# Effect of Type of Surface Treatment and Adhesive System on Shear Bond Strength of Composite Resin to a Non-Precious Metal Alloy

E. Yasini<sup>1</sup>, M. Mirzaie<sup>2</sup>, H. Kermanshah<sup>2</sup>, E. Habibi<sup>3</sup>, F. Motevasselian <sup>24</sup>.

<sup>1</sup> Professor, Dental Research Center, Dentistry Research Institute, Department of Restorative Dentistry, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

<sup>2</sup> Associate Professor, Dental Research Center, Dentistry Research Institute, Department of Restorative Dentistry, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

<sup>3</sup> Specialist in Restorative and Esthetic Dentistry, Tehran, Iran

<sup>4</sup> Assistant Professor, Department of Restorative Dentistry, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

#### Abstract

**Background and Aim:** Fractured metal-ceramic restorations may be repaired with composite in some cases to postpone the fabrication of a new restoration. Knowledge about the bond strength can help predict the success rate of this treatment modality. The aim of this study was to assess the effect of two types of mechanical surface treatment of metal along with the use of different adhesive systems on bond strength of composite to a non-precious metal alloy.

**Materials and Methods:** In this in vitro experimental study, 110 metal discs were fabricated of nickel chromium alloy and were randomly divided into two groups of surface preparation with sandblasting (S) and bur (B). In each group, the samples were divided into five subgroups based on the adhesive system and composite resin used: Group NC: Z350 composite without application of adhesive; group AC: Alloy primer/Clearfil AP-X; group ZA: Z-Prime Plus/Aelite; group MT: Monobond Plus/Tetric N Ceram; group AZ: Adper Single Bond Plus/Z250. In the positive control group (PC), metal discs were covered with feldspathic porcelain. All samples were then subjected to 1000 thermal cycles and shear bond strength was measured. Data were analyzed using one-way ANOVA, two-way ANOVA and Tukey's HSD test (P<0.05).

**Results:** The interaction effect of type of surface treatment and type of adhesive system on bond strength was significant (P<0.05). The highest bond strength (148.7 MPa) was noted in group PC and the lowest bond strength (2.78 MPa) was noted in group B+NC. The bond strength was 13.72 MPa in group S+AZ, 10.84 MPa in group B+AZ and 12.72 MPa in group S+ZA, which did not have a significant difference with the bond strength of group PC.

**Conclusion:** Type of surface preparation and adhesive affect the bond strength. Surface preparation by sandblasting or bur combined with the use of Adper Single Bond Plus and also combination of Z-Prime Plus adhesive and sandblasting yielded the highest bond strength value.

Key Words: Dental Bonding, Adhesives, Shear Strength, Composite Resins, Metal Ceramic Alloys

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Corresponding author: F. Motevasselian, Assistant Professor, Department of Restorative Dentistry, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

f-motevasselian@sina.tums.ac.ir

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## Introduction

Despite the growing interest in use of all-ceramic restorations and recent advances in dental ceramics, metal-ceramic restorations are still considered а suitable choice for dental rehabilitation due to stable mechanical properties and optimal durability [1]. However, fracture of porcelain in metal ceramic restorations may occur. Porcelain fracture may be seen in the form of delamination. fracture or chipping of the veneering porcelain [1]. Fracture of the porcelain veneering is one of the causes of failure of metal ceramic restorations [2]. Moreover, fractures often occur in areas that are quite visible and compromise esthetics [2]. Different types of fracture of the porcelain veneering may occur. Porcelain fracture may be cohesive within the porcelain, or can be a combination of metal exposure and porcelain fracture or extensive exposure of metal [3]. High cost, shortage of time, difficult retrieval of restoration and the risk of damage to the underlying tooth structure may complicate or delay the replacement of metal ceramic restorations [4]. Therefore, as long as the health of tooth and periodontium can be preserved, a restoration can be repaired instead of replacement if the latter is difficult or not feasible [5]. Chipped porcelain can be repaired using different adhesive materials to restore function and esthetics. Composite resin has been applied for the repair of fractured metal porcelain restorations using different adhesive systems [6]. To improve the bond strength, surface treatments can be applied to provide mechanical or chemical retention for the repairing material. Surface treatments can provide mechanical or chemical bond between the two surfaces [7]. Abrasion of surfaces with aluminum oxide particles, roughening the surface with rotary diamond burs, and etching with hydrofluoric acid can enhance mechanical attachment while use of silane and adhesive primers may enhance chemical adhesion [4]. Currently, some bonding systems are available providing acceptable bond strength to porcelain [8]. Bond strength to base metal alloys in different adhesive systems is highly variable and has a wide range [5,7,9]. Considering all the above, this study aimed to assess the effect of different mechanical surface preparations and different adhesive

systems on shear bond strength of composite resin to a non-precious metal alloy.

## **Materials and Methods**

In this in vitro, experimental study, 110 metal discs measuring 10x2 mm were fabricated of nickel chromium alloy (Verabond, AlbaDent, USA) according to the manufacturer's instructions. The wax models of metal discs were designed, invested and cast using centrifuge casting machine. The surface of metal discs was sandblasted and cleaned. To prepare the surfaces for bonding, they were polished with 120, 400 and 600-grit silicon carbide papers. The 100 invested discs were divided into two groups of 50 for surface treatment by sandblasting or bur. Half of the samples were sandblasted and the other half were treated with fissure diamond bur (0463; Larmrose, Switzerland). Samples were sandblasted with an intraoral sandblaster (Microetcher, Danville Engineering, USA) with 50µ aluminum oxide particles and 35 Psi pressure from 1cm distance perpendicular to the surface for 15 seconds. The samples were rinsed with water for five seconds and dried with oil-free air. Each group was divided into five subgroups (n=10) based on the type of adhesive and composite resin. Silicon molds measuring 3x5 mm were used for composite application in three increments each with 1 mm sickness after the application of adhesive. Each layer was light cured for 20 seconds using a light curing unit (Optilux 501, Kerr, Orange, CA, USA) with a light intensity of 400 mW/cm<sup>2</sup>. Table 1 summarizes the composition of adhesives used in this study.

The subgroups were as follows:

Group 1 (negative control or NC): Z250 composite (3M ESPE, St. Paul, MN, USA) was directly applied on the metal surface with no adhesive.

Group 2: Two layers of alloy primer (Kuraray, Tokyo, Japan) were applied on the surface and gently air sprayed for five seconds. Clearfil AP-X composite (Kuraray, Tokyo, Japan) was used for the fabrication of composite cylinder.

Group 3: Two layers of Z-Prime Plus (Bisco, IL, USA) were applied on the surface and gently air sprayed for five seconds. Aelite (Bisco, IL, USA) composite cylinder was then fabricated. Group 4: Two layers of Monobond Plus (Ivoclar

Material	Composition	Manufacturer	
Alloy primer	MDP, VBATDT, Acetone	Kuraray, Japan	
Z-Prime Plus	HEMA, BPDM, MDP, ethanol	Bisco, USA	
Monobond Plus	Silane methacrylate, phosphoric acid ester,	Ivoclar Vivadent, Schwan,	
	sulfide methacrylate, ethanol	Lichtenstein	
Adper Single Bond Plus	BisGMA, HEMA, dimethacrylate,	3M ESPE, St. Paul, MN, USA	
	methacrylate functional copolymer of		
	polyacrylic and poly-itaconic acids ethanol,		
	water, silica filler		

Table 1. Adhesive systems used in this study

Vivadent, Schaan, Liechtenstein) were applied on the surface and gently air sprayed for five seconds. Tetric N-Ceram (Ivoclar Vivadent, Schaan, Liechtenstein) composite cylinder was then fabricated.

Group 5: Two layers of Adper Single Bond Plus (3M ESPE, St. Paul, MN, USA) were applied on the surface and gently air sprayed for five seconds. Z250 (3M ESPE, St. Paul, MN, USA) composite cylinder was then fabricated.

Ten metal discs were fabricated as the positive control group according to the manufacturer's instructions for the application of feldspathic porcelain (Ceramco II, Ceramco Inc., Burlington, NJ, USA). After the use of white stone bur made of aluminum oxide, the metal surface was sandblasted with 50µ aluminum oxide particles with 55 Psi pressure in one direction and was then immersed in an ultrasonic bath containing distilled water for 10 minutes. Degassing was performed in a porcelain furnace (Vacumat 200; Vita Zahnfabrik; Bad Sackingen; Germany) at 650-980°C temperature. Silicone molds were used for the application of porcelain. The mold was placed at the center of metal disc and two thin layers of opaque porcelain and one layer of dentin porcelain were applied and each layer was separately light cured according to the manufacturer's instructions.

All samples were subjected to 1000 thermal cycles (TC-300, Vafaie Inc., Tehran, Iran) between 5-55°C with a dwell time of 30 seconds. After completion of thermocycling, the samples were mounted in auto-polymerizing acrylic resin in a brass mold and subjected to a universal testing machine (Zwick Roell, Ulm, Germany) applying shear load at a crosshead speed of 0.5 mm/minute,

and bond strength was recorded in mega pascals (MPa).

Data were analyzed using SPSS version 18. Two-way ANOVA was applied to assess the effect of type of primer and surface treatment and their interaction effect on shear bond strength. Since their interaction effect was significant (P<0.001), the effect of each independent variable namely surface preparation and type of adhesive on bond strength was separately assessed using one-way ANOVA. Since the variances were equal, Tukey's HSD test was applied.

#### Results

Table 2 shows the mean micro-shear bond strength of the groups. The highest bond strength was noted in samples prepared with bur or by sandblasting and use of Adper Single Bond Plus adhesive as well as in sandblasted samples with the use of Z-Prime Plus. These values were not significantly different from the positive control group. The remaining experimental groups showed lower bond strength (Table 2). Independent samples t-test was applied to assess the effect of surface preparation separately for each adhesive system.

Effect of adhesive type:

One-way ANOVA revealed a significant difference among adhesive systems in samples subjected to sandblasting surface treatment. The shear bond strength in Adper Single Bond Plus and Z-Prime Plus groups was significantly higher than that in other adhesive groups. Monobond Plus and alloy primer adhesive groups showed statistically similar values to the NC group (Diagram 1).

One-way ANOVA showed that in samples subjected to bur preparation, a significant

Adhesive system	Treatment surface	Mean± standard deviation	P value**
No odbosivo (NC)*	Bur	$2.78 \pm 1.39$	<0.001
No adhesive (INC)*	Sandblasting	$6.32\pm2.03$	≥0.001
Adreas Single Dend Dive	Bur	$10.84 \pm 3.79$	077
Auper Single Donu Plus	Sandblasting	$13.72 \pm 3.03$	.077
7 Duine Ding	Bur	$6.14 \pm 1.25$	<0.001
<i>L</i> -Prime Flus	Sandblasting	$12.72\pm2.9$	≥0.001
Manahand Dhua	Bur	$7.6 \pm 2.31$	0.226
Wionoboliu Pius	Sandblasting	$6.31 \pm 2.26$	0.220
Alloy primer	Bur	8 ± 1.97	0.912
	Sandblasting	$8.2\pm1.55$	0.812
Porcelain (PC)*		$14.77 \pm 5.97$	-

 Table 2. Mean and standard deviation of micro-shear bond strength of adhesive to nickel chromium alloy with different surface preparations (n=10)

\*NC: Negative control: PC: Positive control

\*\* P values for comparing bur and sandblast subgroup in each adhesive system



Diagram 1. Error bar and 95% confidence interval of the mean bond strength in the groups

difference was noted among the adhesive subgroups. The lowest and the highest bond strength values were found in the NC group and Adper Single Bond Plus, respectively and the difference in shear bond strength of the latter group with other groups (except for alloy primer) was statistically significant (P<0.05, Diagram 1).

### Effect of surface treatment:

The results showed that no significant difference was noted in bond strength of adhesive groups between bur and sandblasting surface preparations except for the control and Z-Prime Plus groups (Table 2).

#### Discussion

Fracture of metal-ceramic restorations is a challenge for dentists. Composite resin is the material of choice for repair of fractured porcelain restorations [10]. Several techniques are used for intraoral repair of fractured metal-porcelain restorations [11,12]. The current study assessed the micro-shear bond strength of four adhesive systems for intraoral repair of metal-ceramic restorations with two surface treatment methods to enhance the bond of composite to non-precious metal alloy.

No significant difference was observed among the

sandblasting and bur surface treatment methods in different adhesive groups except for the NC and Z-Prime Plus groups. This might be due to the adequate surface roughness created by the two methods. The higher bond strength in the NC group following sandblasting in comparison to diamond bur treatment might be due to increased micromechanical retention created by sandblasting. In addition, the higher bond strength values in Z Prime Plus adhesive group after metal treatment using sandblaster in comparison to diamond bur preparation might be attributed to improved metal surface wetting by adhesives after the former treatment method. Jain et al. found no significant difference in shear bond strength of composite resin to metal after surface preparation of metal with bur or sandblasting in Porcelain Repair (3M ESPE) and Clearfil Repair (Kuraray) systems [3]. In the current study, the lowest bond strength was obtained in the diamond bur treated group with no adhesive application (2.78MPa). Adhesive application increased the bond strength in all groups. This finding shows that the primers have the ability to chemically bond to metal and improve composite-metal bond. Higher shear bond strength values in Adper Single Bond Plus group compared to other primers may be attributed to superior chemical bond provided by this adhesive and its hydraulic stability. Nevertheless. micro-mechanical roughening of the surface seems favorable in all adhesive groups since it increases the surface area for wetting by the adhesives [4, 5, 7].

In the current study, application of Adper Single Bond Plus following two types of surface treatments yielded the highest bond strength with no significant difference in comparison to the values obtained in Z-Prime plus adhesive group applied over sandblasted samples. Mohammadi et al. [13] used different adhesive systems to bond the composite resin to feldspathic porcelain and explained that high bond strength obtained by Adper Single Bond may be due to hydraulic stability of this adhesive [13,14].

In our study, combination of sandblasting and Z-Prime Plus was much more effective than alloy primer and Monobond Plus. According to the manufacturer, Z-Prime Plus should be applied on the metal surface before the application of composite resin in the repair process. But, in use of alloy primer, following the use of bifunctional primers, application of one layer of bonding agent is recommended by the manufacturer, which was not done in the current study in order to shorten the procedure and evaluate its individual effect on bond strength separately. Bifunctional monomers can serve as a coupling agent between the organic content of composite and inorganic content of metal and enhance the wetting of surface and increase the bond of composite resin [15-17]. Alloy primer contains MDP and VBATD; VBATD has been added to enhance the bond to resin cement or composite resin [18]. In our study, low bond strength in this group can be due to absence of a bonding layer, and the bonding agent of this adhesive is suggested to be used in addition to the primer in repair of metal surfaces to enhance the bond strength. Monobond Plus is a universal primer for bond of indirect restorative materials, such as precious and non-precious metals, glass ceramics and ceramic oxides and contains trimethoxysilanealcoholic solution, phosphoric acid methacrylate and sulfide methacrylate [19]. But, pH of 3.1 is required for combination of silane component with phosphate monomers, which results in silane instability and consequent hydrolysis and significant loss of bond strength [20]. This might explain the low bond strength values obtained using Monobond Plus. The high bond strength values in Z-Prime Plus samples might be explained by its composition. It contains carboxylic monomers and phosphate with no silane component, which may result in a more stable composition. In addition, higher concentration of phosphate monomers probably improves adhesion to metal oxides [20].

Z-Prime Plus contains carboxylic monomers and phosphate with no silane component. Thus, it seems that a more stable compound is formed and higher concentration of phosphate monomers can result in greater adhesion to metal oxides [20]. Moreover, carboxyl groups can bond to metal oxides [1] and enhance the bond strength. Adper Single Bond Plus includes Bis-GMA, HEMA, di-methacrylate and methacrylate functional copolymer of polyacrylic and poly itaconic acids. Presence of polyalkenoic acids is effective for moisture resistance [21]. Moreover, presence of

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polyalkenoic acid may increase the bond to metal oxides [22] and enhance the bond strength. The manufacturer of this adhesive recommends it for repair on metal surfaces [21]. Moreover, this adhesive contains 10wt% silica fillers [21], which might have resulted in formation of a thicker adhesive layer compared to other adhesives in our study. A thicker adhesive layer may serve as an intermediate elastic layer to resist polymerization shrinkage [23] and thermal stresses [24]. Formation of a thicker layer is not recommended in use of adhesive systems without fillers [23] because they have lower mechanical properties [23]. Moreover, thermal stresses created during thermocycling can degrade the metal-composite bond due to difference in coefficient of thermal expansion of materials and degradation of bond via hydrolysis [25]. Furthermore, higher bond strength in Adper Single Bond Plus may be attributed to the presence of Bis-GMA in chemical composition of this adhesive, which can result in better surface wetting and enhanced bond strength to metal surface. A previous study assessed the effect of addition of Bis-GMA to different zirconia primers on shear bond strength to a resin cement and it was noted that addition of this resin to Monobond Plus primer increased the bond strength. In this study, Z-Prime Plus resulted in the highest bond strength; it was attributed to the specific chemical formulation of this primer that contains phosphate monomers and carboxylate. Another explanation is the presence of Bis-GMA in its composition, which can result in better wetting of surface by resin cement [26].

Studies on use of dentin bonding agents for bond of composite resin to porcelain or metal are limited. Knight et al. used different bonding systems in bond of composite resin to base metal and showed that the highest bond strength was obtained by All Bond 2 followed by Single Bond and Optibond FL [9].

The bond strength range of composite to non-precious metal by different surface treatments and adhesives in previous studies has been similar to the range reported in our study (2.78 to 13.72 MPa). Gourav et al. [1] showed that the bond strength values varied between 3 to 10 MPa; this value was 11 to 16 MPa in the study by Knight et al, [9] and 9-18 MPa in the study by Jain et al, [7] who reported the lowest values in Monobond S applied over bur treated surface and the highest values for the same adhesive applied over sandblasted surfaces; this was attributed to the presence of phosphate ester groups and the ability to form chemical bond with the oxide layer on the alloy surface.

According to Karla et al. [27] the minimum bond strength required for intraoral repair is 8 to 9 MPa. Based on our results, bond strength in use of Adper Single Bond Plus with both surface preparation methods and Z-Prime Plus with sandblasting was higher than the expected bond strength, which might explain the adequacy of these adhesive systems.

In conclusion, our results showed that application of Adper Single Bond Plus over bur treated surfaces caused similar bond strength values in comparison to samples treated with more complex surface treatments i.e. sandblasting by use of Al2O3 particles. However, further in vitro studies with higher thermal cycles are recommended for assessment of durability of bond.

## Conclusion

Within the limitations of this study, the shear bond strength values of composite resin to a non-precious metal substrate were not significantly different between the two surface treatment methods except for Z-Prime Plus and NC groups. Adhesives systems played a more important role in increasing the bond strength in comparison to surface roughening methods. Adper Single Bond Plus application on the metal surface following both treatment methods and Z-Prime Plus application after sandblasting produced the highest bond strength values.

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