Evaluation of Shear Bond Strength of Composite to Feldspathic Porcelain after Porcelain Surface Treatment with CO\textsubscript{2} and Er:YAG lasers

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\textbf{Abstract}

\textbf{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\textsubscript{2} and Er:YAG laser porcelain surface preparation.

\textbf{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\textsubscript{2} 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.

\textbf{Results:} The mean shear bond strength values (MPa) were 13.03±2.57%, 12.02±3.4 and 19.23±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 (\(P=0.778\)).

\textbf{Conclusion:} Considering the study results, CO\textsubscript{2} or Er:YAG laser irradiation is not suggested as an appropriate alternative to hydrofluoric acid for surface preparation of feldspathic porcelain.

\textbf{Key Words:} Dental porcelain, laser, hydrofluoric acid, shear strength

\textbf{Introduction}

Demand for esthetic dental treatments is rapidly growing. In a research by Goldstein about the principles of facial beauty, it was stated that the smile ranks second after eyes as the most important parameter of facial beauty and dentists play an important 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 different physical
properties of porcelain and metal in 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 service 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 CO2 laser irradiation (Super Pulse, 2W, 20 seconds) provided sufficient bond of brackets to feldspathic porcelain and silane application increased the bond stability [17]. Akyl 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 condition ingalone [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 need 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 CO2 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 CO2 and Er:YAG (Deka, Italy) lasers were tested on 12 feldspathic porcelain blocks and the SEM (Scanning Electron Microscopy) results were reexamined by three experts as single blind to find out which CO2 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 a 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, 500 micrometer, 500 J/m² energy, 15 seconds exposure time and 5 mm beam diameter was irradiated in CO2 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/mm² energy density with surface at focal distance was irradiated for 15 seconds and then CO2 laser with 2.4 W power, 10600 nanometer wavelength, 20 Hz frequency, 2.5 millisecond pulse duration, 0.008
J/mm² energy density and 1 mm beam diameter 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 CO₂ 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/ Cm² 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 Z₂₅₀ (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, preload of 2 N 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 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 CO₂ 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).

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 for statistical

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**Fig 1:** Porcelain surface prepared with CO₂ 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 for statistical...
analysis, univariate ANOVA were applied and re-
vealed significant differences in meanshear bond
strength of different understudy groups (P<0.001).
The results of Tukey’s HSD test demonstrated sig-
nificantly high shear bond strength in acidtreated
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

<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>7/11</td>
<td>15/94</td>
<td>13/03±2/57</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>6/49</td>
<td>15/65</td>
<td>12/02±3/4</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>11/63</td>
<td>24/91</td>
<td>19/23±4/62</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Failure type</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesive</td>
<td>8</td>
<td>10</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Cohesive</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Mixed</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>

**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 crownsis increasing
because of their high translucency and excel-
llentbiocompatibility [3, 8]. Full porcelain
crowns may undergo fracture or chipping during
their clinical use; in these cases we may use com-
posite 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 CO2 laser and 4 and 5 W powers of
Er:YAG laser 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:YAG laser do not have an adequate
effect on porcelain surface and are not able to cre-
ate optimal surface roughness [18,19]. The conven-
tional 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 fol-
lowing porcelain surface preparation with hydro-
fluoric acid was greater than the rate following
porcelain surface preparation with CO2 and
Er:YAG lasers. Due to the dissolution of minerals
by hydrofluoric acid, porosities are formed on the
porcelain surface causing micromechanical retent-
ion; while CO2 and Er:YAG laser create porcelain
surface roughness but are not able to dissolve the
mineral content yielding low or no micromechanical
retention.

Akova et al, in their study on porcelain surface
preparation with CO2 laser for bonding of brackets
to feldspathic porcelain in ceramic-metal crowns
concluded that CO2 laser can provide sufficient
bond between the bracket and feldspathic porcelain
of ceramic-metal crowns. Akwile et al evaluated
the shear bond strength of composite resin to
feldspathic porcelain after porcelain surface treat-
ment 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. Ferreira et 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 efficacyporcelain 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 dif-
ferent bonding agents and composite resins.
The mode of failure was adhesive or mixed in CO2
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 sur-
face 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 CO2 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.

REFERENCES
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