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ORIGINAL ARTICLE

Laser Etched *vs* Conventional Etched Enamel: Effect on Shear Bond Strength of Orthodontic Brackets

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ABSTRACT

Aim: The purpose of this study was to assess the shear bond strength of the teeth prepared for bonding with different power outputs of Erbium, Chromium doped: Yttrium-Scandium-Gallium-Garnet (Er,Cr:YSGG) laser etching and to compare different power outputs of laser etching with 37% phosphoric acid.

Materials and methods: A total of 105 premolars, extracted for orthodontic purposes were randomly divided into five groups. Different methods were used in each group to prepare the tooth enamel for bonding. The methods are as follows: Etching for 15 seconds with 37% phosphoric acid; irradiation with 1.5 W/10 Hz Er,Cr:YSGG laser, 1.5 W/20 Hz, 2 W/10 Hz and 2 W/20 Hz Er,Cr:YSGG laser. After surface preparation standard edgewise stainless steel premolar brackets were bonded and was examined under scanning electron microscope. The brackets were debonded 24 hours later and shear bond strengths were measured.

Results: Enamel etching with 37% phosphoric acid for 15 seconds provides a higher shearbond strength for orthodontic bonding but laser etching with 2 W/20 Hz produced a comparable level of shearbond strength to phosphoric acid etched group. While 1.5 W/20 Hz and 2 W/10 Hz produced clinically acceptable shear bond strength for orthodontic bonding and 1.5 W/10 Hz produced the least shearbond strength and not acceptable for orthodontic bonding. Statistical significance was found between the groups ($p < 0.01$). Group 1 is the highest followed by group 5.

Conclusion: Irradiation with 1.5 W/20 Hz and 2 W/10 Hz were irregular and superficial, in contrast to phosphoric acid. But etching with laser 2 W/20 Hz produced adequate bond strength and could be a viable alternative to other methods.

Keywords: Enamel etching, Laser etching, Shear bond strength, Phosphoric acid etching, Er,Cr:YSGG laser.

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INTRODUCTION

It has been widely recognized for many years that accurate bracket positioning and durable bonding is of critical importance in the efficient application of biomechanics and in realizing the full potential of any appliance.

The first application of lasers in dentistry was reported in 1964. The lasers were used to inhibit caries by increasing the resistance of enamel to demineralization. Lasers were also demonstrated to vaporize and crater enamel surface with a high energy beam. Since then, the attention has been focused on the treatment of soft and hard tissue lesions. In recent years, there has been growing interest and advancement in the application of lasers for treating medical and dental faculties. These different laser systems evolved for different needs.

Laser radiation in particular, causes thermally induced changes on the enamel surface. It causes surface roughening and irregularity similar to that of acid etching to a depth of 10 to 20 µm, depending on the type of laser and the energy applied to the surface. In effect, the etching is through a process of continuous vaporization and microexplosions resulting from vaporization of water trapped in the hydroxyapatite matrix. The energy level basically depends on the energy. Laser etching is painless and does not involve heat, making it highly attractive for routine use. Furthermore, laser etching of enamel or dentine has been reported to yield a fractured or uneven surface susceptibility to acid attack and caries. It has also been suggested that laser etching might create remineralization of microspaces that trap free ions. Then laser induced caries resistance would be of great importance in orthodontics.

In this context the present study was conducted to evaluate and compare the shear bond strength of stainless brackets bonded after etching using Erbium, Chromium doped: Yttrium-Scandium-Gallium-Garnet (Er,Cr:YSGG) laser (1.5 W/10 Hz, 1.5 W/20 Hz, 2 W/10 Hz and 2 W/20 Hz) and conventional phosphoric acid etching (37% for 15 seconds). Additionally the enamel surface topography was also evaluated using scanning electron microscope (SEM).

MATERIALS AND METHODS

A total of 105 extracted sound human (maxillary and mandibular 1st and 2nd) premolars were selected with following criteria:

- Teeth without enamel defects
- Teeth without morphological defects
- Teeth without decalcification
- Teeth that were not previously bonded
- No cracks caused by extraction forceps.

These teeth were washed in water to remove any trace of blood. Teeth were cleaned off from adherent tissue tags and debris with ultrasonic scaler. The samples were stored in saline solution until ready for use.

They were randomly divided into five groups of 21 each. Teeth were mounted vertically in self-cure acrylic resin block so that the crown was exposed.

The buccal enamel surfaces of the teeth were pumiced, washed for 30 seconds and dried for 10 seconds with a moisture free air spray. All groups had 20 teeth for shear bond testing and 1 tooth for SEM evaluation.

The groups were as follows:

- Group 1 – the enamel was etched with 37% phosphoric acid for 15 seconds.
- Group 2 – Er,Cr:YSGG laser etching was done at 1.5 W power output for 10 Hz.
- Group 3 – Er,Cr:YSGG laser etching was done at 1.5 W power output for 20 Hz.
- Group 4 – Er,Cr:YSGG laser etching was done at 2 W power output for 10 Hz.
- Group 5 – Er,Cr:YSGG laser etching was done at 2 W power output for 20 Hz.

For hard tissue procedures it utilizes advanced laser and water atomization technologies to safely and efficiently perform tissue cutting, contouring, etching and resection. It provides optical energy to a user controlled distribution of atomized water droplets. The water droplets absorb the optical energy in hydrophotonic cutting effects. The hydrophotonic process refers to removal of tissue with high energized water particles. Strong absorption of laser energy by atomized water droplets results in intense yet controlled water particle excitation and microexpansion. The resulting forces induce mechanical separation of surface material quickly and cleanly removing hard tissue.

The optical power output and atomized water spray may be adjusted to specific use. It generates precise hard tissue cuts by laser energy interaction with water above and at the enamel surface.

The hard tissue laser device operates at a wavelength of 2,780 nm, a Turbo handpiece was used with pulse duration of 140 µm. The average pulse repetition rate can be varied from 10 to 50 Hz. Two pulse repetition rates of 10 and 20 pulses/second (10 and 20 Hz) were used. The average power output can be varied from 0.1 to 8 W. Two power settings (1.5 and 2 W) were used. The air and water levels were 90 and 80% respectively. The laser beam was perpendicular to the enamel at a distance of 0.5 to 3 mm (Fig. 1).

After etching, stainless steel standard premolar brackets (0.018 inch, 3M Gemini) were bonded. These brackets had a bonding area of 9.816 mm^2. A thin uniform coat of adhesive was applied to the etched surface. After the application of bonding material (Transbond XT, 3M Unitek), the bracket was placed on the tooth surface, adjusted to its final position and pressed firmly. Excessive sealant and adhesive were removed from the periphery of the bracket base to keep each bond area uniform. Each side of the tooth (mesial, distal, occlusal and gingival) was light cured using LITEK 680, a curing light for 10 seconds, for a total of 40 seconds. After that the specimens were stored in deionized water for 24 hours before debonding.

Fig. 1: Laser etching

Debonding Procedure

The FIE make universal testing machine Unitek model (94100) was used to test the shear bond strength of each tooth. The sample was mounted in lower arm of machine (Fig. 2) in such a way that the applied force was parallel to the tooth surface (gingivo-occlusally).

An acrylic with the wire loop was fixed to the upper arm of FIE, Unitek universal testing machine at a crosshead speed of 1 mm/min. The force required to debond each bracket was registered in Newton to surface area of the bracket base (MPa = N/mm^2).

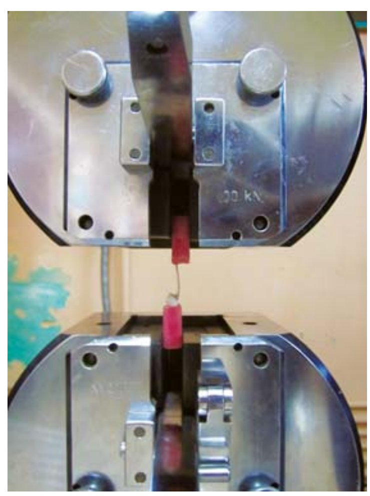


Fig. 2: Bond strength testing using FIE—Unitek 94100

RESULTS

For statistical study, to test the significant difference among groups, analysis of variance (ANOVA) (Table 1) (one-way ANOVA) at 5% confidence level was used. From the obtained statistical result we observed a significant difference among the groups ($p < 0.01$). Group 1 is the highest followed by group 5.

DISCUSSION

Many researchers have studied adhesion to enamel,[1,2] although different modalities have been tested,[3-5] phosphoric acid etching is the best method of bonding resins to enamel. A potential disadvantage of enamel acid etching is the demineralization of the most superficial layer, a matter of concern for orthodontist.[6-8] As a result of demineralization, the surface becomes more susceptible to long-term acid attack and caries, especially when resin impregnation is defective because of air bubbles or saliva contamination. These effects are particularly important because plaque tends to accumulate adjacent to the bonded orthodontic attachments. Maleic and polyacrylic acid have been used to control the enamel loss as alternatives to phosphoric acid.[9] The use of polyacrylic acid has resulted in reduced bond strength. Thus, laser-induced caries resistance would be of great importance in orthodontics.

The required time for acid etching varies from 15 to 60 seconds. Osorio et al.[10] reported that 15 seconds of enamel etching with phosphoric acid is longer than necessary for successful orthodontic bonding. Fifteen seconds of water spraying and 15 seconds of air drying are also necessary in phosphoric acid etching. A total of 45 seconds for each tooth is needed with phosphoric acid.

The first commercially available lasers, such as carbon dioxide and Neodymium-doped: Yttrium-Aluminum-Garnet, were suitable only for soft tissue treatments, especially in periodontics. The main disadvantage for application on dental hard tissues was the thermal side effects. Erbium-doped: Yttrium-Aluminum-Garnet and Er,Cr:YSGG laser systems are capable of ablation in both soft and hard tissues without thermal side effects.[11-13] In orthodontics, lasers are mainly used for etching the enamel surface, curing and debonding the brackets.

Dai P Roberts in 1992 used pulsed hard tissue laser to etch the enamel surfaces of teeth *in vivo* prior to the bonding of orthodontic brackets with composite resin. Er,Cr:YSGG laser etching is painless and does not involve either vibration or heat; also, the easy handling of the apparatus makes this treatment highly attractive for routine clinical use. Laser etching of enamel creates microcracks that are ideal for resin penetration. Hossain et al. reported an increase in the calcium to phosphorus ratio achieved during laser irradiation, which helps in caries inhibition.

Enamel consists of 85% mineral by volume. The remaining 15% consists of free water and equal amounts of protein and lipid.[14] The strongly absorbed laser energy in the enamel is converted to heat that boils water abruptly. The boiled water forms high pressure steam that leads to the ablation process when the pressure exceeds the ultimate strength of the tooth. During the ablation process, water evaporates explosively with tooth particles. The ablated materials and their successive recoil force create craters on the surface. And the irradiated surface becomes a flaky structure with an irregularly serrated and microfissured morphology.

Caldas et al.[15] (2003) have described that the degree to which bonding material cures depends on the intensity and quality of light to which it is exposed and the curing time. Aguair et al.[16] (2005) have demonstrated that once the light has left the curing unit, factors such as composite type, composite shade, thickness of resin increment or overlying tooth structure, the distance and orientation of the light tip and the diameter of the light tip may reduce intensity and provide a variable degree of polymerization. In this study, the influence of all factors was negated by the use of the same curing unit (Litex 680A), same adhesive for all the samples in a group (Transbond XT, 3M Unitek) and maintaining the same adhesive thickness over the bracket base by pressing the bracket firmly against tooth surface by a single operator (Dr Krishnan KV) for all the samples. Each side of the tooth (mesial, distal, occlusal and gingival) was light cured using Litex 680A curing light for 10 seconds,

Table 1: Comparison between groups 1, 2, 3, 4 and 5

Groups	*N*	*Mean*	*SD*	*F-value*	*p-value*
G1 [PE (37% 15 seconds)]	20	9.76	3.61	3.240	0.01 (S)
G2 (LE 1.5 W/10 Hz)	20	6.01	2.07		
G3 (LE 1.5 W/20 Hz)	20	7.35	1.27		
G4 (LE 2 W/10 Hz)	20	8.17	1.85		
G5 (LE 2 W/20 Hz)	20	9.43	2.84		
Total	100	6.14	2.55		

Note: From the obtained statistical result, there is a significance difference among the groups ($p < 0.01$). Group 1 is the highest followed by group 5; S: Significant for a total of 40 seconds. A FIE make universal testing machine (Unitek 941000) was used to apply forces of uniform nature in shear mode to all samples at crosshead speed of 5 mm/minute.

Conventional Acid Etching

In this study conventional acid etching for 15 seconds provided higher shear bond strength for bracket bonding. This confirmed previous studies [Nordenvall[17] (1980), Barkmeier[18] (1985), Labart[19] (1988), Carstensen[20] (1986), Der Horng[21] (1993), Raquel Osorio[10] (1999)] that 15 seconds acid etching is enough to create sufficient retention on the enamel surface for bracket bonding.

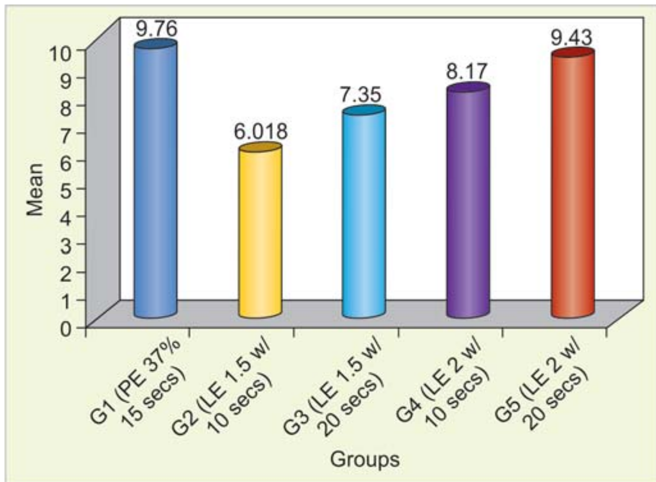
Er,Cr:YSGG Laser Etching

Er,Cr:YSGG laser system creates precise hard tissue cuts by the virtue of laser energy interacting with water at the tissue interface, called a hydrokinetic system. The average power output can vary from 0.1 to 8 W. For cutting enamel, high irradiation outputs from 2.5 to 6 W can be used. However, lower power outputs that would probably etch enamel (1.5 and 2 W) were used in the present study. The laser power outputs were varied in order to determine the shear bond strengths and surface characteristics of brackets bonded to enamel etched with an Er,Cr:YSGG laser operated at different power outputs. The usage of different power outputs causes different effects.

The varying power outputs and duration of laser irradiation make different etching patterns: 1.5 W/10 Hz laser irradiation had lower shear bond strength, whereas 1.5 W/20 Hz is superior to 1.5 W/10 Hz but 1.5 W/20 Hz is inferior to 2 W/10 Hz. But 2 W/20 Hz is superior to all other laser etched groups and showed comparable shear bond strengths with phosphoric acid. Laser irradiation with 1.5 W/10 Hz showed statistically significant differences in shear bond strengths, and also the mean shear bond strength was less than clinically acceptable limits described by Maijer and Smith.[22]

Laser etching with 1.5 W/20 Hz and 2 W/10 Hz produced clinically acceptable shear bond strength. Reynolds[23] (1975) reported that 6 to 8 MPa were clinically acceptable bond strengths, whereas Maijer and Smith[22] (1986) found 8 MPa to be adequate. Laser etching with 2 W/20 Hz produced comparable levels of shear bond strengths to phosphoric acid etching group.

The mean bond strength (Graph 1) of laser 1.5 W/10 Hz (group 2) has lesser bond strength when compared to other groups in the study (6.01 ± 2.07). The mean bond strength of laser 1.5 W/20 Hz (group 3) has higher mean bond strength (7.35 ± 1.27) than laser 1.5W/10 Hz (group 2) (6.01 ± 2.07), but less than 2 W/10 Hz (group 4) (8.17 ± 1.85) which is inferior to 2 W/20 Hz (group 5) (9.43 ± 2.84). So laser etching with 2W/20 Hz showed higher bond strength compared to all other laser etched groups but showed lesser bond strength than (acid etched: 37%/15 seconds (group 1) (9.76 ± 3.61).



Graph 1: Bond strength

In previous study Torun Ozer et al.[24] (2008) a similar bond strength was reported with acid etching (8.23 ± 2.3 MPa) and laser irradiation (6.72 ± 1.91 and 11.33 ± 3.40) indicating that the mean bond strengths in this study were reliable.

There are some contradictory findings concerning the use of lasers for enamel etching. Researchers von Fraunhofer et al.[25] (1993) stated that bond strength increases with increase in power output and laser etching of enamel shows lesser bond strength compared to the conventional acid etching; Usumez et al.[4] (2002) stated that etching of laser yielded similar but lower and less predictable bond strength than acid etching and bond strength increases with increase in power output. However, the present findings are in agreement with Vissuri et al.[26] (1996), Hossain et al.[27] (2003), and Lee et al. (2003) who reported that mean bond strength of Er:YAG laser etching was giving similar bond strength that of acid etching. They also reported about the clinical advantages of laser etching such as caries control, no heat or vibration is produced during lasing, more control on the etching area, time saving and pain less procedure.

SEM Evaluation

Results suggest that there is no specific etching pattern produced in human dental enamel. Such, differences produced by acids and laser are difficult to explain on the basis of variation in chemical composition and crystalline orientation. This further highlights the variation in structure that occur in enamel not only from tooth to tooth or surface to surface but also from site to site on a single tooth surface[28] (Figs 3 to 7).

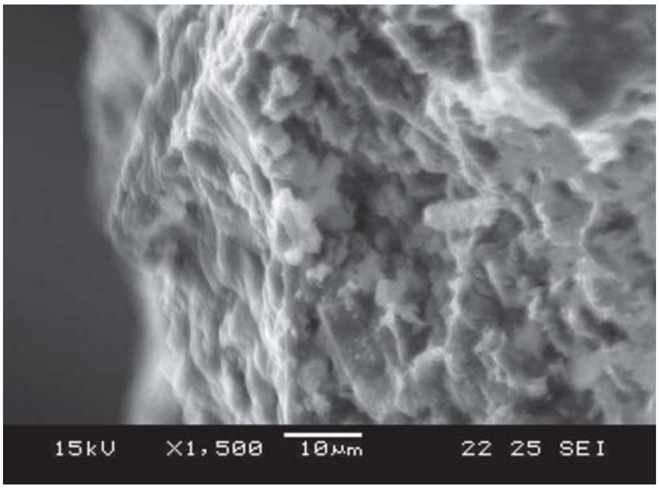


Fig. 3: SEM: 37% phosphoric acid 15 seconds

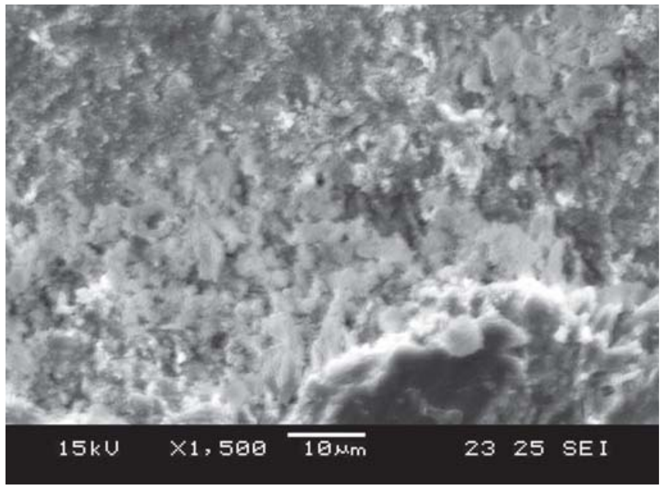


Fig. 6: SEM: Laser 2 W for 10 Hz

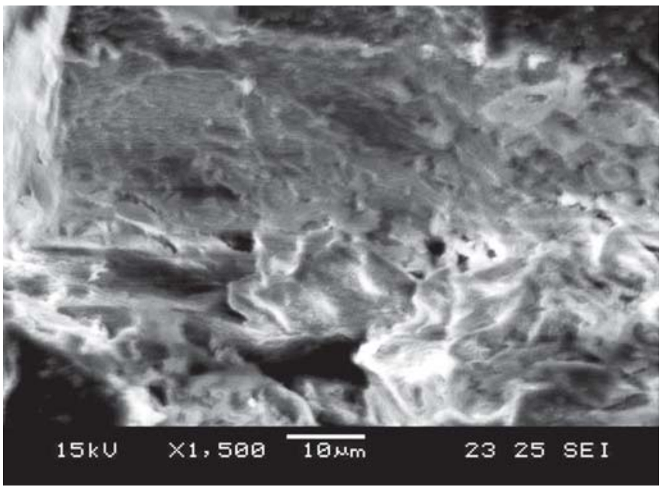


Fig. 4: SEM: Laser 1.5 W for 10 Hz

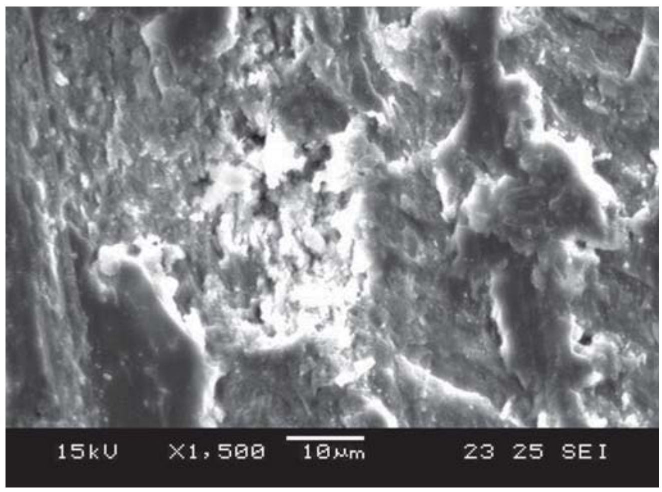


Fig. 7: SEM: Laser 2 W for 20 Hz

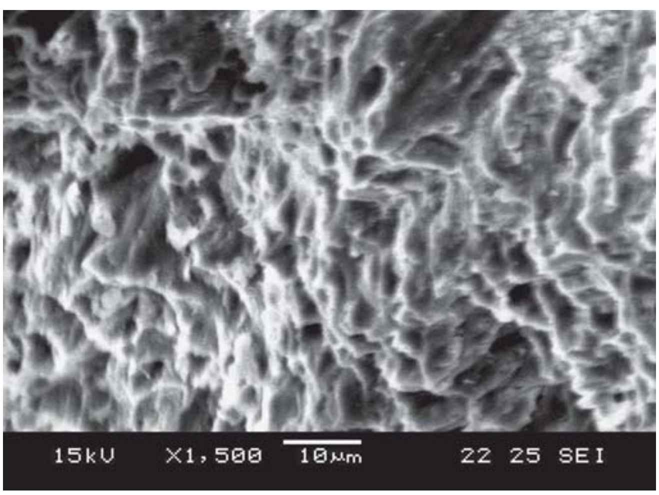


Fig. 5: SEM: Laser 1.5 W for 20 Hz

SUMMARY AND CONCLUSION

- Enamel etch pattern exhibited by laser (1.5 W/20 Hz and 2 W/10 Hz) were irregular and superficial, in contrast to phosphoric acid etching.
- Enamel etching with laser (2 W/20 Hz) produced adequate bond strength and could be a viable alternative to other methods.
- The results of the study indicate that etching of enamel surface with an Er,Cr:YSGG hydrokinetic laser system yielded statistically similar but lower and less predictable bond strengths than did acid etching with 37% orthophosphoric acid for 15 seconds.
- On the other hand, laser etching was found to be more practical and faster than conventional acid etching.
- Laser-induced caries resistance would also be of great importance in orthodontics. Furthermore, lasers might save some clinical time; however, time savings are not yet great enough to justify the capital expenditure necessary to acquire laser units, and the time saved might be spent performing additional clinical work after debonding.
- Several factors can make bond strength comparisons among *in vitro* tests and between *in vitro* tests and *in vivo* studies difficult (PK Sinha et al., 1995). It must

be taken into account that *in vitro* bond failures occur under static loading whereas *in vivo* bond failures occur under variable cyclic loading. Direct extrapolation from *in vitro* bond strength to conclusion regarding bond failure rate under clinical conditions may be erroneous. However, *in vitro* test still provides an insight on the performance of different system intended for the same application.

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