]

The preference of the laser etched surface is resistance to dental caries.[4,8,9] Laser etching of dental hard tissue changes the calcium to phosphate ratio, and forms a more stable and less acid soluble compounds, therefore, decreases the susceptibility to acid attack and caries.[8,9]

In addition, with laser etching, procedural errors can be reduced and time saved.[8]

The family of erbium lasers is among the most promising systems because their wave lengths coincide with the main absorption peak of water and hydroxyapatite.[10] Erbium lasers remove hard tissues without causing thermal damage to the pulp.[11] Additionally it has been proved that this laser has an antimicrobial effect.[1,2,12]

Thus, Er: YAG, laser etching method might be a suitable technique to etch the enamel for orthodontic bonding.[1,2,5,12] Usumez and Aykent[13] and von Franunhofor *et al*.[14] found that laser irradiation was not able of etching the enamel, while Ozer *et al*.[5] and Lee *et al*.[15] stated that laser etching could be a successful alternative to conventional acid etching. In addition, Tanji *et al*.[16] reported that the Er: YAG laser interacts well with dental hard tissue and produced higher bond strength in comparison with acid etching.[16] In contrast, Cardoso *et al*.[17] and Hossain *et al*.[18] showed that the mean shear bond strength of laser etching was lower than acid etching. Based on contradictory findings concerning the use of lasers for enamel etching, the aim of this study was to determine the shear bond strength and the adhesive remnant index (ARI) of teeth prepared for bonding with Er:YAG laser etching and compare them with that of acid etching.

MATERIALS AND METHODS

This prospective *in vitro* study was accomplished in Torabinejad Dental Research Center of Isfahan Dental School.

Forty eight human maxillary premolars with intact buccal enamel, extracted for orthodontic purposes, were used in this study. Teeth with caries, cracks or enamel defects were excluded. The teeth were stored in the 0.1% thymol solution for 1 week and then they were washed with distilled water. The teeth were mounted vertically in a self cure acrylic (Rapid Repair, Detrey Dentsply Ltd, Surrey, U.K.) cylinder. The long axis of each tooth was aligned vertically to the base of cylinder.

The buccal enamel of the teeth were polished with pumice without fluoride (Prophylaxis Paste, Golchai Co, Tehran, Iran), and were washed and dried with an air Spray. The teeth were randomly divided into three groups of 16 teeth each.

Acid-etched group (control group)

In this group, the buccal enamel was etched with 37% phosphoric acid (American Orthodontics Co., WI, U.S.A) [Figure 1] for 30 s, rinsed with water thoroughly and then they were dried with an oil free air spray until the etched enamel showed chalky frosty appearance.

Laser-etched groups (100 and 150 mj)

Laser etching was preformed with an Er:YAG laser device (Fotona 1210, Ljubljana, Slovenia) [Figure 2] of a wavelength of 2940 nm at 20 HZ, SP mode for 25 s. The two different power settings used in this study were 100 and 150 mj.

The laser was applied on enamel with contact mode and water spray, and then the teeth were dried with an oil free air spray until the chalky frosty appearance of enamel was visible. The calculated energy densities per single dose were 23.59 J per square centimeter and 15.72 J per square centimeter for the 150 and 100 mj lasers, respectively.

Bonding procedure

A thin coating of Transbond XT primer (3 M Unitek, Monrovia, CA, U.S.A) was applied to the etched enamel surfaces. Stainless-Steel 0.018"-slot brackets (Standard edgewise, Ortho organizer, CA, U.S.A.) were bonded with Transbond XT adhesive resin (3 M Unitek, Monrovia, CA, U.S.A) and light cured with Starlight (Dentsply GAC International, NY, U.S.A) for 40 seconds.

The samples were stored in distilled water at 37°C for 24 h and then they were thermocycled for 500 cycles from 5°C to 55°C.

Evaluation of shear bond strength

The shear bond strength (SBS) of the sample was measured with Zwick testing machine (Z020, Zwick Gmbh and Co, Ulm, Germany).

The blade of machine was inserted between bracket and resin and started to force vertically in an occluso-gingival direction [Figure 3] at a cross head speed of 1 mm/min. The measured bond strength in Newton was divided by the contact surface of bracket mesh (11.55 mm^2) to change it to megapascal.

Residual adhesive

The surface of remained resin on enamel was observed under stereomicroscope (X 10 magnification, Olympus,

Figure 1: Phosphoric acid etching solution (American Orthodontics Co., WI, U.S.A)

Figure 2: Er: YAG laser device (Fotona 1210, Ljubljana, Slovenia)

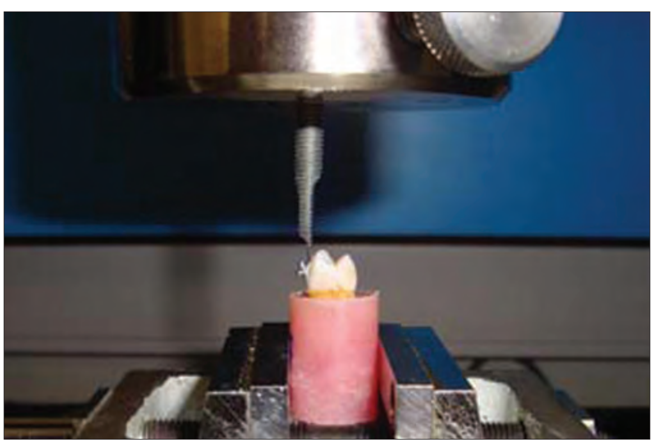

Figure 3: Placing the blade of Zwick machine vertically between the base of bracket and the resin

SZX9, Olympus Corporation, Shinjuku- Ku, Japan), and the amount of remained adhesive was evaluated according ARI developed by Artun and Bergland.[19]

Table 1: Descriptive statistics of shear bond strength of acid etching and laser etching with two different power doses

Groups	Number	Mean	Standard Deviation	Min	Max
Acid-etched (Control)	16	15.2681	4.16160	8.55	21.81
150 mj laser etching	16	12.2690	4.76848	3.66	19.54
100 mj laser etching	16	9.0400	3.16055	3.56	15.47

The scores of ARI are as:

"0": no adhesive remained on the tooth; "1": less than half of the enamel bonding site was covered with adhesive, "2": more than half of the enamel bonding site was covered with adhesive; "3": all of the enamel bonding site was covered with adhesive.

Statistical analysis

The data were analyzed with SPSS software (SPSS for windows, version 11.0 SPSS Inc, Chicago, IL, U.S.A.)

Descriptive statistics including the mean, standard deviation, maximum and minimum, were evaluated for each group. The normal distribution of SBS was performed with one sample Kolmogorov–Smirnov test and after test of homogeneity of variances; one-way analysis of variances (ANOVA) evaluated the difference in mean SBS between the groups followed by Post Hoc test of Tukey. Then, the Kruskal Wallis test was performed to determine the difference in ARI between the groups. Significance for all statistical tests was predetermined at $P < 0.05$.

RESULTS

In Table 1, descriptive statistics including mean, standard deviation, minimum and maximum of the three groups are reported.

The one-sample Kolmogorov–Smirnov test was used for analysis of normal distribution of data and then, test of homogeneity of variances was done. The results of the one- way ANOVA showed that there was significant difference in mean SBS between the groups ($P < 0.001$). The Post Hoc Tukey's test detected no significant difference between control group and 150 mj group ($P = 0.106$) and between 150 and 100 mj group ($P = 0.076$), but there was significant difference between control group and 100 mj group ($P < 0.001$).

Table 2: Distribution of Adhesive remnant Index scores for acid etching and laser etching with two different power outputs

Groups		Adhesive remnant index				
		Non adhesive	<50% adhesive	>50% adhesive	100% adhesive	Total
Acid-etched (control)	Number	7	4	5	0	16
	Percent	43.8	25.0	31.3	0	100
150 mj laser etching	Number	10	6	0	0	16
	Percent	62.5	37.5	0	0	100
100 mj laser etching	Number	12	4	0	0	16
	Percent	75.0	25.0	0	0	100

Distribution of ARI in three groups is presented in Table 2. The Kruskal Wallis test showed no significant difference in ARI between the groups (P = 0.067).

DISCUSSION

According to previous studies, the best method for etching enamel is phosphoric acid etching.[8]

One of disadvantages of acid etching is the demineralization of enamel which makes the enamel prone to future acid attacks and increases the risk of dental caries.[20,21]

Nowadays, an alternative to acid etching is laser etching.[8]

The first developed lasers such as CO2 laser and Nd: YAG laser were used extensively in periodontics and for soft tissue procedures.[6] However, this group of lasers, when applied on dental hard tissues, led to increase in temperature and resulted in inflammation of dental pulp.[6] With Er-YAG laser system the temperature could be controlled and easy handling of the device makes this type of laser attractive for clinicians.[4,18,22] Laser irradiation alters the calcium phosphate ratio and makes more stable and less acid soluble compounds; thus the resistance of enamel to caries would increase.[12,23-25]

The results of this study showed that the mean SBS of 100 mj group was significantly lower than the mean SBS of control group (P < 0.001), but there was no significant difference in the mean SBS between control group and 150 mj group (P = 0.106).

Although the SBS of 100 mj group was significantly lower than control group, it was higher than the lower limit of SBS Suggested for clinical use by Smith and Maijir.[26]

The findings of this study were consistent with the results of previous studies.[5,15,18,22,27-32] and supported the efficacy of laser etching for enamel bonding. Conversely, Usumez *et al*.[13] reported that the half of brackets bonded with laser etching had a SBS lower than the value suggested by Smith and Maijir[26] and they rejected laser etching for bonding in orthodontics.[8] Some other studies similar to Usumez *et al*. don't support the efficacy of laser etching.[14,33-35] Berk *et al*.[4] and Basaran *et al*.[36] showed that when the power of laser is lower than 1 W, the SBS of sample is not acceptable and the scanning electron microscopy does not show the pattern of etched enamel.[36]

The average power output of the laser varies from 0 to 6 W. Cutting the enamel occurs at higher outputs.[29] In the current study we used 100 and 150 mj for etching the enamel.

The differences in reports of previous studies either supporting or rejecting laser etching might be due to differences in emission mode, contact or non contact mode, irradiation time, water cooling, irradiation distance, power output, and pulse repetition rate.[10,37] The hand motion during laser etching may result in uneven etching patterns and higher standard deviations of SBS, as it can be seen in the literature,[8,36] so this problem should be overcome in future investigations.

In the current study, most of the samples in groups bonded with laser etching had the score "0" of ARI. This reveals that after debonding of brackets no adhesive remains on the enamel. This finding is consistent with the results of some previous studies.[5,8,15] This could be considered a disadvantage of laser etching because although it takes less time to remove remained adhesive on the enamel, this mode of failure may lead to enamel cracks or fracture during debonding and increases the risk of enamel loss specially with debonding of ceramic brackets.

CONCLUSIONS

1. The mean SBS of brackets bonded with 150 mj Er:YAG laser etching is comparable to acid etching.
2. Although the mean SBS of brackets bonded with 100 mj Er:YAG laser is lower than acid etching, it is high enough for bonding orthodontic brackets.
3. The site of failure in brackets bonded with laser etching is dominantly at adhesive enamel interface and is not safe for enamel during debonding.

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