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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 theshear 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) ($\alpha = 0.05$). 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, micro tensile, bond strength, field-emissionscanning, electron microscope.

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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 ceramicrestoration. The gold standard for ceramic–tooth bonding involves achieving micromechanicalretention using hydrofluoric acid (HF) and forming a chemical bond usingsilane.[2-8] HF partially dissolves the glass phase of a ceramic matrix, thereby increasingthe 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 theconcentration, application time, temperature, and dilution level of HF.After inducing mechanical interlocking by creating irregularities on the inner surfaceof a ceramic restoration using HF, a silane coupling agent is applied to bond the inorganicceramic surface with an organic resin matrix. Silane, which has been used as a bondenhancer since 1977, has two reactive groups: one that reacts with methacrylate and anotherthat reacts with the silica of a hyaline.[9] Silane forms a siloxane bond and increases thesurface energy of a ceramic as well as the cement wettability, thereby inducing microscopicinteractions between the two materials.[3]

Other methods can also be used to improveceramic-resin bonding, such as airborne-particleabrasion with 50-lm aluminum oxide and employmentof primers containing silane mixed withphosphate acid monomers, such as 10-methacryloyloxydecyldihydrogen phosphate (MDP).[10,11] These phosphateacid monomers are used because of theirability to chelate bond with metallic cations presentin some ceramics (mainly the polycrystalline ceramics)as well as in hydroxyapatite while having theability to covalently bond with methacrylate groupsof resin cements.[12] Thus, when silane and aphosphate acid monomer are combined in a ceramicpriming agent, a "universal ceramic primer" iscreated because it has the potential to chemicallybond to a high number of restorative and toothsubstrates.

Thus, these phosphate acid monomers are alsofound in some enamel-dentin adhesives (self-etch ormultimode) to act as coupling agents betweencomposite resin and calcium present in hydroxyapatiteof dental tissues. Silane is incorporated inthose adhesives, providing a class of materials called"universal bonding solutions," and are to be usedwith enamel, dentin, ceramic, and metal substrates.[13]Because silane and MDP are incorporated into thoseadhesive compositions, these products may also beindicated to enhance bonding between resin cements and glass and nonglass ceramics. Therefore, theseuniversal systems have a great potential for providingadhesion to a wide variety of substrates and forsimplification of many dental procedures throughuse of only one product for many clinical purposes.[14]. Thus, the needfor this in vitro study was toevaluate the effect of a silane-containing, universaladhesive on theshear bond strength betweenresin cement and glass ceramic.

Aim of the study

Purpose of ourresearch was to assess the effect of silane-containing universal adhesive (UA) on theshear 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 classifiedas adhesive (the complete ceramic surfacewas visible), mixed (both the ceramic surface anda cement layer were visible), cohesive within theresin cement (almost all of the surface was coveredwith resin cement) and cohesive within theceramic. 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 allfractures occurred within the adhesion zone: noceramic fractures were noted.

Discussion

According to Makishi et al., the 3 silanol groupsresulting from the hydrolysis of the silane RX (which contains 3-methacryloxypropyltrimethoxysilane)form covalent bridges with thehydroxyl groups of the glass-ceramic phase.[15]Afterward, the organofunctional groups of thesilane react with the resin monomers of the resincement.[16] The application of only a silane couplingagent (RX group) over the etched surface hasbeen indicated for a long time as a chemicaltreatment to improve the bonding at theglass-ceramic/resin cement interface.[17,18]. The shear test is the most suitable method to evaluate bondstrength when using brittle materials such as glass ceramics andenamel, where the specimens do not require sectioning. Sectioningof brittle materials for the microtensile bond strength tests can result ina large number of cohesive failures.[19,20]Interface bond strength tests using lithium disilicate glass ceramichave shown that surface treatment protocols, as well as the type ofadhesive protocol used for cementation can affect the performance ofthe final restoration.[21]

The amount of silane present in the universal adhesive may, therefore, not be enough to provide the sameeffect of when it is applied prior to the universal adhesive, showingthat the bond strength is higher when applied in separate steps. Thisresult suggests application of silane independent of the presence of silanewithin the universal adhesive solution. Similar results wereobserved in the study of Kavalacharla and others, where it was emphasized that the application of silane prior to universal adhesiveproduced higher bond strength. The author still suggested that if thesilane is not to be used, etching time should be increased from 20 to60 seconds, because adhesion to the ceramic surface becomes totallydependent on the micromechanical retention promoted by etchingwith hydrofluoric acid.[5]

In this study, even though the majority of failures were adhesive and mixed failures. Other studies have also reportedcohesive failures in lithium disilicate substrate,[22,23] however, if a failureis not purely cohesive in ceramic and occurs in more than one substrate,most studies classify it as a mixed failure, thus it is normallyunderreported.[24] Although pure adhesive failures demonstrate a betterstress distribution during the test set-up, other studies have stated thatmicro-shear bond strength test can still present some of the disadvantagesof the conventional “macro” shear bond strength test, such asnonuniform stress distribution concentrated in the substrate.[25]

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.[26]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.[27] 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.[28] 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.

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