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Shear bond strength of composite resins to lithium disilicate ceramics using universal bonding and different methods of surface preparation

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ABSTRACT

Background: Porcelain fracture or chipping is one of the limitations of all ceramic restorations. This study investigated the shear bond strength (SBS) of composite resins to lithium disilicate ceramics using universal bondings and different methods of surface preparation.

Materials and Methods: In this experimental study, 72 specimens of e.max computer-aided design and computer-aided manufacturing (CAD/CAM) ceramic blocks were divided into six groups of 12 according to surface treatment: Group I-Hydrofluoric (HF) acid etching + All-Bond Universal bonding (ABU), Group II-Bur roughening (BR) + HF + ABU, Group III-BR + HF + Bis-Silane (Si) + ABU, Group IV-Sandblasting (SB) + ABU, Group V-SB + HF + ABU, Group VI-SB + HF + Si + ABU. After bonding of composite resin to the prepared ceramic surface and storage of samples in distilled water for 24 h, SBS test was done using the universal testing machine at a crosshead speed of 0.5 mm/min. Data were analyzed using the analysis of variance and Tukey's *post hoc* test ($\alpha = 0.05$).

Results: The mean values of SBS in six studied groups were 6.65 ± 2.78 MPa, 8.56 ± 2.69 MPa, 8.49 ± 2.14 MPa, 3.13 ± 1.66 MPa, 7.94 ± 2.4 MPa, and 10.04 ± 2.47 MPa, respectively. The mean values of SBS were significantly different ($P < 0.001$). The highest value of SBS was observed in Group VI and the lowest in Group IV.

Conclusion: Ceramic sandblasting followed by HF etching, Bis Si, and ABU resulted in a higher SBS of composite resins to lithium disilicate ceramics.

Key Words: Ceramics, composite resins, dentine-bonding agents, silanes

INTRODUCTION

In recent years, the demand for more esthetic restorations has led clinicians to use all-ceramic restorations. All ceramic veneers and crowns can be one of today's most esthetic restorations.[1] With the introduction of all-ceramic systems such as zirconia and CAD/CAM techniques, the path to using all-ceramic restorations has changed.[2] All-ceramic coatings typically consist of a high-strength core, covered with veneering porcelain. The mechanical properties of the core and veneering porcelain should

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be compatible with each other in order to achieve a strong and solid bond. The presence of this solid bond is essential to ensure the structural integrity of the restoration under functional forces and to prevent the veneer from detachment or chipping.[3] Distribution of stress is more complex in a two-phase structure than in a single-phase one. Therefore, more factors should be taken into account in layered restorations because the contact surface between the core and veneer is one of the weakest areas in all-ceramic restorations. Correcting the restoration contours and coloring them require repeated firing of the restoration.[4]

One of the most important advantages of ceramics is their superb beauty and the capability of reconstructing the color, texture, and translucency of the tooth. Nonetheless, the inherent weakness of these materials against tensile and shear forces is still one of the most important disadvantages of these restorations that limits their use.[5] The first all-ceramic restorations were porcelain jacket crowns that were only used in single crowns due to their low strength.[6] Various factors including the inherent strength of the material, the size and distribution of surface cracks, the stress remaining in the ceramic from the preparation process, the forces exerted on the restoration, and the cutting design,[7] affect the ultimate strength of an all-ceramic restoration.

Among these systems, the most commonly used ceramics can be classified into pressable, slip-casting, milling, or sintering ceramics based on the laboratory processing procedure,[8] and into feldspar (high leucite and low leucite), glass ceramic (lithium disilicate and mica), and core-reinforced (alumina, magnesia, and zirconia) based on the chemical composition.[9] The mechanical properties of alumina and zirconia ceramics, which have high performances, have caused these materials to be propounded as suitable options for being used as all-ceramic restorations for posterior teeth.[10]

Despite their clinical efficacy and lifespan, metal ceramic restorations are susceptible to fracture, in a way that the second reason for the replacement of these restorations is porcelain fracture or chipping.[11] The prevalence of porcelain fracture has been reported 2.3%–8%. Replacement of a chipped porcelain restoration is not economical and time-consuming. Therefore, ceramic repair using composite resin is considered an alternative solution. Nonetheless, when a fracture makes the core visible, an appropriate repair of the fractured area becomes complicated because the bond strength of composite resin to the core is less than that of porcelain.[11,12]

Various mechanical and chemical methods have so far been introduced to create an acceptable bond between metal or ceramic substrates and composite resin. Air abrasion with aluminum oxide and a combination of sandblasting and etching with hydrofluoric (HF) acid improves the bond strength between the metal or ceramic surface and composite resins. In addition to mechanical methods, chemical methods using different bonding systems, silane (Si) or special primers have also attracted some attention, but few studies have been conducted on the repair of all-ceramic restorations using composite and universal bonding, and their performance in this area is still on doubt.

The aim of the present study was to investigate the shear bond strength (SBS) of repairing lithium disilicate ceramics using composite resins and universal bonding with different methods of surface preparation.

MATERIALS AND METHODS

In this experimental study, lithium disilicate glass ceramic blocks (IPS e.max CAD, Ivoclar Vivadent, Amherst, NY, USA) in the bisque form were sectioned into 8 mm × 8 mm × 3 mm 3 plates using a low-speed cutting device (Isomet, Buehler Ltd, Lake Bluff, IL, USA). Seventy two specimens were divided into six groups of 12 with confidence level of 95%. Samples were sintered according to the manufacturer's instructions; the ceramic blocks were fired at 840°C for 15 min. The present study was funded by Isfahan University of Medical Sciences and was performed for obtaining DDS degree (396404).

Each experimental group was described in Table 1.

Group I (hydrofluoric/All-Bond Universal bonding)

Etching of ceramic surface with 9.5% HF acid gel + ALL-Bond Universal bonding (ABU) + composite resin.

Group II (bur roughening/hydrofluoric/All-Bond Universal bonding)

Roughening the ceramic surface with coarse diamond cylindrical bur (Meisinger, Germany) in high speed handpiece with air/water spray + etching with 9.5% HF acid gel + ABU + composite resin.

Table 1: Detailed preparation technique of each group and testing process

Group number	Preparation method in detail	Testing steps (identical among the groups)
Group I (HF/ABU)	Etching of ceramic surface by applying 9.5% HF gel for 30 s + washing off acid using air/water spray for 30 s + drying surface using air pressure for 15 s + Rubbing ABU bonding onto the surface with microbrush for 15 s + air drying gently after 10 s + light cured for 20 s at the light intensity of 700 mW/cm^2 + composite resin	Orthorings (Power Sticks-USA) with an inner diameter of 2 mm were placed on the ceramic surface as a mold to pack the composite resin on the prepared ceramic surface + A piece of Roeko transparent matrix band (Roeko, Coltene, Swiss) was placed on the composite surface, and while using a glass slab to exert pressure on it, the composite resin was cured at a light intensity of 700 mW/cm^2 for 40 s The specimens were kept in 37°C distilled water for 24 h. The interface of composite-ceramic was subjected to shear forces using instron testing machine (Walter + Bai, Switzerland) at a crosshead speed of 0.5 mm/min. The shear force at failure point was calculated in mega pascal and the mean SBS of each group was calculated
Group II (BR/HF/ABU)	Roughening the ceramic entire surface using a coarse cylindrical diamond bur with 1 mm diameter. The technique was performed by gentle pressing of the handpiece and 6 movements from the beginning to the end of each surface of the ceramic specimen by one person + applying 9.5% HF gel for 30 s + washing off acid using air/water spray for 30 s + drying surface using air pressure for 15 s + Rubbing ABU bonding onto the surface with microbrush for 15 s + air drying gently after 10 s + light cured for 20 s at light intensity of 700 mW/cm^2 + composite resin	
Group III (BR/HF/Si/ABU)	Roughening the ceramic entire surface using a coarse cylindrical diamond bur with 1 mm diameter. The technique was performed by gentle pressing of the handpiece and six movements from the beginning to the end of each surface of the ceramic specimen by one person + applying 9.5% HF gel for 30 s + washing off acid using air/water spray for 30 s + drying surface using air pressure for 15 s + application of one layer of Si onto the surface for 20 s using microbrush + drying the surface for 10 s using gentle air pressure + the surface impregnated with Si was washed with 70°C water for 5 s + drying with air pressure for 20 s + Rubbing ABU bonding onto the surface with microbrush for 15 s + air drying gently after 10 s + light cured for 20 s at light intensity of 700 mW/cm^2 + composite resin	
Group IV (SB/ABU)	SB the ceramic entire surface using 50-micron Alumina powder at a pressure of 60 psi and 10 mm distance for 3 s + rinsing with air/water spray for 20 s + + Rubbing ABU bonding onto the surface with microbrush for 15 s + air drying gently after 10 s + light cured for 20 s at light intensity of 700 mW/cm^2 + composite resin	
Group V (SB/HF/ABU)	SB the ceramic entire surface using 50-micron alumina powder at a pressure of 60 psi and 10 mm distance for 3 s + rinsing with air/water spray for 20 s + applying 9.5% HF gel for 30 s + washing off acid using air/water spray for 30 s + drying surface using air pressure for 15 s + + Rubbing ABU bonding onto the surface with microbrush for 15 s + air drying gently after 10 s + light cured for 20 s at light intensity of 700 mW/cm^2 + composite resin	
Group VI (SB/HF/Si/ABU)	SB the ceramic entire surface using 50-micron alumina powder at a pressure of 60 psi and 10 mm distance for 3 s + rinsing with air/water spray for 20 s + applying 9.5% HF gel for 30 s + washing off acid using air/water spray for 30 s + drying surface using air pressure for 15 s + application of one layer of bis Si onto the surface for 20 s using microbrush + drying the surface for 10 s using gentle air pressure + the surface impregnated with Si was washed with 70°C water for 5 s + drying with air pressure for 20 s + Rubbing ABU bonding onto the surface with microbrush for 15 s + air drying gently after 10 s + light cured for 20 s at light intensity of 700 mW/cm^2 + composite resin	

HF: Hydrofluoric acid etching, ABU: ALL-Bond Universal, BR: Bur roughening, Si: Silane, SB: Sandblasting, SBS: Shear bond strength

Group III (bur roughening/hydrofluoric/silane/All-Bond Universal bonding)

Roughening the ceramic surface with coarse cylindrical diamond bur in high speed handpiece with air/water spray + etching with 9.5% HF acid gel + application of Bis-Si + ABU + composite resin.

Group IV (sandblasting/All-Bond Universal bonding)

Sandblasting (SB) the ceramic surface + ABU + composite resin.

Group V (sandblasting/hydrofluoric/All-Bond Universal bonding)

SB the ceramic + etching with 9.5% HF acid gel + ABU + composite resin.

Group VI (sandblasting/hydrofluoric/silane/All-Bond Universal bonding)

SB the ceramic + etching with 9.5% HF acid gel + using Bis-Si + ABU + composite resin.

After preparing the ceramic surfaces in different groups, composite resin was bonded to the prepared

surfaces. In the present study, 9.5% HF acid gel (Porcelain Etchant, Bisco, USA) was used to etch the ceramic surfaces. The bonding used was ALL-Bond Universal (Bisco, USA), the Si used was Bis-Si produced by Bisco (Bisco, USA), and the composite resin used to repair the ceramic surface was Gradia anterior composite in A2 color (GC, Japan). Materials used in this study are presented in Table 2. The surface of the specimens was prepared and the test was performed as described in Table 1.

The shear force at the failure point was calculated in Mega Pascal and the mean SBS of each group was calculated. The obtained data were analyzed using SPSS 22 (IBM, NY, USA) software and through descriptive statistical methods, one-way analysis of variance (ANOVA), and Tukey's complementary test ($P < 0.05$ was considered significant).

RESULTS

In this study, the mean SBS of composite resin to IPS e.max CAD glass ceramic with different methods of surface preparation was recorded 6.65± ue2.78 MPa, 8.56 ± 2.69 MPa, 8.49 ± 2.14 MPa, 3.13 ± 1.66 MPa, 7.94 ± 2.4 MPa and 10.04 ± 2.47 MPa for Group I to VI, respectively.

The results of the study are presented in Table 3 and Figure 1.

In general, according to the obtained results, Group IV (SB/ABU) showed the lowest mean SBS and Group VI (SB/HF/Si/ABU) showed the highest mean SBS. The mean SBS of different groups was significantly different according to the one-way ANOVA test ($P < 0.001$). Comparison of mean SBS between different groups is presented in Tables 3 and 4.

According to the Tukey's *post hoc* test, the SBS of Group I (HF/ABU) was significantly different from Group IV (SB/ABU) ($P = 0.008$) and Group VI (SB/HF/Si/ABU) ($P = 0.012$), but no significant difference was reported with other three groups.

A comparison of SBS between Group II (Bur roughening [BR]/HF/ABU) and the other five groups showed that the SBS of this group was significantly different from Group IV (SB/ABU) ($P < 0.001$), but no significant difference was reported with the other four groups.

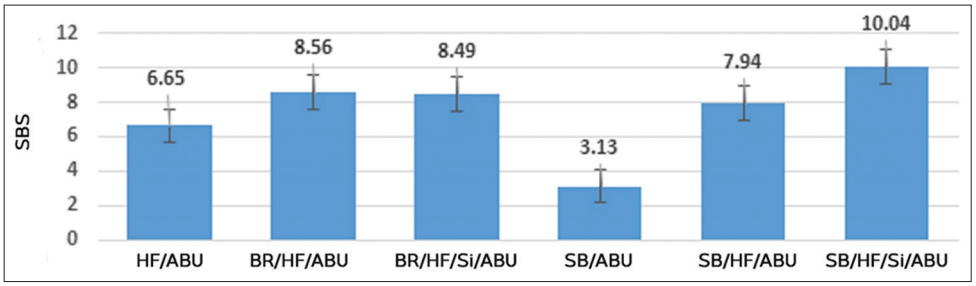

Figure 1: Shear bond strength in different groups.

Table 2: List of equipment and materials used in this study

Equipment/material	Composition	Manufacturer	Instruction for use
Porcelain etchant	9.5% HF	Bisco Inc	Etch for 30 s, rinse for 30 s with air/water spray and excess water is removed
Bis-Si	Part A: γ –MPTS, ethanol; Part B: ethanol	Bisco Inc	Mix, apply 1 coat, wait for 20 s and air-dry for 10 s, washed with 70°C water for 5 s air dried 20 s
ABU	10-MDP, 2-HEMA, BisGMA, Ethanol, water, photoinitiator	Bisco Inc	One coat of ABU is rubbed for 15 s, air thinned for 10 s and light-polymerized for 20 s
Lithium disilicate ceramic blocks	SiO_2, Li_2O, Al_2O_3, K_2O, P_2O_5, ZrO_2	Ivoclar Vivadent AG	Ceramic blocks were fired at 840°C for 15 min
Gradia anterior composite	Micro-filled hybrid resin composite	GC, Japan	Composite resin was packed into orthorings on the prepared ceramic surface and light cured under pressure with the light intensity of 700 mW/cm^2 for 40 s
Valo light-curing unit		Ultradent, USA	
SB machine		DENTO-PREP, Denmark	
Testing machine		Walter + Bai AG, Switzerland	

HF: Hydrofluoric acid etching, ABU: ALL-Bond Universal, Si: Silane, SB: Sandblasting, MPTS: Mercaptopropyl trimethoxy silane, MDP: Methacryloyloxydecyl dihydrogen phosphate , HEMA: Hydroxyethyl methacrylate, BisGMA: Bisphenol A-Glycidyl methacrylate

Table 3: Mean shear bond strength of six studied groups (MPa)

Group	Mean±SD	Minimum	Maximum
I (HF/ABU)	6.6535[a]±2.7833	2.97	11.2
II (BR/HF/ABU)	8.5562[a,c]±2.6930	5.03	13.91
III (BR/HF/Si/ABU)	8.4898[a,c]±2.1363	3.81	12.39
IV (SB/ABU)	3.1282[b]±1.6609	0.6	7.14
V (SB/HF/ABU)	7.9427[a,c]±2.3958	4.21	13
VI (SB/HF/Si/ABU)	10.0378[c]±2.4664	6.07	15.95

Groups with the same superscript have no significant difference.
HF: Hydrofluoric acid etching, ABU: All-Bond Universal, BR: Bur roughening, Si: Silane, SB: Sandblasting, SD: Standard deviation

Table 4: Comparison of shear bond strengths in different groups

Source of comparison	Groups	*P*
HF/ABU	BR/HF/ABU	0.38
	BR/HF/Si/ABU	0.42
	SB/ABU*	0.008
	SB/HF/ABU	0.70
	SB/HF/Si/ABU*	0.012
BR/HF/ABU	BR/HF/Si/ABU	0.99
	SB/ABU*	<0.001
	SB/HF/ABU	0.99
	SB/HF/Si/ABU	0.65
BR/HF/Si/ABU	SB/ABU*	<0.001
	SB/HF/ABU	0.99
	SB/HF/Si/ABU	0.61
SB/ABU	SB/HF/ABU*	<0.001
	SB/HF/Si/ABU*	<0.001
SB/HF/ABU	SB/HF/Si/ABU	0.38

*There is a significant difference. HF: Hydrofluoric acid, ABU: All-Bond Universal, BR: Bur roughening, Si: Silane, SB: Sandblasting

The SBS of Group III (BR/HF/Si/ABU) was significantly different from Group IV (SB/ABU) ($P < 0.001$). No significant difference was recorded with other groups.

The SBS of Group IV (SB/ABU) was significantly lower than Group I ($P = 0.008$) and the other four groups ($P < 0.001$).

The SBS of Group V (SB/HF/ABU) was significantly different from that of Group IV (SB/ABU) ($P < 0.001$). No significant difference was recorded with other groups.

The mean SBS of Group VI (SB/HF/Si/ABU) was significantly different from Group I (HF/ABU) ($P = 0.012$) and Group IV (SB/ABU) ($P < 0.001$). No significant difference was recorded with other groups.

DISCUSSION

The null hypothesis of this study was that the application of HF acid, universal bonding, sandblasting, BR and Bis-Si implementation do not increase the SBS of composite resins to lithium disilicate glass ceramics, which was rejected.

The values for SBS were significantly different in the six studied groups [Tables 2 and 3]. The highest SBS was reported in Group VI, where a combination of sandblasting, etching with HF acid, and application of Si and ABU was carried out. This result can be caused by the strengthening and intensifying effect of these actions on each other. The lowest SBS was reported in Group IV, where a combination of sandblasting and application of ABU was carried out.

IPS e.max glass ceramic is an etchable glass ceramic which is reinforced with lithium disilicate and is available in two forms: Pressed and CAD/CAM blocks. CAD/CAM blocks are milled according to restoration design. The milled restoration is put into the oven at a temperature of 840°C for 15 min. During the heat process, lithium meta-silicate glass ceramic is transformed into lithium disilicate glass ceramic which is more stable and esthetic which improves the properties of the final glass ceramic including mechanical and optical properties. The ceramic final composition consists of 70% glass matrix and needle-like crystals. In the pressed type, the crystallites are 4 μm long and 0.6 μm width, but in the CAD/CAM type, the length of the crystallites is 1 μm and the width is 0.4 μm. Ceramic crystals are composed of SiO_2, Li_2O, Al_2O_3, K_2O, P_2O_5, and ZrO_2 contained up to 4 wt% ZrO_2 along with additives such as colors and fluorescence. The final flexural strength of the ceramics is 440–480 MPa.

Glass ceramics reinforced with lithium disilicate are very suitable for veneers, anterior coatings, posterior coatings, and in general for integrated restorations.[13]

ceramics, one layer of adhesive is rubbed on the ceramic surface for 10–15 s, and then air dried for 10 s and light cured.

In a study conducted by Kitayama *et al.*, it was concluded that conventional surface conditioning with Si and adhesive results in higher micro SBS of resin cement to leucite reinforce ceramics than universal bondings.[14] In a review article by Mejía *et al.* about different treatments for adhesion to lithium disilicate ceramics, they concluded that etching with HF acid and application of Si, results in the highest bond strength values and is reliable over time, according to the literature.[15] However, the modification in the application of HF and Si can achieve optimization

of bond strength results. The use of universal and multipurpose adhesives can promote chemical adhesion to lithium disilicate ceramics, especially at the time of ceramic repair with composite resin. However, Sis and phosphate monomers (MDP) are the only molecules responsible for promoting true chemical adhesion to lithium disilicate ceramics.[16]

A study conducted by Ito *et al.* showed that the tensile bond strength of universal bondings, which were single-bottle, used to repair ceramic restorations, was equal to that of ordinary adhesives.[16] It should be noted that universal bondings have been globally used in the recent years, and that few studies have been conducted in this regard. In a study by Passia *et al*. on the tensile bond strength to lithium disilicate, it was concluded that using universal bondings, not containing Si, should be avoided.[17] In a study about the tensile bond strength of universal adhesives to zirconia and lithium disilicate ceramics, it was shown that the application of Si coupling agent is important for bonding to lithium disilicate ceramics. Furthermore, the effect of Si incorporated in a universal multi-mode adhesive might be limited and less durable. They also concluded that the tensile bond strength to zirconia ceramic and lithium disilicate ceramic is material dependent and significantly influenced by the primer/adhesive used.[18]

In a study conducted by Yoshihara, Scotchbond Universal was used for the bonding of lithium disilicate ceramics. The results of the study showed that the effectiveness of the Si existing in the Scotchbond Universal composition was less than that when applying Si separately.[19] A study conducted by Kim showed that the Si existing in bondings was not effective and stable in general and that using a separate Si primer was clinically more effective.[18]

In a study by Lanza *et al*. about the effect of separate Si application on the bond strength of single bond universal which contains primer in the composition to a lithium disilicate ceramic, they concluded that separate Si application may improve the bond effectiveness of universal adhesives.[20] The findings of the mentioned study are comparable to the present study, which both concluded that the application of Si positively affects the bond strength.

Another study showed that the application of Si as a separate step is recommended prior to cementation of lithium disilicate ceramics, independent of the presence of Si within the universal adhesive in order to achieve durable bond to lithium disilicate ceramics.[21]

Sis are substances invented to improve the process of creating bonding to various substrates in dentistry. Sis are silicone-based chemicals containing both mineral and organic constituents in one molecule. One of them is an organic functional group, and the other is a hydrolysable esteric group, which reacts with water to form an acid-activated hydrophilic silanol group. Sis act in an interface between a mineral substrate (such as glass, a metal, or a mineral) and an organic substrate (such as an organic polymer) to bond two dissimilar materials together.[21]

In a study by Kalavacharla *et al.*, they concluded that the Si and MDP included in the composition of universal adhesive were not effective for optimizing the lithium disilicate ceramic-resin bond, Si should always be applied to lithium disilicate prior to bonding.[22]

A study by Fugolin showed that tensile bond strength in ceramics reinforced with lithium disilicate was significantly under the influence of Si material when using the etch-and-rinse and resin cement systems.[23]

This finding was also observed in our study; that is to say, the bond strength was significantly higher in the group where Bis-Si was used.

In our study, HF etching was used as a baseline method in all groups except group IV. The impact of etching on bond strength has been investigated and confirmed in previous studies. In the meantime, using this mechanical surface treatment with other mechanical or chemical surface treatments such as sandblasting or Si application can improve effect of etching. In addition, the concentration of HF acid may also affect the bond strength value; as in the study by Fugolin, concentrations of 1% and 2.5% and the duration of etching had effects on SBS, but the values for SBS within a duration of 20 s were not significantly different at concentrations of 5%, 7.5%, and 10%.[23]

In a study by Guimaraes *et al.*, they concluded that the surface treatment with HF and Si is an effective and simple alternative to bond resin luting cement to lithium disilicate ceramics; the use of universal adhesive did not exempt the application of a Si.[24]

In the present study, the significant difference between Group I and Group IV shows that using 9% HF acid is necessary for creating bonding of composite to the glass ceramic surface, and that failure to use HF acid results in a significant decrease in SBS. It also

shows that using sandblasting alone is not effective as an alternative to HF acid. In addition, the absence of a significant difference between Group I and Groups II, III and V shows the importance of using HF such that despite roughening with burrs and application of Si, the difference is not significant. The significant difference between Group I with Group VI shows that using acid together with surface roughening through sandblasting, application of HF, and eventually using Si and ABU leads to the best results for the SBS of composite resin to IPS e.max glass ceramic. SB with 50-micron alumina particles creates superficial roughness on the ceramic surface. When such a surface is etched with 9.5% HF acid, the superficial roughness increases micromechanically, thus increasing the surface area available for the penetration of bonding. The application of Bis-Si to such a surface changes the nature of the surface from a mineral surface to an organic one, which, when in contact with the bonding, produces a chemical bond; and eventually, the composite resin is bonded to the bonding surface.

The absence of a significant difference between Groups II and III shows that in case of surface preparation using rough burs, HF acid, and ABU, separate application of Bis-Si will not have any effects on improving the bonding between the composite resin and IPS e.max ceramic. This shows that the Si contained in All-Bond Universal will have the necessary efficacy if used with HF acid while the surface is roughened with bur. Moreover, the absence of a significant difference between Groups II and V shows the same efficacy of roughening with burrs and sandblasting in case of using HF acid and ABU.

The absence of a significant difference between Groups III and VI shows that roughening with bur or sandblasting has the same effect on the SBS between the composite and glass ceramic in case of using HF acid, Bis-Si, and ABU.

In the present study, the lowest SBS between the composite resin and IPS e.max ceramic was observed in Group IV, which was significantly different from that in the other groups. In this group, only sandblasting with alumina was performed on the ceramic surface, after which ABU was used. Such a result suggests that using HF acid is an important and fundamental stage for repairing IPS e.max glass ceramics using composite resins, and that skipping this step in repairing IPS e.max glass ceramics can greatly reduce SBS.

The absence of a significant difference between Groups VI and V shows that Bis-Si will have no effect on improving SBS in case of using HF acid, sandblasting and ABU, which again shows the importance of using HF acid.

In the present study, the best results for SBS were observed in Group VI, which underwent application of sandblasting, HF acid, Bis-Si and ABU. Although the difference between Group VI and Groups II, III, and V was not statistically significant, it was significant between Group VI and Groups I and IV. The significant difference between Group VI and Group I shows the great effect and high efficacy of sandblasting and using Bis-Si in addition to using HF acid and ABU. The absence of a significant difference between Group III and Group VI shows that in the case of using HF acid, ABU and Si, the efficacy of roughing with bur and that of sandblasting will be the same. Furthermore, the absence of a significant difference between Group V and Group VI shows that in case of using HF acid, sandblasting, and using ABU, application of Bis-Si will have no effect on improving the SBS, and it can be excluded.

In a study by Chen *et al*. about the effect of Si on the performance of universal adhesives, they concluded that presilanization will further improve the SBS of universal adhesives or self-adhesive resin cements when bonded to lithium disilicate. This was because bonding improvement of silane to lithium disilicate can be attributed to hydrolysis of Si to silanol and formation of a Si/OSi bond between Si and silica.[21]

Still in another study conducted on the efficacy rate of the Si contained in Scotchbond Universal bondings, it was concluded that the Si contained in this type of bonding was neither efficient nor stable, which was probably due to the dehydration of the acidic solution; and it was clinically recommended that a separate stage for using Si be performed.[19]

It has to be mentioned that some of the means of the present study are very low compared to similar studies. That could be due to the differences in the testing machine or the preparation methods.

It seems that the effect of universal bonding systems on the SBS of composite resins to lithium disilicate glass ceramic depends on the composition of the bonding, mechanical and chemical preparation of the ceramic surface and storage time of the specimens.

CONCLUSION

Given the limitations of this study, the following can be concluded:

1. Application of 9.5% HF acid is more effective than sandblasting with 50-micron alumina
2. In the case of using alumina sandblasting, HF acid and ABU, the application of Bis-Si will have no effect on the immediate SBS of composite resins to lithium disilicate glass ceramics
3. In the case of using BR, HF acid and ABU, the application of Bis-Si will have no effect on the immediate SBS of composite resins to lithium disilicate ceramics
4. The best results for the SBS of composite resins to lithium disilicate ceramics are achieved through the application of alumina sandblasting, HF acid, Si and eventually using ABU.

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Conflicts of interest

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