Bond strength of silane-containing adhesive to glass-ceramic material

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Abstract---The objective this study was to assess the effect of silane-containing universal adhesive (UA) on the shear bond strength (SBS) of dual-cure resin cement to glass-ceramic material. IPS e.max CAD, IvoclarVivadent blocks were prepared, polished, acid etched with a 5% hydrofluoric acid etchant and then randomly distributed into three groups (n = 15) according to the priming material applied for each material. In group 1 (control), no priming was performed prior to the application of a resin cement (Multilink automix, IvoclarVivadent). In group 2, a silane-based primer (Monobond Plus, IvoclarVivadent) was applied onto the ceramic surface while in group 3, a silane-containing universal adhesive, single bond universal, 3M was used as a primer. The resin-ceramic bonded specimens were subjected to artificial aging via 10k thermocycling before the SBS was assessed using a universal testing machine at a crosshead speed of 1 mm/min. Failure mode patterns were evaluated using a scanning electron microscope. The SBS data were statistically analysed using one-way analysis of variance (ANOVA) (α = 0.05). Despite that Single Bond Universal, 3M priming significantly (p < 0.05) improved the SBS compared with the control group, Monobond Plus, IvoclarVivadent priming yielded significantly higher (p < 0.05) SBS compared with Single Bond Universal, 3M. Mixed failure mode patterns were the most predominant in groups 2 and 3. The use of the universal adhesive tested as a primer to promote bonding to glass ceramic materials may result in suboptimal resin-ceramic SBS compared with the application of silane-based primer.

Keywords---lithium disilicate, silane, universal adhesive, microtensile, bond strength, field-emissionscanning, electron microscope.
Introduction

The aesthetic limitations of metal-ceramic restorations have increased the search for new materials to use in clinical restorations. Currently, many ceramic systems are commercially available. Dental ceramics with a high aesthetic standard are predominantly glazed, also known as dental porcelains (glazed and translucent white ceramic), used to cover infrastructures, but having low mechanical properties. The search for a sturdier material for infrastructures involved an increase in the crystalline content, thus resulting in ceramics with better mechanical properties but with reduced aesthetic potential.1

Excellent materials and a bonding process are necessary for a successful ceramic restoration. The gold standard for ceramic–tooth bonding involves achieving micromechanical retention using hydrofluoric acid (HF) and forming a chemical bond using silane.2-8 HF partially dissolves the glass phase of a ceramic matrix, thereby increasing the contact area and interactions between the luting agent and ceramic. The irregularities on a ceramic surface created by HF etching are reported to be affected by the concentration, application time, temperature, and dilution level of HF. After inducing mechanical interlocking by creating irregularities on the inner surface of a ceramic restoration using HF, a silane coupling agent is applied to bond the inorganic ceramic surface with an organic resin matrix. Silane, which has been used as a bond enhancer since 1977, has two reactive groups: one that reacts with methacrylate and another that reacts with the silica of a hyaline.9 Silane forms a siloxane bond and increases the surface energy of a ceramic as well as the cement wettability, thereby inducing microscopic interactions between the two materials.3

Other methods can also be used to improve ceramic-resin bonding, such as airborne-particle abrasion with 50-μm aluminum oxide and employment of primers containing silane mixed with phosphate acid monomers, such as 10-methacryloyloxydecyldihydrogen phosphate (MDP).10,11 These phosphate acid monomers are used because of their ability to chelate bond with metallic cations present in some ceramics (mainly the polycrystalline ceramics) as well as in hydroxyapatite while having the ability to covalently bond with methacrylate group of resin cements.12 Thus, when silane and a phosphate acid monomer are combined in a ceramic priming agent, a “universal ceramic primer” is created because it has the potential to chemically bond to a high number of restorative and tooth substrates.

Thus, these phosphate acid monomers are also found in some enamel-dentin adhesives (self-etch or multimode) to act as coupling agents between composite resin and calcium present in hydroxyapatite of dental tissues. Silane is incorporated into those adhesives, providing a class of materials called “universal bonding solutions,” and are to be used with enamel, dentin, ceramic, and metal substrates.13 Because silane and MDP are incorporated into those adhesive compositions, these products may also be indicated to enhance bonding between resin cements and glass and nonglass ceramics. Therefore, these universal systems have a great potential for providing adhesion to a wide variety of substrates and for simplification of many dental procedures through use of only one product for many clinical purposes.14 Thus, the need for this in vitro study
was to evaluate the effect of a silane-containing, universal adhesive on the shear bond strength between resin cement and glass ceramic.

**Aim of the study**

Purpose of our research was to assess the effect of silane-containing universal adhesive (UA) on the shear bond strength (SBS) of dual-cure resin cement to glass-ceramic material.

**Methodology**

IPS e.max CAD, IvoclarVivadent blocks were prepared, polished, acid etched with a 5% hydrofluoric acid etchant and then randomly distributed into three groups (n = 15) according to the priming material applied for each material.

- **Group 1** (control)- No priming was performed prior to the application of a resin cement (Multilink automix, IvoclarVivadent).
- **Group 2**- A silane-based primer (Monobond Plus, IvoclarVivadent) was applied onto the ceramic surface.
- **Group 3**- A silane-containing universal adhesive, single bond universal, 3M was used as a primer.

The resin-ceramic bonded specimens were subjected to artificial aging via 10k thermocycling before the SBS was assessed using a universal testing machine at a crosshead speed of 1 mm/min. Failure mode patterns were evaluated using a scanning electron microscope. Failure mode was classified as adhesive (the complete ceramic surface was visible), mixed (both the ceramic surface and cement layer were visible), cohesive within the resin cement (almost all of the surface was covered with resin cement) and cohesive within the ceramic. The SBS data were statistically analysed using one-way analysis of variance (ANOVA) (α = 0.05).

**Results**

The shear bond strength (SBS) was influenced significantly by the type of surface treatment applied (p<0.001). Despite that Single Bond Universal, 3M priming significantly (p < 0.05) improved the SBS compared with the control group, Monobond Plus, IvoclarVivadent priming yielded significantly higher (p < 0.05) SBS compared with Single Bond Universal, 3M. Mixed failure mode patterns were the most predominant in groups 2 and 3. (Table 1) The failure analysis results correlated with the bond-strength data, and all fractures occurred within the adhesion zone: no ceramic fractures were noted.

**Discussion**

According to Makishi et al., the 3 silanol groups resulting from the hydrolysis of the silane RX (which contains 3-methacryloxypropyltrimethoxysilane) form covalent bridges with the hydroxyl groups of the glass-ceramic phase. Afterward, the organofunctional groups of the silane react with the resin monomers of the resincement. The application of only a silane coupling agent (RX group) over the
etched surface has been indicated for a long time as a chemical treatment to improve the bonding at the glass-ceramic/resin cement interface. The shear test is the most suitable method to evaluate bond strength when using brittle materials such as glass ceramics and enamel, where the specimens do not require sectioning. Sectioning of brittle materials for the microtensile bond strength tests can result in a large number of cohesive failures. Interface bond strength tests using lithium disilicate glass ceramics have shown that surface treatment protocols, as well as the type of adhesive protocol used for cementation can affect the performance of the final restoration.

The amount of silane present in the universal adhesive may, therefore, not be enough to provide the same effect as when it is applied prior to the universal adhesive, showing that the bond strength is higher when applied in separate steps. This result suggests application of silane independent of the presence of silanewhich is within the universal adhesive solution. Similar results were observed in the study of Kavalacharla and others, where it was emphasized that the application of silane prior to universal adhesive produced higher bond strength. The author still suggested that if the silane is not to be used, etching time should be increased from 20 to 60 seconds, because adhesion to the ceramic surface becomes totally dependent on the micromechanical retention promoted by etching with hydrofluoric acid.

In this study, even though the majority of failures were adhesive and mixed failures. Other studies have also reported cohesive failures in lithium disilicate substrate, however, if a failure is not purely cohesive in ceramic and occurs in more than one substrate, most studies classify it as a mixed failure, thus it is normally underreported. Although pure adhesive failures demonstrate a better stress distribution during the test set-up, other studies have stated that micro-shear bond strength test can still present some of the disadvantages of the conventional “macro” shear bond strength test, such as nonuniform stress distribution concentrated in the substrate.

The current market trend is to launch adhesives considered “universal” or “multi-mode”. Some of these adhesives have components that allow them to bond to the glass or zirconium ceramic, noble and non-noble alloys, and composites. According to the manufacturers, they still have the advantage of being compatible with all the resin cements. Therefore, they are adhesives that seek to reduce the sensitivity of the technique with simplification of its use. However, the universal adhesives have only been on the market for a short time and little information is available about their performance on ceramic surfaces. Some authors report that, although the bond strength between resinous materials with the ceramic surface based on leucite conditioned with fluoride acid was improved when universal adhesives were used, conventional surface treatment using a silane is preferable to a simplified procedure that uses only universal adhesive. In addition, other authors have reported that the capacity of universal adhesives to obtain an appropriate and lasting bond to ceramics based on lithium disilicate seems limited, and an effective bond is found with the use of specific, traditional silane as a separate step after conditioning with HF acid. The results of the present study corroborate these findings since the best bond strength results occurred when traditional silane was used.
Conclusion

The use of the universal adhesive tested as a primer to promote bonding to glass ceramic materials may result in suboptimal resin-ceramic SBS compared with the application of silane-based primer.

References

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