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Bond Strength of a Novel Universal Resin Cement to Dentin With or Without an Adhesive Bonding Agent

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Abstract

Recently, a novel universal resin cement (RelyX Universal Resin Cement, 3M) has been marketed for indirect bonding applications as either a stand-alone self-adhesive cement or as an adhesive cement depending on the clinical indication. The purpose of this study was to evaluate the bond strength to dentin of the universal resin cement compared to self-adhesive and adhesive resin cements with and without an adhesive bonding agent. Seventy-two molar teeth were sectioned to expose coronal dentin, divided into 3 groups, and assigned to RelyX Universal (universal), RelyX Ultimate (adhesive), or RelyX Unicem 2 (self-adhesive) cements from 3M. The three groups were further subdivided into two subgroups of 12 specimens each, with or without the use of an adhesive bonding agent. Lithium-disilicate discs (IPS e.max CAD, Ivoclar) were milled, crystallized, etched (HF), silanated, and bonded to the dentin surface using the cements. All specimens were light cured, stored for 24 hrs (37°C) in distilled water, and subjected to 2000 thermocycles before shear bond strength testing. Data were analyzed with T-tests, ANOVAs, and Tukey's post hoc tests (alpha=0.05). Significant differences in bond strength were found between groups based on cement or use of a bonding agent ($p<0.05$). Both the universal and adhesive cements had significantly greater bond strengths to dentin with use of a bonding agent versus no bonding agent. With the self-adhesive cement, there was no significant increase in bond strength to dentin with the use of a bonding agent. The novel universal resin cement (RelyX Universal) had similar bond strengths to dentin as the adhesive cement (RelyX Ultimate) with the use of a bonding agent, and similar bond strengths to dentin as the self-adhesive cement (RelyX Unicem 2) without the use of a bonding agent, suggesting it may be used as both a self-adhesive, or an adhesive resin cement, depending on the clinical situation.

Introduction

Historically, resin cements have been organized into two categories: adhesive and self-adhesive (1). Recently, a novel universal resin cement (RelyX Universal, 3M, St. Paul, MN) has been introduced that reportedly bonds to tooth structure with or without an adhesive bonding agent. The bonding strategy for adhesive resin cements can be with either an etch-and-rinse or self-etch approach. Etch-and-rinse bonding agents utilize a multistep system consisting of a phosphoric-acid etch, primer, and an adhesive that develops a hybrid layer between the resin cement and the dentin surface (2). Self-etch bonding agents use an acidic primer that integrates the smear layer residues into the adhesive interface while slightly decalcifying superficial hydroxyapatite in dentin and enamel (1). Conventional adhesive resin cements require multiple steps, and may be more technique sensitive and time consuming (3). Adhesive resin cements may be preferred in certain clinical situations. For example, esthetic ceramic restorations such as veneers that bond primarily to enamel may require an etch-and-rinse resin-bonding system for maximum retention (4). Tooth preparations with reduced retention and resistance form (inlays and onlays) may benefit from using an adhesive cement with a self-etch bonding agent due to a primary bonding interface of dentin (4).

Alternatively, self-adhesive resin cements work in a single-step process that does not require any separate etchants, primers, or bonding agents (5). Self-adhesive cements create a low initial pH that etches dentin creating a micromechanical and chemical bond with hydroxyapatite when the cement polymerizes (6). However, conventional adhesive resin cements have been shown to have higher adhesive performance than self-adhesive resin cements based on a recent systematic review of laboratory studies (6). The increase in performance of adhesive resin cements may be due to their penetrating ability of the primer and bonding agent around demineralized dentin substrate (6). Nevertheless, the ease of use and good dentin bond strength of self-adhesive cements still may make them an excellent cement choice for all-ceramic crown restorations (1).

New dental adhesives and cements have been recently launched with a special focus on their user-friendliness by reducing the number of components and/or clinical steps. Examples include universal adhesives and more recently, universal resin cements.

3M recently introduced a novel universal cement, RelyX Universal Resin Cement, as a cement that reportedly meets all dental cementation needs. RelyX Universal Resin Cement uniquely functions as either a self-adhesive cement or an adhesive (etch-and-rinse or self-etch) resin cement utilizing Scotchbond Universal Plus Adhesive (3M) (7). Used in either light-cure or self-cure mode, the manufacturer claims that RelyX Universal Resin Cement contains a novel amphiphilic redox initiator system (AIS) that allows the unique amphiphilic adhesion monomers to diffuse into the dentin smear layer and form a strong bond to dentin (7). The AIS then reportedly causes polymerization between the amphiphilic adhesion monomers in the dentin and the dimethacrylate monomers in the resin cement creating a highly cross-linked polymer network of over 90% conversion at the dentin interface (7). Manufacturer instructions for use recommend using RelyX Universal Resin Cement in etch-and-rinse mode for enamel overlays, veneers or resin bridges; self-etch mode with selective etching of enamel for inlays and onlays; and self-adhesion mode for posts, crowns, and bridges (7). 3M thus markets the RelyX Universal Resin Cement as the solution to reduce the large armamentarium required for the several different types of cementation procedures used in dentistry. However, there are no similar products on the market and no previous published research to substantiate those claims.

To evaluate the performance of the novel RelyX Universal Resin Cement, cements from the adhesive and self-adhesive category such as RelyX Ultimate Resin Cement (3M) and RelyX Unicem 2 Self-Adhesive Resin Cement (3M) were used as a comparison. RelyX Ultimate is an adhesive resin cement that is a used with either a self-etch or etch-and-rinse bonding protocol (8). RelyX Unicem 2 Self-Adhesive Resin Cement is a self-adhesive cement that uses surface etching by methacrylate monomers that etch and diffuse through the dental surface to achieve the mechanical and esthetic adhesive properties of a resin-based cement (9). Limited research is available evaluating the bond strength to dentin of self-adhesive resin cements or the new universal resin cement, RelyX Universal, with and without an adhesive bonding agent (9-11). The purpose of this study was to evaluate the bond strength to dentin of RelyX Universal Resin Cement compared to Rely Unicem 2 Self-Adhesive Resin Cement and RelyX Ultimate Resin Cement when used with and without the universal adhesive bonding agent, Scotchbond Universal Plus. The null hypotheses tested for this study were that there would be (1) no differences in bond strength to dentin between the three cements per cementation mode, and (2) no differences per cement with or without a bonding agent.

Materials and Methods

Seventy-two non-carious extracted human third molars were used in this study. Following extraction, the teeth were debrided and stored in 0.5% Chloramine-T (Science Stuff, Austin, TX) at 4°C. The teeth were mounted using dental acrylic in polyvinyl chloride (PVC) pipes with the crown exposed. Using a diamond saw (Isomet, Buehler, Lake Forest, IL), 2mm or more of the coronal tooth structure was removed to adequately expose the dentin surface for bonding. Each specimen was examined under a stereomicroscope (SMZ-1B, Nikon, Melville, NY) at x10 magnification to ensure complete enamel removal. A smear layer was created by using 120- and 400-grit silicon carbide paper with 10 passes on the dentin surface. The 72 tooth specimens were randomly divided into three groups of 24 each. A random group of 24 specimens were assigned to RelyX Universal Resin Cement, another group of 24 were assigned to RelyX Ultimate Resin Cement and the last group of 24 specimens to RelyX Unicem 2 Self-Adhesive Resin Cement. Twelve of the specimens from each cement groups were tested with an adhesive bonding agent and the other 12 specimens were tested with the cement alone without a bonding agent to represent the self-adhesive groups.

For the adhesive bonding groups, Scotchbond Universal Plus Adhesive was applied per manufacturer's instructions to the dentin, scrubbed for 20 seconds, air dried for 5 seconds and light cured for 20 seconds. Lithium-disilicate discs (IPS e.max CAD, shade A2, LT, Ivoclar, Schaan, Liechtenstein), 4 mm in diameter × 2 mm thick, were designed in CAD software (SolidWorks CAD 3-D, Dassault Systemes, Velizy-Villacoublay, France) and milled (CEREC MC XL, Dentsply Sirona, Charlotte, NC). The sprue was removed, and the discs were crystallized in a porcelain oven (Programat P500, Ivoclar) according to the manufacturer's instructions. Hydrofluoric acid (IPS Ceramic Etching Gel, Ivoclar) was applied for 20 seconds, rinsed, and dried. Silane (Bis-Silane, Bisco, Schaumburg, IL) was mixed, applied to the etched lithium-disilicate surface, and allowed to dwell for 30 seconds before air drying. Each of the three resin cements were separately mixed according to the manufacturer's instructions and placed onto the bottom surface of the lithium disilicate cylinder. The cylinder was placed onto the bonded dentin surface and a 100gm weight was placed onto the cylinder for 30 seconds. The weight was removed, and the specimens were light cured for 20 seconds (Valo Grand, Ultradent Products, South Jordan, UT).

For the self-adhesive groups, each of the three resin cements were utilized without an adhesive bonding agent. Each of the three resin cements were separately mixed according to the manufacturer's instructions and placed onto the bottom surface of the resin cylinder as before. The cylinder was placed onto the dentin surface and a 100gm weight was placed onto the cylinder for 30 seconds. The weight was removed, and the specimens were light cured for 20 seconds as before.

After application of each cylinder and cement, the specimens were stored in distilled water at 37°C in a laboratory oven (Model 20 GC, Quincy Labs, Chicago, IL). After 24 hours, the specimens were subjected to 2000 cycles of thermocycling in distilled water at 5 and 55°C with a dwell time of 30 seconds at each temperature (Sabri Dental Enterprise, Downers Grove, IL). Next the specimens were loaded perpendicularly at the bonded interface with a knife-edge probe in a universal testing machine (Model 5943, Instron, Norwood, MA) using a crosshead speed of 1.0 mm/minute until failure. Shear bond strength values in megapascals (MPa) were calculated from the peak load of failure (Newtons) divided by the specimen surface area. The mean and standard deviation were determined for each group. The data were analyzed with a two-way analysis of variance (ANOVA) and Tukey's post hoc test to evaluate the effect of cement type or adhesive mode on the bond strength of the resin cement to dentin using statistical software (SPSS, version 26, IBM, Chicago, IL). The data were further evaluated with multiple one-way ANOVAs and unpaired t-tests per adhesive mode or cement type (alpha=0.05). Following testing, each specimen was examined using a 10× stereomicroscope to determine if the failure mode was an adhesive fracture at the resin cement-dentin interface, a cohesive fracture in the resin cement, a mixed (combined adhesive and cohesive) fracture in the resin cement or dentin, or a cohesive fracture in the dentin. Fracture mode data were analyzed with a Kruskall-Wallis and Mann-Whitney U tests to determine if there were any differences in fracture modes between the groups (alpha=0.05)

Results

The results of the two-way ANOVA found significant differences based on adhesive mode ($p<0.001$), but not on type of cement ($p=0.102$) with significant interactions ($p=0.014$). The results of the one-way ANOVAs and Tukey's post hoc tests found that RelyX Universal (22.0 ± 9.8 MPa) had the greatest shear bond strength to dentin with the use of the bonding agent, and it was significantly greater ($p=0.030$) than RelyX Unicem 2 (13.5 ± 7.1 MPa). However, RelyX Universal was not significantly different ($p=0.085$) from RelyX Ultimate (15.0 ± 6.0 MPa). Without a bonding agent, RelyX Unicem 2 (11.8 ± 6.2 MPa) had the greatest shear bond strength, and it was significantly greater ($p=0.047$) than RelyX Ultimate (7.4 ± 2.0 MPa). However, RelyX Unicem 2 was not significantly different ($p=0.299$) from RelyX Universal (9.1 ± 3.7 MPa). The results of the unpaired t-tests found that both RelyX Universal and RelyX Ultimate had significantly greater shear bond strength with the use of the bonding agent compared to no bonding agent ($p<0.001$). Although RelyX Unicem 2 had greater bond strength with the use of a bonding agent (13.5 ± 7.1 MPa), the difference was not significant ($p=0.545$) compared to no bonding agent (11.8 ± 6.2 MPa). See Figure 1.

The adhesively bonded RelyX Universal specimens had the greatest percentage of mixed and cohesive fractures (66.6%), followed by RelyX Unicem 2 (50%) and RelyX Ultimate (16.7%). The fracture mode of all three cements without the use of a bonding agent was entirely adhesive (100%). See Figure 2. With the use of a bonding agent, there were significant differences in failure modes between RelyX Universal and all other groups except RelyX Unicem 2 ($p < 0.033$). Without the use of a bonding agent, there was no significant differences between the cements ($p>0.514$).

Discussion

The first null hypothesis was rejected, a significant difference in shear bond strength to dentin was found between the three cements per cementation mode. RelyX Universal had the greatest shear bond strength when using the adhesive bonding agent, but it was not significantly different from the adhesive resin cement, RelyX Ultimate. However, the majority of the specimens from RelyX Universal demonstrated mixed or cohesive fractures compared to RelyX Ultimate, which primarily had adhesive fractures. Mixed or cohesive type failures have been associated with greater adhesion (12). When evaluating RelyX Universal cement in a self-adhesive mode, it was found to have statistically similar shear bond strength to RelyX Unicem 2, a cement specifically marketed as a self-adhesive resin cement. However, both RelyX Universal and RelyX Unicem 2 without a bonding agent exhibited only adhesive failures.

The second null hypothesis was also rejected, differences were found with or without the use of an adhesive bonding agent with both RelyX Universal and Ultimate. Interestingly, even though the shear bond strength of RelyX Unicem 2 with a bonding agent was not statistical different without the use of a bonding agent, RelyX Unicem 2 with a bonding agent had a higher amount of mixed fracture modes, alluding to a potential better adhesion to dentin. As expected, utilizing an adhesive resin cement (RelyX Ultimate) without an adhesive bonding agent resulted in significantly reduced shear bond strengths to dentin.

Fernandes et al (2015) demonstrated that the microtensile bond strength of RelyX Unicem to dentin was significantly increased with the use of two-step etch & rinse adhesive (Single Bond 2, 3M ESPE, St. Paul, MN) (9). Meharry et al (2020), found that the addition of the primer only from a two-step self-adhesive bonding agent (ClearFil SE Protect, Kuraray, Tokyo, Japan) improved the bond strength of RelyX Unicem 2 to dentin compared to not using a primer. However, the authors did not thermocycle their specimens nor bond a glass ceramic to the substrate prior to shear bond strength testing as was done in this study (10). Similar to this study, Atalay et al. (2021) evaluated the shear bond strength of RelyX Universal to dentin with and without Scotchbond Universal bonding agent. The authors noted only a slight increase (8%) in the mean shear bond strength with use of Scotchbond Universal (11). In contrast, this study showed a significant increase (141%) in shear bond strength with the use of the same bonding agent and the novel cement. However, a glass ceramic (IPS e.max CAD) was bonded to the dentin using the resin cements under a 100gm load in this study, potentially providing a more clinically relevant cementation procedure than simply applying the cement passively to the dentin surface.

The performance of RelyX Universal Cement was similar to an adhesive cement with a bonding agent (RelyX Ultimate) and to a self-adhesive cement (RelyX Unicem 2) without a bonding agent. This implies that RelyX Universal cement can be used in both a self-adhesive and adhesive mode depending on the clinical application and could be used to reduce the dental clinic's armamentarium. Limitations to this study include the use of a single manufacturer for the tested materials and the potential for changes in bond strength with different substrates or bonding adhesives. More studies are required to evaluate the novel RelyX Universal Cement in all of its marketed applications.

Conclusions

The novel universal resin cement (RelyX Universal) had similar bond strengths to dentin as the adhesive cement (RelyX Ultimate) with the use of a bonding agent, and similar bond strengths to dentin as the self-adhesive cement (RelyX Unicem 2) without the use of a bonding agent, suggesting it may be used as both a self-adhesive or as an adhesive resin cement, depending on the clinical situation.

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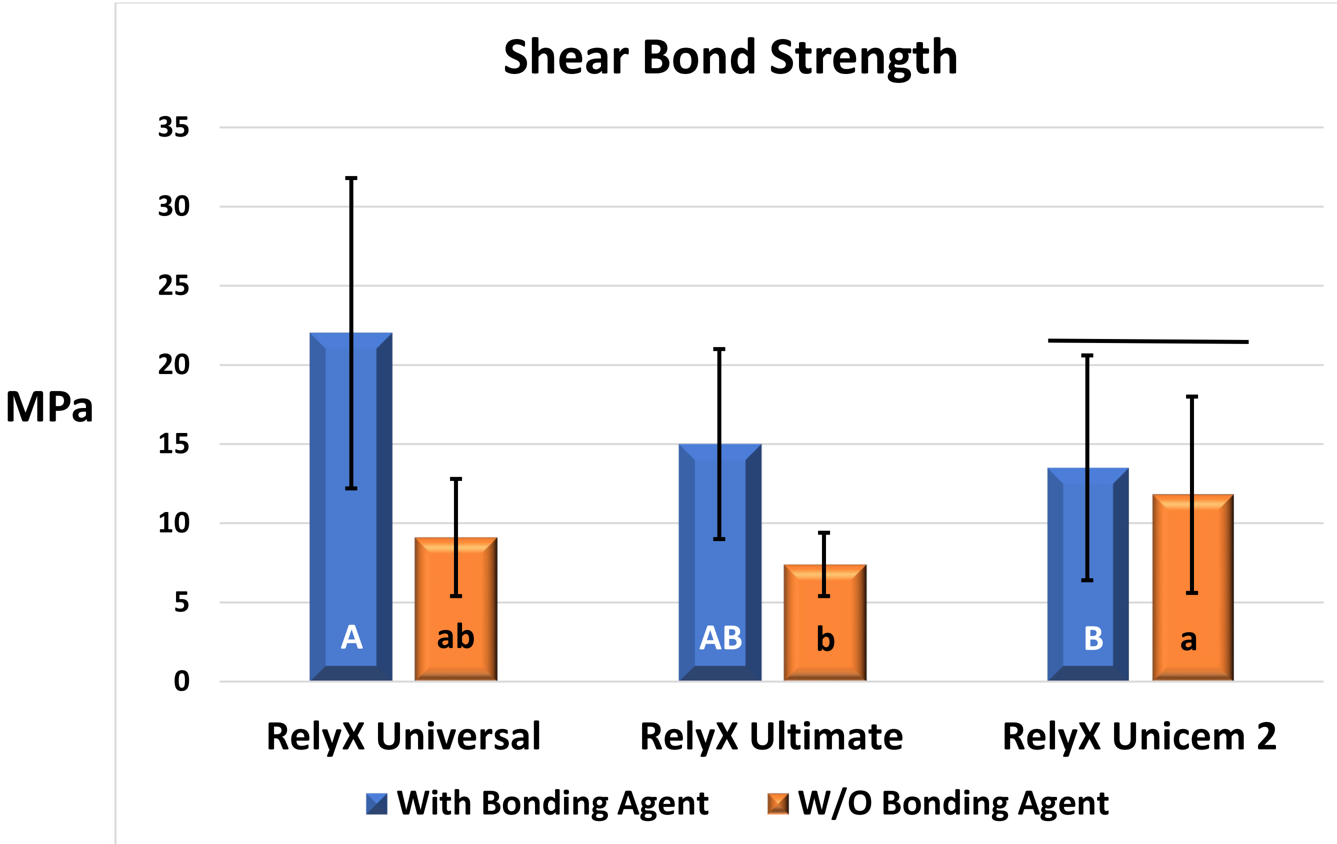

Figure 1: Mean shear bond strength and standard deviation of the three cement types with and without a bonding agent. Groups with the same uppercase or lowercase letters per cementation mode, or with a horizontal bar per cement type are not significantly different ($p>0.05$).

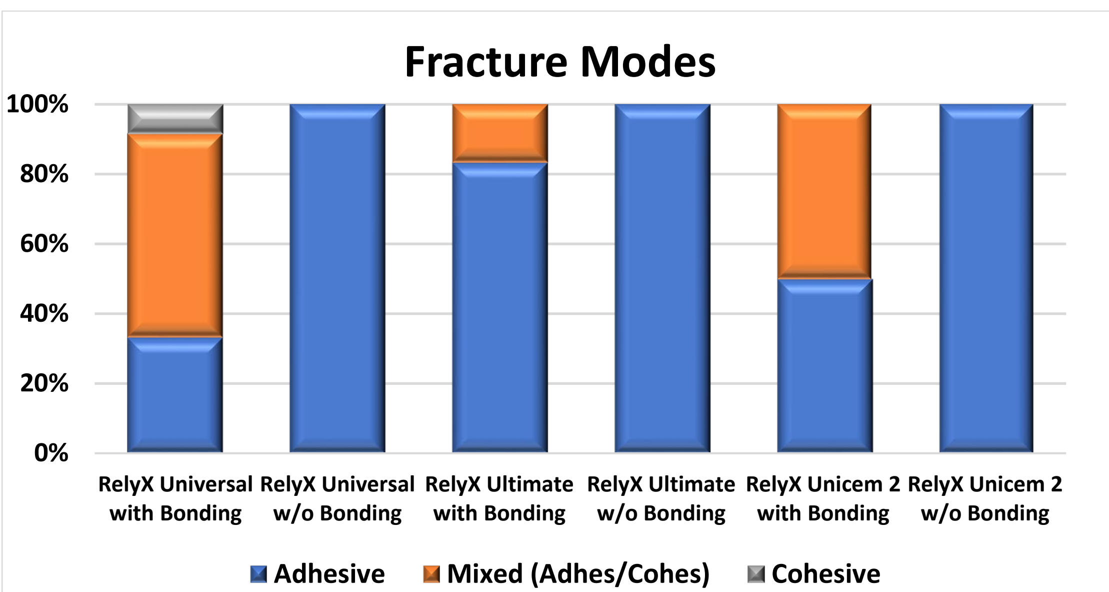

Figure 2: Fracture modes of the various groups