Effect of bioglass and silica coating of zirconia substrate on its bond strength to resin cement

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This study aimed to assess the effect of bioglass and silica coating of zirconia substrate on its bond strength to resin cement. A total of 120 specimens were used in this in-vitro, experimental study. Zirconia discs measuring 10×7×2 mm were cut from Y-TZP zirconia blocks, sintered, cleaned and received different surface treatments of sandblasting, bioglass powder coating+etching, bioglass powder coating+etching+silanization, bioglass slurry coating+etching, bioglass slurry coating+etching+silanization, silica coating+silanization, silica coating+etching+silanization and no treatment group (control). Then the microshear bond strength testing and scanning electron microscope (SEM) analysis were done. Data were analyzed using the Mann Whitney U and the Kruskal Wallis tests. Significant differences existed in bond strength of different groups (p<0.001). The sandblasted and bioglass coated groups showed higher and the colloidal silica-coated groups showed lower bond strength compared to the control group.

Keywords: Bioglass, Microshear bond strength, Resin cement, Zirconia

INTRODUCTION

Recent advances in ceramic dental materials led to the production of high-strength zirconia-based ceramics. These materials, in comparison with porcelain and other non-metal alternatives, provide potentially higher fracture resistance and durability11. Zirconia has several applications in dentistry and is used for the fabrication of orthodontic brackets2, endodontic posts3, abutments4, single-unit crowns5 and fixed partial dentures (FPD)6. CAD/CAM technology facilitates the fabrication of complex zirconia restorations with high accuracy7. Despite the favorable mechanical properties of zirconia, the conventional cementation techniques do not provide adequately high bond strength to zirconia8. In order to achieve high retention, prevent microleakage, and increase fracture- and fatigue resistance of restorations, the bond to zirconia must be enhanced31.

Adequate bond to zirconia has been the subject of many investigations in the recent years9,10. Since the introduction of zirconia, several techniques have been suggested to enhance its bond strength to resin cement; these include surface abrasion with burs and abrasive papers and sandblasting11, silica (tribochemical) coating12-14, silica coating15, using glass micropearls16, glazing17-20, selective infiltration etching technique21, hot etching22,23, use of phosphate-ester monomers24 and laser irradiation25. Despite extensive studies in this field, the only consensus reached is that hydrofluoric (HF) acid etching and silanization are not effective for zirconia ceramics and there is no specific surface treatment to maximize bonding to zirconia26.

Considering the importance of this issue and the complexity of most techniques used to improve resin cement bond strength to zirconia, this study aimed to assess the effect of glass and silica coating of zirconia on its bond strength to resin cement. The null hypothesis was that glass and silica coating would have no significant effect on bond strength of resin cement to zirconia.

MATERIALS AND METHODS

Surface treatment and microshear bond strength testing A total of 120 specimens were used in this in-vitro, experimental study. Sample size of 15 specimens in each group was calculated by conduction of a pilot study. Zirconia discs measuring 10×7×2 mm were cut from Y-TZP (ICE Zirkon, ZirkonZahn, Italy) zirconia blocks and sintered according to the manufacturer’s instructions. Before any surface treatment, all discs were cleaned in an ultrasonic bath (Sigma-Aldrich, MO, USA) containing 96% ethanol (Bidestan, Tehran, Iran) for 10 min. Zirconia discs were evaluated in 8 groups of 5 each and treated as demonstrated in Fig. 1. Control group specimens received no surface treatment.

In the sandblast group, discs were sandblasted by 50 μ aluminum oxide particles (True Etch, Orho Technology, FL, USA) at 40 PSI pressure from 10 mm distance for 15 s using a microetcher (Danville Engineering, CA, USA) and then cleaned with 96% ethanol in an ultrasonic bath for 10 min to eliminate any loose particles due to sandblasting from the zirconia surface. Bioglass coating was applied by two methods. In the first method (10 discs), a layer of PVA binder (Poly vinyl alcohol, Merck, Germany) was applied to the substrate surface followed by the application of bioglass powder. Powder was placed on a flat glass plate and its surface was smoothed by a spatula. After the application of binder to the zirconia surface, the disc was placed on the...
powder upside down. In the second method (10 discs), slurry of bioglass powder (500 μg), distilled water (1 cc) and PVA binder (1 cc) was prepared and applied to the surface of discs by a fine microbrush (TPC Advanced Technology, CA, USA). The specimens were then heated up in a furnace at a rate of 100°C/h by up to 1,200° and remained at this temperature for 2 h. Then, they were cooled down at a speed of 200°/h. The composition of the bioglass powder used (manufactured by the Materials and Energy Research Center of Iran) was similar to that of 45 S5 bioglass developed by Hench. The grain size of glass powder was less than 210 μm, as it was passed from the no.70 mesh. The discs in each method of coating (bioglass powder and slurry) were divided into two groups. In the first group, disc surface was etched by HF acid (Ultradent Porcelain Etch, Ultradent Products, UT, USA) for 60 s followed by rinsing and air-drying for 90 s with air-water spray. In the second group, the specimens were etched with HF acid, rinsed and dried for 90 s, silanized (Ultradent Products) according to the manufacturer’s instructions and allowed to dry at room temperature.

Two other groups received silica coating. Zirconia discs were immersed in colloidal silica (BINDZIL 2040, WesBond, Wilmington, DE, USA). After removal, they were dried and subjected to the thermal protocol described for the bioglass coated groups. Specimens in one of these two groups were etched with HF acid for 30 s, rinsed and dried for 90 s and silanized. The second group only received silane.

After surface preparation, Panavia F 2.0 cement (Kuraray Medical, Tokyo, Japan) was applied to the specimen surface using Tygon tubes (Norton Performance Plastics, OH, USA) with 0.7 mm diameter and light cured with a diode light-curing unit (Radiolus, SDI, Victoria, Australia) for 40 s. Three rods were fabricated on the surface of each disc; therefore, 15 specimens in each group and a total of 120 specimens were prepared.

Discs were immersed in distilled water and incubated at 37°C for 24 h (Model PL-455G, PECO, Pooya Electronic, Tehran, Iran). Next, the discs were transferred to a microtensile tester (Bisco, IL, USA) for measurement of the microshear bond strength of resin cement to zirconia. Cast cylinders were vertically soldered to the jig of microtensile tester machine to convert the applied tensile load to shear load. Load was applied at a crosshead speed of 0.5 mm/min and the load at failure was recorded. The microshear bond strength was calculated using the following equation:

$$S = \frac{F(N)}{A (\text{mm}^2)}$$

Where F is the applied load at fracture in Newton and A is the cross sectional area in mm².

Mode of failure
After measuring the microshear bond strength, the fracture surfaces were evaluated under a light stereomicroscope (Carl Zeiss, Jena, Germany) with an external light source (LED radiation, BO913 Jansjo, China) at 4.0× magnification. The mode of failure was classified as adhesive (fracture at the cement-zirconia, cement-coating or zirconia-coating interface), cohesive (fracture within the cement layer, coating or zirconia substrate) or mixed (a combination of both adhesive and cohesive failures).

Thickness of coating
In groups that received coating, disc thickness was measured before and after the application of coating by a digital micrometer (Mitutoyo, Mitutoyo, Japan) with 1 μ accuracy. The difference between the two values was indicative of coating thickness.

Scanning electron microscopic analysis
Eight discs were prepared for SEM analysis from the following groups: control, sandblast, bioglass powder coating, bioglass powder coating+HF acid etching for 60 s, bioglass slurry coating, bioglass slurry coating+HF acid etching for 60 s, colloidal silica coating and colloidal silica coating+HF acid etching for 30 s. Of the two groups that received bioglass coating, one disc was allocated for SEM evaluation of the bioglass-zirconia interface.

Statistical analysis
The mean, standard deviation (SD), maximum and minimum values of microshear bond strength in different groups were calculated. Distribution of data was checked using Kolmogorov-Smirnov test. The Kruskal Wallis and the Mann Whitney U test were applied for statistical analysis of data. The Mann Whitney U test was also used for the comparison of coating thickness among the coated groups.

RESULTS

Microshear bond strength
The obtained bond strength values are demonstrated in detail in Table 1. According to the Mann Whitney U test, the mean bond strength of silica-coated
Table 1  Bond strength values

| Groups                              | Mean   | Median | SD    | Minimum | Maximum |
|-------------------------------------|--------|--------|-------|---------|---------|
| Control                             | 24.42  | 23.66  | 4.148 | 17.41   | 30.16   |
| Sandblasting                        | 44.84  | 44.20  | 7.236 | 34.58   | 58.75   |
| Bioglass powder coating+etching     | 39.50  | 40.56  | 7.675 | 26.52   | 52.52   |
| Bioglass powder coating+etching+silanization | 42.69  | 41.08  | 6.952 | 32.00   | 59.54   |
| Bioglass slurry coating+etching     | 38.38  | 37.44  | 4.719 | 32.86   | 46.28   |
| Bioglass slurry coating+etching+silanization | 42.41  | 40.82  | 7.716 | 32.42   | 55.38   |
| Silica coating+silanization         | 13.55  | 11.18  | 5.525 | 9.09    | 27.56   |
| Silica coating+etching+silanization | 13.25  | 11.18  | 4.719 | 8.31    | 27.04   |

Table 2  Results of bond strength testing (Mann Whitney U test)

| Mann Whitney U test                     | Group                                      | p     |
|-----------------------------------------|--------------------------------------------|-------|
| Sandblasting (n=15)                     | Bioglass powder coating+etching (n=13)     | 0.17  |
|                                        | Bioglass powder coating+etching+silanization (n=15) | 0.49  |
|                                        | Bioglass slurry coating+etching (n=13)     | 0.01  |
|                                        | Bioglass slurry coating+etching+silanization (n=14) | 0.42  |
|                                        | Silica coating+silanization (n=13)         | 0.001 |
|                                        | Silica coating+etching+silanization (n=14) | 0.001 |
|                                        | Bioglass powder coating+etching+silanization (n=15) | 0.42  |
|                                        | Bioglass slurry coating+etching (n=13)     | 0.52  |
|                                        | Bioglass slurry coating+etching+silanization (n=14) | 0.61  |
|                                        | Silica coating+silanization (n=13)         | 0.001 |
|                                        | Silica coating+etching+silanization (n=14) | 0.001 |
|                                        | Bioglass slurry coating+etching (n=13)     | 0.04  |
|                                        | Bioglass slurry coating+etching+silanization (n=14) | 0.74  |
|                                        | Silica coating+silanization (n=13)         | 0.001 |
|                                        | Silica coating+etching+silanization (n=14) | 0.001 |
| Bioglass powder coating+etching+silanization (n=15) | Bioglass slurry coating+etching (n=13) | 0.18  |
|                                        | Bioglass slurry coating+etching+silanization (n=14) | 0.01  |
|                                        | Silica coating+silanization (n=13)         | 0.001 |
|                                        | Silica coating+etching+silanization (n=14) | 0.001 |
| Bioglass slurry coating+etching (n=13) | Bioglass slurry coating+etching+silanization (n=14) | 0.01  |
|                                        | Silica coating+silanization (n=13)         | 0.001 |
|                                        | Silica coating+etching+silanization (n=14) | 0.001 |
| Bioglass slurry coating+etching+silanization (n=14) | Silica coating+silanization (n=13) | 0.001 |
|                                        | Silica coating+etching+silanization (n=14) | 0.001 |
| Silica coating+silanization (n=13)     | Silica coating+etching+silanization (n=14) | 0.73  |
highest frequency (58.33%) followed by adhesive (25%) and cohesive (16.66%) fractures. In the bioglass powder+etchant group, no adhesive fracture occurred. The mode of failure was mixed in the majority of specimens (83.33%) and a smaller percentage of samples (16.66%) showed cohesive failure. No adhesive failure occurred in the bioglass powder+etchant+silane group and mixed and cohesive failures had a similar frequency (50%). All mixed fractures in the bioglass powder groups occurred at the cement-bioglass interface. In the bioglass slurry+etchant group, all (100%) fractures were mixed; 91.66% occurred at the cement-bioglass interface and 8.33% occurred at the bioglass-zirconia interface. In the bioglass slurry+etchant+silane group, mixed fractures had the highest frequency (83.33%). Of mixed fractures in this group, 80% occurred at the cement-bioglass interface and 20% occurred at the bioglass-zirconia interface. Adhesive and cohesive failures had a similar frequency of 8.33% and adhesive failure in this group occurred at the interface of glass-zirconia. All fractures in the two silica-coated groups (silica+silane and silica+etchant+silane) were adhesive and the zirconia surface was denuded in all adhesive failures (Table 3).

Coating thickness

The mean, SD, minimum and maximum values of coating thickness are presented in Table 4. The Kruskal Wallis test was applied for statistical analysis of coating thickness; which revealed significant differences in this respect among groups. The Mann Whitney U test revealed significant differences in coating thickness between the bioglass powder and the bioglass slurry ($p=0.004$) groups and also between the bioglass powder and silica ($p=0.004$) coated groups. Also, the coating thickness in the bioglass powder group was significantly higher than that in the other two groups. The difference between the bioglass slurry and silica-coated groups was borderline significant ($p=0.078$).

**SEM results**

SEM analysis of the surface revealed that at 1,000× magnification, only some lines due to the use of abrasive instruments were seen in the control group (no surface treatment). Higher magnification revealed an almost uniform (in terms of size and density of particles) granular pattern and the granules had clearly visible margins. Sandblasting caused significant surface roughness and at higher magnifications, the granules no longer had visible margins. In the bioglass coated groups, a layer of bioglass was seen on the surface; in those subjected to etching with HF acid, a rough surface with variable porosities (in terms of depth) and cracks was observed. The two methods of bioglass coating (bioglass powder and slurry) were not significantly different in this respect.

### Table 3  Mode of failure in different groups

| Groups                        | Adhesive(%) | Mixed(%) | Cohesive(%) |
|-------------------------------|-------------|----------|-------------|
| Control                       | 75          | 25       | 0           |
| Sandblasting                  | 25          | 58.33    | 16.66       |
| Bioglass powder coating+etching| 0           | 83.33    | 16.66       |
| Bioglass powder coating+etching+silanization | 0           | 50       | 50          |
| Bioglass slurry coating+etching | 0           | 100      | 0           |
| Bioglass slurry coating+etching+silanization | 8.33       | 83.33    | 8.33        |
| Silica coating+silanization  | 100         | 0        | 0           |
| Silica coating+etching+silanization | 100       | 0        | 0           |

### Table 4  Coating thickness in different groups

| Groups               | Coating thickness (micrometer) |
|----------------------|--------------------------------|
|                      | Mean  | Median | SD     | Minimum | Maximum |
| Bioglass powder coating | 270.83| 283.50 | 58.595 | 191     | 352     |
| Bioglass slurry coating  | 46.67 | 37.00  | 23.594 | 29      | 91      |
| Silica coating        | 76.50 | 79.00  | 21.815 | 40      | 108     |
SEM analysis of the surface of specimens coated with colloidal silica before etching revealed that the coating was incomplete and defective and the silica layer was cracked.

SEM analysis of the surface after 30 s of etching revealed that the majority of silica had been washed off the surface.

In the bioglass coated groups, SEM analysis of the interface at 1,000× and 5,000× magnifications showed no composite layer (bioglass penetration in-between zirconia particles). However, a glass layer was observed that was in close contact with the zirconia substrate. The bioglass-zirconia interface in both methods of coating was uniform and intact with no voids or defects.

The only difference between the bioglass powder and bioglass slurry groups was the smaller thickness of the glass layer in the bioglass slurry group (Figs. 2, 3 and 4).

Fig. 2 SEM micrographs.
- a: control group at 1,000× magnification; b: control group at 2,500× magnification; c: control group at 5,000× magnification; d: sandblasted group at 1,000× magnification; e: sandblasted group at 2,500× magnification; f: sandblasted group at 5,000× magnification.

Fig. 3 SEM micrographs at 1,000× magnification.
- a: control group; b: sandblasted group; c: bioglass coated group; d: HF acid etched+bioglass coated group; e: slurry glass coated group; f: HF acid etched+slurry glass coated group; g: silica-coated group; h: HF acid etched+silica-coated group.
DISCUSSION

In this study, we used bioglass to form an etchable coat with minimal thickness on the zirconia substrate and then, we evaluated its effect on the bond strength of zirconia to resin cement. The effect of thin colloidal silica coating of zirconia on its bond strength to resin cement was evaluated as well.

Favorable mechanical properties of zirconia enable its application in FPDs with a significantly reduced core thickness; which is especially important for application in areas where esthetics and strength are critical\(^1\). However, there is no reliable technique to facilitate the bonding of zirconia to tooth structure via resin luting agents. As a result, application of zirconia is limited to tooth preparations with retentive forms. Achieving a reliable bond may enable the application of zirconia restorations in resin-retained bridges\(^2\).

Bond strength

In the current study, microshear bond strength testing was performed to assess the effect of bioglass and silica coating on bond strength of resin cement to zirconia. This test is easily performed and several specimens may be tested on one substrate\(^3\). Sandblasted specimens comprised the positive control group in our study because this method in some studies is considered as the most effective surface treatment for zirconia since it increases surface roughness and results in micromechanical interlocking of the luting agent\(^4\). In our study, bond strength significantly increased following sandblasting compared to the control group; which is in accord with the results of the afore-mentioned studies. However, in some studies, sandblasting did not significantly improve the resin cement bond to zirconia\(^5\). Some researchers believe that sandblasting only slightly roughens the zirconia surface\(^6\) and this roughness is not adequate to achieve a reliable resin bond\(^7\). Furthermore, sandblasting has the drawback of creating defects and superficial cracks that decrease the strength and fracture toughness of zirconia restorations\(^8\). Moreover, this method may affect the long-term service of zirconia ceramics due to surface defects and conversion of tetragonal to monoclinic phase\(^9\).

In our study, bioglass was used as a coating for zirconia substrate using firing technique in order to create an intermediate, etchable layer on the zirconia surface. Many studies have used this type of coating on zirconia implants to benefit from the bioactive properties of glass and mechanical properties of zirconia\(^10\). Bond strength values of different bioglass-coated groups in the current study were comparable with that of the sandblasted group (positive control). The only exception was the bioglass slurry+etchant group that showed a lower bond strength compared to the sandblasted group and this difference was borderline significant. In the bioglass slurry group, slurry was prepared by mixing glass powder, water and binder and applied to the zirconia surface. In this technique, smaller amounts of glass particles are applied to the surface compared to the glass powder group and therefore some discontinuities may be seen in the coating in some areas. However, when silane was applied to specimens in this group after etching, the bond strength increased to the level of the bond strength of the sandblasted group. Due to the dissimilarity of the used materials and different surface preparation methods, precise comparison of our results with those of previous studies was not feasible.

In a study by Valentino et al. in 2012, glazing yielded a higher bond strength compared to sandblasting with 50 μ alumina particles\(^11\); which is different from our obtained result. Considering the similar sandblasting conditions in the two studies, this difference may be explained by the different composition of the coating layer and duration of acid etching since the etching time was shorter (20 s) in Valentino’s study\(^12\). Cura et al. in 2012, acid etched and silanized the zirconia surface after applying glaze and increased the shear bond strength of resin cement. But application of MDP-containing primer instead of silane could not efficiently increase the bond strength\(^13\). Usumez et al. in 2013 demonstrated that application of MDP-containing primers to glazed and etched specimens was not as effective as in sandblasted samples\(^14\). MDP enhances the bond of resin cement to zirconia ceramic\(^15\). Glaze coating of the zirconia surface seems to neutralize the effect of MDP containing primers\(^16\). We used Panavia resin cement in the current...
study, which contains MDP monomer. However, glass-coated groups after etching showed bond strength values as high as that of the sandblasted group. In comparison with previous studies, this increase may be attributed to the different composition of bioglass coating and higher surface roughness in etched bioglass-coated groups. In the mentioned study, a glaze coat with a low melting point was used, which formed an amorphous layer. But, in our study, crystallization of bioglass coat probably occurred during the firing process and thus, after etching with HF acid, a different etching pattern was obtained. In our study, silanization of bioglass-coated specimens did not significantly increase the bond strength; but a small increase occurred, which, in the bioglass slurry group, increased the bond strength to the level of sandblasted group. Silanization of silica-based ceramics results in formation of a siloxane network on the ceramic surface and increases the bond strength of ceramic to resin cement\(^1\). In the study by Valentino et al. in 2012, glazing did not significantly increase the bond strength after etching and silanization; this finding is in agreement with our results. They explained the reason to be the loss of a significant part of the glaze layer due to the process of etching and sandblasting\(^2\).

Kitayama et al. in 2009 reported that silanization of coated porcelain significantly increased its bond strength to resin cement; which is in contrast to our findings\(^3\). In our study, silanization increased the bond strength due to the silica content of bioglass coating. However, due to having small silica content (45%) in comparison to the feldspathic porcelain, this increase was insignificant.

In silica-coated groups, bond strength values were significantly lower than those of the control and sandblasted groups. This method of coating appears not to be successful probably due to the insufficient wetting of the zirconia surface by silica, not using a binder or different CTE of silica and zirconia. The lower bond strength values of the experimental groups compared to that of the control group may be attributed to the presence of silica with a weak bond at the cement-zirconia interface interfering with the bond.

### Mode of failure

Evaluation of the glass-zirconia interface under a light microscope revealed that most fractures were mixed (83.33%) in the bioglass powder+etchant group. By using silane coupling agent, the frequency of mixed fractures decreased while the frequency of cohesive failure of the cement increased. This finding shows that silane improved the resin cement bond to glass.

Additionally, in these groups, no fracture was observed at the bioglass-zirconia interface; suggesting that the bioglass-zirconia bond in bioglass powder coated specimens was stronger than the resin cement-bioglass bond. In the bioglass slurry+etchant group, all fractures were mixed. In one specimen, the mixed fracture occurred at the glass-zirconia interface, showing the weaker bond of bioglass in this coating technique or incomplete surface coating, that is in agreement with the results of bond strength testing. In this method of coating, after the use of silane, cohesive failure occurred in resin cement in 8.33% of cases indicating increased bond strength to resin cement after silanization. Also, in the mentioned group, one adhesive failure and two mixed failures occurred at the interface of bioglass-zirconia; showing weaker bond of bioglass in this coating method or incomplete surface coating.

Kitayama et al. in 2009 reported no adhesive failure at the zirconia-veneer interface in the porcelain-coated group. No cohesive failure occurred in veneering porcelain either showing that the bond between the veneering porcelain and zirconia was stronger than the cement-porcelain bond\(^4\). In a SEM study in 2012, Everson et al. demonstrated that the majority of failures in the glazed group were mixed\(^5\), which is in line with our results.

In silica-coated groups, all failures were of adhesive type and observed at the zirconia-coating interface; which further confirms inadequate bond between the silica layer and underlying zirconia.

### Thickness assessment

In the current study, the bioglass slurry group had the thinnest coating thickness. In a study by Ferraris et al. in 2000 zirconia samples were directly coated with bioglass powder yielding a coating thickness of 100–300 μm\(^6\). This finding is in agreement with our results. Krajewski et al. in 1998 used bioglass suspension and the thickness of the obtained layer based on the fluidity of suspension used varied between 40 to 100 μm. Everson et al. in 2012 used a glaze-on technique and reported 120 μ thickness. CAD/CAM technology has the ability to consider the thickness of the internal coating to achieve a perfect fit and enhance seating of the restoration. However, adhesive bridges with retaining wings have simpler geometry and subsequently less misfit\(^7\).

Considering the obtained results, future studies are required to assess the effect of aging on the bond strength of zirconia with different surface coatings. The influence of surface treatments on the zirconia strength must be evaluated as well. Also, the bioactivity of bioglass should be decreased by modifying its composition. Furthermore, future investigations are recommended to focus on techniques for applying a coating with minimal but uniform thickness.

### SEM results

SEM results in our study revealed significant surface changes due to sandblasting with 50 μ alumina particles, which explains the high bond strength values obtained in this group. In a study by Usumez et al., sandblasting with 110 μ particles caused a surface with uniform irregularities and pits; which was slightly different from the control group; SEM results in their study were also confirmed by surface roughness measurements\(^8\). Such contradictory results may be related to the different sandblasting conditions in terms of size and shape of particles, pressure and distance from the substrate surface. The effect of these factors on surface changes has been discussed in many studies\(^9,10\).
SEM micrographs of the bioglass coated groups indicated formation of a bioglass layer. Etching of this layer had caused a rough surface with porosities of various sizes and depths. The bioglass used in the current study forms separate silicate-rich and phosphate-rich phases as the result of heat treatment; the observed etching pattern may be attributed to selective etching of these phases. Ntala et al. in 2010 applied a glaze coating containing hydroxyapatite to some specimens and noticed that acid etching of these specimens yielded a completely cracked surface providing no mechanical retention for the adhesive. They concluded that this material was not suitable for enhancing zirconia bonding. In our study, emergence of cracks after etching may be related to the presence of phosphate-rich phases.

Krajewski demonstrated that in substrates with high sintering temperature like zirconia, a glass system with a high melting point must be used for surface coating. Thus, excessive sliding of glass and ion exchange will be prevented at high temperatures. Ferraris reported that by heating bioglass above its melting point, glass penetrates into the zirconia substrate and zirconia granules are surrounded by the glass matrix. As the result, a tough composite layer with a mean thickness of 25 μ is formed with thermal and mechanical properties in between those of zirconia substrate and glass coat. Ferraris observed three layers in AP40 bioglass coated specimens under SEM: a composite layer comprising of glass phase, zirconia particles and glass layer, that based on the type of thermal treatment during cool off was seen in glassy or glass-ceramic forms. SEM analysis in our study at 1,000× and 5,000× magnifications revealed no composite layer. However, the two materials were in close contact with one another and the bioglass-zirconia interface in both bioglass slurry and bioglass powder groups was uniform and intact with no voids or defects.

SEM micrographs of the silica-coated groups revealed partial surface coating and numerous cracks, indicative of the failure of this method of coating.

CONCLUSION

Bioglass coating effectively increases the bond strength of zirconia to resin cement in short-term and is as effective as sandblasting treatment. Bioglass slurry coating provides the thinnest coating on the zirconia surface. Colloidal silica coating must be avoided since this method decreases the bond strength of resin cement to zirconia.

CONFLICT OF INTEREST

This article has no conflict of interest.

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