Original Article

Bond Strength of Resin Cements to Noble and Base Metal Alloys with Different Surface Treatments

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Abstract

Objectives: The bond strength of resin cements to metal alloys depends on the type of the metal, conditioning methods and the adhesive resins used. The purpose of this study was to evaluate the bond strength of resin cements to base and noble metal alloys after sand blasting or application of silano-pen.

Materials and Method: Cylinders of light cured Z 250 composite were cemented to "Degubond 4" (Au Pd) and "Verabond" (Ni Cr) alloys by either RelyX Unicem or Panavia F2, after sandblasting or treating the alloys with Silano-Pen. The shear bond strengths were evaluated. Data were analyzed by three-way ANOVA and t tests at a significance level of P<0.05.

Results: When the alloys were treated by Silano-Pen, RelyX Unicem showed a higher bond strength for Degubond 4 (P=0.021) and Verabond (P< 0.001). No significant difference was observed in the bond strength of Panavia F2 to the alloys after either of surface treatments, Degubond 4 (P=0.291) and Verabond (P=0.899).

Panavia F2 showed a higher bond strength to sandblasted Verabond compared to RelyX Unicem (P=0.003). The bond strength of RelyX Unicem was significantly higher to Silano-Pen treated Verabond (P=0.011). The bond strength of the cements to sandblasted Degubond 4 showed no significant difference (P=0.59). RelyX Unicem had a higher bond strength to Silano-Pen treated Degubond 4 (P=0.035).

Conclusion: The bond strength of resin cements to Verabond alloy was significantly higher than Degubond 4. RelyX Unicem had a higher bond strength to Silano-Pen treated alloys. Surface treatments of the alloys did not affect the bond strength of Panavia F2.

Key Words: Resin Cements; Silano-Pen; Sand Blast

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INTRODUCTION

Indirect restorations are used in a variety of clinical situations among which loss of tooth structure due to caries and trauma is of utmost importance [1]. Some of indirect restorations are fabricated using metal alloys.

The composition of alloys used in metal based indirect restorations varies.

Base metal and noble alloys are examples of the currently used alloys [2-6]. Base metals possess higher free surface energy compared to noble alloys resulting in thicker oxide layer formation and higher reactivity [2]. Reports indicate that enhancement of alloy nobility decreased the adhesive strength [7]. On the other hand, noble alloys have a number of advantages over base metal alloys including esthetics and the ability of bonding to ceramics and they are also less technique sensitive [8].
Adhesion of the cements to the intaglio surface of indirect restorations is imperative to durability of the restoration, particularly when there are difficulties during the restoration process due to shortness of the tooth and/or tapering caused by preparation [2]. Additionally, adhesion highly depends on the surface treatment of both the tooth and the indirect restoration and also the chemical composition of the cement [9].
Practically, adhesion can be reached via chemical reaction, luting or micromechanical retention [1]. In order to enhance bonding strength, various surface treatments are performed including i) sandblasting, ii) application of metal primers, iii) tin plating and iv) silicoating [3, 8]. Since the debris on the surface is removed during sandblasting, this technique improves adhesiveness and it is an inexpensive technique [2].
Studies have shown excellent bonding of resins to sandblasted base metals [10-12].
Since 1984 it has been possible to create a chemical bond between dental alloys and composite resins resembling the metallo-ceramic bond (silicoater), and since then some researchers have evaluated its performance[13-15]. The mechanism is to place an intermediate layer of silicon dioxide (SiO2) providing sufficient bonding to resin via silane application. The phenomenon introduces a durable and reasonably strong bond between resin and noble alloys as well as resin and base metals [15]. Silano-Pen is an easy to use and inexpensive device, basically designed on the silicoater technique [3,14-16]. In the past decade researchers have tried to improve the adhesion of resins to dental alloys.
Dual cure resin cements are polymerized via light or chemical reactions [1,17,18]. Combination of these two mechanisms makes it possible to provide resin luting materials for permanent cementation of indirect restorations fabricated by base metals. Moreover, these cements have high mechanical strengths compared to zinc phosphate and glass ionomer [19]. Studies have shown that a newer version of phosphate resins, RelyX Unicem (3M ESPE), can chemically interact with treated surfaces of metals and increase the retention of restorations [1,19, 20].
To achieve optimum bond strength of cements to indirect restorations, multiple factors should be considered.
Bond strength of alloys and cements are reported to vary depending on the type and composition of the alloy, surface treatment, type of cement and the testing methods [2, 16]. The aim of this study was to evaluate the effect of sandblasting or applying Silano-Pen on the bond strength of resin cements to base and noble metals.

MATERIALS AND METHODS

The composition of resin cements and metal alloys used in this study is summarized in Table 1.
Eighty discs, 6 mm in diameter and 2 mm in thickness from two different alloys of nickel chrome (Verabond; Alba Dent, USA) and gold palladium (Degubond 4; DeguDent GmbH, Germany) were prepared according to the manufacturers' instructions.
Consequently, the discs were mounted in self-cure acrylic (Acropars, Marlik, Tehran, Iran) to enhance the accuracy of preparing the samples. All the samples were polished by 600 grit silicon carbide abrasive paper.
Half of the samples were selected randomly from both alloys and sand-blasted with 50µ $Al_2 0_3$ under 3 bar pressure at the distance of 10

mm for 14 seconds, followed by cleaning with 96% isopropyl alcohol via ultrasonication.
Then they were air dried.
The remaining samples were sandblasted with 110µ AL203, then flamed (5sec/cm^2) with Silano-Pen device (Bredent GmbH Senden Germany) based on the manufacturer's instruction. After cooling down to room temperature, the Silano-Pen bonding agent was brushed on and air dried for 3 minutes.
Plastic tubes (3 mm inner diameter, 3 mm height) were filled with shade A3.5 of resin composite (FiltekZ 250, 3M ESPE) and covered with glass slide to achieve a uniform surface.
Then both sides of the composite were light cured for 40s using LED Bluephase 16i Ivoclar_Vivadent with minimum intensity of 600 mw/cm^2.
Afterwards, the composite cylinders were perpendicularly bonded to the pre-treated substrates with either Panavia F2 or RelyX adhesive resin cements. A primary curing was done and the excess marginal cement was removed. An oxygen blocking gel (Oxyguard) was applied for 3 minutes when Panavia F2 was used. Final curing was done along all four sides for 20 seconds for each side and the samples were kept at 37°C in distilled water for 24 hours.

Table 1. Compositions of Resin Cements and Metal Alloys

Material	Composition	Lot no	Manufacturer
Panavia F2.0	**Paste A**: MDP, hydrophobic aromatic dimethacrylates, hydrophobic aliphatic dimethacrylates, hydrophilic aliphatic dimethacrylates, silanated silica filler, silanated colloidal silica, dl-camphorquinone, initiators **Paste B**: Hydrophobic aromatic dimethacrylates, hydrophobic aliphatic dimethacrylates, hydrophilic aliphatic dimethacrylates, silanated barium glass filler, initiators, accelerators, pigments	61138	Kuraray (Japan)
RelyX Unicem	**Catalyst Paste:** Methacrylate monomers Alkaline (basic) fillers Silanated fillers Initiator components Stabilizers Pigments **Base paste:** Methacrylate monomers containing phosphoric acid groups Methacrylate monomers Silanated fillers Initiator components Stabilizers	240529	3M ESPE (Germany)
Verabond (casting alloy)	Ni 77.95%, Cr 12.60%, Mo 5.00 %, Al 2.90%, Co 0.45%, Be 1.95%		Alba Dent (USA)
Degubond 4 (casting alloy)	Au 49.60%, Pd 29.00 %, Ag 17.5%, Sn 3.00%, Ir 0.10 %, Ga 0.50, Ta 0.10%, Re 0.20%		Degu Dent (Germany)

The final products were subjected to 2000 thermal cycles in water baths (5-55°C) with 30 seconds dwell time and 10 seconds transfer time.

After drying at room temperature, all specimens were mounted in universal testing machine (Zwick/RoellZo 50) at a crosshead speed of 0.5 mm/min until failure occurred.

The diameter of bonding surface was measured in three different areas and the average was recorded.

The shear bond strength was calculated by dividing the failure load over the bonding area and was recorded as MPa. The mode of failure was studied via stereomicroscope (Nikon SMZ 800) with a magnification of 40 and identified as **i)** adhesive failure in the interface of metal-resin and **ii)** mixed failure (visible remnants of cements and/or composites on the metal surfaces). The data were analyzed by three-way ANOVA (α=0.05) followed by t tests. The primary error was corrected by Boneferroni method.

RESULTS

The bond strength of all groups is listed in Table 2.

The bonding strength of resin cements to Verabond alloy was significantly higher than Degubond 4, irrespective of surface treatment methods (P< 0.001).

When the alloys were treated by Silano-Pen, RelyX Unicem showed a higher bond strength to both alloys, Degubond 4 (P=0.021) and Verabond (P< 0.001).

On the other hand no significant difference was observed in the bond strength of Panavia F2 to both alloys, Degubond 4 (P=0.291) and Verabond (P=0.899), with either of the surface treatments.

When Verabond alloy was sandblasted, Panavia F2 showed a significantly higher bond strength compared to RelyX Unicem (P=0.003).

In case of surface treatment by Silano-Pen, the bonding strength of RelyX Unicem cement was significantly higher (P=0.011).

When Degubond 4 was sandblasted, the bond strength of both cements was the same (P=0.59).

On the other hand, when the surface was treated with Silano-Pen, RelyX Unicem cement had a higher bonding strength (P=0.035) compared to Panavia F2.

Table 2. Bond Strength of Resin Cements to Metal Alloys After Using Silano-Pen or Sandblasting

Alloy	Treatment	Cement	Mean ± SD (MPa)	P Value
Verabond	Sandblast	RelyX Unicem	13.06 ± 1.23[a]	0.003
		Panavia F2	18.66±4.92[b]	
	Silano-Pen	RelyX Unicem	22.88±3.36[c]	0.011
		Panavia F2	18.89±2.91[b]	
Degubond 4	Sandblast	RelyX Unicem	8.62 ± 2.15[d]	0.59
		Panavia F2	8.14±1.69[d]	
	Silano-Pen	RelyX Unicem	10.63±1.31[e]	0.035
		Panavia F2	8.97±1.89[d]	

Fig 1. Depicts the adhesive failure between the cement and alloy.

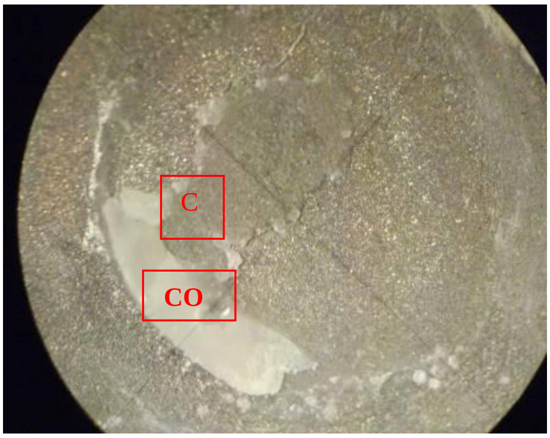

Fig 2. Mixed failure. C represents the cement and Co represents the composite.

Inspection of the failed surfaces by stereomicroscope revealed that the majority of failures in Verabond alloy were mixed. However, in Degubond 4 alloy the failure mode was both adhesive and mixed. (Figures 1 and 2)

DISCUSSION

Choosing a better combination of available cements and surface treatments to get a reliable bond of cements to metals is a main concern in dental research. In this study, it was observed that compared to Degubond 4, Verabond alloy had a stronger bond to both cements irrespective of surface treatment. It was concluded that the type of alloy is a determinant factor for bonding.

This conclusion is in agreement with various reports that have studied the role of alloys in alloy-resin bond strength [6, 21-23]. However, Abreu et al. have reported that the type of metal did not affect the bond strength of resin cements [2, 24]. The disagreement between the findings of this research with the study conducted by Abreu et al. may be due to the different alloys used [2, 24]. Base metals are oxidized rapidly at room temperature [6]

The oxides formed on the surface of the alloy play an important role in wettability, resulting in the formation of chemical bonds with resin cements [7, 23].

Stereomicroscopic images confirm this phenomenon, for example the mode of failure in Verabond group was dominantly mixed. Sandblasting causes complex morphological changes at the surface of metal along with accumulation of particular ions on its surface [25].

Additionally, mechanically removing debris can improve the wettability of cements [26, 27]. This procedure is relatively inexpensive and does not have the sensitivity of other alloy surface treatments [24].

Therefore, all the samples in this study were sandblasted prior to bonding. 50 µm aluminum oxide is reported to be the best sandblasting material that creates high mechanical bond strength [10, 28].

In the current study, Panavia F2 strongly bonded to sandblasted Verabond alloy (18 MPa). Various studies also have shown high bond strengths of Panavia cement to sandblasted base metal alloys [10-12].

Adhesives with acidic groups such as phosphoric acid, tiophosphoric acid or carboxylic acid can form bonds with oxides on the surface of metals.

Panavia F2 contains a phosphate monomer [10-Methacryloloxydecyl dihydrogen phosphate (MDP)] that is extremely effective for bonding to enamel, dentin and metal alloys.

Moreover, researchers believe that a covalent bond forms between adhesive and the remaining alumina deposited on the surface after sandblasting [29, 30].

Nowadays the use of self-adhesive cements has increased. These systems are made to combine the advantages of various available cements, facilitate luting and reduce the vulnerability of the material to probable mishandlings [31-33]. RelyX Unicem, a self- adhesive cement, is made of a monomer, filler and a novel initiator [34]. Based on the manufacturer's claim, the organic matrix is made of multipurpose phosphoric acid methacrylate.

Phosphoric acid methacrylates react with basic fillers in the luting cement and dental hydroxyapatite [34, 35]. That explains the satisfactory bonding (13 MPa) of sandblasted Verabond with RelyX Unicem cement. A lot of studies have evaluated the bond strength of resin cements [36-38].

However, the outcomes may vary due to the different metals used as well as preparation methods and the type of adhesives.

Another important factor would be the testing methods that differ from one study to the other. Therefore, comparison of the exact values may not reflect the reality [39]. Since the bond strength of enamel to resin systems is within the range of 13-20 MPa; therefore, bond strengths within this range are defined as amenable [38].

Durable bonding in clinic is defined to be within the range of 10 to 13 MPa [40]. In this respect, although the bond strength of RelyX Unicem to Verabond was stronger than Panavia F2, the range of both was within the acceptable clinical range of bonding strengths. Our study demonstrated that when sandblasted Degubond 4 was used, the bond strength did not depend on the cement type. This finding is in agreement with the study conducted by Piwowarczyk et al. [1].

The other type of surface treatment that was used in this study was silicoating with Silano-Pen.

The instrument is a chair side silicoater that can be used with a hand-held igniter [14, 15]. The preparation in this method is via flame. Ignition of the surface starts a reaction in which tetra etoxy silane is decomposed to organic Si (SiOx-C) and covers the surface. This layer has glass like qualities that can silanate with (3- Methacryloyloxy Propyl trimethoxy Silane (MPS). Simultaneously, Silane is capable of polymerizing with other acrylic and methacrylic functional groups and a strong bond can form [41].

This phenomenon explains the stronger bond formed when using Silano-Pen compared to sandblasted alloys, although this difference was not significant when using Panavia F2 cement. There is lack of available information regarding the nature of both Silano-Pen surface treatment and its impact on bond strength. Further studies are required to elucidate these phenomena. In addition, studies on the impact of fatigue and cyclic loads are required to understand the long-term durability of this technique.

CONCLUSION

The alloy, resin cement and the surface treatment were important factors in achieving a strong and durable bond. The bond strength of RelyX Unicem to both Verabond and Degubond 4 alloys treated by Silano-Pen was higher compared to sandblasting. As for Panavia F2, the bond strength did not depend on the surface treatment technique.

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