Alternative Pretreatment Modalities with a Self-Adhesive System to Promote Dentin/Alloy Shear Bond Strength

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Abstract

Purpose: The aim of this study was to evaluate alternative pretreatment modalities to enhance the dentin/alloy shear bond strength using a self-etch adhesive system.
Material and Methods: Ninety discs were fabricated and divided into three groups ($n = 30$). The discs of the first group were cast in gold palladium (Au-Pd); those of the second group were cast in palladium silver alloy (Pd-Ag); the discs of third group were cast in nickel chromium alloy (Ni-Cr). Each group was further divided into three subgroups ($n = 10$) according to the dentin pretreatment used to lute the discs. Subgroup U (no pre-treatment): Rely X Unicem resin cement. Subgroup GU: G-Bond then Rely X Unicem. Subgroup ZU: Zinc-Zeolite pretreatment then Rely X Unicem. Shear bond strength was determined using a compressive mode of force applied at the dentin/alloy interface using a monobevelled chisel-shaped metallic rod. Data were collected and statistically analyzed to assess the effect of alloy type, pretreatment modality, and their interactions on the shear bond strength. Scanning electron microscopic examination (1000×) at the dentin/resin interface was performed. Two-way ANOVA was used in testing significance for the effect of pretreatment, alloy, and their interaction. Duncan's post hoc test was used for pairwise comparison between the means when the ANOVA test was significant. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with SPSS 15.0®.
Results: Regarding the pretreatment modality, the mean shear bond strength and 95% CI of subgroups ZU (18.00 MPa; 16.8 to 19.2) and GU (16.91 MPa; 15.4 to 18.4) were significantly higher than subgroup U (12.81 MPa; 11.4 to 14.2). Regarding the alloy type, the mean shear bond strength and 95% CI of Ni-Cr groups (18.39 MPa; 16.9 to 19.9) were significantly higher than Au-Pd (15.33 MPa; 13.8 to 16.8) and Pd-Ag (13.99 MPa; 12.3 to 15.7).
Conclusions: Pretreatment of dentin with G-Bond and Zinc Zeolite improved the dentin/alloy shear bond strength. Base metal alloys provided superior bond strength values with any adhesive modality compared to noble alloys. Treatment of the dentin surface prior to the application of a self-adhesive system is of great importance to enhancement of the dentin/alloy bond strength.

The metal–ceramic restoration is widely used in prosthetic dentistry for construction of indirect restorations to restore the function and esthetics of the natural tooth. It combines the natural shade of porcelain with the durability, strength, and marginal fit of metal casting.[1] Indirect restorations include inlays, onlays, cast dowels, crowns, and fixed partial dentures (FPDs). Metal–ceramic alloys are classified into three categories: high noble, noble, and predominantly base metals. High noble, such as gold palladium (Au-Pd), and noble alloys, such as palladium silver (Pd-Ag) are selected in fixed prosthodontics due to their high corrosion resistance and high density, and resulting better marginal integrity. On the other hand, base metal alloys, such as nickel chromium (Ni-Cr) alloys, are relatively inexpensive compared with the former alloys. They therefore remain popular despite the known allergenic potential of nickel; however, despite their high hardness, elastic modulus, and superior sag resistance at elevated temperatures, base metal alloys are more difficult to cast and pre-solder than noble alloys.[2–6]

Dental luting cements form the link between the fixed restoration and the supporting tooth structure. Mechanical interlocking and chemical bonding are desirable factors in their fixation mechanisms and are critical for achieving suitable retention for indirect restorations.[7] Moreover, luting cements play a pivotal role in sealing margins and overcoming preparation design errors.

One of the most important changes in materials relating to retention of crowns and fixed prostheses has been the introduction and widespread use of adhesive resin cements.[8,9] Contemporary dentin adhesives rely on two major bonding approaches. The first uses the total-etching technique to simultaneously remove the smear layers from both enamel and dentin surfaces followed by the application of a one-bottle agent that combines the primer and the adhesive in one solution. The second approach is the use of self-etching primers. Their bonding mechanism is based upon the simultaneous etching and priming of the smear-covered dentin using an acidic primer followed by the application of an adhesive resin. Self-etching primers eliminate the separate acid-etching and rinsing steps, simplifying bonding technique and reducing its technique sensitivity. All-in-one adhesive systems have recently been introduced to simplify the bonding procedures even more. These are also named self-etching adhesives and combine etching, priming, and bonding procedures in one step.[10]

The unique resin cement product Rely X Unicem self-adhesive universal resin cement (3M ESPE, Seefeld, Germany) has been recently introduced. The manufacturer advocates no pretreatment of tooth structure, thus simplifying the cementation procedure, making the use of strong resin cement very easy and predictable. This cement is essentially a filled, self-etching primer that provides the physical properties of resin cement without the threat of postoperative tooth sensitivity. The objective in developing this cement was to combine the ease of handling offered by glass-ionomer cements with the favorable mechanical properties and good adhesion of resin cements. The adhesive properties are claimed to be based upon acidic monomers that de-mineralize and infiltrate the tooth substrate, resulting in micromechanical retention. Secondary reactions have been suggested to provide chemical adhesion to hydroxyl-apatite, a feature currently only proven for glass-ionomers.[11-13] A new self-etching adhesive system, G-bond (GC, Tokyo, Japan), has been developed and marketed to produce a very thin (0.3 μm or less) layer, which is regarded as a chemical reacted layer when applied to dentin.[14-16]

The choice of alloy may also affect retention of the cemented indirect restorations. Although many comparative studies exist showing metal bonding of various types of resin composite material used for resin-retained FPDs, limited information is available concerning the retentive strength of noble and base metal alloys cemented with different cements.[17]

In an effort to enhance the bond strength of adhesive luting materials to dentin, a suggested method employing dentin surface treatment with mineralizing solution is believed to be effective. The technique proved successful in increasing the bond strength of dentin to polycarborylate cement and composite resins.[18-20] Moreover, with the use of a suitable mineralizing solution, the performance of an adhesive primer was improved. Based on the earlier work with the use of different mineralizing solutions to dentin, it is suggested to chemically modify the dentin surface aiming to improve the resin/dentin bond. Zeolites are a popular group of minerals typically found in the voids of volcano rocks and are formed as a result of low-grade metamorphic changes. The name "Zeolite" comes from the Greek words zeo (to boil) and lithos (stone). They are formed of a crystalline aluminosilicate framework consisting of interlocking SiO_2 and AlO_4. This aluminosilicate structure is negatively charged and attracts the positive cations residing within.

Unlike most other silicates, Zeolites have large vacant cages in their structure, allowing spaces for relatively large molecules and cation groups such as water. Zeolites are characterized by their ability to lose and absorb water without damage to their crystalline structure in addition to possessing antimicrobial properties. Zeolite acts as a molecular sieve, as it has selective adsorption properties. A representative empirical formula of a Zeolite is: $M_{2/n}O\ Al_2O_3\ xSiO_2\ yH_2O$, where M represents the exchangeable cation of valency n. M is generally a group I or II ion, to balance the negative charge created by the presence of Al in the structure. Zinc was added to Zeolite to attain the advantages of being a divalent cation in addition to acting as a scavenger.[21-25] Through this technique, a surface layer of minerals that may play a role in improving the bonding qualities to dentin will be created. Even though resin cements combined with adhesive systems have been recommended for cementation of indirect restorations, the purpose of this study was to assess the efficacy of two dentin pretreatment modalities with a self-adhesive luting system in improving dentin/alloy shear bond strength.

Materials and methods

Disc preparation

Ninety metallic disc specimens were fabricated and classified into three groups (n = 30). Group one representing an Au-Pd alloy (Deva 4, Degussa, Hanau, Germany), group two representing a Pd-Ag alloy (Pors-on 4, Degussa), group three representing an Ni-Cr alloy (Viron 99, Bego, Bremen, Germany). For the purpose of standardization, wax patterns (Kerr, Orange, CA) of the discs were fabricated using a specially constructed split copper mold (2-mm thick, 5-mm internal diameter). The wax patterns of the discs were sprued and invested using phosphate-bonded investment (Deguvest, Degussa and Bellavest, Bego). Burn-out, casting, and divesting procedures for each type of alloy were performed according to the manufacturer's instructions. Surfaces of the discs were subjected to 50 μm aluminium oxide blasting for 15 seconds, bar pressure 60 psi, at a standardized distance of 1 cm from the blasting nozzle of the sandblasting machine (Bego). Finally the specimens were ultrasonically cleaned in distilled water for 10 minutes (Jelcraft, Jelenko, Armonk, NY), then air dried.

Preparation of dentin specimens

Ninety mandibular molars were collected. The teeth were prepared by sectioning the crown perpendicular to the long axis of the tooth using a low-speed diamond disc under water coolant to remove occlusal enamel and expose a flat dentinal surface.

The teeth were then embedded in self-cured acrylic resin using a cylindrical Teflon mold such that the long axis of the tooth was perpendicular to the surface of the mold. The dentinal surfaces were abraded with 360-grit silicon carbide paper under running water to create a flat, uniform, smooth dentinal surface.[14,15] The bonding procedure was performed immediately.

Cementation of the alloy specimens to the dentin specimens

Each group of alloys was divided into three subgroups.

Subgroup U – Rely X Unicem

The self-adhesive approach was employed using Rely X Unicem resin cement (3M ESPE) according to the manufacturer's instructions for luting the discs. The resin capsules were activated for 10 seconds (Rotomix, 3M ESPE), applied to the disc surface, and then seated on the dentin surface. Excess cement was removed, followed by light curing for 20 seconds.

Subgroup GU – G-Bond prior to Rely X Unicem

An application of G-bond (GC Corporation, Tokyo, Japan) on untreated dentin preceded the use of Rely X Unicem resin cement for luting the discs. G-Bond is composed of 4-MET (methacryloyloxyethyl Trimellitate), phosphoric ester monomer, UDMA, acetone, and camphorquinone. It was applied to the dried dentin surface, and left undisturbed for 10 seconds before drying under maximum air pressure for 5 seconds. It was then light cured for 10 seconds, according to the manufacturer's instructions.

Subgroup ZU – Zinc-Zeolite prior to Rely X Unicem

Colloidal solution of Zinc Zeolite: Zeolite is a crystalline aluminosilicate with fully cross-linked open framework structures made of corner-sharing SiO_2 and AlO_4 tetrahedron. It acts as a molecular sieve, as it has selective adsorption properties.

Preparation of Zinc Zeolite salt: Zinc Zeolite salt was prepared by adding the zinc nitrate salt to Zeolite[24] powder. A standardized amount of Zeolite mixture (7 g) was added to 50 ml distilled water, and then the mixture was put in a stirrer for 1 hour to allow the reaction between the zinc salt and Zeolite powder. The mixture was removed from the stirrer and filtered using a filter paper under continuous washing with tap water to remove any impurities. The Zinc Zeolite was removed from the filter paper and put in the glass beaker. Again, distilled water was added. The mixture was shaken well and left for 10 minutes until the excess powder was precipitated, leaving the colloidal solution above the precipitate.

The chemically prepared Zeolite liquid was applied once, using a brush to the dentin surface in one direction and left for 30 seconds, and then gently air dried to allow evaporation of water, leaving the dentin surface moist. Rely X Unicem resin cement was applied to the disc and seated on the treated dentin surface.

Rely X Unicem resin cement was applied to the metal disc and seated on the pretreated dentin surface. A standardized static load of 2 kg was applied with a specially fabricated stainless steel loading device. The cementing device is formed of two shelves connected by four metal arms. On the lower shelf, the specimen is placed to receive the load from above. The upper shelf has a central hole through which a metallic cylinder protrudes downward to be centered on the specimen. This centralized metallic cylinder has a spring coil placed between the upper shelf and a metal ring acting as a load carrier. A 2 kg load was placed on top of the metal ring. In turn, the load compresses the coil, causing the centered cylindrical metal bar to go downward, pressing on the specimen producing the static load required during cementation. The excess cement was removed while loading was maintained for 15 minutes. The cemented specimens were stored in water at 37°C in an incubator (Torre, Picenardi, Italy) for 24 hours.

Shear bond strength testing procedure

The specimens were individually mounted on a computer-controlled material testing machine (Model LRX-plus, Lloyd Instruments Ltd, Farefam, UK) with a load cell of 5 KN, and data were recorded using computer software (Nexygen-MT, Lloyd Instruments). Each specimen was secured to the lower fixed compartment of the testing machine by tightening screws. Shear bond strength was determined by compressive mode of force applied at the dentin/alloy interface using a monobevelled chisel-shaped metallic rod attached to the upper moveable compartment of the testing machine traveling at a crosshead speed of 0.5 mm/min. The load required to cause debonding was recorded in N. The load at failure was divided by bonding area to express the bond strength in MPa. The load-deflection curves were recorded using computer software (Nexygen-MT).

Scanning electron microscopic examination at dentin/resin interface

Six molars were collected, and their surfaces were prepared as mentioned above to expose the dentin surface for morphologic evaluation of the dentin/resin interfaces by SEM (Jeol, XL, Phillips, Eindhoven, The Netherlands). Two teeth were selected to represent each subgroup with its above-mentioned protocol of adhesive application to the dentin surface but without the alloy specimens. A split Teflon mold was used (with a central hole of 3-mm diameter and 2-mm depth) for resin cement application. Representative specimens (two teeth) from each of the three subgroups were sectioned longitudinally through the dentin/resin interface perpendicular to the bonded surface of each tooth, using a low-speed rotary cutting machine under copious water coolant. After the surfaces were polished with Sof-Lex polishing discs (3M ESPE), they were immersed in 6 mol/l hydrochloric acid (HCl) for 30 seconds to demineralize any minerals within the hybrid layer. This was followed by rinsing the specimens with water for 1 minute. The specimens were then immersed in 1% sodium hypochlorite (NaOCl) for 10 minutes to dissolve all exposed collagen beneath the hybrid layer, followed by thorough rinsing with water for 5 minutes. The specimens were dehydrated in ascending concentration of alcohol, subjected to critical point drying, and gold sputtered. The hybrid layer and the resin tags at the dentin/resin interfaces of these specimens were observed with SEM at magnification 1000×.

Table 1 Means and standard deviations of the shear bond strength values (MPa) for the different dentin pretreatments (n = 10 for each subgroup of alloy used)

Alloy (group)	Treatment (subgroup)	Mean	SD
Ni-Cr	U	15.50	±1.58
	GU	19.78	±2.05
	ZU	19.90	±2.07
Pd-Ag	U	10.42	±1.43
	GU	15.24	±1.64
	ZU	16.30	±1.56
Au-Pd	U	12.50	±1.58
	GU	15.70	±1.58
	ZU	17.80	±1.58

Statistical analysis

The distribution of shear bond strength was explored for normality using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The assumption of normality was rejected if a p-value less than 0.05 was observed. A 2-way ANOVA model was used in testing significance for the two main effects, dentin pretreatment and alloy, and their interaction. When the F-test for a main effect was significant, Duncan's post hoc test was used for pairwise comparison between the means. All calculated p-values were 2-sided and p-values less than 0.05 were considered statistically significant. Statistical analysis was performed with SPSS 14.0® (Statistical Package for Scientific Studies, Chicago, IL) for Windows.

Results

The mean shear bond strength ranged from 10.42 MPa for Pd-Ag alloy with pretreatment U to 19.90 MPa for Ni-Cr alloy with pre-treatment ZU (Table 1). Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, and no significant departures from normality were observed (all p-values >0.20 and >0.63, respectively). The results of the 2-way ANOVA model to assess the effect of alloy and pretreatment on shear bond strength showed that the regression model fit well to describe the relationship between the studied variables, with an overall model R2 of 0.79. There was no evidence to suggest a significant interaction effect between pretreatment and type of alloy ($p = 0.63$); however, both main effects (pretreatment, type of alloy) were statistically significant ($p < 0.001$). There was no statistically significant difference between the mean shear bond strength of subgroups ZU and GU (Table 2); however, both subgroups had significantly higher mean bond strengths than subgroup U. Ni-Cr alloy had the significantly highest mean shear bond strength, followed by Au-Pd alloy, while Pd-Ag (P) alloy showed the significantly lowest mean (Table 3).

The lack-of-fit test revealed $p = 0.664$, which means that the model adequately fits to describe the relationship between dependent and independent variables. Residual plots (Observed*Predicted*standardized residuals) for the dependent variable were produced. The points representing the residuals lie close to a line, indicating a normal probability plot of the residuals.

The SEM micrograph of the dentin/resin interface of self-etch adhesive (U) presented in Figure 1 reveals a gap-free attachment. Well-formed resin tags were in the hybrid layer, with long, thick resin tags forming a bundled appearance, resulting from resin penetration into the dentinal tubules. A gap-free attachment between the adhesive resin and the dentin was evident. Zeolite pretreatment to dentin prior to application of a self-etch adhesive system (ZU) presented in Figure 2 resulted in increased resin tag formation in a bundled appearance. The tags are connected with a resin-infiltrated dentin surface. Resinous branches with long, thick coagulated patterns were evident. A stereomicroscope (SZ-PT, Olympus, Tokyo, Japan) with ×40 was used to examine the failure mode from the dentin side and from the alloy side, and the failure was adhesive–cohesive for all specimens. The remnants of cement either on the dentin side or on the alloy side varied in each subgroup and with each alloy. More cement remnants were evident when the dentin was pretreated as in subgroups GU and ZU, which coincided with the obtained high shear bond strength compared to the untreated dentin in subgroup U. Regarding the failure mode on the alloy

Table 2 Comparison between the means and 95% CI for the shear bond strength values (MPa) of the different pretreatments

Zeolite/Unicem ZU		Control (Unicem) U		G Bond/Unicem GU			
Mean (MPa)	95% CI	Mean (MPa)	95% CI	Mean (MPa)	95% CI	f-Value	p-Value
18.00[a]	16.8–19.2	12.81[b]	11.4–14.2	16.91[a]	15.4–18.4	39.434	<0.001*

Significant at $p \leq 0.05$, Different letters indicate statistically significant differences according to Duncan's test.

Table 3 Comparison between the means and 95% CI for the shear bond strength values (MPa) of the different alloys

Ni-Cr		Pd-Ag		Au-Pd			
Mean (MPa)	95% CI	Mean (MPa)	95% CI	Mean (MPa)	95% CI	f-Value	p-Value
18.39[a]	16.9–19.9	13.99[c]	12.3–15.7	15.33[b]	13.8–16.8	26.826	<0.001*

Significant at $p \leq 0.05$, different letters indicate statistically significant differences according to Duncan's test.

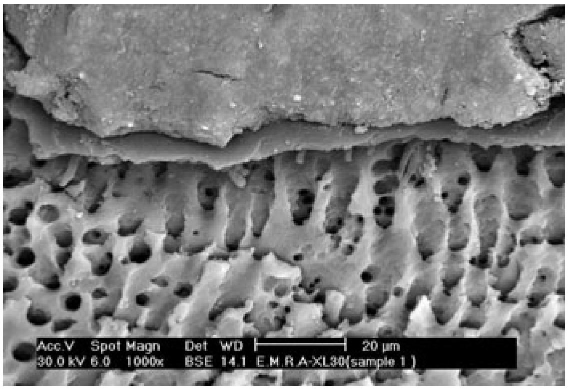

Figure 1 SEM photomicrograph (×1000) of dentin/resin interface of subgroup U.

side, adhesive–cohesive failure was obtained with more remnants of cement covering the Ni-Cr alloy specimens compared to the Au-Pd and Pd-Ag alloys.

Discussion

Current dentin adhesives employ two means to achieve the goal of micromechanical retention between resin and dentin.[26-28] The first method, the total-etch or etch-and-rinse technique, attempts to remove the smear layer completely via acid-etching and rinsing. The second approach, the self-etch technique, aims at incorporating the smear layer as a bonding substrate. The efficiency of bonding to dentin depends on the demineralizing potential of the etchant or the acidic primer, which depends on the dissociation coefficient (pKa), application duration, pH, wettability, viscosity, and concentration of water of the etchant or the acidic monomer.[29] The bond strength of the etch-and-rinse dentin adhesive was calculated as the sum of the strengths of resin tags, surface adhesion, and hybrid layer.[30] These factors are also calculated for the self-etch adhesives in addition to the chemical bond that might occur at various extents, depending on the monomer systems used. Furthermore, other factors, such as solvent concentration,[31] adhesive conversion,[32] and cohesive strength of the adhesive,[33] affect the bond strength.

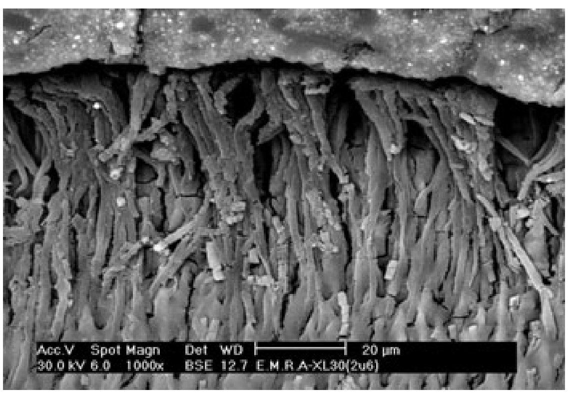

Figure 2 SEM photomicrograph (×1000) of dentin/resin interface of subgroup ZU.

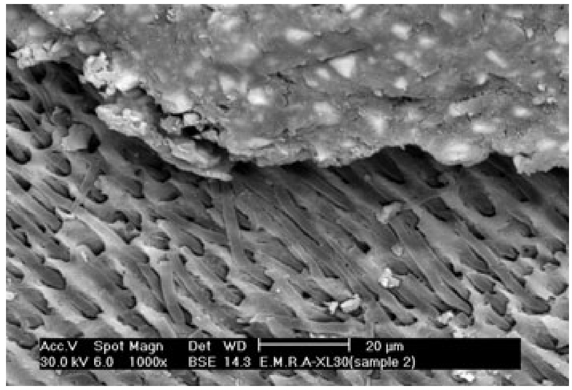

Figure 3 SEM photomicrograph (×1000) of dentin/resin interface of subgroup GU.

The low shear values of subgroup U (Table 2) may be related to the mechanism of bonding of Rely X Unicem to dentin. The formulation of Rely X Unicem contains specific multifunctional phosphoric acid methacrylates, which are supposed to interact with the tooth surface in multiple ways, as by forming complex compounds with calcium ions by different kinds of physical interactions like hydrogen bonding or dipole-to-dipole interactions.[34]

De Munk et al[35] rejected the hypothesis that the bonding mechanism of Rely X Unicem to dentin is similar to that obtained with a self-etch adhesive. Their study demonstrated that no distinct demineralization and hybridization was observed as commonly seen with self-etch adhesives. The transmission electron microscopic images of other studies[36,37] indicated that there was no hybrid layer comparable to total-etch adhesives. Previous studies coincide with the results of the SEM in Figure 3. G-Bond used in the current study is a new generation of "one-bottle-one-step" HEMA-free adhesive systems. Some authors suggest that an extremely thin (300 nm or less) interface is formed, and that in this area, functional monomers (phosphoric ester monomer) bond immediately with hydroxyapatite at the "nano" level, to form insoluble calcium salts with different dissolution rates.[38] The dissolution rate might be important in preventing loss of calcium from the matrix over time.[39] According to the adhesion-decalcification concept, the less soluble the calcium salt of an acidic molecule, the more intense and stable the molecular adhesion to a hydroxyapatite-based substrate.[40,41] Therefore, the interface formed by G-bond is expected to be stronger and more durable than that formed by other bonding materials. It would appear appropriate to call the interface exhibiting this property a Nano Interaction Zone (NIZ), or a chemically reacted layer at the "nano" level, as opposed to the traditional hybrid layer appellation.[38,39,42]

Contradictory findings were demonstrated by Spreafico et al,[43] who reported that because G-Bond contains acetone as a solvent (HEMA free), the evaporation of the acetone in G-Bond could result in phase separation of the components with subsequent blister formation. It was recommended in the manipulation protocol of G-bond that strong air blowing is to be performed for 5 seconds, thus preventing pooling of adhesive on the substrate surface. Consequently, it was revealed in our study that G-Bond application with strict adherence to the manufacturer's instructions prior to application of Rely X Unicem resulted in significantly higher shear values for all tested alloys compared to subgroup U without dentin pretreatment. G-Bond application prior to cementation with Rely X Unicem significantly improved the shear bond strength. This may be attributed to the synergistic effect obtained with the presence of the acidic monomer of G-Bond plus the phosphoric acid monomer of Rely X Unicem, thus having the potential to diffuse through the dentin surface and partially demineralize the smear layer, increasing the surface energy and improving wettability. This might have created enough porosity for effective resin retention. In addition, possible chemical reaction may thus have taken place between the functional monomer (phosphoric-ester monomer of G-Bond) and the calcium available in dentin of the prepared tooth, serving as a receptor for strong ionic bond formation.[36] Therefore, a twofold mechanism (micromechanical and chemical) contributed to the significantly increased shear bond values when G-Bond was applied prior to cementation with Rely X Unicem. It was noticed in subgroup GU that the hybridization and resin infiltration was enhanced by G-Bond application (Fig 3). G-Bond is considered a mild self-etch adhesive (pH $\sim$ 2), which dissolves the dentin surface only partially with resin infiltration and hybrid layer formation. Within such submicron hybrid layers, collagen fibrils are not completely deprived from hydroxyapatite. This residual hydroxyapatite served as a receptor for additional intermolecular interaction with the phosphate group of the functional monomer. This twofold mechanism was advantageous in terms of high shear bond strength.[44]

Interestingly, Zinc Zeolite dentin pretreatment resulted in a significant increase in the shear bond strength values with the self-etch adhesive approach (ZU). These results may be attributed to the strong adsorption of the Zeolite onto the dentin surface, which in turn increased the wettability of the surface to absorb the bonding resin component. These components subsequently entered the Zeolite sieve, thus, ion exchange between them and the dentin substrate might have taken place. SEM (Fig 2) confirmed this finding, where the Zeolite penetration and reaction with the interface could be seen resulting in increased resin tag formation in a bundled appearance. They are connected with a resin-infiltrated dentin surface. Resinous branches with long, thick, coagulated patterns were evident.

The use of the two bond-enhancing agents (G-Bond, Zinc-Zeolite) resulted in shear bond strength increases of less than 50% as compared to the control group. It is possible that if a different self-adhesive resin cement was used, much higher values would be obtained. Also, if a conventional resin cement that uses an etch-and-rinse step to condition dentin was used, bond strength values would likely be much higher. De Munk et al[35] and Frankenberger et al[16] reported that etch-and-rinse adhesives remain the gold standard in terms of adhesion durability; however, Hikita et al[12] and Ibarra et al[13] reported that following a correct application procedure, the etch-and-rinse, self-etch, and self-adhesive luting agents are equally effective in bonding to enamel and dentin. A comparison of contemporary adhesives is recommended to be further studied and compared with the results of the present study to eliminate the limitations within this work.

It was obvious in the proposed study that Ni-Cr alloys, cemented with any of the tested adhesive luting modality, recorded significantly higher shear values than the Au-Pd and Pd-Ag alloys (Table 3). This was attributed to the chromium oxide that is always present on base metal alloys (Ni 65%, Cr 22.5%). This oxide layer plays an important role in the wettability and formation of chemical bond with adhesive resin cements, whereas the Pd-Ag alloy used in the study contained tin (Sn) 6% and indium (In) 4%; for Au-Pd alloy, the In content was 9%. These elements responsible for the chemical bond with the adhesive resin cements formed less surface oxides than Ni-Cr alloys. These results coincide with the results of previous investigators.[17,45,46] The results of this study indicated the effectiveness and versatility of G-Bond application and Zinc Zeolite pretreatment prior to cementation with a self-adhesive resin cement system in improving the dentin/alloy shear bond strength. Bond strength tests are the most frequently used tests to screen adhesives. As the forces exerted clinically on restorations or teeth are complex in nature, neither tensile nor shear bond strength tests simulate the intraoral forces sufficiently well; however, bond strength tests may still provide useful information on procedural changes, even though the bond strength values themselves may have little meaning.[15] Although the present in vitro investigation was made to closely simulate the clinical situation, a clinical trial remains the final instrument to definitively answer the question regarding the appropriate adhesive luting modality in cementing indirect cast restorations.

Conclusions

Pretreatment of dentin with G-Bond and Zinc Zeolite improved the dentin/alloy shear bond strength. Base metal alloys provided superior bond with any adhesive modality compared to noble alloys.

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