EVALUATING THE EFFECT OF ER,CR.YSGG LASER AND PHOSPHORIC ACID ETCHING ON SHEAR BOND STRENGTH OF COMPOSITE ON ENAMEL OF PRIMARY TEETH (IN VITRO STUDY)

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ABSTRACT

INTRODUCTION: Enamel surface etching improves the bonding of the composite resin material. Acid etching is the conventional method. Recently, erbium lasers have been used for this purpose.

OBJECTIVES: This study is to compare the shear bond strength of composite resin bonded to enamel of primary teeth after etching using Erbium chromium –YSGG laser and phosphoric acid etching.

METHODOLOGY: An experimental in vitro study was conducted on thirty extracted or exfoliated primary molars that were divided into three groups. Group I Er,Cr:YSGG Laser etching with power set at 1W, group II Er,Cr:YSGG laser with power set at 1.5W and group III acid etching using phosphoric acid. Specimens were assigned for shear bond strength (SBS) evaluation test. Only six specimens were evaluated qualitatively to asses enamel surface topography using scanning electron microscope.

RESULTS: SBS of acid etching group showed the highest followed by 1.5W laser-etching group, while 1W laser etching group demonstrated the least mean shear bond strength. The acid etched enamel was statistically significantly higher (P < <0.0001) than that other groups.

CONCLUSIONS: The mean SBS of composite with acid etching is significantly higher in comparison to Er, Cr: YSGG (operated at 1W & 1.5W for 10 s) laser-etched enamel.

KEYWORDS: Primary teeth, Erbium chromium: YSGG, Laser etching.

RUNNING TITLE: Effect of Er,Cr.Ysgg laser and acid etching on SBS

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INTRODUCTION

Buonocore (1) was the first to introduce the use of phosphoric acid on tooth surfaces. Since its development in 1955, this approach has been the traditional method of enamel pretreatment (2, 3). Enamel acid etching increases retention by hydroxyapatite dissolving leading to the production of resin tags which facilitates its penetration (4).

In contrast to permanent teeth, primary teeth possess enamel that is more organic in composition, thinner, and has a distinct surface charge (5). Due to the increased pore volume and permeability, it has an opaque white appearance (6). In morphological investigations, the outer surface zone of enamel is also observed as a prismless tissue structure known as the prismless layer. This layer is observed more commonly in primary teeth, characterized by a wider zone, in comparison to permanent teeth (7). The aforementioned characteristics collectively explain the discrepancies observed in etching capability, bonding process, and bonding efficacy. Therefore, this method is regarded as difficult and necessitates thorough examination (8).

Surface pretreatment is an important step for improving the bond strength between the resin composite and the tooth (9).

Acid etching is associated with several limitations, such as technique sensitivity and challenges in isolating the material. However, its most significant drawback is that acid demineralization can result in a more susceptible tooth structure to caries, especially in cases where resin impregnation is compromised by air bubbles or saliva contamination (9).

Extensive studies have been conducted to find alternative methods of conditioning the enamel surface in order to avoid the phosphoric acid etching's major disadvantage (10). Many studies have been examined the probability of substituting acid etching with more advanced methods such as laser etching (11).

The advancement of laser technology in dentistry has facilitated the refinement of numerous procedures that include both soft and hard tissues. The aforementioned procedures include soft tissue surgeries, tooth preparation, and restorative treatments, all of which are performed painlessly (12). There are numerous varieties of lasers utilized in the dental field, including the carbon dioxide laser, which may cause an increase in pulpal temperature (13), and the Nd:YAG laser, which is poorly absorbed by hard dental tissues. These restrictions have been eradicated since the erbium (Er) family of lasers was introduced in 1998. The FDA has granted authorization for the use of these lasers to irradiate tooth surfaces (14).

Operating at a wavelength of 2780 nanometers, the Er,Cr:YSGG (Erbium, Chromium: Ytrium Scandium Gallium Garnet) laser is a hydrokinetic laser system. It was initially proposed by Uşümez et al., who observed that it induced enamel ablation (15). By combining laser energy with water at the interface of the tissue, the hydrokinetic system is capable of producing accurate and precise incisions in hard tissue. In general, the mean power output exhibits variation from 0.1 to 8 watts (16).

The purpose of this research is to assess and compare the shear bond strength of composite materials adhered to enamel of primary teeth using an erbium chromium:YSGG laser etching and phosphoric acid etching.

The study's null hypothesis stated that there is no statistically significant difference between phosphoric acid etching and laser etching in terms of the shear bond strength (SBS) of composite materials adhered to the enamel of primary teeth.

MATERIALS AND METHODS

This study was performed after approval of the research ethic committee https://orcid.org/ 0000-0002-1897-1986. in Faculty of Dentistry, Alexandria University, Egypt.

The sample size was estimated assuming a 5% alpha error and 80% study power. The mean (SD) shear bond strength was 10.4847 (1.16553) MPa, 4.7967 (1.35669) MPa, and 8.3800 (1.10823) MPa for the Acid etching, Laser etching (1W, 10 sec), and Laser etching (1.5W, 10 sec), respectively (17). The highest sample was calculated based on the comparison between the Acid etching and Laser etching (1.5W, 10 sec) using the highest SD = 1.35669, to ensure enough study power. A required sample size of 8 specimens per group, was increased to 10 specimens to make up for processing errors. Total sample= number per group x number of groups= 10 x 3 = 30 specimens. This sample size was calculated using G*Power 3.1.9.7 (18).

Thirty extracted primary molars were obtained from public hospitals and the outpatient clinic of the faculty of dentistry, for exfoliation or orthodontic purposes. The sample teeth were selected based on their absence of caries on the buccal surfaces and the absence of enamel defects or fissures. Following this, ten specimens from each of the three groups were assigned at random in accordance with the enamel pretreatment protocol:

Group I: Teeth were treated using Er, Cr:YSGG laser with power output set at 1 W and enamel surfaces were lased for 10 s.

Group II: Teeth were treated using Er, Cr:YSGG laser with power output set at 1.5 W and enamel surfaces were lased for 10 s.

Group III: teeth were treated using a 37% Phosphoric acid etching for 15s.

The extracted teeth were rinsed by distilled water examined for defects according to previous inclusion criteria. All the specimens were fixed in a self-cure acrylic resin so that only the buccal surfaces were unprotected for bonding in order to permit for standardized and secured placement throughout SBS testing (19).

The surface was prepared for the adhesion of composite resin through this procedure. The surfaces of the specimens were then meticulously cleansed using an ultrasonic cleaner and flowing water to eliminate any debris (20).

Group I (power set at 1 W) & group II (power set at 1.5W) Laser etch, the buccal surfaces of both groups were thoroughly cleaned for 30 s and air dried for 20 s. Later, the samples were etched with an Er, Cr:YSGG laser (Waterlase MD, Biolase Technology, USA) working at a wavelength of 2780 nm and a repetition rate of 50 Hz along with an air-water spray (80% and 60%, respectively, as recommended by manufacturer) to avoid the enamel surface's overheating. Laser energy was delivered using sapphire tip with 600 µm in diameter recommended by manufacturer for etching (21) and enamel surfaces were lased for 10 s as recommended by previous study by Baygin et al. (22) in a sweeping motion utilizing a 45degree angulation with working distance of 1 mm from the enamel surface, achieving approximately 3 mm × 3 mm laser-etched enamel surface area (Figure 1).

Group III - Acid etch, the buccal surfaces were thoroughly cleaned for 30 s and air dried for 20 s. Later, the samples were etched with a 37% phosphoric acid (Meta Biomed Etchant, 37% phosphoric acid gel, Syringe 3g, Korea) for 15 s then were washed by distilled water for 15 s and air dried for 10 s (23).

After etching, adhesive agent was applied to all the samples (Bisco All Bond Universal, USA.) for 15 s accompanied via gentle air drying of the surface for 5 s, and light curing for 20 s with woodpecker LED light cure with an intensity of 1200 Mw/cm2 which was periodically checked using a radiometer (24). Plastic cylindrical shaped mold with 3 mm height and 3 mm internal diameter was located prependicular on the etched enamel surfaces to create a standrized bond area. It was stabilized for final positioning by sticky wax and was filled with composite (Ivoclar Vivadent Tetric N-Ceram Refill 3.5G, Switzerland.), excess adhesive was hand removed then light cured for 40 s light.

Shear bond strength testing

Specimens were stored in a normal saline at 37°C for 24 h to prevent desiccation and cracking. Later, all the samples were subjected for shear bond strength testing using universal testing machine (Figure 2) with a constant cross head speed of 0.5 mm/min, using a chisel driving the load onto the specimen at the enamel- composite interface, the diameter of each cylindrical mold was verified before each measurement. SBS was expressed in Megapascals (MPa) (20).

Shear bond strength in MPa = the maximum failure load recorder in Newtons (N)/ surface area of the bonded interface (mm^2). The shear force was applied in a direction parallel to the bonded interface using universal test machine at a crosshead speed 0.5mm/minute until de-bonding occurs (25).

Following the measurement of maximal load for each sample, SBS was converted to megapascals (MPa). The mode of failure was documented by a single operator through the evaluation of all debonded surfaces of the specimens using a stereomicroscope (b016, Olympus optical co. Ltd, 2-43-2, Japan). Cohesive within the substrate (enamel or composite resin), adhesive between adhesive and enamel, or combined (if adhesive and cohesive fractures occurred simultaneously) failure mode will be determined upon examination.

Scanning electron microscope (qualitative evaluation) (24)

Out of the total samples, six primary molars were used for surface roughness evaluation after etching by scanning electron microscope (SEM). Two specimens from each group were left unbonded after etching and not subjected to SBS. The treated surfaces were evaluated by SEM at X250 and X3000 magnifications to examine the Micro-morphological alterations on the enamel surfaces (total specimens = 6).

Statistical Analysis

Data were analyzed using IBM SPSS version 23, Armonk, NY. USA. Data normality was checked utilizing Shapiro wilk test. Shear bond strength was normally distributed. All values were presented utilizing mean, standard deviation, 95% confidence interval, median, minimum, and maximum values. One Way ANOVA accompanied via Tukey's post hoc test with Bonferroni correction. It was analyzed using Kruskal Wallis test accompanied by Dunn's post hoc test with Bonferroni correction. All tests were two tailed and the significance level was set at p value≤0.05.

Figure (1): Enamel surface of specimen etched with Erbium, chromium:yttrium, scandium, gallium, garnet laser.

Figure (2): Enamel share bone strength testing with Universal testing machine.

RESULTS

Comparisons between the groups exhibited that Group III demonstrated the greatest mean shear bond strength (6.2 ± 1.3MPa) accompanied by group II, (4.9 ± 0.5MPa,). While group I indicated the least mean shear bond strength (3.8 ± 0.1). The difference between the groups was statistically significant (P <0.0001).

Pairwise comparisons were statistically significant in which group I and II (p_1=0.012), group I and III (p_2<0.0001) and group II and III (p_3=0.004). (Table 1), (Figure 3).

Failure mode assessment results

Mixed mode of failure was presented in all of the groups.

Results of Scanning electron microscope (qualitative evaluation) :

Micro-morphological alterations on the enamel surface were assessed at X250 and X3000 magnifications via an environmental scanning electron microscope. Surface characteristics of the samples were identified through SEM analysis.

Group I (laser etching at 1 W power output)

A definite roughness in the enamel surface was observed with a power output of 1 watt under low power magnification (250x), in comparison to the adjacent intact enamel. The normal appearance of the enamel prisms was maintained in most areas (honeycomb-like structure).

Confluence of the prismatic and inter-prismatic structure was noted in some areas with irregular cracks was noted at higher power magnification (3000 x). (Figure 4A,B)

Group II (laser etching at 1.5 W power output)

A definite change in the surface of the enamel showing numerous micro-porosities was noted at low power magnification (250 x) as compared to the adjacent sound enamel.

Most of the enamel prisms are interrupted showing an irregular outline. In some areas the enamel prism boundaries were indistinct giving an irregular surface with confluence of the prismatic and interprismatic structures at high power magnification (3000 x). (Figure 5A,B)

Group III acid etching

SEM of Acid etching group showed surface roughness and scratches on the enamel surface at low power magnification (250 x).

SEM of Acid etching group showed Surface roughness and micro-porosities on the enamel surface was noted at high power magnification (3000 x). (Figure 6A,B)

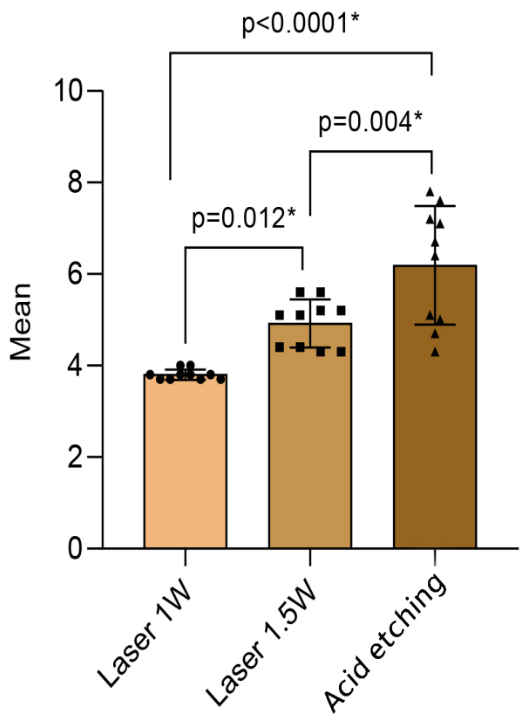
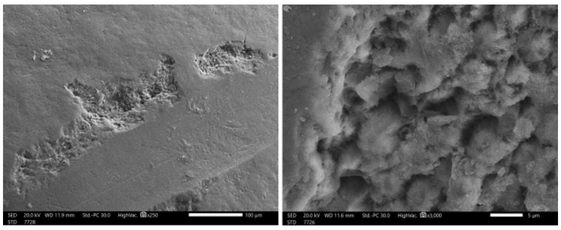
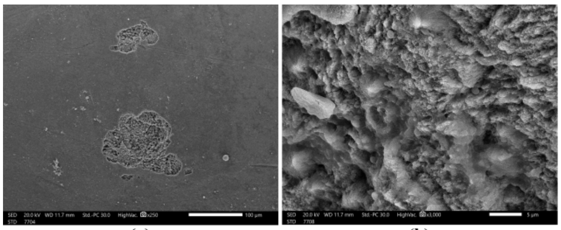


Figure (3): Comparisons of SBS between the study groups.



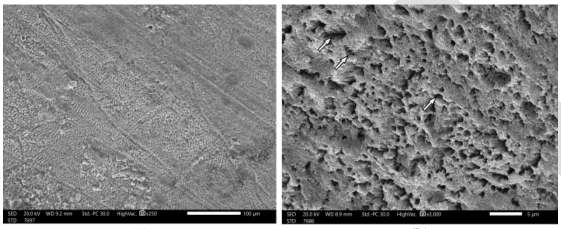
(a) (b)

Figure (4): (a) SEM of laser etching group at 1 W power output at low power magnification (250 x). **(b)** SEM of laser etching group at 1 W power output at higher power magnification (3000 x) image.



(a) (b)

Figure (5): (a) SEM of laser etching group at 1.5 W power output. **(b)** SEM of laser etching group at 1.5 W power output.



(a) (b)

Figure (6): (a) SEM OF Acid etching group at low power magnification (250 x). **(b)** SEM OF Acid etching group at high power magnification (3000x). Micro-porosities on the enamel surface (arrows).

Table 1: Comparison of shear bond strength (SBS) between the study groups.

	Group I Laser 1W (n=10)	Group II Laser 1.5W (n=10)	Group III Acid etch (n=10)
Mean ± SD	3.8 ± 0.1	4.9 ± 0.5	6.2 ± 1.3
95% CI	3.7, 3.9	4.6, 5.3	5.5, 7.1
F Test (p value)	22.433 (<0.0001*)		
Pairwise comparison	p_1=0.012*, p_2<0.0001*, p_3=0.004*		

* Statistically significant difference at $p<0.05$, p_1: comparison between group I and II, p_2: comparison between group I and III, p_3: comparison between group II and III

DISCUSSION

The use of erbium lasers have been contributed to the establishment of a favorable treatment environment with pediatric patients. Laser etching is painless and does not involve heat, making it highly attractive for routine use as it reduces anxiety and fear.

The patient is comfortable, has no vibratory sensations, and there is no contact between the tooth and the laser's fiber optic tip (27). Er,Cr:YSGG lasers can be used for successful dental ablation due to their shorter wavelength and high absorption by the enamel. The water-cooled system of the laser enables regulation of the pulpal temperature (28), making laser etching effective without obtaining isolation and overcome the disadvantages of the acid etch as it is a technique sensitive especially in pediatric patients.

Laser energy is delivered through a fibre optic system to a sapphire tip terminal with an air-water spray (80% and 60%, respectively, as recommended by manufacturer) to prevent the enamel surfaces from overheating. In the present study, lower power outputs that would probably etch enamel (1W and 1.5 W) were used as Recently, Berk et al. (22) detected by SEM analysis. The time used was 10 s for laser etching and for acid etching was 15 s as recommended by previous study by Baygin et al. (21).

The objective of this research was to determine the viability of laser etching as a substitute for phosphoric acid etching in primary teeth.

In the current study shear bond strength was evaluated using universal testing machine. It was found that the mean SBS values of composite bonded to enamel of primary teeth after acid etching were significantly higher as compared to Er,Cr:YSGG (operated at 1W and 1.5W for 10 s).

This decline in the average of SBS could potentially be attributed to the formation of subsurface fissuring and microcracks as concluded by Martinez-Insua et al. (29). This might have an adverse effect on sufficient resin penetration at the tooth laser-etched surfaces' interface.

The effects of laser pretreatment prior to bonding to enamel of primary teeth cannot be predicted using the same methods that are applied to permanent tooth substrates, due to the unique characteristics of enamel in primary teeth. While certain investigations examining the shear bond strength to primary tooth enamel discovered that the Er:YAG laser group achieved superior outcomes in comparison to acid etching (30,31).

In agreement with the present study, surface cracking was also manifest in studies done by Uşümez et al. (15) in which laser etching at 1W and 2W were utilized and exhibited a significant difference of SBS values between the acid-etched and 1W laser-etched.

On the other hand, Ozer et al. (32) used a lower power setting and found that Irradiation with the 0.75-W laser obtained lower shear bond strengths than the acid etching and no cracks was observed in their investigation.

This study showed a significant difference between laser etching groups operated at 1W and 1.5W for 10 s and acid etching group.

In this study, mixed mode of failure was found in all of the groups. SEM demonstrated that 1, 1.5 W irradiation produced acceptable etching patterns. Laser etching with power output set at 1 W showed a definite roughness in the surface of the enamel. The normal appearance of the enamel prisms were maintained in most areas (honeycomb-like structure) at low power magnification (250 x). However, irregular cracks were noted at high power magnification (3000 x). While laser etching at power output set at 1.5W at 250 x magnification revealed a definite change in the surface of the enamel showing numerous micro-porosities.

However, at 3000 x magnification most of the enamel prisms are interrupted producing an irregular outline. This result was in agreement with the findings of a study by Pires et al. (9), which showed a typical honey comb pattern of etching after irradiation by Er laser.

While, SEM of phosphoric Acid etching group showed type III etching pattern with surface roughness and scratches on the enamel surface at 250 x magnification, also it showed Surface roughness and micro-porosities on the enamel surface was noted at 3000 x magnification.

One of the limitations of laser use is that application of erbium lasers is highly technique sensitive and requires training. Also, safety guidelines while using lasers should be followed by both the operator and the patient. Any stray radiation from the laser beam may affect the cornea or the eye lens, since both tissues are rich in water. The cost and level of expertise required for using the machinery is high. Moreover there is no standards for laser energy output and time required for etching to achieve favorable shear bond strength.

CONCLUSIONS

Dependent on the limitations of this study, it was presumed that enamel etching using phosphoric acid etching revealed a better results than Er,Cr:YSGG laser etching. Further research is needed to explore the potential of utilizing higher power outputs of the Er,Cr:YSGG (Er, chromium: yttrium–scandium–gallium–garnet) laser for etching applications to fully assess its potential as an alternative to traditional phosphoric acid etching.

Considering the limitations and findings of the study, the null hypothesis that there is no significant difference between phosphoric acid etching and laser etching regarding shear bond strength of composite bonded to enamel of primary teeth was rejected.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

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