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Assessment of Tensile Bond Strength of Fiber-Reinforced Composite Resin to Enamel Using Two Types of Resin Cements and Three Surface Treatment Methods

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Abstract
Background: Resin-bonded bridgework with a metal framework is one of the most conservative ways to replace a tooth with intact abutments. Visibility of metal substructure and debonding are the complications of these bridgeworks. Today, with the introduction of fiber-reinforced composite resins, it is possible to overcome these complications. The aim of this study was to evaluate the bond strength of fiber-reinforced composite resin materials (FRC) to enamel. Methods: Seventy-two labial cross-sections were prepared from intact extracted teeth. Seventy-two rectangular samples of cured Vectris were prepared and their thickness was increased by adding Targis. The samples were divided into 3 groups for three different surface treatments: sandblasting, etching with 9% hydrofluoric acid, and roughening with a round tapered diamond bur. Each group was then divided into two subgroups for bonding to etched enamel by Enforce and Variolink II resin cements. Instron universal testing machine was used to apply a tensile force. The fracture force was recorded and the mode of failure was identified under a reflective microscope. Results: There were no significant differences in bond strength between the three surface treatment groups (P=0.53). The mean bond strength of Variolink II cement was greater than that of Enforce (P=0.04). There was no relationship between the failure modes (cohesive and adhesive) and the two cement types. There was some association between surface treatment and failure mode. There were adhesive failures in sandblasted and diamond-roughened groups and the cohesive failure was dominant in the etched group. Conclusion: It is recommended that restorations made of fiber-reinforced composite resin be cemented with VariolinkII and surface-treated by hydrofluoric acid.

Keywords: Tensile bond strength; surface treatment methods; fiber-reinforced composite resin

Introduction

Micromechanical bonding technique of composite resin to etched enamel has led to a widespread use of resin-bonded bridgeworks, with less preparation and tooth structure removal compared with conventional

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bridgeworks. The classic design of these bridgeworks consists of a metallic framework along with porcelain veneering in the pontic area. This bridgework is bonded to the lingual surfaces of abutments using composite resin and acid-etch technique. Bonding of composite resins to metallic surfaces is possible via various techniques. The major disadvantages of these bridgeworks are a decrease in esthetic properties due to the underlying metal framework, and debonding due to failure to achieve a proper bond between the metal and composite resin, resulting in less longevity compared with conventional bridgeworks (1).

Several studies have been carried out on these bridgeworks. Sheriff et al. evaluated the effect of resin cement and surface preparation of the alloy on the retention of resin-bonded bridgeworks (2). They evaluated the force required to debond the retainer fabricated of base metal alloys from the inner surfaces prepared by three different techniques (sandblasting, particle roughening, and electrochemical etching). They used four resin-bonding materials in their study because composite resins had a great role in the retention of these restorations; the materials included Panavia EX, Conclude, Microfill, and Comspan. They reported that sandblasting with 250µm aluminum oxide particles resulted in greater retention compared with two other surface preparation techniques. Regardless of the surface preparation, Panavia EX and Comspan significantly exhibited higher retention rates compared with two other materials (2). The results of their study were in contrast to those of studies by Dhillon et al. and Ferrari et al., in which electrochemical etching resulted in a stronger bond compared with sandblasting (3,4).

The effect of thermocycling on the bond and retention of resin-bonded bridgeworks has been evaluated in vitro as well. Saunders reported no significant differences in tensile bond strength between different designs subsequent to thermocycling (5). In addition, Brantley et al. reported that thermocycling had no effect on the tensile strength of porous infrastructures etched by electrolytic technique; however, bond strength was affected (6).

Latzel and colleagues compared fracture resistance of bridgeworks fabricated by using Targis-Vectris with IPS Empress II and IPS Empress. They reported that bridgeworks made of Targi-Vectris had the highest fracture resistance (7). In addition, Kolbeck et al. compared fracture resistance of bridgeworks fabricated by using Targis-Vectris with Connect/Belle Glass, and reported significantly higher fracture resistance in bridgeworks made of Targis-Vectris (8). Loose et al. carried out a similar study on two types of bridgeworks made of Targis-Vectris and Inceram aluminum oxide ceramic, and revealed the same results (9). In a clinical report, Cha et al. explained the technique by which resin-bonded bridgeworks were fabricated using the Inceram and Targis-Vectris systems (10).

The aim of the present study was to evaluate the tensile bond strength of fiber-reinforced composite resins (Targis-Vectris) to tooth enamel. In case the bond strength of these materials to tooth enamel is appropriate compared to that of metals, conventional materials (metal frameworks with porcelain veneering) can be replaced by these materials in order to fabricate the resin-bonded bridgeworks using Targis-Vectris (Vectris framework with Targis veneering).

Materials and methods

In this analytical in vitro study, 72 cross-sections were prepared from the labial surfaces of sound extracted central incisors, measuring 5×6×8 mm, using a diamond disk under running water. The samples were stored in normal saline. A total of 72 trapezoid samples,

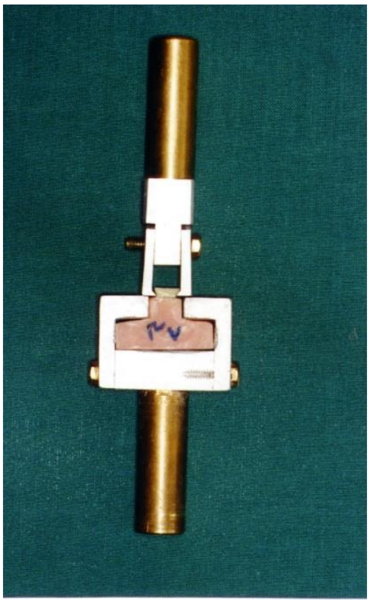

Figure 1: Surrounding of the FRC samples bonded to tooth surfaces from the sides by the test equipment

measuring 5×5×0.5 mm, were prepared from fiber-reinforced composite resin, with the proprietary name of Vectris (Ivoclar, Schann, Liechtenstein); a layer of Targis (Ivoclar, Schann, Liechtenstein) was placed on the samples and cured to achieve a sample thickness of 2 mm. Then the samples were divided into 3 groups (n=24) in order to prepare the surface of Vectris: In group 1 the samples surfaces underwent a surface sandblasting (S) treatment with 50µm aluminum oxide particles from 2 cm distance of the instrument tip at a pressure of 4 bars for 10 seconds. In group 2 the sample surfaces were etched (E) with 9% hydrofluoric acid for 10 seconds. And the sample surfaces in group 3 were roughened (R) with a fissure diamond bur.

Subsequently the sample surfaces in all the groups were etched with 37% phosphoric acid for 20 seconds for enamel bonding; then the surfaces were rinsed for 30 seconds and divided into two subgroups. In subgroups 1 and 2, bonding procedures were carried out using Enforce (Dentsply) and Variollink II (Vivadent, Schann, Liechtenstein) resin cements, respectively (according to the manufacturer's instructions). The cementation procedures were carried out under a 500 g force for 5 minutes in a pressure tool.

In order to simulate the oral cavity conditions and carry out the bond strength test in relation to hydrolytic stability, the samples underwent a thermocycling procedure with thermal and moisture fluctuations for 4000 cycles at 5/55°C. Then Instron test equipment was used to apply a tensile force at a crosshead speed of 0.5 cm/min. The force was applied up to a point at which the Vectris-Targis plates were debonded from the tooth surface (adhesive failure) or the failure occurred within the sample (cohesive failure).

It should be pointed out that samples should be trapezoid in shape and should measure 5×5×2 mm in size to undergo tensile strength test in Instron test equipment. Therefore, a special device was designed and manufactured so that its upper arm could surround the FRC samples attached to teeth, from the sides during force application (Figure 1). Subsequent to tensile tests of all the samples, a reflective light microscope was used to determine failure patterns, which were categorized into 4 groups: (A) adhesive failures in which the V/T sample had completely debonded from the enamel surface along with the cement; (C) cohesive failures in which fracture had occurred only within the V/T sample and a part of the sample was still attached to the tooth surface, and Mixed: This group of failures was in turn subdivided into two:

M1: Failures in which more than 50% of the failures were of the adhesive type

M2: Failures in which more than 50% of the failures were of the cohesive type Finally, data underwent analysis by two-way univariate ANOVA and Pearson chi-square test using SPSS statistical software to evaluate the relationship

					95% CI for Mean			
	N	Mean	SD	SE	Lower	Upper	Minimum	Maximum
Sandblasted	18	4.51911	3.773728	0.889476	2.64248	6.3974	0.4675	16.3600
Roughened	19	4.94558	3.817571	0.875811	3.10577	6.78559	0.4675	13.0900
Etched	16	4.03281	2.794897	0.698724	2.54352	5.2211	0.9350	12.1600
Total	53	4.52519	3.477498	0.477671	3.56667	5.8471	0.4675	16.3600

Table 1: Statistics of the three surface preparation techniques

between the cement type and preparation technique on one hand and the failure mode and tensile bond strength on the other hand. A P value less than 0.05 was considered as statistically significant.

Results

In the present study, samples with a numerical bond strength value of zero were excluded from the study and were not included in statistical analyses. The results of two-way ANOVA showed that the preparation technique and the cement type had no reciprocal effects on each other (P=0.78). Therefore, it was possible to evaluate the effect of each factor separately. The surface preparation technique had no significant effect on bond strength, i.e. the mean bond strength values were almost the same in all the three preparation methods (P=0.53, Table 1).

The cement type influenced the mean bond strength value (P=0.04), i.e. Variolink II cement had a higher mean bond strength value compared with Enforce cement (Figure 2).

In addition, the results of Pearson chi-square test showed no relationship between the type of the cement and failure mode (adhesive on cohesive) (P=0.18). However, there was a relationship between the surface preparation technique and failure mode (P=0.008, Figure 3), i.e. there were more adhesive failures with sandblasting surface preparation technique and roughening with a bur and cohesive failure was more common in surfaces etched with hydrofluoric acid.

Discussion

A large number of studies have evaluated the effect of surface preparation of indirect restorative materials on their bond strength to tooth structures and contradictory results have been achieved. D'Arcangelo et al. evaluated the effect of three different surface preparation techniques on the tensile bond strength of indirect composite resins to dentin and concluded that the bond strength of composite resin to dentin is significantly under the influence of surface preparation technique (11). In their study, the highest bond strength was achieved with sandblasting of the composite resin surface and hydrofluoric acid had no effect on bond strength (11). The results of the present study did not show that surface preparation technique had any significant effect on the bond strength of Vectris. This lack of any significant effect might be attributed to the following reasons: (1) The adherent nature of polymeric materials and their chemical bond with resin cements have a key role in their bond with tooth structures, i.e. none of the surface preparation techniques, which are mainly used to improve mechanical retention, can influence it. (2) It might be possible that

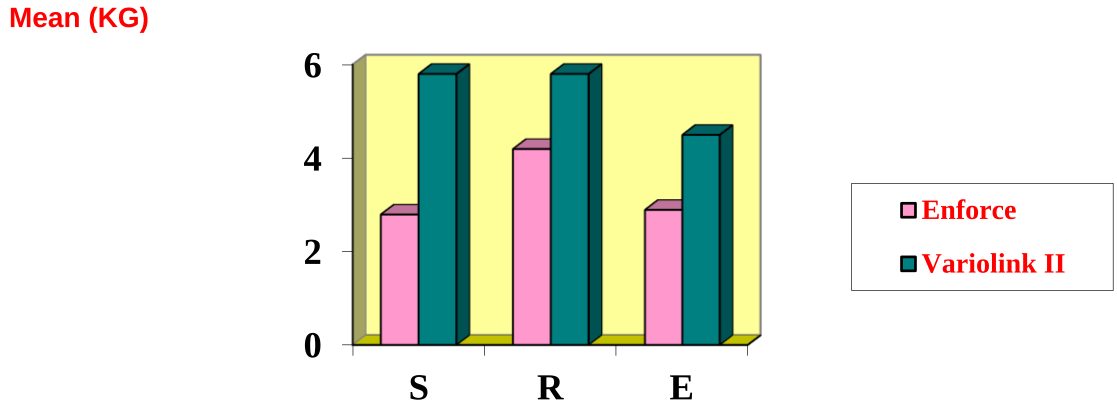

Figure 2: Mean strength values with the two Enforce and Variolink II cements at each surface preparation techniques

use of etching agents with different concentrations and times and also different particle sizes in sandblasting and the force applied might have had a role in obtaining these results, which are contrary to the results reported by D'Arcangelo (11).

In the present study, the type of the cement had an effect on the mean bond strength, i.e. Variolink II cement exhibited a higher mean bond strength compared with Enforce cement. Several studies have evaluated the effect of cement type on the bond strength of indirect restorative materials to tooth structures. It has been reported that the bond strength of RXU and Panavia F cements to sandblasted ceramic (Procera All Ceram) and alloys with a higher content of gold is higher than that of Variolink II. On the other hand, the bond strength of RXU and Variolink II cements to IPS Empress II ceramic, etched with hydrofluoric acid, was higher than that with Panavia F (12,13). One study showed that the bond strength of autocuring Rly X Unicem was less than that of dual-cured Variolink II cement (14), which is contrary to theoretical beliefs that chemically cured cements have higher bond strength due to a higher flow resulting from a slow-setting polymerization process (15). The push-out bond strength values might be influenced by the type of the cement and post; in this context, a study showed that a combination of Variolink II cement and a fiber post gives rise to the highest bond strength (16). By considering the results of all these studies it can be concluded that Variolink II cement results in a higher bond strength when it is used to bond fiber-containing materials along with preparation of the surface with hydrofluoric acid.

The present study also revealed that the cement type had no effect on the failure mode. On the other hand, the technique used to prepare the surface of Vectris influenced the failure mode (cohesive or adhesive), i.e. type A failure was more common with sandblasting and surface roughening with a bur and type C failure was more prevalent in surface preparation by hydrofluoric acid etching. In addition, as the efficacy of a bond is determined by the cohesive failure of the veneer, M1, M1 and C failure modes which have some degrees of the cohesive component are more important than type A failure in relation to the evaluation of bond strength. Therefore, by considering the failure mode, etching the surface of Vectris with hydrofluoric

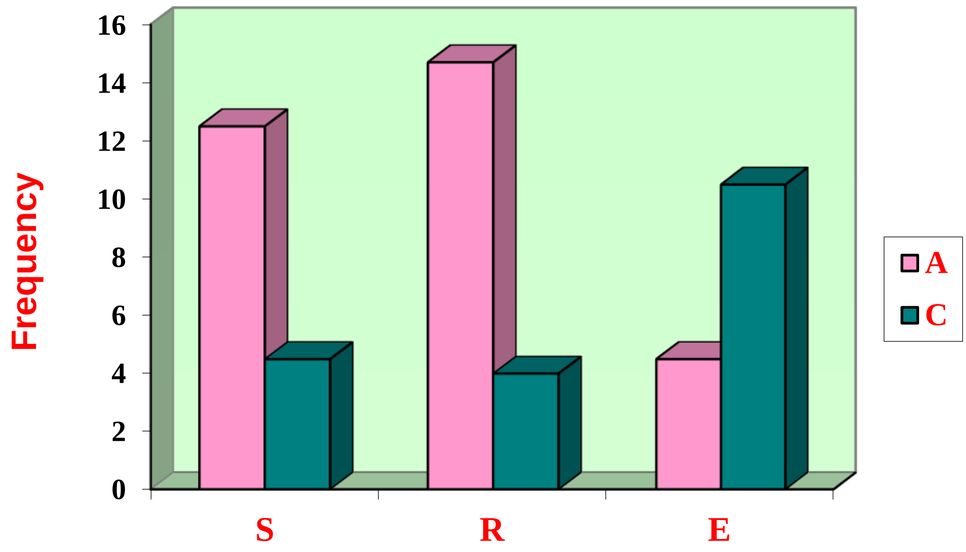

Figure 3: Frequencies of type A and C failure modes with the three surface preparation techniques

acid is the best surface preparation technique. However, the mean bond strength was identical with all the surface preparation techniques.

In the present study, adhesive failures were defined as those failures in which the samples had debonded from the tooth surface along with cement and the cement had completely remained on the sample surface. Therefore, the cement had debonded from the tooth surface before debonding of the cement from the surface of Vectris sample. The opposite of this situation is usually encountered in acid etching of conventional bridgeworks with a metallic framework. The adhesive failures in the present study showed a higher bond strength between the cement and Vecteris compared with that between the cement and tooth structure (18.9% of the total failures was of the adhesive type). On the other hand, completely cohesive failures are important because in such failures the cement remained on both the Vectris and tooth surfaces; such failures comprised 22.6% of all the failures in the present study. Only in M1 and M2 failure modes the cement had debonded from the surface of Vectris to some extent (more in M2 compared with M1). M1 failure mode, the most common failure mode in the present study (43.4%), had a greater adhesive component and more cement had remained attached to the surface of Vectris and less cement had debonded from the surface. M2 failure, the least common failure mode (15.1%), had more cohesive component and more cement had debonded from the surface of Vectris. Therefore, it can be concluded that only in 15.1% of the cases the bond between the resin and Vectris had failed and this bond was intact in the majority of cases.

The present study is comparable to a study by Watanabe et al, in which the tensile bond strength of three adhesive cements and two resin-bonded bridge cements to two alloys were evaluated in vitro (17). The alloys consisted of sandblasted and electro-etched Ni-Cr-Be and sandblasted and tin-plated type III gold. The highest bond strength was achieved with the use of adhesive cements. Comparison of the results of that study with those of the present study showed that the mean bond strength in the present study was almost twice higher than the maximum bond strength in the study by Watanabe et al. (17), indicating higher bond strength of Vectris to resin compared with that of metal to resin.

Ernst et al. evaluated the tensile bond strength of cast gold crowns to three cement types of Compomer (Dyract Cem), glass-ionomer (Ketac Cem) and a type of resin cement (F21) (18). They reported that the highest tensile bond strength was related to Ketac Cem (2.36 N/mm2), and the Dyract Cem (1.85 N/mm2) and F21 (0.60 N/mm2) ranked the second and third, respectively (18). Comparison of the results of that study with those of the present study showed that the mean tensile bond strength of Variolink II (2.07 μ/mm2) is a little less than that of Ketac Cem and more than those of Dyract Cem and F21. However, the results of a study by Utz et al. showed that the tensile bond strength of Ketac Cem was less than that of Variolink II but less than that of Enforce (19). In the present study, all the bond strength values were higher than the predictable debonding forces (40 N) in clinical situations (2). It can be justifiably claimed that each cement can produce the maximum bond strength with a specific restorative material and a specific surface preparation technique.

In conclusion, restorations fabricated with the use of fiber-reinforced composite resins (Targis-Vectris) are best cemented with Variolink II cement and should undergo surface treatment with hydrofluoric acid.

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