Microshear bond strength of self-adhesive composite to ceramic after mechanical, chemical and laser surface treatments

Maryam Ghavam 1, Marjan Soleimanpour 2, Sedighe Sadat Hashemikamangar 3, Hooman Ebrahimi 2, Mohammad Javad Kharazifard 4

1: Department of operative dentistry, Dental school, Tehran University of Medical Sciences, Tehran
2: Dental school, Tehran university of medical sciences, International campus
3: Department of operative dentistry, Dental school, Tehran university of medical sciences, International campus
4: Department of epidemiology and biostatistics, Faculty of public health, Tehran University of Medical Sciences, Tehran

Objectives: This study aimed to assess the microshear bond strength of a repairing self-adhesive flowable composite to ceramic after mechanical, chemical and laser treatment of the ceramic surface.

Materials and Methods: Forty zirconia and forty feldspathic ceramic blocks measuring 8 x 8 x 2 mm were fabricated. Feldspathic blocks were divided into four groups of control (1), laser (2780 nm) (2), sandblasting + hydrofluoric (HF) acid + silane (3) and laser (2780 nm) + HF acid + silane (4). Zirconia blocks were also divided into four groups of control (1), laser (2780 nm) (2), sandblasting + Z-Prime Plus (3) and laser (2780 nm) + Z-Prime Plus (4). Vertise Flow composite was bonded to treated ceramic surfaces as a repairing material, then the samples were subjected to 1000 thermal cycles. Repair bond strength was measured by Instron machine and data were analyzed using one-way ANOVA and post hoc test (P < 0.05).

Results: Maximum and minimum bond strength values were observed in zirconia-control (22.57 ± 4.76 MPa) and feldspathic-control (8.65 ± 6.41 MPa) groups, respectively. There was no significant differences between subgroups within the zirconia or feldspathic groups (P > 0.05), however the bond strength of zirconia subgroups was significantly higher than that of feldspathic subgroups.

Conclusion: Vertise Flow provides relatively good bond strength to ceramic even with no surface treatment.

Introduction

Ceramics are extensively used in dental clinics for crowns, veneers, inlays, onlays, implant abutments and fixed partial dentures 1). They can be categorized to feldspathic and non-feldspathic ceramics. Felspatic ceramics are etchable by hydrofluoric acid. Some of non-feldspathic ceremics like zirconia-based ceramics are not etchable 1). Reliable bond of composite resin to ceramic is required for clinical applications e.g. adhesive cementation of indirect restorations and repairing of defective restorations 2). Etching with hydrofluoric acid (HF) is effective to enhance the bond of composite to glass ceramics 3). Although ceramic restorations are a reliable esthetic dental treatment, they may suffer from some minor defects like cracks, chipping or fracture, especially in patients with heavy occlusion. Even under ideal conditions, long-term function in the oral cavity, functional habits such as daily or nocturnal bruxism and trauma may cause porcelain fracture 4).

Decision regarding replacement or repair of the defective restoration depends on the clinical judgment and experience of the clinician, patient’s financial status and insurance coverage. However, replacement of all-ceramic or PFM restorations may damage the tooth and

Address for Correspondence:
Dr. Sedighe Sadat Hashemi Kamangar, Associate Professor Tehran University of medical sciences, International campus, Navab St, Tehran, Iran.
Tel: 02155851151 Fax: 02155851149-113
email: smhk58950@gmail.com

Received date: May 24th, 2017
Accepted date: August 15th, 2017

©2017 JMLL, Tokyo, Japan
soft tissue or cause total loss of the tooth. Currently, porcelain chipping may be repaired with composite resin in dental office 5). Composite resins are suitable for repairing of porcelain fractures. Composite resins have different viscosities based on the filler content, formulation of matrix and method of fabrication 6, 7, 8). For better adaptation to substrate, composites with lower viscosity are preferred and it is believed that flowable composites are favorable for this purpose 7, 9). Vertise Flow by Kerr is a new generation of flowable composites recently introduced to the market 10). This self-adhesive composite does not require a bonding agent or separate etching for bond to tooth structure 11, 12). The manufacturer claims that this composite enhances the process of restoration since it does not require a separate bonding step 13-10. It is also claimed that it can provide effective bonding to enamel and dentin with different degrees of wetness and also a reliable bond to a porcelain substrate can be achieved without the need for HF etching and silane primer treatment, offering a simplified restorative procedure for porcelain repair 17). It is used as a liner beneath hybrid composites as a shock and stress absorber 17-21) and is also suitable for direct use 22).

Adequate bond between porcelain and composite has long been a challenge. Micromechanical surface treatments such as sandblasting with aluminum dioxide particles, acid etching of feldspatic porcelain surface with 9% HF acid and use of silane coupling agent and resin to obtain better chemical retention have been suggested for use in the clinical setting 23). Silane coupling agent creates a chemical bridge between composite and porcelain 24). Microporosities due to the application of HF allow for the penetration of bonding agent into the porcelain structure. Longevity and strength of bond depend on the method of application of silane coupling agent 25). Zirconia-based ceramics are not able to be etched by HF; so achieving acceptable repair bond in these kind ceramics are more difficult.

There are some health concerns with regard to the use of HF acid for dental purposes. Although 9% buffered HF acid is used for dental purposes, concerns regarding its safety for use still exist and there seems to be a need to find an alternative to HF acid etching. Laser seems to provide promising results for this purpose. Since 1960, laser has gained increasing popularity in dentistry and has been the topic of many studies 26, 27). Of different types of lasers, Erbium lasers have been more commonly evaluated. They are used for surface treatment as well. These lasers increase the surface roughness and create a surface topography that enhances resin cement bond to ceramic 28). Evidence shows that Er,Cr:YSGG (2780 nm) laser is efficient for surface roughening and the resultant ceramic surface after its use is comparable to enamel and dentin surface topography after acid etching 29-31). This study aimed to assess the repair bond strength of Vertise Flow self-adhesive composite to both zirconia and feldspatic ceramics treated with mechanical and chemical surface treatments and laser. The null hypothesis was that neither the type of ceramic nor the surface treatment has any effect on bond strength of Vertise flow to the ceramic surface.

Materials and Methods

Forty zirconia (Kuraray Noritake Dental Inc., Okayama, Japan) and forty feldspatic (Ceramico, Dentsply, USA) ceramic blocks measuring 8 mm in length, 8mm in width and 2mm in thickness were fabricated and polished. All blocks were rinsed under running water and dried with air spray. Dried blocks of each ceramic were randomly divided into four groups (n = 10) and coded. Surface treatments were performed as follows:

Feldspatic ceramic surface treatments:

Group 1 (control; FC): No surface treatment was performed.

Group 2 (Er,Cr:YSGG laser; FL): Surface of samples was subjected to Er,Cr:YSGG laser irradiation with 2780nm wavelength, 4W power, 140 µs pulse width, 20Hz frequency, 66.8 J/cm² energy density and 50% air, 50% water using mz 8,800 µm quartz tip (Biolase, Waterlase). Laser was irradiated perpendicularly (non-contact) to the surface via scanning or painting technique (with horizontal strokes parallel to the surface).

Group 3 (sandblasting + HF acid etching + silane coupling agent; F.S.HF): The samples were sandblasted with 50 µ aluminum oxide particles (60° angle relative to the bonding surface, 20 Psi pressure, 20 seconds time, 10mm distance). Each sample was rinsed for 20 seconds under running water and dried with air spray.

Samples were then subjected to etching with 9.5% HF acid gel (Porcelain Etchant Gel, Bisco, Schaumburg, IL, USA) for 90 seconds. The samples were rinsed with water and dried (chalky white appearance was seen). To completely eliminate the salt and debris following etching, all samples were immersed in an ultrasonic bath containing 96% isopropyl alcohol for three minutes, rinsed and air sprayed for 30 seconds. Porcelain primer was then applied. One drop of each of the A and B bottles of porcelain primer (Bis-Silane, Bisco, Schaumburg, IL,
USA) were mixed by a microbrush and applied on the etched and dried porcelain surface in two thin layers. It was allowed 30 seconds and then gently dried with air spray.

Group 4 (Er,Cr:YSGG laser + HF acid + silane coupling agent; F.L.HF): Samples were subjected to Er,Cr:YSGG laser irradiation as explained earlier, etched as in group 3 and porcelain primer was applied.

Zirconia ceramic surface treatments:

Group 1 (control; ZC): No surface treatment was performed.

Group 2 (Er,Cr:YSGG laser; ZL): Surface of samples was subjected to Er,Cr:YSGG laser irradiation with 2780 nm wavelength, 4W power, 140 µs pulse width, 20 Hz frequency, 66.8 J/cm² energy density and 50% air, 50% water using mz 8,800 µm quartz tip (Biolase, Waterlase). Laser was irradiated perpendicular to the surface via scanning or painting technique (with horizontal strokes parallel to the surface).

Group 3 (sandblasting + Z-Prime Plus; Z.S.ZP): The samples were sandblasted with 50 µ aluminum oxide particles (90° angle relative to the bonding surface, 35 Psi pressure, 10 seconds time, 10mm distance). Each sample was rinsed for 20 seconds under running water and dried with air spray. Zirconia primer (Z-Prime Plus, Bisco, Schaumburg, IL, USA) was applied in two layers by a microbrush and dried with air spray for 3-5 seconds.

Group 4 (Er,Cr:YSGG laser + Z-Prime Plus; Z.L.ZP): Samples were subjected to Er,Cr:YSGG laser, and zirconia primer was applied as in group 3.

Fabrication of ceramic-composite samples:

Eighty Tygon tubes with an internal diameter of 1mm and height of 3 mm were filled with Vertise Flow composite (Kerr, Orange, CA, USA). Composite samples were directly placed on ceramic surfaces without using adhesive (care was taken to place the tubes perpendicular to the ceramic surface). Excess composite resin was removed by an explorer prior to curing. Polymerization was carried out by a led light curing device (LIANG YA, LED, B 200 Japan) for 20 seconds as recommended by the manufacturer. Each sample was light cured for 80 seconds (20 seconds from each side) to ensure complete polymerization. Tygon tubes were then gently cut by a scalpel and removed.

Data collection:

Samples were immersed in distilled water at 37°C for 24 hours and were then thermocycled (1000 cycles between 5-55°C). The samples were then subjected to microshear bond strength test in an Instron machine at a crosshead speed of 1mm/min (load was applied parallel to the ceramic-composite interface). Microshear bond strength was measured in megapascals (MPa). Data were analyzed using one-way ANOVA and post hoc test by SPSS version 20. P < 0.05 was considered the level of significance.

Results

Table 1 shows the mean, minimum, maximum and standard deviation of bond strength in the study groups. As seen in Table 1, group Z.C showed the highest (22.57 ± 4.76 MPa) and group F.C. showed the lowest (8.65 ± 6.41 MPa) mean bond strength.

One-way ANOVA showed that the groups were significantly different in terms of micro shear bond strength (P < 0.001). Thus, post-hoc test was applied, which showed that neither zirconia nor feldspathic ceramic subgroups were significantly different within each group (P > 0.05) but all zirconia subgroups had significant differences with feldspathic ceramic subgroups (P < 0.05). The bond strength of all zirconia subgroups was significantly higher than that of felds-
pathic ceramic subgroups (P < 0.05) as shown below:

Bond strength of Z.C, was significantly higher than that of F.S.HF (P = 0.001), F.L.HF (P = 0.0002), F.L (P = 0.0001) and F.C (P = 0.0001).

1. Bond strength of Z.L.ZP, was significantly higher than that of F.S.HF (P = 0.010), F.L.HF (P = 0.004), F.L (P = 0.0001) and F.C (P = 0.0001).
2. Bond strength of Z.S.ZP, was significantly higher than that of F.S.HF (P = 0.019), F.L.HF (P = 0.008), F.L (P = 0.0001) and F.C (P = 0.001).
3. Bond strength of Z.L was significantly higher than that of F.S.HF (P = 0.029), F.L.HF (P = 0.012), F.L (P = 0.0001) and F.C (P = 0.001).

**Fig. 1** shows the mean and standard error of each group.

**Discussion**

Ceramic restorations are esthetic but fragile and may undergo chipping or fracture due to trauma. It has been reported that fracture toughness of glass ceramics is one-third and their flexural strength is one-fourth of that of alumina porcelain or zirconia. Zirconia ceramics have high strength but clinical studies regarding all-ceramic zirconia restorations have shown that fracture has been the main reason of their failure.

In this study, feldspathic and zirconia ceramics were prepared with commonly used surface treatments and laser, then subjected to repair with Vertise Flow composite, a self-adhesive composite recently introduced by the market. Evidence shows that in bonding systems, procedural steps may lower the reproducibility and accuracy of procedure and compromise the outcome thus, attempts have been made to develop one-step adhesive systems and composites with bonding agent incorporated into their formulation.

The results showed that surface preparation separately in each group had no significant effect on microshear bond strength to composite, but bond strength was significantly higher in zirconia ceramic group compared to feldspathic group. Since all groups were subjected to thermocycling, the obtained microshear bond strength results were quantitatively acceptable.

Thurmond et al. used shear test and reported a mean bond strength similar to the present study with the exception that they did not obtain significantly lower bond strength values in any of the groups compared to HF acid. Valian and Moravej Salehi reported that feldspathic porcelain after etching with 9.5% HF acid for 120 seconds showed deeper porosities compared to sandblasting. The main advantage of shear test to tensile test is its ease of application, however some authors believe that this test underestimates the quantitative results. Due to the increased bonding ability in new adhesive systems, bond strength is higher than the cohesive strength of substrates and thus, may not well reflect the result of adhesive bond...
to substrate. According to Della Bona and Van Noort, in shear testing, stress is accumulated in the substrate and results in early failure. That is why microshear test was used in this study. Similar to microtensile test, a high number of substrate samples can be provided while there is no need to trim and section, which applies unwanted stress to microtensile samples. Also, microtensile test sectioning can hardly be performed for zirconia ceramics due to their hardness. Microshear test can be easily performed using Tygon tubes with an internal diameter of 1mm. An et al. evaluated feldspathic and zirconia ceramic repair with pink and tooth-colored composite resins. They used Ivoclar ceramic repair kit and microtensile bond strength test. The results of feldspathic ceramic repair in their study were similar to ours but composite bond to zirconia was much lower than our results. (4.64 MPa for tooth-colored and 3.74 MPa for pink composite). Kursoglu et al. evaluated the effect of Er,Cr:YSGG (2780 nm) laser on resin cement bond to lithium disilicate ceramic and compared it with HF acid and showed that HF acid etching resulted in significantly higher bond strength (8.42), which was quantitatively similar to the value obtained in our control group. However in the present study use of laser and HF showed the same results, both acceptable, which may be due to the self-adhesive composite used. Ural et al. compared the effect of CO2 laser with sandblasting and HF acid etching for zirconia repair with Panavia F2 resin cement and showed that laser significantly increased the bond strength. The highest bond strength was 20.9 MPa in their study while this value was 13.4 in the control group and 14.1 MPa in the sandblasted group. In our study, bond strength was 22.57 MPa in the control, 20.15 in laser and 20.45 MPa in sandblast and Z-Prime group. Sadeghi et al. evaluated the effect of different powers of Er:YAG (2940 nm) laser compared with HF acid for composite bond to feldspathic ceramic and reported no positive effect of laser compared to HF acid etching; although bond strength was 8 MPa in 5W laser and 12.29 MPa in HF group. Lower powers of laser resulted in bond strength values lower than that of the control group (3.76 MPa). In our study, control and laser groups in feldspathic porcelain showed 8.65 and 10.5 MPa microshear bond strength, respectively. Our study results were in line with those of Akyil et al, since they reported that Er:YAG (2940 nm) and Nd:YAG (1064 nm) lasers had no significant effect on repair bond strength of feldspathic ceramic compared to etched and silane groups.

Kasraei et al. evaluated the effect of CO2 laser on zirconia and reported that it had a significant positive effect on bond strength compared to the control group and yielded tensile bond strength of 12.12 MPa, which is much lower than the results of present research. Arami et al. evaluated the effect of Er:YAG and Nd:YAG lasers on composite bond to zirconia and reported no significant effect compared to sandblasting. They reported a bond strength of 17.24 MPa, which was lower than the value in our control group with no treatment and much lower than the Er,Cr:YSGG (2780 nm) lased group. The quantitative values obtained in our study were in agreement with those reported by Kirmali et al, who evaluated the shear bond strength of composite to zirconia ceramic treated with bur roughening, sandblasting, Nd:YAG (1064 nm) and Er,Cr:YSGG (2780 nm) laser. In their study laser significantly increased the bond strength.

Er,Cr:YSGG and Er:YAG lasers operate at 2,780 and 2,940nm wavelengths. These wavelengths are compatible with water absorption peak in infrared spectrum and since the absorption coefficient of Er,Cr:YSGG laser is lower than that of Er:YAG, it penetrates deeper. However, this study showed that this laser with the chosen power and pulse duration had no significant effect on bond strength of Vertise Flow to ceramic. As mentioned earlier, Vertise Flow is self-adhesive. OptiBond has been incorporated into the formulation of this composite to enhance bonding. By eliminating etching, bonding, rinsing and drying steps, complexity of the work and risk of errors decrease and more predictable results can be obtained. This study showed that even without surface treatment (control group), this product yielded optimal bond strength values, which were even higher than the values reported in some studies after surface treatment. Erdemir et al. used self-etch system for bond to lithium disilicate and performed shear test. They reported that roughening the surface with diamond bur and HF acid application yielded higher bond strength than other surface treatment methods. Their results were not in agreement with the present study, but since they used Er:YAG (2940 nm) laser, which has shallower effect than Er,Cr:YSGG (2780 nm) laser, it is reasonable that bond strength values in this study is higher. Moreover, they used shear test. It can be stated that the results of the present study are more reliable because of micro shear testing. Evidence shows that a direct association does not necessarily exist between zirconia substrate roughness and bond strength. In fact, bond strength of resin cement to ceramic depends on the type of cement especially after thermocycling. This was confirmed in this study, since type of preparation did not

**Microshear bond strength of self-adhesive composite to ceramic**

301
affect the bond strength in zirconia or feldspathic ceramic groups. Even the control groups showed significantly high bond strength with use of Vertise Flow self-adhesive composite alone. The results show a promising role for Vertise Flow in ceramic repairing procedures, however electron microscopic assessments can be used to clarify this subject.

Conclusion

Under the limitation of this study, Vertise Flow provides relatively good bond strength to ceramic even with no surface treatment.

References

17: Vertise Flow - Kerr Dental Corporationwww.kerrdental.fr/catalog-files/
21: Van Meerbeek B, Willems G, Celis JP, Roos JR,
Microshear bond strength of self-adhesive composite to ceramic


Dental Research, 76:1298-307.

The authors claim no conflict of interest with materials and devices used in this research.