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Evaluation of the bond strength of different composite resins to porcelain and metal alloy

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Abstract

This study was carried out with the purpose of testing the bond strength of three different composite resins bonding to different base substrates.

Substrates to which composite resins would be applied were prepared in three different ways: porcelain, metal and porcelain–metal in a 10-mm diameter and 4 mm thickness. Operating surfaces were air-abraded with Al_2O_3 and they were cleaned in distilled water in ultrasonic cleaning equipment for 10 min. After completing the preparation of the surface, three different composite resins with single bond agent in a 3.5-mm diameter and 2 mm thickness were applied to the central region of the specimens. All specimens were thermocycled between 5 and 55 °C for 200 cycles with a 30-s dwell time. After thermocycling, specimens were stored in 37 °C distilled water for an additional 7 days before being subjected to a shear load. Shear test was applied in using a Hounsfield test machine.

The univariate analysis of variance and the Duncan multiple comparison test were used for statistical assessment. It was found that both type of composite material and of substrate led to statistically significant differences in bond strength ($p < 0.01$).

It was found that there was higher bond strength in Filtek Z 250 and metal substrate (16.19 MPa) and there was lower bond strength in Surefil and porcelain base substrate (1.09 MPa).

Keywords: Composite resin; Bond strength; Porcelain; Metal

1. Introduction

Porcelain fused-to-metal crowns are widely accepted and used in clinical dental practice. However, they occasionally demonstrate fracture of the brittle ceramic veneer. Failure resulting from porcelain fracture has been reported to range from 2.3% to 8% [1–3]. The cause of clinical fracture of veneering porcelain on ceramometal crowns is multifactorial. Lack of proper framework support for the porcelain, intraceramic defects, or parafunctional occlusion can cause this inconvenient problem [4,5]. Ideally, remaking of the restorations is desirable, but it is not always feasible. The ability to perform an intraoral repair can be of great benefit to the patient [6].

Three conditions are suggested for repair of porcelain fractures: (1) fracture in porcelain only with no metal exposure, (2) fracture with both porcelain and metal exposure, and (3) fracture with substantial metal exposure [7].

Various procedures for intraoral porcelain repair have been suggested. Composite resins with silane coupling agents are the material of choice for porcelain repair, and several investigators have reported the bond strengths of these systems [8–14]. Nevertheless, they tend to have many shortcomings, such as staining, poor wear characteristics, and a weak bond strength in load-bearing areas. A decrease in bond strength over time is also noted in many systems [11,12,14,15].

Some studies focused on the bond between HF acid etched porcelain and composite resin and reported the bond strength to be stronger than the cohesive strength of

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the individual materials [16,17]. Two other studies compared bond strengths of HF acid to acidulated phosphate fluoride (APF) gels, another porcelain etchant [18,19]. One study found that both HF acid and APF gel produced cohesive failure if used in conjunction with a silane coupling agent [19]. The study also showed that the use of silane coupling agent was a more significant factor than an HF acid etch in improving bond strength, which contraindicates the previous literature [17].

Acidulated phosphate fluoride (APF) gel is a topical fluoride gel commonly present in dental offices. Hydrofluoric acid is a poisonous and extremely caustic substance. The widely accepted theory that HF acid enhances the composite-resin-to-porcelain bond more than and APF gel was not substantiated by this investigation. As such, the intraoral use of HF acid appears unwarranted at this time [20].

If a small part of the porcelain is missing, it might be a reasonable solution to repair intraorally with a light-curing composite resin. A large fracture of porcelain can also be repaired by the same technique, but the result will never be as durable or esthetic as the original restoration [21].

This study was carried out with the purpose of testing the bond strength of three different composites bonding to different base substrates.

2. Materials and methods

Three different composite resins, three different substrates and one bonding agent were used in this study (Table 1). Composite resins were bonded to different substrates with Single bond.

A total of 36 cylindrical specimens were fabricated; 12 from porcelain (Ceramco, Burlington NJ, Weybritge UKKT 15 2S, USA), 12 from a Ni–Cr alloy (Wiron 99, Bego, Bremen, Germany), and 12 from a Ni–Cr alloy and porcelain. Specimens were divided into three groups for bonding with one of the three different composites with Single bond. Fabrication of the specimens was as follows:

Porcelain specimens. Porcelain was condensed in a split brass mold (1.0-cm diameter and 0.4-cm thickness) with Modisol separating agent (Vident). Condensed cylinders were placed on a platinum foil sagger tray and fired at 940 °C under vacuum in a calibrated porcelain furnace (Ugin/Dentaire (Elips), France).

Porcelain and metal specimens. Inlay wax cylinders (1.0-cm diameter, half of the cylinder 0.4-cm thickness and the other half 0.2-cm thickness) were invested and cast with the use of Ni-Cr alloy. The metal cylinders were air-abraded with 50 μm aluminum oxide. The opaque layer (Burlington NJ, Weybritge UKKT 15 2S, USA) was applied to the side of lower thickness section surfaces and porcelain was condensed. The metal and porcelain surface was finished flat with a laboratory medium-grit sintered diamond.

Metal specimens. Inlay wax was flowed into a silicone mold (1.0-cm diameter and 0.4-cm thick). The wax cylinder was invested and cast with the use of a Ni–Cr alloy. The cylinders were cleaned in an ultrasonic unit in distilled water (Fig. 1).

Each of substrates was embedded in a phenolic resin ring (Buehler Ltd, Lake Bluff, III) with polymethyl methacrylate resin (De Trey RR, Dentsply, England). Bonding surfaces were prepared by wet sanding first with 240-grit and then 600-grit silicon carbide abrasive (3 M, Minneapolis, Minn.). This was followed by surface treatment with 50 μm aluminum oxide in an air abrasive unit. The specimens were ultrasonically cleaned in distilled water for 10 min and stored in distilled water for 24 h before bonding.

Resin composite was applied to each specimen with the use of a Teflon split matrix (3.5-mm diameter and 2-mm thick; Ultradent, South Jordan, Utah) and bonding agent and resin composites were polymerized according to the manufacturer's instructions with the use of a visible light application (Elipar II, 3 M ESPE, Seefeld, Germany).

All specimens were stored in 37 °C distilled water for 24 h before being thermocycled between 5 and 55 °C for 200 cycles with a 30-s dwell time. After thermocycling, specimens were stored in 37 °C distilled water for additional 7 days before being subjected to a shear load. Hounsfield testing machine (Hounsfield Test Equipment Company, HTE 37 Fullerton Road, Croydon, England) with a 0.5 cm/min crosshead speed, and a chisel apparatus was used to direct a parallel shearing force as close as possible to the resin/substrate interface. The shear load in newtons at the point of failure was noted and force was calculated in megapascals (MPa).

Table 1
Bonding agents and restorative material used in this study

Material		Manufacturers
Composite materials	Alert	Pentron, Wallingford, USA
	Filtek Z 250	ESPE Dental AG, Germany
	Surefill	Dentsply International
Bonding agent	Single Bond	3 M, Pithiviers-France

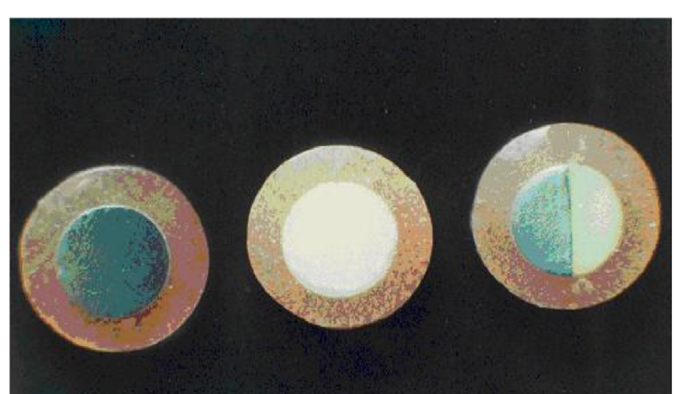

Fig. 1. Metal, porcelain, and metal-porcelain specimens.

Univariate analysis of variance was applied to the data. Comparisons between substrates were made with the Duncan multiple comparison tests.

3. Results

The mean and standard deviation results of the data obtained were shown in Table 2. It was found that the samples with Filtek Z 250 and metal substrate showed the highest bonding strength (16.19 MPa), while the samples with Surefil and porcelain substrate showed the lowest bond strength (1.09 MPa).

It was determined through the univariate analysis of variance that the type of the composite and the substrate caused statistically significant (Table 3) differences in bond strength.

The Duncan multiple range test demonstrated significant differences between Filtek Z 250 and others composite materials, and between each substrates (Tables 4 and 5).

Table 2
The mean and standard deviation results of the results obtained

Composite Materials	Substrate*	*N*	Mean (MPa)	SD
Alert	P	4	2.00	0.996
	M-P	4	7.46	0.996
	M	4	10.55	2.372
Filtek Z 250	P	4	6.00	3.191
	M-P	4	4.00	1.652
	M	4	16.19	3.718
Surefil	P	4	1.09	0.406
	M-P	4	6.55	0.761
	M	4	9.46	0.498

*P; porcelain, M–P; metal–porcelain, M; metal substrate.

Table 3
Results of univariate analysis of variance

Source	Type III Sum of Squares	df	Mean square	F	P
Composite	71.977	2	35.988	9.162	0.001
Substrate	636.639	2	318.320	81.035	0.000
Composite X Substrate	159.077	4	39.769	10.124	0.000
Total	3237.288	36			
Corrected Total	1009.107	35			

Table 4
Results of the Duncan test for composite materials

Substrate	Mean shear strength (MPa)	Duncan groups*
Surefill	5.70	A
Alert	6.67	A
Filtek Z 250	8.73	B

*Means with the same letter are not significantly different.

Table 5
Results of the Duncan test for substrates

Substrate	Mean shear strength (MPa)	Duncan groups*
Porcelain	3.03	A
Porcelain–metal	6.00	B
Metal	12.07	C

*Means with the same letter are not significantly different.

4. Discussion

Intraoral repair of fractured porcelain restorations with composite presents a substantial challenge for a dentist. Newer generation, multipurpose adhesive systems involve several treatment steps and agents for porcelain repair with composite. A bonding agent is commonly used for bonding composite to porcelain. There are conflicting opinions about the long-term effectiveness of bonding agents commonly used for bonding composite to porcelain [11,13,15].

This study examined the shear bond strengths of composite material used for repair in three representative situations: fracture within porcelain, fracture within porcelain with exposure of some ceramic alloy, and fracture with complete porcelain delamination and exposure of a large section of alloy. It was determined that the samples with repair to metal substrate showed a higher bonding strength that the other samples did, and that the samples with a porcelain and metal–porcelain substrate showed almost similar degrees of bond strength, with no statistically significant differences. This result was attributed to the procedures done to the sample surfaces and to the bond applied, and was seen to be in harmony with the results or findings of the following researchers.

Chung and Hwang [22], in their study in which they applied different composite resins and their bonds to different substrates, determined that the highest degree of bonding strength was in the samples with the metal substrates.

It is advisable to create mechanical retention by using a coarse diamond when a repair involves a large surface of exposed metal [23]. High composite alloy bonds have been reported with base metal alloy treated with corundum blasting [24,25]. Improvements in adhesion of composites to base metals were recently made by the addition of adhesive monomers to various composite formulations and these composites bond to corundum-blasted base metal surfaces [26,27]. Porcelain surface corundum blasted with alumina resulted in micromechanical roughening and covering with small alumina particles [28]. The reported bond strengths of corundum blasted porcelain surface ranged from 9 to 17 MPa [29].

Bond strengths between composite resins and a noble metal alloy have been reported by several authors [30,31]. According to Anusavice [32], an infinite number of fracture paths of the veneer porcelain can occur. Clinically, porcelain fracture can be seen with no exposure of the metal substrate, or with complete de veneering of porcelain with extensive metal exposure. Repairs made on multiple substrates may behave differently than those made only on a ceramic surface. Previous studies have primarily examined repairs made solely to a porcelain or alloy substrate [4,11,15,33–35]; few have tested bond strengths to a combined surface [22]. Bond strength values depended on the system used, with the strongest bonds to porcelain substrate [11,36]. Although no agreement exists on minimal bond strength for successful bonding, a reasonable goal of 20 MPa (composite to dentin) has been discussed [32].

Shear bond strength of composite to porcelain with the use of various porcelain repair systems have been reported in the range of 6 to 29.9 MPa [3,22,29,33,34,36].

In this study the lowest degree of bonding strength was found in the samples with a porcelain substrate (1.09 MPa), a value which is within the limits reported by the above researchers.

Agents such as cyanoacrylates, acrylic resins, or composites have been used to repair metal ceramic restorations with limited clinical success because of inherent physical properties [37]. A number of systems have been developed to facilitate bonding of composites to porcelain and metal [8,9,27,33].

The bond strength of composite resin to porcelain is also affected by the bonding agent and type of composite resin used for repair [3,12,13,38]. For example, hybrid composite resins generally provide higher bond strengths than microfilled composite resins [12].

As our purpose in this study was to compare the bonding strengths of the composite resins, a single type of bond was used to strengthen the bonding and it was found that the composites used showed different degrees of bonding strength. The highest degree of bonding strength was found in Filtek Z 250 composite resin, while the lowest was in the Surefill composite resin.

This result is in accordance with the findings by the following researchers.

Berksun and Saglam [39] found in their study that the composite resins they used showed different degrees of bonding strength.

Research on porcelain repair has included shear, tensile, and 3-point loading. The porcelain–resin interface has also been subjected to fatigue loads [15]. The concept of fatigue testing is applicable to brittle ceramic materials [32], but when such testing is applied to the porcelain resin interface, large standard deviations suggest an abnormally distributed populations because some specimens do not fail [15]. A shear test was chosen for this study because multiple substrates were used. In addition, anterior restorations were subjected primarily to shear stresses, and the shear test was considered appropriate for quantifying the strength of porcelain repairs [40].

The use of thermocycling is variable in the literature. Most studies using thermocycling have reported that bond strengths are reduced by thermocycling [14,41]. A common finding among many of these studies was a reduction in shear bond strength after prolonged water storage and/or thermocycling [3,11,14,15,33,35]. The effects of moisture, thermal stress and fatigue on bond strength have been explored [3,14,15].

Since the effect of thermocycling was not examined in the study, we could not use a control group. So thermocycling was applied in the way recommended in the literature [3,11,14,15,33,35,41].

5. Conclusion

It was found that there was higher bond strength in Filtek Z 250 and metal substrate (16.19 MPa). There was lower bond strength in Surefil and porcelain base substrate (1.09 MPa). The highest bond strength values were found when used metal substrate. These differences were significant in all cases ($p < 0.01$).

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