

Research Report

The difference between porcelain and composite resin shear bond strength in the administration of 4% and 19.81% silane

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ABSTRACT

Background: Damage to porcelain restorations such as fractures requires a repair that can be performed either directly or indirectly. Direct repair involves directly performing restoration of fractured porcelain with a composite resin application. This technique has more advantages than indirect repair because it requires no laboratory work and can be completed during a single visit. Silane, on the other hand, has been widely used and is reported to increase porcelain and composite resin attachments during the direct repair process. **Purpose:** This study aimed to determine the differences in shear bond strength between porcelain and composite resin during the administering of 4% and 19.81% silane. **Methods:** 27 porcelain samples were divided into three groups, namely: Group A - 4% silane, Group B - 19.81% silane and Group C - no silane, prior to the application of composite resin. Each sample was tested for shear bond strength by means of Autograph and fracture analysis performed through stereomicroscope and scanning electron microscope tests. Data analysis was subsequently performed using an ANOVA test. **Results:** There was a significant difference between the three groups with $p=0.000$ ($p<0.005$). The lowest bond strength was found in the group without silane, while the highest was in the group with 4% silane ($p<0.005$). **Conclusion:** The use of 4% silane can produce the highest shear bond strength of porcelain and resin composite.

Keywords: porcelain repair; shear bond strength; silane

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INTRODUCTION

Porcelain restoration has been widely used as an indirect form of repair because of its benefits.¹⁻³ Nevertheless, it also suffers from certain drawbacks leading to restoration failure in the form of fractures.^{2,4} A previous investigation found that 5-10% of fractures occur in porcelain restorations which have been utilized for more than ten years, while 2.3-8% of fractures in porcelain are fused to metal restorations.⁵ The high risk of fracture explains the demand for repair of porcelain restorations. There are two types of repair, direct and indirect, relating to fractured porcelain restorations. Direct repair offers more advantages than the indirect variety, since it requires less time, utilizes a less complicated technique and is more affordable.^{2,5} Moreover, Direct repair it will also produce a positive prognosis if the cause of the fracture constitutes a trauma to the anterior

teeth. Other prior research even shows that direct repair of porcelain with composites on anterior teeth has a higher success rate than that of posterior tooth restorations in addressing damage to the occlusal and proximal marginal ridge areas involving proximal contact.^{6,7}

Employing composite resins as porcelain fracture repair materials has been widely developed. The mechanism of composite attachment to porcelain consists of two forms, namely; micromechanical and chemical. Micromechanical attachment using an adhesive system involves etching on porcelain with such agents as hydrofluoric acid. Meanwhile, chemical attachment is conducted by introducing silane solution between the porcelain layer and the composite.⁸

Silane, a coupling agent employed as a bonding material between organic and inorganic materials, is a bifunctional molecule consisting of functional and non-functional molecules. The functional molecule in silane can

polymerize with a functional group in an organic matrix of a composite resin. Furthermore, silane can react with free radicals produced during composite resin polymerization, while also belonging to a degradable functional group that will polymerize the organic matrix of the resin. Meanwhile, non-functional molecules in the alkoxy silane group can react with inorganic substrates in porcelain. In addition, silane contains silicone dioxide which can react with OH groups on the porcelain surface enabling it to form chemical attachments there.^{1,2,9}

Silane solution has also been widely employed as an adhesive material in porcelain fracture repair and is reported to increase the strength of the composite attachment to porcelain. A previous investigation comparing forms of porcelain fracture repair indicated that a group without silane has the lowest attachment strength compared to one with silane.⁸ One case report even argues that the direct repair of fractured porcelain restoration of anterior teeth with composites and silane additions can be well preserved for up to three years.⁶

In this research, silane products were used with ethanol solvent whose concentrations were 4% and 19.81%. A previous piece of research states that a relationship exists between the concentration of silane and the shear bond strength of the metal bracket to the porcelain surface. The highest shear bond strength is achieved by the use of silane at a concentration of 2.5% compared to that at concentrations of 5-15% and 15-20%.¹⁰

In addition, a low silane concentration has more beneficial properties than a high one because the auto-polymerization process of silane becomes optimal in its solvent.¹¹ Thus, the higher the concentration of silane, the less perfect the chemical bonds formed since the formation of bridges between organic and inorganic components is inhibited.¹² Unfortunately, it is not yet known whether different silane concentrations have any effect on shear bond strength during porcelain repair. Consequently, this research aims to determine the differences in shear bond strength between porcelain and composite resin using 4% and 19.81% silane.

MATERIALS AND METHODS

This research used 27 samples in the form of cylindrical porcelain with a diameter of 4 mm and a height of 2.5 mm. The criteria applied to the porcelain samples employed included a flat, smooth and unglazed surface without cracks and/or porous sections.¹¹ Moreover, this research also used silane with ethanol solvent at concentrations of 4% and 19.81% determined according to the presence of silane products on the market.

The samples were subsequently divided into three groups, namely: Group A with 4% silane, Group B with 19.81% silane and Group C without silane. Porcelain samples were inserted into acrylic molds and etched with 9% hydrofluoric acid (Porcelain etch, Ultradent, USA)

for 90 seconds. Thereafter, 4% silane (Monobond Plus, Ivoclar, Germany) was applied to Group A and 19.81% silane (Porcelain Repair Primer,Ormco, North America) to Group B for 60 seconds. Bonding agent (Adper Single bond, 3M, USA) was then applied to all groups and illuminated by means of a light curing unit (LED-E Curing Light, Woodpecker) in accordance with factory rules. Composite (Estelite γ Quick, Tokuyama Dental, Japan) was then applied to porcelain samples using a layering technique.

A shear bond strength test was performed using Autograph (Shimadzu, Japan) with a cross head speed of 0.5 mm/minute. Each sample was then placed on the plunger. The shear bond strength score shown on the tool was observed, especially when the sample experienced adhesive failure and recorded by a kN unit. The sample interface was then checked using a stereomicroscope at 20x magnification and a scanning electron microscope (SEM) at 50x and 150x magnification to determine the locations of the sample fractures.

The results of the research were calculated to determine their mean value and standard deviation (Table 1). A Shapiro-Wilk test was subsequently conducted to determine the normality of data distribution followed by a homogeneity test. In order to reveal differences, an ANOVA test with a significance level of 0.05 and a Tukey HSD test was then carried out.

RESULTS

According to the Shapiro-Wilk test results, the p value in all groups was more than 0.05 which indicated that the research data was normally distributed. A homogeneity test and Levene test were, therefore, performed, the results of which showed a p value of 0.159 ($p > 0.05$) indicating the homogeneity of the research data.

An ANOVA test was conducted in order to establish whether a difference in the research data existed. The results showed a p value of 0.000 ($p < 0.005$) indicating a significant contrast between the research groups. Consequently, a Tukey test was conducted in order to identify differences between each pair within the research groups.

The Tukey test result values of $p = 0.000$ ($p < 0.005$) indicated significant differences in silane at contrasting concentrations between the research groups (Table 2). In other words, the concentration of silane demonstrated a significant difference from the shear bond strength. To find the location of the sample fractures, a stereomicroscope analysis was carried out followed by SEM on the porcelain surface which involved selecting one sample randomly from each group.

In the groups with 4% silane and 19.81% silane (Figures 1, 2 and 3), fractures were in the form of mixed failure. This means that the adhesive failure occurred partially in composite resin and adhesive material. On the other hand, in the group without silane, a fracture occurred in the form of adhesive failure. This indicates that adhesive failure

Table 1. The mean value and standard deviation of the shear bond strength of porcelain and composite resin using different silane concentrations (MPa).

Treatment groups	n	\bar{x}	SD
4% silane	9	28.7933	0.98574
19.81% silane	9	19.8178	0.64128
Without silane	9	16.9122	0.50840

Table 2. The results of Tukey test on the shear bond strength of porcelain and composite resin.

Silane concentration	Without silane	4%	19.81%
Without silane		0.000*	0.000*
4% silane			0.000*
19.81% silane			

* Significant difference $p < 0.05$

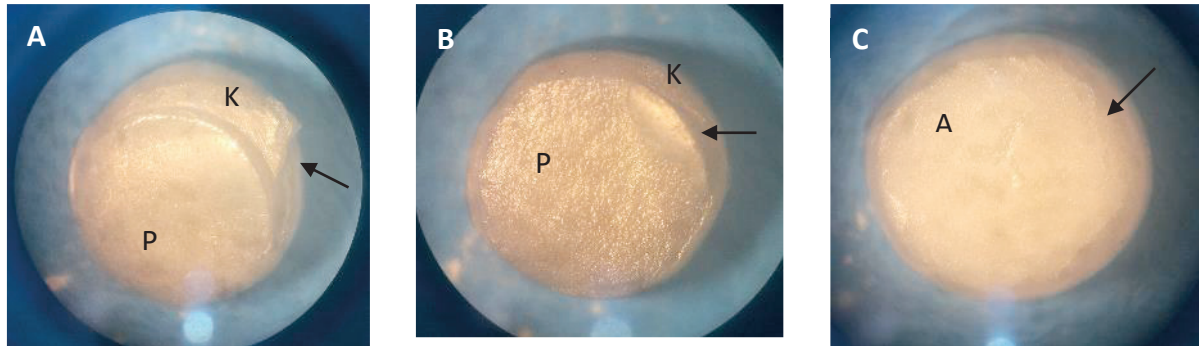


Figure 1. The pictures of porcelain surfaces under stereomicroscope with 20x magnification. Arrows indicate porcelain and composite fracture areas. (Note: P: porcelain, K: composite. A: adhesive (bonding)). A) 4% Silane; B) 19.81% Silane; C) Without Silane.

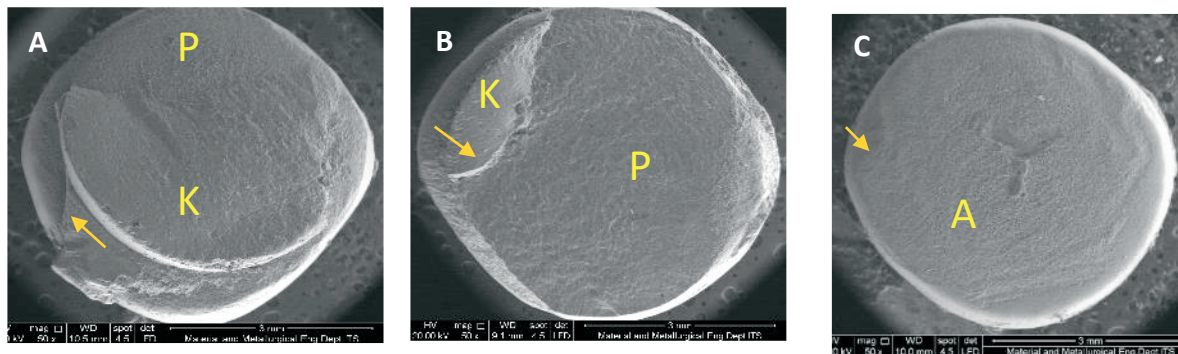


Figure 2. The pictures of porcelain surfaces under SEM with 50x magnification. Arrows indicate porcelain and composite fracture areas. (Note: P: porcelain, K: composite. A: adhesive (bonding)). A) 4% Silane; B) 19.81% silane; C) Without silane.

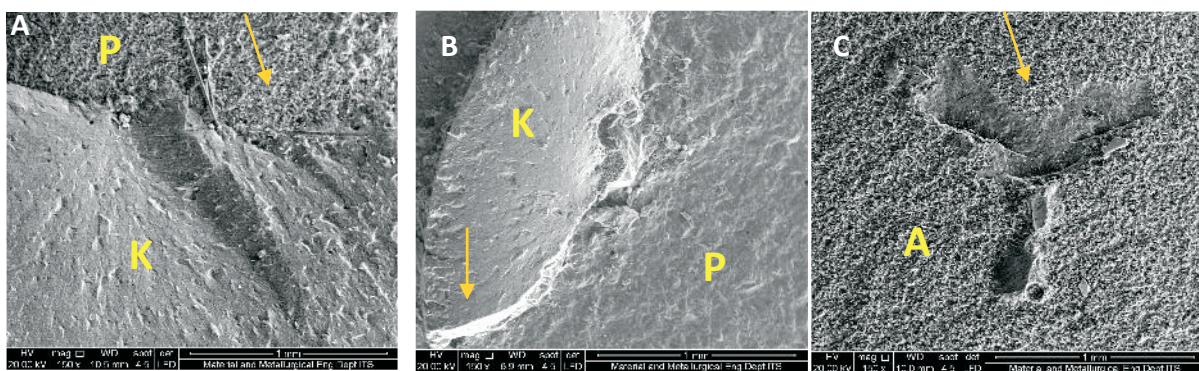


Figure 3. The pictures of porcelain surfaces under SEM with 150x magnification. Arrows indicate porcelain and composite fracture areas. (Note: P: porcelain, K: composite. A: adhesive (bonding)). A) 4% Silane; B) 19.81% Silane; C) Without silane.

occurred in the adhesive material interface. Moreover, it can also be said that the shear bond strength of porcelain and composite resin interface in the group without silane was not as great as that in the groups with silane.

DISCUSSION

The high risk of fracture in porcelain restoration requires a feasible repair treatment, one of which is direct repair which uses composite resin and has been widely applied in the field of dentistry with positive results. The attachment of composite resin to porcelain can occur both micromechanically and chemically. Micromechanically, the attachment of composite resin to porcelain can occur through an etching process using hydrofluoric acid (HF) while, chemically, it involves administering silane solution before applying composite resin to the porcelain.

In the direct porcelain repair process, silane also plays a role as an adhesive between two substances such as porcelain (inorganic) and composite (organic) materials in order to increase the shear bond strength between them. Silane also has the potential to react with alkoxy groups which can be activated through a hydrolysis technique involving a reaction of silicone dioxide with the OH/Hydroxyl group on porcelain surfaces which can result in a chemical attachment (SiOr becomes SiOH).^{9,12} In order to determine the effects of silane concentration contained in the product on the shear bond strength between porcelain and composite resin, this research used silane products at concentrations of 4% and 19.81%.

The shear bond strength in the control group was the lowest since the surface of the porcelain was not treated with silane, but merely etched and bonded. This finding was in line with that of research conducted by Newburg *et al*, comparing porcelain fracture repairs using silane and ones without silane. The results of this previous research suggested that the group without silane had the lowest shear bond strength compared to the groups with silane.⁸ According to a case report, the application of silane to porcelain repairs using composite resins can increase attachment by up to 25%.² This signifies that silane has a higher adhesive strength.

Silane, given its function as a coupling agent for organic and inorganic substrates, must be salinized first through hydrolysis or an activation process and, subsequently, by condensation. Following the hydrolysis process, siloxane oligomers will react with each other, forming a branch of hydrophobic siloxane (-Si-O-Si). This group can react with an inorganic matrix.¹¹ Meanwhile, the silane attachment with composite resin can occur through a reaction of silane with free radicals derived from polymerization of composite resin involving the formation of a C-C group.^{1,2,9}

A concentration of silane which is too high can cause obstruction of bridges between organic and inorganic components and reduce attachment. Meanwhile, low silane concentration can produce superior attachment since the

auto-polymerization process of the silane molecule in the solvent becomes optimal. Moreover, the low concentration of silane produces a thinner siloxane layer which can increase the attachment of composite and metal/porcelain resins.^{13,14} At low concentrations, silane also produces higher siloxane absorption during silane activation process than saline at high concentrations.¹⁵ In addition, the high concentrations of silane can interfere with oligomer formation in the process of siloxane formation in silane, thus compromising the adhesion of silanes to inorganic matrices.¹⁶

The two products employed in this research also contained solvent. The concentration of silane in a product is not considered to be the only major factor in the activation and condensation processes of silane. Another factor affecting the processes is solvent whose concentration in silane products affects moisture and wettability. Products with a lower concentration of silane and larger solvents will produce high humidity which facilitates penetration of composite resin into the porosity of the surface of the porcelain and increases the adhesion strength between porcelain and composite resin.¹⁵ Hence, in this research the highest shear bond strength was found in silane at a concentration of 4%.

Based on the results of the stereomicroscope and SEM tests, it can be argued that in the group without silane adhesive failure occurred only in the adhesive material. In contrast, in the groups with silane at concentrations of 4% and 19.81%, the adhesive failure occurred partially in both adhesive and cohesive materials (mixed failure). In other words, in the groups with silane at these concentrations, the failure occurred in the form of mixed failure; partly in the composite resin and partly in the adhesive/bonding material. This shows that the composite can bind well to the porosity of the surface of the porcelain.

In contrast to the other groups, the failure in the control group (without silane) occurred only in the adhesive material. It can be argued that, unlike in the groups with silane, there was no damage to the composite resin in the control group. This indicates that silane can increase the attachment of composite resin and porcelain by forming optimal bonds between composites and porcelain. Therefore, it can be concluded that silane at a concentration of 4% can enhance the shear bond strength between porcelain and composite resin.

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