

# Shear Bond Strength of Composite-Resin to Porcelain: Effect of Thermocycling

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## Abstract:

**Objective:** Different ceramic repair systems have been reported for fractured ceramics. However, limited information is available concerning the bond strength of these systems especially after thermocycling. The aim of this in-vitro study was to determine the effect of thermocycling on the shear bond strength of composite-resin to feldspathic porcelain with and without silane pretreatment.

**Materials and Methods:** In this experimental study, forty porcelain blocks were prepared and randomly divided into four groups (n=10). All porcelain surfaces were etched with 9.6% hydrofluoric acid, rinsed and air dried. In groups 1 and 3, silane pretreatment was applied using Adper Scotchbond Multipurpose Plus (ASMP). Small-particle composite-resin was subsequently added on the ceramic surfaces, and light-cured. Specimens of groups 3 and 4 then subjected to 1000 thermal cycles. Shear bond strength was determined on a universal testing machine at a crosshead speed of 1mm/min. Two-way ANOVA test ( $\alpha=0.05$ ) was used to analyze the bond strength.

**Results:** There were statistically significant differences between study groups ( $P<0.05$ ). Thermocycling caused a decrease in the shear bond strength for both silanized and non-silanized groups.

**Conclusion:** According to the results of this study, shear bond strength after thermocycling reduced considerably in ASMP system. In addition, silane treatment of porcelain was critical for achieving durable bond strength between composite-resin and porcelain.

**Key Words:** Bond strength; Composite-resin; Porcelain; Thermocycling; Porcelain repair systems

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Received: 25 March 2006

Accepted: 2 August 2006

*Journal of Dentistry, Tehran University of Medical Sciences, Tehran, Iran (2007; Vol: 4, No.1)*

## INTRODUCTION

Porcelain fused-to-metal restorations have been widely used for about 50 years, which results in highly functional and esthetic restorations [1]. Bonded porcelain is exceptionally strong; however, porcelain fracture in the metal-ceramic restorations may occur due to repeated stresses and strains during chewing, trauma, lack of proper framework support for the porcelain, technical errors, or parafunctional occlusion [2]. As it is arduous to remove

these restorations from the mouth, intraroral repair of fractured ceramic restorations with composite resins, offers patients a cost-effective alternative to replacement, and may increase the clinical longevity of fractured restorations [2,3].

Numerous bonding systems are now available to the dentist for repairing ceramic fractures. The most commonly used method is bonding composite resin materials to the fractured surface [4-7].

A number of systems have been developed to facilitate bonding of composites to porcelain and metal. In earlier repair systems, mechanical retention was aimed through the porcelain and metal surface treatments such as diamond roughening. Recent developments in modern surface conditioning methods with silane coupling agents have resulted in improved resin-to-ceramic bond strengths [8]. Further improvements includes air-particle abrasion of the surface with aluminum oxide, and etching the fractured ceramic parts with hydrofluoric acid (HF), to enhance bonding the composite resin to the ceramics [9-13]. HF etching procedure provides a porous surface on the porcelain which may facilitate micromechanical retentions. Furthermore, silane-coupling agent forms a chemical covalent bond between silica on the ceramic surface and resin composite which will improve the micromechanical interlock [4]. Theoretically, the silane-bonding combination should provide a stable and durable repair for the fractured porcelain [14]. Silane primers are categorized as unhydrolyzed single liquid silane primers, prehydrolyzed single liquid silane primers and two- or three-liquid silane primers (separate silane coupling agents and acid activators) [7]. In the prehydrolyzed systems, silane primer is applied separately followed by bonding agent application, or mixed with the bonding system and applied in a single step [11,15].

Some studies reported that the chemical composition of different silane solutions can differ substantially, and it is essential that silane and the bonding agent in a ceramic bonding system be compatible [16-18].

Although various silane primers and luting agents have recently been reported for ceramic bonding, limited information is available concerning the bond strength of some of these systems [19]. The effects of storage periods, thermocycling and surface treatments have been evaluated for some bonding systems; however the results were not in agreement

[7,20-25]. Some of these reports indicated that water storage and thermocycling did not stimulate intraoral aging, but influence on the bonding efficacy [7,20,21].

Nowlin et al [8] reported that the effect of thermocycling on the composite/porcelain bond strengths of three resins advocated for repairing dental porcelain was not consistent. The low repair strengths of the tested materials indicate that they can be used as a temporary clinical procedure [8].

Diaz-Arnold et al [21] in their study demonstrated cohesive porcelain failures for most of the non-thermocycled specimens, and that the thermocycling caused a significant decrease in the shear bond strength.

Blatz et al [7] compared shear bond strength of three different resin-based composite cements to two feldspathic porcelain and reported differences in the mean bond strengths among the bonding systems, and between the early and late time points, but did not differ between two ceramic materials. Failure modes were almost exclusively cohesive in the ceramic, which indicates sufficient resin-ceramic bond strength with tested materials [7].

This study compared the shear bond strength of composite-resin to a feldspathic porcelain (Ceramco3) with and without silane applications, and evaluated the effect of thermocycling on the bond strength.

## **MATERIALS AND METHODS**

Forty metal base plates (10×10×0.5mm) were cast according to the manufacturer's instructions using a nickel-chromium alloy, Supercast (Thermabond alloy MFG, Los Angeles, CA) and a 2 mm thick layer of the ceramic (Ceramco3, Dentsply Ceramco Co., Burlington, NJ) was fused to the metal plates. To ensure even smooth surfaces, the specimens were wet grounded with a 240, 320, 400 and 600 grit silicon carbide cylinders (Mounted Stones, American Dent-All Inc, Glendale, CA). All specimens were mounted in cylindrical resin

molds with a flat surface. The grounded ceramic surfaces were conditioned with 9.6% hydrofluoric acid (Porcelain Etch Gel, Pulpdent Co., Watertown, MA) for 3 minutes, rinsed and dried with compressed air for 30 seconds. In 20 specimens, porcelain surfaces were treated with silane (Adper Scotch-bond Multipurpose Plus, 3M ESPE, St. Paul, USA) and left for 1 minute, the silane was not used for the other 20 specimens. Then the resin bonding was applied to all specimens; air thinned and immediately light-cured for 10 seconds, according to the manufacturer's instructions. To simulate the resin composite repairing, cylindrical plastic molds (3 mm in diameter and 5 mm in height) were filled with a small-particle composite resin (Z100, 3M ESPE, USA), and were carefully positioned on the porcelain surfaces. The light curing was carried out with a polymerization unit (Coltolux 2.5, Coltene AG, Feldwiesenstrasse Altstätten/Switzerland) at an intensity of 480 mW/cm<sup>2</sup>, and a distance of 0.5 mm from the specimen surface, for 40 seconds. The resin composite cylinders were light-cured for additional 120 seconds from all three directions. Light was directed approximately 45°C from the intersection of the porcelain. Plastic molds then were removed and all specimens were stored in 37°C distilled water for 24 hours. Then each of the silanized, and non-silanized groups were divided equally in to two groups of 10 specimens. Groups 1 and 3 were kept in distilled water at 37°C; and groups 2 and 4 were subjected to alternating thermal cycles, between 5°C and 55°C for 1000 cycles (Mp Based, KARA 1000, Iran) with 30-seconds dwell time and 12-seconds transfer time. After thermal cycling, the specimens were stored in 37°C distilled water for an additional 48 hours prior to the shear bond test.

To determine the shear bond strength, specimens were placed on a universal testing machine (DARTEC, HC10, England) with a chisel-shaped rod at a crosshead speed of

1mm/min until the fracture. The data were analyzed with two-way ANOVA test. The modes of failure of the composite cylinders were observed under a stereomicroscope (M6C-10, N9116734, Russia) at 30× magnification. Failure modes were divided into adhesive, cohesive, and adhesive-cohesive failures.

## RESULTS

The shear bond strength data obtained for all test groups are shown in Table I. Mean bond strength did differ between the study groups ( $P < 0.001$ ). The highest mean shear bond strength was recorded for samples in the first group 20.47 (1.75) MPa. The lowest shear bond strength 8.07 (2.91) MPa was observed in group 4, in which specimens were not treated with silane before receiving thermal stresses.

Based on the two-way ANOVA, thermocycling had significant effect on the shear bond strength ( $f = 59.17$ ,  $P < 0.001$ ), furthermore silane application improved the bond strength significantly ( $f = 108.23$ ,  $P < 0.001$ ). However, there was not any interaction between thermal cycles and silanization. ( $f = 0.053$ ,  $P = 0.819$ ).

Stereomicroscopic analysis revealed ten cohesive failures in group 1, six cohesive and four adhesive/cohesive failures in group 2, nine cohesive and one adhesive failures in group 3 and finally two cohesive, five adhesive and three adhesive-cohesive failures in group 4. All cohesive failures were cohesive mode within the porcelain. Failure modes are

Table I: Descriptive statistics of shear bond strength (MPa) of the study groups.

Groups	Mean(SD)	Minimum	Maximum
1	20.47(1.75)	18.25	23.63
2	12.89(0.83)	11.60	14.15
3	15.11(2.27)	11.04	18.25
4	8.07(2.91)	3.82	13.44

elaborated in details in the Table II.

## DISCUSSION

Intraoral repair of the fractured porcelain restorations with composite-resins presents a substantial challenge for a dentist. Newer generation, multipurpose adhesive systems involve several treatment steps and agents for porcelain repair with composite resins [19].

A silane coupling agent is commonly used for this purpose. There is controversy regarding the long-term effectiveness of silane coupling agents in adhesive bonding [7,20-22]. This study examined the use of silane (Rely x ceramic primer) of ASMP system and the effect of thermal stresses on the shear bond strength.

The results of this study strongly suggested that silane is a crucial component in providing an effective bond between composite resin and ceramic, the effect of the silane treatment was particularly evident in groups 1 and 3. After water storage the bond strength in group 1 (silane group) was substantially greater than the non-silanized group (group 2). The shear bond strength using silane treatment was also higher after thermocycling. These results was in accordance with previous studies which suggested that the application of silane-coupling agents, in addition to micro-mechanical interlocking to ceramic etched surface, forms a chemical covalent bond between silica and resin, which improves the bond strength [7,20,21,24].

According to the result of this study, not only silane-coupling agent is a main factor in a

strong ceramic-composite bond, but also silanization the ceramic surface after etching with the HF acid was superior to etching alone; specially, this effect was more prominent after thermocycling. These findings confirm results of the previous studies [7,21,22].

Accuracy and clinical relevance of various in vitro bond strength testing methods for ceramic-composite bonding have been discussed extensively. Common testes are three-point bending, tensile, microtensile, and shear bond strength tests [7,25]. The porcelain-resin interface has also been subjected to fatigue loads [21]. A shear test was selected for this study due to its simplicity and use of multiple substrates [21].

Pratt et al [18] reported a significant decrease in the shear bond strength of composite resin bonded to porcelain, using six porcelain repair system after three months, at 37°C water storage and 500 thermal cycles.

In the present study thermocycling decreased shear bond strength significantly in both silanized and non-silanized groups. Comparison Between groups 3 and 4 also showed shear bond strength using silane treatment was higher after thermocycling.

In the oral condition, saliva and repeated thermal changes continuously degrade and hydrolyze the ceramic-composite-resin interface. Long-term water storage and thermocycling are accepted methods for the simulation of such aging and stressing conditions. Even though direct clinical correlations and conclusions can not be drawn from these aging methods, their significant effects on the bonding interface have been demonstrated in different studies [7,18,20,21].

The number and frequency of the cyclic thermal loading considered in the present study was based on the assumption that at least 10 thermal cycles would occur per day [25]. Accordingly, for a three months services of a repaired restoration, 1000 cycles was applied, which was inline with the experimental and

**Table II:** Failure modes of the study groups.

Groups	Mode of Failure		
	Cohesive	Adhesive	Cohesive/Adhesive
1	100%	–	–
2	60%	–	40%
3	90%	10%	–
4	20%	50%	30%

clinical studies. Some researchers believed that applying thermal stresses may affect the adhesion, however it has never been demonstrated that cyclic thermal testing is related to clinical failures. In addition, different cyclic thermal loading used in various studies makes comparison difficult. It could be assumed that longer thermal stress further diminishes long-term bonding durability [21]. However, most water sorption by polymers occurs within the first 24 hours of storage [25]; as a result 1000 thermal cycles offered a practical evaluation of initial adhesion in this study.

A reduced shear bond strength after prolonged water storage and/or thermocycling is a common finding in different studies [21,24,25]; however, regarding the number and conditions of cycles, the reduction in shear bond strength in the present study was considerable. In the present study, 1000 thermal cycles, dramatically decreased resin bonds to the feldspathic porcelain. This study confirms the previous studies which found repeated thermal cycles significantly decrease bond strength [20,21]. Due to the differences in coefficients of thermal expansion, it was expected that the introduction of thermal stress would weaken the bond strength [8].

Analysis of the failure sites with stereomicroscopic provided additional evidence that silane application was critical for composite-ceramic bonding. In all porcelain surface treated with HF and silane, the failure mode was of cohesive type within the porcelain. Also, in previous studies, it was reported that the most observed failures in composite resin repair of porcelain were of cohesive mode within the ceramic [16,21]. However, bond strength was exceeded the fracture resistance of the porcelain (90-100% cohesive failure in porcelain) for the ASMP system before thermal stresses. Therefore, it is unclear whether the decrease in bond strength is mainly due to a weakening in the resin-based composite cements or the ceramic material weakness.

The occurrence of cohesive failures in porcelain was markedly less for groups exposed to thermal stresses.

In addition, in the present study the results of shear testing were in accordance with the mode of failure, as in group one with the highest shear bond strength all fractures was seen within ceramic, and in other groups, with less shear bond strength, the more adhesive and adhesive-cohesive failure were observed.

As many variables involve in porcelain fracture, the in vivo behavior of these materials as porcelain repair agents remains to be fully evaluated. To ensure the optimal performance, it is recommended that the underlying cause of porcelain fracture be identified and corrected.

## CONCLUSIONS

Within the limitation of present study, the following conclusions can be made:

- 1- To achieve durable bond strength of composite resin to a repaired ceramic, silane pretreatment of the etched surface is essential.
- 2- Thermocycling caused a statistically significant decrease in the mean bond strength.

## ACKNOWLEDGMENT

This study was supported by Research Center of Isfahan University of Medical Sciences and Health Services grant. Authors also wish to thank dean and staff members of Prof. Torabinejad Dental Research Center.

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