Shear Bond Strength of a Light-Cured Veneering Composite to Fiber-Reinforced Composite Substrates

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Purpose: The aim of this study was to compare the shear bond strength of a veneering composite to 2 differently treated fiber-reinforced composite (FRC) substrates and to a base metal alloy. ***Materials and Methods:*** A veneering composite (SR Adoro) was bonded to the following substrates: *(1)* a nickel-chromium base metal alloy (control, group A), *(2)* an FRC substructure (Vectris) with a flat surface (group B), and *(3)* an FRC substructure (Vectris) with retentive rods 0.5 × 0.5 mm in cross section and 10 mm in length, positioned parallel to each other at a distance of 0.5 mm (group C). Thirty-nine specimens were fabricated and divided into 3 groups of equal size. All specimens were thermocycled for 5,000 cycles at 5°C and 55°C with dwell time of 30 seconds in each bath. Evaluation of shear bond strength was performed at a constant crosshead speed of 0.5 mm/min according to ISO 10477. ***Results:*** The mean values for the shear bond strength were 19.29 MPa for the control group (group A), 16.66 MPa for group B, and 16.74 MPa for group C. Despite a tendency to higher bond strength of group A specimens, no statistically significant difference was recorded between the groups ($P > .05$). ***Conclusions:*** No statistically significant difference was found between the metal and FRC substructures. Retentive rods on the FRC substructure do not seem to increase the bond strength significantly. *Int J Prosthodont 2008;21:45–49.*

The attempt to replace the metal substrate in crowns and fixed partial dentures (FPDs) has led to the introduction of new esthetic core and veneering materials. Most of them are stable and esthetic ceramic materials that can be veneered with dental feldspathic porcelain. Different proposed techniques are available for concrete indications for crowns and small FPDs that overcome all the drawbacks of the metallic substrates[1] (poor color, toxicity, corrosive or allergenic qualities). Although the evolution of all-ceramic systems continues, the high abrasion ability of the porcelain[2] and the brittleness[3] of ceramics have provoked interest in developing esthetic resin composite materials for crown and FPD veneering.

The fiber-reinforced composites (FRCs) are one such result; these are translucent, with a "shine through" effect that contributes to the positive esthetics of the restoration. They consist of fiber material held together by a resinous matrix.[4] They offer good flexural strength and mechanical properties.[5] They have been introduced for a variety of dental restorative applications, including endodontic posts,[6,7] splints,[8] crowns, FPDs,[9–15] and denture bases.[16–20] In fixed prosthodontics, FRCs are recommended for use as substructures to provide increased strength and rigidity beneath the newer hybrid particulate filler composite veneering materials.[21–23] During the last few years, several commercial FRC products have been introduced for clinical use. Suitable FRC products for dental use include glass fibers that are preimpregnated with monomer or polymer systems. The current knowledge of FRCs in dental applications suggests that they might provide functional and esthetic prosthetic devices for long-term service.[24] However, their clinical use has not yet been adequately documented. Although it is reported that FRC substrates have high strength,[25] it

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has been pointed out that the bonding of the veneering composite to the FRC frame might be inferior.[26]

The aim of this study was to compare the shear bond strength of a veneering composite to 2 differently treated FRC substrates. The bond strength of a base metal alloy with the same veneering composite was used as a control.

Materials and Methods

Thirty-nine specimens were fabricated and divided into 3 groups of equal size. In group A, SR Adoro (Ivoclar Vivadent) veneering composite was bonded to a cast nickel-chromium base metal alloy (4all, Ivoclar Vivadent); these specimens served as the control group. In group B, SR Adoro was bonded to a Vectris (Ivoclar Vivadent) FRC substructure with a flat surface, and in group C, SR Adoro veneering composite was bonded to a Vectris FRC substructure with a surface with retentive rods 0.5 × 0.5 mm in cross section and 10 mm in length, positioned parallel to each other at a distance of 0.5 mm.

Specimen Preparation

The castings of the specimens of group A were rectangular (10 × 10 × 1 mm), with retention beads (200 to 300 μm) on one flat surface. After they were finished, they were air-abraded with 100-μm aluminum oxide (Al_2O_3) particles; all residues were removed by tapping. A bonding agent (SR Link, Ivoclar Vivadent) was applied with a clean, disposable brush and allowed to react for 3 minutes. An adhesive tape with a circular internal hole 5 mm in diameter was positioned to define the bonding area on the specimen. Two opaque layers were applied on the bonding area, and each was precured for 20 seconds with a halogen light-curing unit (Trilight, 3M/ESPE). The specimens were then thermophotopolymerized in a special furnace (Targis Power Upgrade, Ivoclar Vivadent) at 110°C for 11 minutes. The inhibition layer was thoroughly removed from the opaque surface using a disposable sponge. A translucent celluloid tube with inner diameter of 5 mm was used for the application of SR Adoro Dentin, which was applied in 2 layers. Each layer was 1.5 mm thick and was precured for 20 seconds using the Trilight unit. SR Gel (Ivoclar Vivadent) was applied on the entire veneering surface to prevent the formation of an inhibition layer, and SR Adoro Thermo Guard (Ivoclar Vivadent) was applied to all exposed metal parts to provide a thermally absorbing effect, which influences the tension at the interface between the metal and the composite. Specimens of group A were polymerized in the Targis Power Upgrade furnace for 25 minutes.

The group B specimens were fabricated into rectangles (10 × 10 × 1 mm) by pressing the unpolymerized FRC Vectris-Pontic (Ivoclar Vivadent) into a silicone mold that was moistened with Vectris Glue (Ivoclar-Vivadent), along with a transparent polyester film sheet (Mylar) and a glass plate. Then the mold was put into a light and vacuum-forming oven (Vectris VS1, Ivoclar Vivadent) for 10 minutes according to the manufacturer's recommendations. After polymerization, Vectris Frame (Ivoclar Vivadent) was pressed onto the Vectris Pontic with a Mylar sheet and a glass plate, and the sample was polymerized again in the oven for another 10 minutes.

To fabricate the group C specimens, a metallic jig was cast with dimensions 10 × 10 × 1 mm, with retentive rods 10 mm long with a cross section 0.5 × 0.5 mm, positioned parallel at a distance of 0.5 mm from each other. The jig was placed into the silicon mold used for preparation of the group B specimens. A separator was then applied and an impression was made with a translucent vinyl polysiloxane (Transil, Ivoclar Vivadent). Then, with the Transil impression, unpolymerized Vectris Pontic was pressed into the silicon mold used for the preparation of the group B specimens, moistened with Vectris Glue, and polymerized in the Vectris VS1 oven for 10 minutes. After polymerization, Vectris Frame was pressed onto the Vectris Pontic with the Transil impression; samples were again polymerized in the oven for an additional 10 minutes.

Excess material was removed from the group B and C specimens with carbide burs, and specimens were carefully air-abraded with 100-μm Al_2O_3 particles at 1 bar according to the manufacturer's recommendations. Residue was removed by tapping, and Vectris wetting liquid (Ivoclar Vivadent) was applied immediately after. The liquid was allowed to react for 60 seconds. A tape with an inner hole 5 mm in diameter was applied to the surface to be bonded, and a thin layer of SR Adoro liner (Ivoclar Vivadent) was applied and photo cured for 20 seconds. The resulting oxygen inhibition layer was removed thoroughly with a disposable sponge. The composite was applied through a tubular mold of celluloid (5 mm in diameter and 3 mm in height) in 2 layers, each 1.5 mm thick. Each layer was photo cured for 20 seconds. Then, SR Gel was applied to the entire veneering surface, and the specimens were polymerized in a Targis Power Upgrade furnace for 25 minutes.

All specimens were embedded in self-polymerizing acrylic resin to meet the dimensions of the universal testing machine. Then they were thermocycled for 5,000 cycles at 5°C and 55°C, with dwell time of 30 seconds in each bath. Shear strength testing was performed using a universal testing machine (Testometer 10, Monsanto) at a constant crosshead speed of 0.5 mm/min according to ISO 10477.[27]

Table 1 Shear bond strength values (in MPa)

Group	Type of substructure	Mean	SD	n
Group A	Metal	19.29	5.64	13
Group B	FRC-flat	16.66	8.91	13
Group C	FRC-with rods	16.74	5.81	13

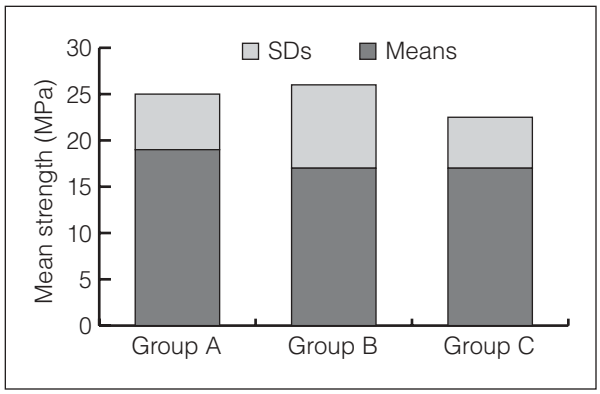

Fig 1 Shear bond strength values (means and SDs).

Statistical Analysis

One-way analysis of variance was applied to the data. The assumptions of normality and homogeneity of variances were tested by applying the Kolmogorov-Smirnov and Levene tests and it was confirmed that they held. The statistical package SPSS 13.0 for Windows was used to perform the statistical analyses.

Results

The mean bond strengths of the 3 groups are presented in Table 1 and Fig 1. Mean shear bond strength ranged from 16.66 MPa to 19.29 MPa. The highest mean shear bond strength value was obtained in group A (19.29 MPa) and the lowest was seen in group B (16.66 MPa), although the corresponding mean value of group C did not differ much (16.74 MPa). On the other hand, the shear bond strength of group B showed greater variability in the sample (SD = 8.91 MPa) compared to groups A (SD = 5.64 MPa) and C (SD = 5.81 MPa), meaning that the corresponding mean may be considered as less representative. Nevertheless, no statistically significant differences were observed among the bond strengths to metal and FRC substructures ($P > .05$).

Discussion

From the results of the present study it is obvious that Vectris FRCs behaved nearly identically to the nickel-chromium base alloy with respect to the bond strength of the substrate to the SR Adoro veneering composite material. The most recently developed FRCs, although they are not well documented clinically, seem to be a reliable alternative to the cast alloy substrates for fixed prosthodontics. The silanated glass-fiber FRCs are preimpregnated with a monomer system, which after polymerization is either a highly crosslinked thermosetting polymer or a multiphase polymer,[28] and thus offer new possibilities for a chemical adhesion with the newly developed veneering composites. SR Adoro is a modern resin composite with a high content of inorganic fillers (65% by weight) in the nanoscale range and an aromatic-aliphatic urethane dimethacrylate monomer with improved mechanical and physical properties.[29] Bonding between the Vectris FRC substrate and the particulate resin composite involves 2 components: a resin-resin bond and a glass-resin bond. The first component is between the polymer matrix of the FRC substrate and that of the composite. It is a methacrylate-methacrylate bond and is attributed to uncured composite material that remains on the surface of the FRC (inhibited layer). The free methacrylate groups present in this layer may chemically react with the monomers that are contained in the resin applied. The second component involves the bond between glass fibers and the resin matrix.[30,31] Silane forms a covalent bond at the glass surface and in turn demonstrates a functional methacrylate group, which may copolymerize with the methacrylate of the matrix.

Chemical adhesion is also a target for the metal-composite system, and numerous chemical bonding agents have been developed recently to improve bonding strength. The SR Link bonding system is based on a phosphoric ester with a methacrylate function. The phosphoric acid group of the molecule is a strong acid, which reacts with the metal. The methacrylate group of the phosphoric acid reacts with the monomer components of SR Link, forming a copolymer and thereby providing a bond to the veneering resin.[32,33] Metal-composite bonding agents and especially agents based on phosphoric esters provide adequate bond strength and reduce microleakage at the metal-resin interface, preventing discoloration of the veneering resin.[34] Although increased bond strength with the use of bonding agents in the metal-composite combination has been reported,[35] mechanical retention is still a

necessity for achieving clinically reliable bond strength. Small beads (200 to 300 μm), which are recommended by the manufacturer of SR Adoro composite veneering material, nearly eliminate the esthetic problem and provide micromechanical retention.

The mean shear bond strength of the metal-composite combination that was recorded in this study (19.29 MPa) is in accordance with that seen in other studies[36–38] under the experimental circumstances of each research. According to Matsumura et al,[39] the resin-metal shear bond strength must exceed 10 MPa to ensure clinically satisfactory results. On the other hand, the metal-composite bond strength did not exceed the metal-ceramic bond strength,[38] which, according to ISO 9693 for metal-ceramic dental restorative systems,[40] must not be less than 25 MPa. Many studies[36,37,41] have recorded significantly higher mean shear bond strengths between porcelain and different metals and between resin and different metals; further development of the esthetic resin-metal materials is necessary.

No statistically significant differences were found in bond strength among the materials investigated, although the metal substructures exhibited higher mean bond strength than the FRC substructures. Perhaps some aspects of the fabrication of FRC specimens weakened the FRC–resin composite bond. For example, the use of a Mylar sheet during the polymerization process does not permit oxygen to inhibit radical polymerization of FRC. Therefore, a very thin layer of uncured composite material remains on the surface of the FRC, and consequently the number of free methacrylate groups that might react chemically with the monomers contained in the composite is also low. Furthermore, the use of Vectris Frame, a FRC net that holds the fibers closely together to strengthen the FRC substructure, might inhibit penetration of the resin into the fibers.[28]

Several studies[42–44] have investigated bond strength between FRC and resin composite in various applications. A wide range of bonding values has been seen; these are in accordance with the bond strength values of the present study.

The surface morphology of the FRC framework does not seem to influence the value of the FRC–resin bond strength, although group C samples exhibited a slightly higher mean bond strength and a lower standard deviation. The lower standard deviation might suggest that perhaps the rods have a tendency to make the bond strength more predictable in clinical practice, preventing very low values that might lead to prosthetic failure.

Thermocycling, although it was not specifically investigated in the present study, is reported to reduce the mean bond strength of the investigated systems.[28,34,35]

Conclusions

Under the limitations of this experimental laboratory study, 2 main conclusions can be derived:

1. Shear bond strength values of all investigated groups were lower than the minimum acceptable limit (25 MPa) for the ceramic-metal bond.
2. No statistically significant differences were found in mean shear bond strength of Adoro veneering composite material to a nickel-chromium prosthetic alloy and to Vectris FRC substrates, regardless of the existence of retentive rods.

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