

# Evaluation of Shear Bond Strength of Composite to Feldspathic Porcelain after Porcelain Surface Treatment with CO<sub>2</sub> and Er:YAG lasers

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## Abstract

**Background and Aim:** Fractured ceramic crowns can sometimes be repaired with composite resin. The aim of the current study was to determine the shear bond strength of composite to feldspathic porcelain after CO<sub>2</sub> and Er:YAG laser porcelain surface preparation.

**Materials and Methods:** In this in-vitro study, 36 feldspathic porcelain blocks measuring 1\*10\*10 mm were divided into 3 groups of 12. Porcelain surfaces in the first and second groups were treated with 1.8W CO<sub>2</sub> laser and 5W Er:YAG laser irradiation, respectively. Third group specimens were subjected to 9.5% hydrofluoric acid surface conditioning. All groups received application of silane and adhesive afterwards. A composite cylinder with 3.5 mm diameter and 5 mm height was bonded to specimens. In order to evaluate the shear bond strength, a Universal Testing Machine with a crosshead speed of 1 mm/min was used. Statistical analysis was performed using one-way ANOVA and Tukey's HSD test and  $p < 0.05$  was considered statistically significant.

**Results:** The mean shear bond strength values (MPa) were  $13.03 \pm 2.57\%$ ,  $12.02 \pm 3.4$  and  $19.23 \pm 4.62$ , for the first, second and third groups respectively. One-way ANOVA revealed a statistically significant difference in this respect between the three groups ( $p < 0.001$ ).

Tukey's HSD test demonstrated significant differences between the first and third groups ( $p = 0.000$ ) as well as the second and third groups ( $p = 0.000$ ). However, no significant difference was detected between the first and second groups ( $p = 0.778$ ).

**Conclusion:** Considering the study results, CO<sub>2</sub> or Er:YAG laser irradiation is not suggested as an appropriate alternative to hydrofluoric acid for surface preparation of feldspathic porcelain.

**Key Words:** Dental porcelain, Laser, Hydrofluoric acid, Shear strength

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## Introduction

Demand for esthetic dental treatment is rapidly growing. In a research by Goldstein about the principles of facial beauty, it was stated that smile ranks second after eyes as the most important parameter of facial beauty and dentist play an im-

portant role in correcting the smile [1]. Among all esthetic dental treatments, full porcelain crowns can greatly contribute to patients' esthetics due to their excellent biocompatibility and high translucency [2]. Insufficient aesthetics or translucency, inadequate porcelain-metal bond and totally differ-

ent physical properties of porcelain and metal porcelain fused to metal crowns all led to the currently growing popularity of full ceramic crowns [3-6].

In 1980, introduction of enamel etching with phosphoric acid and ceramic etching with hydrofluoric acid techniques led to the application of resin cements for bonding of ceramic to enamel [7]. However, full porcelain crowns in service are at constant risk of porcelain separation, fracture or ditching due to various reasons. In these cases, other parts of the crown usually remain intact. Two solutions are available under these circumstances: Replacement of the full porcelain crown which is expensive and time-consuming or repairing the crown in patient's mouth with composite resin. Among different types of currently used dental porcelains, feldspathic porcelain has many applications due to its high translucency and similarity to tooth enamel and is one of the most commonly used porcelains in dentistry and full ceramic crowns in particular [8]. Several methods have been recommended for composite-porcelain bonding, such as porcelain surface preparation using a coarse bur, sandblasting with aluminum oxide particles and etching with hydrofluoric acid [9,10]. Also, application of Silane Coupling agent has been introduced as an effective measure for increasing bond strength [11-14]. Application of hydrofluoric acid produces porosities and dissolves the glassy phase of ceramic. Silane conditions the surface and enhances the formation of a covalent bond between ceramic and composite [15]. Laser irradiation for porcelain surface preparation is a recent technique for achieving a higher quality bond between the porcelain and composite. Different types of lasers are used in dentistry [16]. Akova et al. showed that CO<sub>2</sub> laser irradiation (Super Pulse, 2W, 20 seconds) provided sufficient bond of brackets to feldspathic porcelain and silane application increased the bond stability [17]. Akyilek et al. reported that application of 9.5% hydrofluoric acid created the highest bond strength to feldspathic porcelain. Also, application of acid and laser together increased the bond strength, but this strength was lower than that of acid conditioning alone [18]. Ferreira et al. demonstrated that Er:YAG laser application caused the highest bond strength followed by acid and Nd:YAG laser application; however, the differences between these

three groups were not significant. They concluded that Nd:YAG and Er:YAG laser can be used instead of acid for porcelain surface preparation [19]. The obtained controversial results indicate that porcelain surface preparation with laser needs to be further investigated. The goal of this study was to determine the shear bond strength of composite to feldspathic porcelain following porcelain surface preparation with CO<sub>2</sub> and Er:YAG lasers.

## Materials and Methods

This laboratory, experimental study was conducted on 48 porcelain blocks.

### *Preparation of porcelain blocks:*

Porcelain blocks measuring 1×10×10 mm were fabricated by using EX3 feldspathic porcelain (Noritake, Japan) in furnace (P30, Ivoclar, Liechtenstein, Switzerland) at 930°C for 15 minutes.

### *Laser irradiation:*

A) Pilot study: Since the majority of studies on porcelain surface preparation are implemented on Zirconium, at first two different powers of CO<sub>2</sub> and Er:YAG (Deka, Italy) lasers were tested on 12 feldspathic porcelain blocks and the SEM (Scanning Electron Microscopy) results were examined by three experts as single blind to find out which CO<sub>2</sub> and Er:YAG laser powers have the greatest effect on feldspathic porcelain for use in this study. Prior to laser irradiation, surface glaze of feldspathic porcelain was removed by composite polishing bur 850.016 (Tizkavan, Tehran, Iran). In Er:YAG laser group, Er:YAG laser with wavelength of 2940 nanometer at two different powers along with Graphite powder (Sosmar, Iran) was used [19]. Porcelain surface was coated with graphite powder prior to laser irradiation. Non-contact mode Er:YAG laser with 4 and 5 W power, 10 Hz frequency, 400 mJ energy, 450 microsecond pulse duration, 0.5 J/mm<sup>2</sup> energy density, 5 mm distance, 15 seconds exposure time and 1 mm beam diameter was irradiated. In CO<sub>2</sub> laser group, first laser with 10600 nanometer wavelength, 1.8 Watt power, 1 mm beam diameter, 10 Hz frequency, 5 millisecond pulse duration and 0.01 J/mm<sup>2</sup> energy density with surface at focal distance was irradiated for 15 seconds and then CO<sub>2</sub> laser with 2.4 W power, 10600 nanometer wavelength, 20 Hz frequency, 2.5 millisecond pulse duration, 0.008 J/mm<sup>2</sup> energy density and 1 mm beam diame-

ter with surface at focal distance was radiated for 15 seconds.

B) Main study: After selecting the power for each laser, 12 porcelain blocks in group 1 and 12 porcelain blocks in group 2 received CO<sub>2</sub> and Er:YAG laser irradiation for surface preparation, respectively.

Porcelain etching:

Surface glaze of 12 porcelain blocks in group 3 was removed by composite polishing bur 850.016 and 9.5% hydrofluoric acid (Basico, USA) was applied to the surface, remained for two minutes, rinsed for 15 seconds and air dried for 5 seconds.

SEM:

Acid and laser-treated specimens were gold coated by Gold- Palladium alloy using Sputter Coater Apparatus model SC7620 (Leo, Germany) and examined by Scanning Electron Microscope model 1450 VP (Leo, Germany) set at 20 kV acceleration voltage, 3 nanometer resolution and 1000 x magnification.

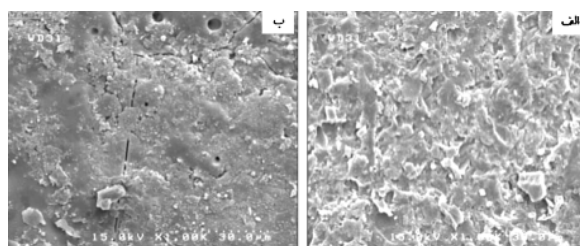
Application of bonding agent and composite resin: First, a thin layer of silane was applied to all samples, air dried for 30 seconds with air spray, and then Scotch bond multi-purpose adhesive (3M, USA) from the third bottle was used. The adhesive was light cured from 1 mm distance for 20 seconds by the light-curing unit (Astralis 7, Vivadent, Liechtenstein, Switzerland) with 450 mW/cm<sup>2</sup> intensity. In order to fabricate a composite cylinder to be bonded to porcelain surface, a transparent cylinder with 2 mm internal diameter and 4 mm height and composite Z<sub>250</sub> (3M, USA) with A2 shade were used. With a suitable hand instrument, the composite was applied to the transparent cylinder. The cylinder was then perpendicularly placed in the center of the porcelain surface and light cured at 1 mm distance from the top and both sides for 20 seconds each. For measuring the shear bond strength, Universal Testing Machine was used with a cross-head speed of 1 mm/minute, pre-load of 2N and 2 kN load cell. The samples were subjected to load until failure. A computer and a data acquisition system recorded the data. Fracture modes were studied by a stereomicroscope (SZ 40, Olympus, Tokyo, Japan) with 40X magnification and were categorized as cohesive (in composite or porcelain), adhesive (at the composite-porcelain interface) and mixed (a combination of both). The

obtained data were analyzed using SPSS version 13.0 software. One-way ANOVA was applied and pair-wise comparison of groups for shear bond strength was carried out using Tukey's HSD test. ( $P < 0.05$ ) was considered statistically significant.

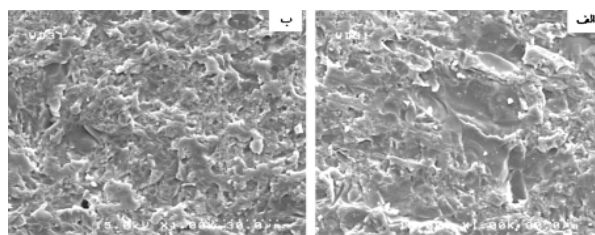
## Results

A) Result of the pilot study:

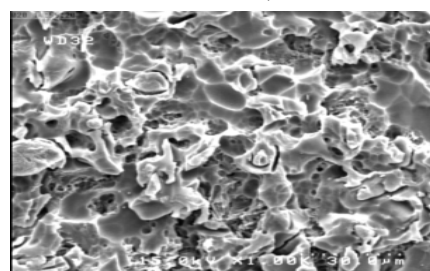
The SEM results revealed that CO<sub>2</sub> laser with 1.8 W power and Er:YAG laser with 5 W power caused minor cracks and the highest surface roughness on feldspathic porcelain (Figure, 1-3).



**Fig 1.** Porcelain surface prepared with CO<sub>2</sub> laser: A) 1.8 Watt and B) 2.4 Watt



**Fig 2.** Porcelain surface prepared with Er:YAG laser: A) 4 W and B) 5 W



**Fig 3.** Porcelain surface prepared with hydrofluoric acid

B) The results of main study:

Mean, standard deviation, minimum and maximum values of shear bond strength (MPa) in 3 study groups are shown in Table 1. In order to ensure the normal distribution of samples, One Sample Kolmogorov Smirnov test and for statistical analysis, univariate ANOVA were applied and revealed significant differences in means shear bond strength of

different understudy groups ( $p < 0.001$ ). The results of Tukey's HSD test demonstrated significantly higher shear bond strength in acid treated group compared to the laser groups ( $p < 0.001$ ). However, no statistically significant differences were noted between the laser groups (1 and 2) ( $p = 0.778$ ). The frequency of various modes of failure is presented in Table 2.

**Table 1.** Porcelain surface prepared with hydrofluoric acid

Group	Number	Minimum	Maximum	Mean $\pm$ SD
1	12	7/11	15/94	13/03 $\pm$ 2/57
2	12	6/49	15/65	12/02 $\pm$ 3/4
3	12	11/63	24/91	19/23 $\pm$ 4/62

**Table 2.** Frequency distribution of different failure modes in understudy groups

Failure type	Group 1	Group 2	Group 3	Total
Adhesive	8	10	3	21
Cohesive	0	0	5	5
Mixed	4	2	4	10

## Discussion

At present, use of laser in dentistry is becoming increasingly popular and it is necessary to clarify its different clinical applications. On the other hand, demand for full porcelain crowns is increasing because of their high translucency and excellent biocompatibility [3, 8]. Full porcelain crowns may undergo fracture or chipping during their clinical use; in these cases we may use composite resins to repair the porcelain. In order to achieve a strong bond between the composite and porcelain, several techniques are used for porcelain surface preparation. Limited number of studies have evaluated porcelain surface preparation with laser yielding different results. In this study, 1.8 and 2.4 W powers of CO<sub>2</sub> laser and 4 and 5 W powers of Er:YA Glaser were selected and then SEM was used to find out the optimal power with the best effect on porcelain. Studies have shown that lower powers of Er:YA Glaser do not have an adequate effect on porcelain surface and are not able to create optimal surface roughness [18,19]. The conventional graphite caused greater absorption of Er:YAG laser by the porcelain surface [19].

In this study, after porcelain surface preparation with acid or laser, silane was applied to enhance the bond between composite and porcelain. Shear bond strength of composite to feldspathic porcelain following porcelain surface preparation with hydrofluoric acid was greater than the rate following porcelain surface preparation with CO<sub>2</sub> and Er:YAG lasers. Due to the dissolution of minerals by hydrofluoric acid, porosities are formed on the porcelain surface causing micromechanical retention; while CO<sub>2</sub> and Er:YAG laser create porcelain surface roughness but are not able to dissolve the mineral content yielding low or no micromechanical retention.

Akovaet al, in their study on porcelain surface preparation with CO<sub>2</sub> laser for bonding of brackets to feldspathic porcelain in ceramic-metal crowns concluded that CO<sub>2</sub> laser can provide sufficient bond between bracket and feldspathic porcelain of ceramic-metal crowns. Akyilet al. evaluated the shear bond strength of composite resin to feldspathic porcelain after porcelain surface treatment with laser and acid etching and concluded that preparation with hydrofluoric acid created higher bond strength than preparation with Er:YAG and Nd:YAG lasers. Ferreiraet al. studied the shear bond strength of resin cement to feldspathic porcelain following porcelain preparation by sandblasting with aluminum oxide particles and Er:YAG and Nd:YAG lasers and demonstrated that the efficacy of porcelain surface preparation with Er:YAG and Nd:YAG lasers was similar to that of hydrofluoric acid providing optimal shear bond strength of resin cement to feldspathic porcelain. However, different results were obtained in our study. This difference may be attributed to different laboratory conditions, use of hydroxyapatite prior to Er:YAG laser irradiation and application of different bonding agents and composite resins.

The mode of failure was adhesive or mixed in CO<sub>2</sub> and Er:YAG laser groups and the cohesive failure was not observed. In hydrofluoric acid group, the observed mode of failure was of cohesive type in the composite resin. The adhesive mode of failure is due to the weak bond between the porcelain surface prepared with laser and composite resin. In laser groups, failures were mostly of adhesive or mixed types at the resin-porcelain interface. In hydrofluoric acid group, the majority of observed

failures were of cohesive type attributed to the higher bond strength of composite to feldspathic porcelain.

### Conclusion

Based on the obtained results, preparation of feldspathic porcelain surface with hydrofluoric acid is more effective than Er:YAG and CO<sub>2</sub> laser application for achieving a suitable bond strength between composite resin and feldspathic porcelain. Role of other laser parameters needs to be illuminated in future studies to further improve the efficacy of laser for porcelain surface treatment.

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