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Comparison of Shear Bond Strength of Esthetic Bracket Bonded to the Ceramic Surface Using Conventional Versus Laser Etching Technique

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ABSTRACT

Background and Objective: As the need for adult orthodontic treatment develops and cosmetic dentistry becomes more fashionable, orthodontists are frequently faced with the issue of bonding attachments to porcelain-restored teeth. The purpose of this study was to determine the most effective surface etching technique to obtain the optimum shear bond strength of ceramic brackets to porcelain surface without damage to the ceramic surface after debonding. Also, different methods were used on the porcelain surface to evaluate the shear bond strength.

Methods: In this study, 40 feldspathic porcelain discs were fabricated and randomly assigned to four groups (n=10). Group (1) ceramic bracket bonded to HFA-etched porcelain discs; Group (2) ceramic bracket bonded to PHA-etched porcelain discs; Group (3) ceramic bracket bonded to 3W Er, Cr: YSGG laser-conditioned porcelain discs; Group (4) ceramic bracket bonded to 6W Er, Cr: YSGG laser-conditioned porcelain discs. Extra samples from each group were selected before bonding to test the topography of the ceramic surface using Scanning Electron Microscopy (SEM). Debonding surfaces were investigated under an optical stereomicroscope.

Findings: Surface treatment conditioning methods caused significant differences in bond strength among groups (p=0.001). The highest bond strength was 22.40±1.74 MPa in the HFA-etched group, and the lowest bond strength was 11.40±2.95 MPa for 6W Er, Cr: YSGG laser-conditioned group. Among all groups, the HFA-etched group exhibited damage to porcelain surfaces on debonding.

Conclusion: According to the results of this study, the Er, Cr: YSGG laser group produced a more consistently conditioned surface treatment for bonding between orthodontic ceramic brackets and feldspathic ceramic surfaces, and minimal surface damage during debonding. Consequently, the Er, Cr: YSGG laser conditioning method is appropriate for ceramic surfaces.

Keywords: *Orthodontics, Feldspathic Porcelain, Ceramic Bracket, Er, Cr: YSGG Laser*.

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Introduction

As the number of adults seeking orthodontic treatment increases, orthodontists are frequently faced with the problem of adhering orthodontic brackets to ceramic restorations (1, 2). Although HFA etching has been demonstrated to provide clinically acceptable bond strength values, the risk of acid burns must be considered (3, 4).

Laser irradiation has also been considered as a possible method for treating porcelain surfaces (5, 6). Laser etching causes no pain or discomfort and takes less time than acid etching. Additionally, the Er, Cr: YSGG laser is thought to be suitable for cutting dentin, enamel, and alveolar bone (7). This type of laser has also been proven to offer enough bond strength between ceramic, aged composite, and zirconia surfaces (8, 9). To the best of our knowledge, there is limited data on conditioning the effect of Er, Cr: YSGG laser on the porcelain layer. Although several studies have tested various laser treatments, no consensus exists on the optimal strategy for achieving the appropriate shear bond strength to various porcelain surfaces.

This in vitro study was performed to find the best method for achieving optimal SBS without causing irreversible ceramic surface damage, considering not only the shear bond strength of ceramic brackets, but also the surface texture changes caused by surface conditioning on porcelain materials, and the examination the topography of the ceramic surface using SEM examination, and study the effect of conditioning with Er, Cr: YSGG laser compared to traditional acid etching methods.

Methods

After approval in the ethics committee of the College of Dentistry, University of Baghdad with the project code No. 607422, this in vitro study was conducted.

Forty discs of glazed porcelain (Vita VMK feldspathic porcelain; Vita Zahnfabric H. Rauter GmbH, Bad Sackingen, Germany) were made from Vita dentine porcelain which is available as a powder mixed with liquid in a ratio according to the manufacturer's instructions.

The sample size was calculated as n=10 in each subgroup using statistical package G power (3.1.9.4) considering $\alpha=0.05$, $\beta=0.2$, study power=0.8, and 95% confidence interval based on previous studies (2, 10, 11). The forty porcelain discs were then randomly divided into four groups (n=10) according to the surface treatment, as follows:

Group 1: ceramic bracket bonded to HFA-etched porcelain discs

Group 2: ceramic bracket bonded to PHA- etched porcelain discs

Group 3: ceramic bracket attached to 3W Er, Cr: YSGG laser -conditioned porcelain discs

Group 4: ceramic bracket attached to 6W Er, Cr: YSGG laser -conditioned porcelain discs.

In the laser group, Er, Cr: YSGG laser (Waterlase iPlus, Biolase Technology, Inc., Irvine, CA, USA) with different power outputs of 3W, and 6W, a frequency of 15Hz, and 300mJ pulse energy were used to etch ceramic surfaces. The laser energy was transferred to the ceramic surface by circular motion with 80% air and 20% water. The etching time was 30 seconds. In groups 1, the porcelain surface was etched with 9% hydrofluoric acid (buffered porcelain etch; Ultradent Products, South Jordan, UT, USA) for 2 minutes; in groups 2, porcelain surface was conditioned with 37%phosphoric acid Gel (SDI, Victoria, Australia) for 30 seconds. This was followed by a silane coupling agent (Ultradent Products, Inc., South Jordan, UT, USA) application in all groups for 60 seconds. After the bonding was done using light-cured orthodontic adhesive material (Transbond XT, South Peak Road, Monrovia, CA, 3M Unitek, USA), and in order to simulate the oral environment, the ceramic discs underwent 500 thermocycles between 5 and 55°C with a dwelling time of 30 sec after the bonding technique was completed.

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The shear test was performed using a universal testing device with a crosshead speed of 1mm/min (12). After that, the force was divided by the surface area of the ceramic bracket base (11.229 mm^2) to obtain an appropriate value in Mega Pascal (MPa) units.
According to Artun et al., as shown in Figure 1, the site of bond failure is scored on a scale of 0 to 3, (13) as follows:
0= no adhesive left on the tooth
1= less than 50% adhesive left on the tooth
2= more than 50% adhesive left on the tooth
3= all adhesive is left on the tooth, with an imprint of the bracket base.

The Porcelain Fracture Index (PFI) was used to examine any porcelain surface damage (Bourke et al.), (14) as shown in Figure 1 (E). The data were statistically analyzed using IBM SPSS Statistics, analysis of variance (ANOVA), post hoc Tukey's multiple comparisons and chi-square test, considering p<0.05 significance level.

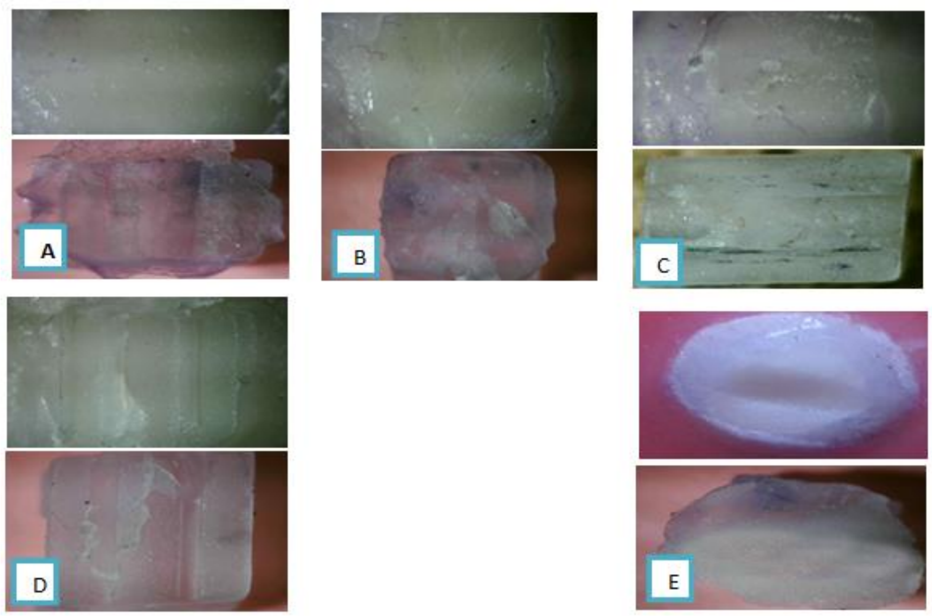

Figure 1. Adhesive remnant index. A: Score 0, B: Score 1, C: Score 2, D: Score 3, E: PFI Score

Results

The descriptive statistics of each group were reported in Table 1 and Figure 2. Considering the surface conditioning treatment, the Hydrofluoric acid (HF) had the highest mean value of shear bond strength (22.40±1.74 MPa) of all groups, while the Er, Cr: YSGG laser (6W) had the lowest mean value of shear bond strength (11.40±2.95 MPa) as shown in Table 1.

The one-way ANOVA showed a highly significant difference in the mean shear bond strength value within and among the four groups (F=25.07, p=0.001), as shown in Table 2. The post hoc Tukey's HSD test revealed that there were highly significant differences between most groups and insignificant differences in other groups as shown in Table 2.

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The frequency percentages for all groups' ARI scores are presented in Table 3. The adhesive form of failure was observed in groups 6W, 3W Er, Cr: YSGG laser, and Control PH Acid. A cohesive type of failure was found in HF group. The porcelain fracture index (PFI), as shown in Table 3, demonstrated that no noticeable ceramic porcelain surface breakage was shown in all groups, except in the HF Acid group, which exhibited localized ceramic damage on debonding.

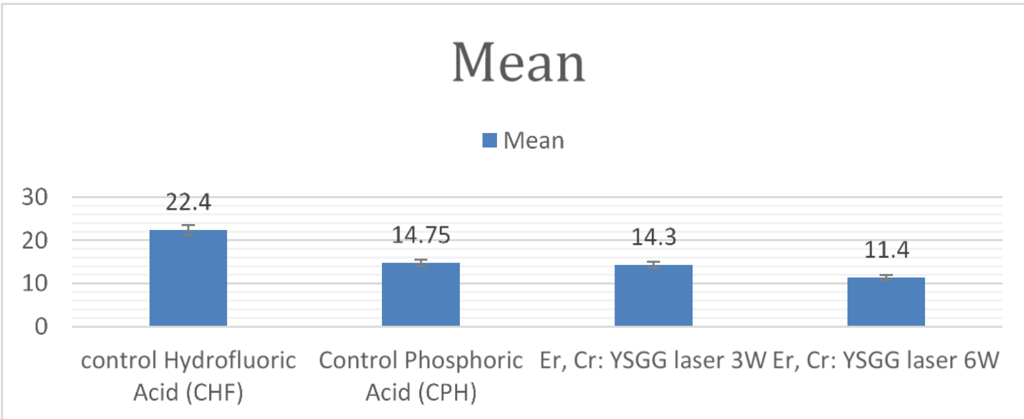

Figure 2. Mean shear bond strength values in each studied group

Table 1. Shear bond strength test descriptive statistics for several groups

Groups	N.	Mean±SD	Standard Error	Minimum value	Maximum value
Hydrofluoric Acid (CHF)	10	22.40±1.74	0.55	19.59	24.93
Control Phosphoric Acid (CPH)	10	14.75±3.32	1.05	10.24	19.59
Er, Cr: YSGG laser 3W	10	14.30±2.43	0.77	11.13	17.9
Er, Cr: YSGG laser 6W	10	11.40±2.95	0.93	8.01	17.9

Table 2. One-way analysis of variance (ANOVA)

Source of Variation	Sum of Squares	Degrees of freedom	Mean Square	F-test	p-value
Between Groups	532.99	3	177.66	25.07	0.001
Within Groups	226.78	32	7.09		
Total	759.77	35			
Treatments pair	**Tukey HSD Q statistic**	**Tukey HSD p-value**			
Hydrofluoric Acid vs Control Phosphoric Acid	9.034	0.001			
Hydrofluoric Acid vs Er, Cr: YSGG laser 6W	9.5725	0.001			
Hydrofluoric Acid vs Er, Cr: YSGG laser 3W	12.9882	0.001			
Control Phosphoric Acid vs Er, Cr: YSGG laser 6W	0.5386	0.9			
Control Phosphoric Acid vs Er, Cr: YSGG laser 3W	3.9542	0.039			
Er, Cr: YSGG laser 6W vs Er, Cr: YSGG laser 3W	3.4156	0.09			

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Table 3. Frequency distribution and Percentage of adhesive remnant index (ARI) & Porcelain fracture index (PFI)

	Scores			
	0	**1**	**2**	**3**
	Number(%)	**Number(%)**	**Number(%)**	**Number(%)**
Groups of adhesive remnant index (ARI)				
Control Hydrofluoric Acid (CHF)	0(0)	0(0)	5(50)	5(50)
Control Phosphoric Acid (CPH)	8(80)	2(20)	0(0)	0(0)
3W Er, Cr: YSGG laser (ECL)	8(80)	2(20)	0(0)	0(0)
6W Er, Cr: YSGG laser (ECL)	10(100)	0(0)	0(0)	0(0)
Groups of Porcelain fracture index (PFI)				
Control Hydrofluoric Acid (CHF)	0(0)	3(30)	3(30)	4(40)
Control Phosphoric Acid (CPH)	6(60)	4(40)	0(0)	0(0)
Er, Cr: YSGG laser 3W	8(80)	2(20)	0(0)	0(0)
Er, Cr: YSGG laser 6W	10(100)	0(0)	0(0)	0(0)

The Chi-square test revealed that all groups had highly significant differences in the site of the bond failure (p=0.001) and showed significant differences of the Porcelain fracture index (p=0.014), as can be seen in Table 4. Yate's corrective test was employed to evaluate the sites of bond failure for every two groups, and showed a significant difference between most groups, whereas there was no noticeable difference between other groups, as shown in Table 4.

Table 4. Chi-square test of adhesive remnant index and Porcelain fracture index (PFI) & Yate's correction

	X^2	**Degrees of freedom**	**p-value**
Adhesive remnant index (ARI)			
Among all groups	27.06	9	0.001
Porcelain fracture index (PFI)			
Among all groups	20.7	9	0.014
Groups of Yate's correction test	**XYATES**		
Control HF Acid-Control PH Acid	2.981	2	0.225
Control HF Acid-Er, Cr: YSGG laser 3W	5.686	1	0.017
Control HF Acid-Er, Cr: YSGG laser 6W	2.981	2	0.225
Control PH Acid-Er, Cr: YSGG laser 6W	5.395	1	0.02
Control PH Acid-Er, Cr YSGG laser 3W	2.690	1	0.1
Er, Cr:YSGG laser 6W-Er, Cr:YSGG laser 3W	5.395	1	0.02

Typical SEM pictures of the ceramic surface before initial bonding and after surface treatment to test the topography and architecture of the ceramic surface were under X1000, and X2000 magnification as shown in Figures 3-6.

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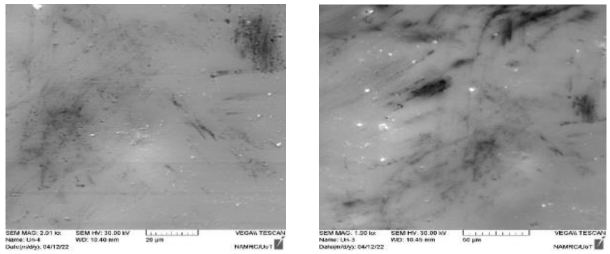

Figure 3. Untreated (control) ceramic surface under X1000, X2000 magnification

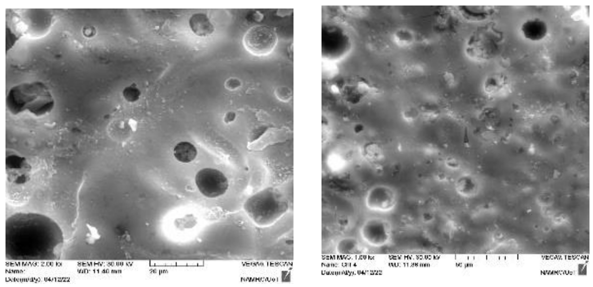

Figure 4. Ceramic surface treated with Hydrofluoric acid under X1000, X2000 magnification

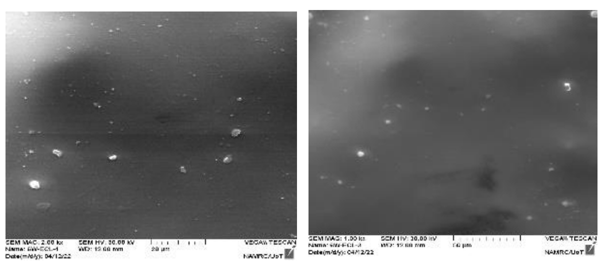

Figure 5. Ceramic surface etched with Er, Cr: YSGG laser 6W under X1000, X2000magnification

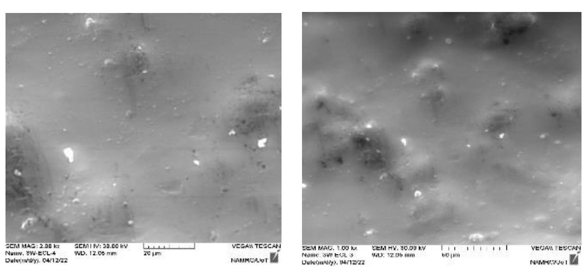

Figure 6. Ceramic surface etched with Er, Cr: YSGG laser 3W under X1000, X2000magnification

Discussion

In this study, at 95% confidence level, the bonding strength of bracket to ceramic surface conditioning by HFA etched group was discovered to be higher than the bonding strength of bracket to ceramic surface conditioning by PHA, and 3W, 6WEr: Cr: YSGG laser groups. The present research investigated the impact of Er: Cr: YSGG lasers at various power settings on the shear bond strength (SBS) between the dental porcelain and orthodontic ceramic brackets in contrast to traditional acid conditioning; based on the

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hypothesis that porcelain surface conditioned with Er: Cr: YSGG laser has acceptable bond strength to the ceramic surface, the hypothesis was accepted.

In the current study, the phosphoric acid-etched control groups had the lowest bond strength than hydrofluoric acid groups; this agrees with Ajlouni et al. (15), but opposed to Pannes et al. (2), Abu Alhaija et al (16). Preparing ceramic surfaces with laser irradiation is one of the least intrusive procedures in this context. Although several laser treatments have been offered and reviewed in the past, there is still no agreement on the best surface treatment strategy for improving bond strength. There is controversy about the kind of laser, and differing laser power settings that can provide different outcomes (17). Research by Hosseini et al. (18) showed that HF etching and Nd: YAG laser treatment produced equal bond strength in feldspathic porcelain. This research is consistent with the present study regarding using laser as an alternative to HF acid, but in contrast with the current study in that HF acid and laser etching produced equivalent bond strength in feldspathic porcelains. This may be due to using different types of laser and different power settings. Alshahrani et al. (19), and Alqerban et al. (20) compared the Er: Cr: YSGG laser to different surface treatments and they offered Er, Cr: YSGG laser as an alternative to HF etching, and these findings are consistent with the present research.

In the present study, surface treatment of ceramic restorations using 300mJ pulse energy but with different laser power settings of the Er: Cr: YSGG, 3W, and 6W showed that the mean shear bond strength of 3W was higher than 6W laser irradiation, which is similar to a study conducted by Kursoglu et al. (21) who compared the influence of laser irradiation with the effects of hydrofluoric acid etching on the ceramic surface, but found that 6 W laser conditioning did not make a substantial difference. Therefore, the increase in laser power setting resulted in the melting of the porcelain surface and destruction of the porcelain which led to the weakening in the bond strength, and the bond strength was shown to diminish as the energy per pulse was increased. As a result, the authors predicted that they could be related to the destruction of the crystal and/or matrix phases or the formation of a heat-damaged layer. These results are consistent with the existing research (22, 23).

In this research, after SEM examination, the ceramic surface treated with the laser group revealed a clean ablated surface, less irregularity, an increase in crystal size, and less microporous material with no smear layer formation which can be seen in acid etching groups. Kursoglu et al. (24) revealed that in the results of the SEM examination, the roughness of the surface increased, resulting in an irregular hollow-like surface. No melting, crystallization, or carbonization was seen in any of the laser-treated surfaces. The Er, Cr: YSGG laser's hydrokinetic system did not cause any thermal damage and revealed that the bond strength decreases with increasing energy per pulse, and these findings agree with the current study. However, cracks were found in the laser-etched porcelain group in a study by Akova et al. (25) who utilized an electron microscope to investigate conditioned porcelain ceramic surface. They determined that as laser power increased, the chance of crack development increased as well.

The therapeutically optimal bracket bond strength is 6-8 MPa (14). Nevertheless, the direct application of this value to clinical circumstances is not generally accepted, since the bracket-porcelain bond is modified by a number of environmental conditions (26). Therefore, a 3W Er, Cr: YSGG laser with a bond strength of 14.30±2.43 MPa could be used as an alternative to conventional acid–etching methods.

In this study, just one kind of laser with two different power settings and one kind of ceramic material is employed. Varied laser conditioning treatments and settings are well-established to have different effects on ceramic materials (19). As a result, the study of various ceramic materials and laser types, different surface treatments, bonding agents (27, 28), different power settings as well as energy factors, may provide different results and implications in ceramic-bracket bond strength, necessitating more research in the future.

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Although shear bond strength was higher when the conventional approach of conditioning with hydrofluoric acid was utilized in porcelain surfaces in contrast to Er, Cr: YSGG laser, laser treatment offers appropriate bond strength between orthodontic ceramic brackets and feldspathic porcelain surfaces. The Er, Cr: YSGG laser is a suitable technique for bonding ceramic brackets and is also suggested for porcelain surface conditioning treatment.

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