

Original Article

Effect of surface treatment with laser on repair bond strength of composite resin to ceramic

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ABSTRACT

Background: Small chipping or fracture of ceramic restorations may be repaired by composite resin instead of replacing the restoration. This method is faster and cheaper compared to restoration replacement. Several strategies have been suggested to obtain a high repair shear bond strength (SBS). This study aimed to assess the efficacy of some new ceramic surface treatments (laser and universal adhesive) to enhance the repair bond strength of composite resin to ceramic compared to the conventional method.

Materials and Methods: This *in vitro* study evaluated 80 IPS Empress Esthetic ceramic plates in eight groups ($n = 10$). The ceramic surface was polished with 320-grit silicon carbide paper under running water, rinsed with water spray for 10 s and dried. The samples were then divided into two subgroups for mechanical surface preparation with hydrofluoric (HF) acid and Er:YAG laser (2 W, 200 m J, 10 Hz, 10 s). Each group was divided into two subgroups for use/no use of silane. The conventional or universal adhesive was then applied on the samples in each subgroup. Composite cylinders were bonded to the ceramic surface using plastic tubes. The samples were stored in distilled water at 37°C for 24 h and subjected to an SBS test. Data were analyzed using one-way ANOVA ($P < 0.05$).

Results: The interaction effect of variables on SBS was significant. Maximum SBS was noted in HF acid + silane + conventional adhesive group (mean: 12.0481 MPa). Minimum SBS was noted in the laser + conventional adhesive group (mean: 2.5766 MPa). Surface treatment with HF acid yielded significantly higher SBS than laser ($P < 0.001$). The interaction effect of conventional/universal adhesive and use/no use of silane on SBS was statistically significant.

Conclusion: The repair SBS was higher in groups treated with HF acid compared to laser. Ceramic surface treatment with HF plus silane plus conventional adhesive yielded a higher SBS as well as HF plus Universal adhesive. Thus, the application of silane as a separate step can be omitted in the repair of ceramic restorations with universal adhesives.

Key Words: Bond strength, ceramic, laser, resin composite

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INTRODUCTION

At present, glass-ceramic restorations are highly popular due to their excellent esthetic appearance and long-term durability.^[1] Nonetheless, defects, chipping, and fracture of these restorations are common. Replacement of the restoration may be required in some cases. Although restoration replacement leads to more favorable clinical and esthetic results, it is not always the best choice because it may cause pulpal damage, is costly and wastes time.^[2,3] Small chipping or fracture of ceramic restorations may be repaired by composite resin instead of replacing the restoration. This method is more conservative and cheaper than restoration replacement and can be performed within single session. The remaining part of the restoration remains intact and the tooth does not need any further preparation. Thus, pulpal irritation is prevented in restoration repair. However, achieving a durable bond between the composite resin and ceramic is challenging.^[4-9] A combination of techniques is often employed to prepare the glass-ceramic surface aiming to enhance the bond of composite resin to ceramic by micromechanical interlocking and chemical bonds. The suggested techniques for this purpose include sandblasting, tooth preparation, surface roughening by bur, silica coating, etching with hydrofluoric (HF) acid, laser irradiation, and application of silane and adhesives.^[5] The commonly used technique for the repair of glass-ceramics involves HF acid etching and the application of silane and adhesive. Application of HF acid following surface roughening enables micromechanical retention. Furthermore, it removes the glassy matrix and reveals the crystalline structure of ceramic.^[10,11] Application of silane as primer enhances the adhesion of the resin to ceramic.^[8,9] Low-viscosity silane results in surface wetting and facilitates microscopic penetration of resin into the porous structure of ceramic and enables adhesion by creating covalent bonds.^[4] Adhesives, mainly conventional adhesives, are applied following the application of silane. Recently, a new generation of adhesives, namely universal adhesives were introduced on the market, which can be used in self-etch, total-etch, and selective-etch modes. Universal adhesives can bond to the tooth structure and indirect restoration surfaces such as ceramic, resin, and metal.^[8]

Kalavacharla *et al.* reported that silane present in the composition of universal adhesives has no significant

effect on bond strength and a separate step of silane application cannot be omitted.^[12] Laser irradiation is among the novel surface treatment techniques. Furthermore, the application of universal adhesives is a more recent technique compared to other methods and evidence is inconclusive regarding their efficacy in the process of ceramic repair. On the other hand, silane is present in the composition of some universal adhesives such as Single Bond Universal (3M), which questions the need for a separate silane application step. This study aimed to assess the effect of mechanical and chemical surface treatments on repair bond strength of composite to ceramic. Furthermore, the efficacy of these novel techniques was compared with that of conventional surface treatment (HF acid etching and application of conventional adhesive). The effect of different surface treatments was evaluated by measuring the repair bond strength of composite to ceramic after 24 h of immersion in distilled water. Moreover, this study aimed to assess the effect of silane application, along with universal adhesive. The null hypotheses were (a) the efficacy of different mechanical surface treatments (laser and HF acid etching) would not be significantly different, (b) application of silane would have no significant effect on repair bond strength, and (c) the effects of conventional and universal adhesives would not be significantly different on repair bond strength.

MATERIALS AND METHODS

It is an experimental study with the following in vitro steps

Fabrication of ceramic blocks

Eighty ceramic blocks (Lucite-reinforced glass-ceramic; IPS Empress; Ivoclar Vivadent, Liechtenstein) were fabricated in a laboratory. In brief, wax molds were fabricated measuring 6 mm × 6 mm with 5-mm thickness and measured with a caliper. After spruing, the molds were poured with dental stone. Ceramic ingots were heated in a furnace at 870°C for 40 min. After removal and cooling, they were sandblasted with aluminum oxide particles, measured again, and glazed. All samples were mounted in acrylic resin such that one surface of the ceramic block remained exposed with 1-mm thickness. The surface of all samples was polished with 320-grit silicon carbide abrasive paper under running water with equal hand pressure for ten times. They were then rinsed with water for 10 s and dried with air spray.

Ceramic surface treatment

The samples were randomly divided into eight groups of 10 for the assessment of three independent variables [Figure 1].

- Group 1: Laser irradiation (Er: YAG laser (Pluser; Dr smile; Italy) + universal adhesive (Single Bond Universal: Scotchbond Universal Adhesive; 3M ESPE; USA)
- Group 2: Laser irradiation + conventional adhesive (AdperScotchbond Multi-Purpose adhesive: 3M ESPE, St. Paul, MN, USA)
- Group 3: Laser irradiation + silane (Silane; Ultradent products; USA) + universal adhesive
- Group 4: Laser irradiation + silane + conventional adhesive
- Group 5: HF acid etching (IPS Ceramic Etching Gel; Ultradent products; USA) + universal adhesive
- Group 6: HF acid etching + conventional adhesive
- Group 7: HF acid etching + silane + universal adhesive
- Group 8: HF acid etching + silane + conventional adhesive.

The surface of samples in the four groups ($n = 40$) was subjected to Er: YAG laser irradiation with 2 W power in pulse mode with 200 mJ energy and 10 Hz frequency for 10 s.^[13] Laser was irradiated in forward and backward motion. The 600 μm tip of the laser handpiece had 1 mm distance from the surface and laser was irradiated under water spray perpendicular to the ceramic surface. The surfaces of samples in the remaining four groups ($n = 40$) were etched with 90% buffered HF acid for 60 seconds,^[14] rinsed with water for 10 s and dried. Silane was applied on the surface of half of the samples in HF and laser subgroups. Silane coupling agent was applied on the surface of samples by a microbrush for 60 s and dried. Subsequently, one of the two adhesives was applied on the ceramic surface. In

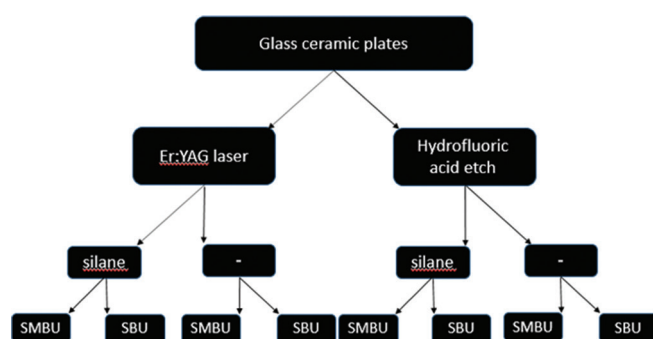


Figure 1: Flowchart of Materials and methods.

the use of conventional adhesive, two layers of AdperScotchbond Multi-Purpose adhesive were applied and air-thinned for 5 s followed by 10 s of curing (1000 mW/cm^2 , Valo, Ultradent, USA). In the application of Single Bond Universal, which contains silane monomer, two layers of the adhesive were applied on the surface, air-thinned for 5 s and cured for 10 s. Next, Z250 composite resin (Z250 composite resin 3M ESPE, USA) was applied into transparent plastic tubes with an internal diameter of 3 mm and 3 mm height, which were placed vertically at the center of the ceramic surfaces and light-cured for 40 s. The plastic tube was then cut with a scalpel (with no pressure to composite) and separated. The composite sample was cured again for 20 s. The entire procedure was performed according to the manufacturer's instructions. Next, all bonded samples were immersed in distilled water at 37°C for 24 h. They were then transferred to a universal testing machine (ZwischRoell, Ulm, Germany) and mounted such that the blade applied load at the bonding interface perpendicular to the longitudinal axis of the samples at a crosshead speed of 1 mm/minute until fracture. The load at fracture was recorded. The shear bond strength (SBS) data were converted to megapascals and analyzed using one-way ANOVA. The study was approved in the ethics committee of Tehran University of Medical Sciences.

RESULTS

One-way ANOVA revealed that the interaction effect of study variables on SBS was statistically significant. Table 1 shows the SBS in different groups.

Comparison of groups revealed that application of HF acid, compared to laser irradiation (irrespective of the type of adhesive and use/no use of silane), significantly increased the SBS ($P < 0.001$). The highest SBS was noted in “HF acid + universal adhesive” and “HF acid + silane + conventional adhesive” groups ($P < 0.5$). In application of HF acid and universal adhesive, the group without silane yielded higher SBS ($P = 0.003$). The lowest SBS was noted in “laser + universal adhesive” and “laser + conventional adhesive” groups [Figure 2].

DISCUSSION

This study aimed to assess the effect of different ceramic surface treatments on repair bond strength of composite to ceramic. Comparison of HF acid

Table 1: Mean±standard deviation shear bond strength (MPa) in the study groups (n=10)

Etching	Silane	Adhesive	Minimum	Maximum	Mean±SD
HF	Yes	Universal	8.13	11.27	9.6684±1.11604
HF	Yes	Conventional	9.74	13.50	12.0481±1.06066
HF	No	Universal	9.76	12.84	11.2834±1.02127
HF	No	Conventional	7.07	10.24	8.6401±1.15728
Laser	Yes	Universal	4.35	8.31	5.9646±1.35850
Laser	Yes	Conventional	4.95	8.02	6.3740±1.14028
Laser	No	Universal	2.37	5.44	4.0512±1.13801
Laser	No	Conventional	1.18	4.22	2.5766±1.24845

HF: Hydrofluoric, SD: Standard deviation

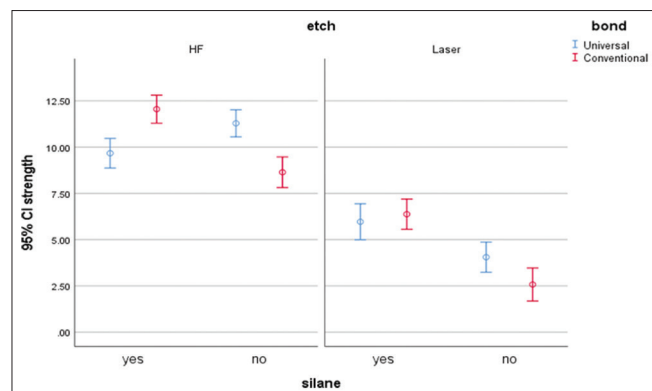


Figure 2: Shear bond strength (MPa) of study groups.

and laser for surface treatment of ceramic revealed that application of HF acid yielded a higher bond strength between the composite and ceramic. Some researchers have reported that HF acid etching is the most effective method for ceramic surface treatment because it increases surface roughness and micromechanical retention.^[13,14] In fact, HF acid creates the highest irregularities on the surface. It reinforces the siloxane bonds and creates the best microstructure for micromechanical bonding (which is the main reason for the superiority of HF acid to laser).^[15,16] These results were in line with those of Özdemiir *et al.*^[17] The reduction in repair bond strength of ceramics treated with laser, compared to those treated with HF acid, can be attributed to the unequal and lower microscopic depth of porosities created and excessive destruction of the matrix phase and crystals or layers damaged by high temperature.^[7] Ebrahimi Chaharom *et al.*^[18] showed that the bond strength was not significantly different in HF and laser groups, which was different from our findings. It might be related to the type of composite they had used which were silorane-based composite.

Comparison of use and no use of silane in all groups, except for the universal adhesive group (which contains silane in its composition), revealed superior

SBS in silane groups. Thus, it may be stated that the highest SBS is achieved when silane is applied. Similarly, Ozden *et al.*, in 1994 indicated that the highest SBS was noted after using silane in combination with a mechanical preparation method.^[19] Goracci *et al.*,^[20] Albaladejo *et al.*,^[21] and Perdigoão *et al.*^[22] reported that silane application is an effective method to increase the bond strength. This can be due to the ability of silane in increasing surface wetting and creating covalent bonds. Silane enhances the adhesion in the presence of epoxy resin polymers; it increases both the chemical bonds between the inorganic substrate and polymer and the surface wettability.^[23] The surface modifiers such as silane have excellent properties for the bond of organic and inorganic materials and organic-inorganic hybrid components which contain silicon-carbon bonds. In resin-based composites, silane can change the filler surface as a coupling agent for bonding of composite to composite and provide a strong chemical bond between them.^[24] Kim *et al.*,^[8] also concluded that separate application of silane improves the repair bond strength. Kupiec *et al.*^[25] pointed to the key role of silane in the process of repair and stated that the highest bond strength was noted in air abrasion plus HF acid group. In this group, silane was applied before the use of adhesive. Sattabanasuk *et al.*^[4] demonstrated that silane significantly increased the bond strength in un-etched samples, which was in agreement with our results.

In contrast to our study, Cho *et al.*,^[26] and Celik *et al.*^[27] stated that the application of silane had no significant effect on bond strength. The reason can be the difference in the concentration and type of materials used in different studies. Thus, it may be concluded that in most studies, irrespective of the concentration of materials and other factors, the highest SBS is achieved when compounds containing silane are used. This finding highlights

the ability of silane to increase surface wetting and create covalent bonds between the OH-groups of inorganic substrates such as glass. In general, silane enhances the adhesion in the presence of epoxy resin polymers. It enhances the chemical bond between inorganic substrates and polymer and increases the surface wettability.^[23] The chemical bond of silane depends on the presence of silica in the ceramic surface, which is rare in the composition of aluminum ceramics and complicates achieving a chemical bond to them.^[28]

The current findings revealed that in the application of HF acid and silane, the SBS results were superior in the group where the conventional adhesive was used because universal adhesive can decrease water evaporation or surface wetting and prevent the bonding of silane to glass ceramic.^[12] Furthermore, in the application of HF acid without silane in our study, universal adhesive yielded higher SBS values. Sattabanasuk *et al.* evaluated the efficacy of universal and conventional adhesives for the repair process and showed that the application of universal adhesive containing silane could not yield a higher SBS, especially when compared to separate applications of silane.^[4] Both the aforementioned studies confirmed the optimal efficacy of silane in universal adhesives. However, Yoshihara *et al.* showed that the silane present in the composition of universal adhesives was not much stable.^[6]

The current results showed that the efficacy of conventional and universal adhesives was not significantly different and “HF acid + universal adhesive” and “HF acid + silane + conventional adhesive” yielded the best results with regard to SBS. On the other hand, using universal adhesive simplify the repairing procedure (by omitting the silanization procedure of ceramic). Obtaining a strong bond by the use of universal adhesives is related to their inherent properties since they contain methacryloyloxy decyldihydrogen phosphate (MDP) monomer in their composition. They form chemical bonds due to the presence of MDP monomer in their composition,^[29] which justifies their optimal etching and bonding ability. The MDP monomer is a phosphate monomer, which enhances the bond between ceramic and composite. The MDP monomer forms highly resistant bonds to metal oxides and silane, and can also bond to SiO₂-based ceramics.^[2,5,30,31] In fact, MDP is a bifunctional adhesive monomer, which bonds to oxides with its hydrophilic phosphate end and bonds

to resin monomers with its hydrophobic methacrylate end.^[8,32]

Considering the current findings, favorable SBS between composite resin and glass ceramics requires micromechanical (HF) and chemical retention (silane). So, for repairing glass-ceramics by conventional adhesives we need HF and silane ceramic treatment but by universal adhesives, just HF treatment.

CONCLUSION

Under the limitation of this study we can conclude that the repair SBS was higher in groups treated with HF acid compared to laser. Ceramic surface treatment with HF plus silane plus conventional adhesive yielded a higher SBS as well as HF plus Universal adhesive. Thus, the application of silane as a separate step can be omitted in repair of ceramic restorations with universal adhesives.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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