

Shear Bond Strength of a Veneering Resin to a Ni-Cr Alloy Using Two Different Surface Treatment Methods

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KEY WORDS

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ABSTRACT

Statement of Problems: A strong and stable bond between veneering materials and metal framework considerably promotes the aesthetic appearance and clinical longevity of a resin type restoration. Various adhesive metal primers have also been studied to enhance the bond strength of the composite resins to different metal surfaces.

Purpose: The purpose of the present study was to evaluate the shear bond strength of one laboratory composite resin bonded to a Ni-Cr alloy by means of two different methods.

Materials and Methods: In this study, 24 wax disks were cast and divided into two equal groups. In the first group, a metal primer was applied to the casting surface, while an opaque porcelain material was used for the second group. After application of the veneering composite resin to the treated surfaces, the specimens were stored in a 37°C water bath for 15 days. At the end of this period, all the specimens were subjected to 1200 thermal cycles (5°C and 55 °C) and then tested for shear strength in a universal testing machine at a crosshead speed of 0.5 mm/min. Fractured specimens were examined, using a scanning electron microscope.

Results: The opaque porcelain group demonstrated higher bond strength (17.55±3.33 Mpa) in comparison to the metal primed surface (15±4.25 Mpa). However, no statistically significant difference was found between the specimens treated with metal primer and those treated with opaque porcelain. The two alloy surface treatments exhibited mixed failures, however. While the nature of failure for opaque porcelain was predominately cohesive, the failure for the metal primed group was adhesive.

Conclusion: It can be concluded that both techniques have potential to significantly improve resin-alloy shear bond strength.

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Introduction

Recently, laboratory-cured resin veneers have been introduced as an alternative veneering material to porcelain as well as conventional acrylic resins. According to the literature, these types of resin veneers have some good features such as aesthetics, abrasion resistance similar to the natural tooth substances, being easily repairable, fast and simple laboratory

procedures and biocompatibility [1,2]. Moreover, the ability of these resins to be used as pontics for resin-bonded fixed partial restorations, overlay material for removable partial prosthesis, veneered crowns and other types of fixed partial dentures can be included[3].

On the other hand, adhesive bonding promoters on the metal surfaces are being used more frequently

in routine dental practices in an attempt to create strong bonding between the metal and composite resins. A strong and stable bond between veneering materials and metal framework considerably promotes the aesthetic appearance and clinical longevity of a resin type restoration. There are many reports regarding various strengthening mechanisms of dental composite resins on the metal surfaces; silicoating [4,5], electro-coating with tin-oxide [6], coating with metal ions [7] and liquid gas-tin alloy [8] are some of the most important ones.

Various adhesive metal primers have also been studied to enhance the bond strength of the composite resins to different metal surfaces [9, 10]. The main advantage of these adhesive agents is the simplicity of their application on the sand-blasted alloy surface without the need for any other specific media [11]. Base metal alloys, however, are largely being used in fabrication of fixed prosthetics especially when increased mechanical strength is preferred [12]. The aim of this study was to evaluate the effect of slurry opaque porcelain as a potential promoter for the metal surface in comparison with a common method in which a metal primer is primarily used for metal surface treatment purposes.

Materials and Methods

Using a pre-made metal split apparatus, twenty-four wax disks (10 mm in diameter and 2.5 mm in thickness) were prepared. The wax disks were then cast using a crown & bridge Ni-Cr alloy (Supercast, 1251 S.LU Cienega Blvd. Los Angeles, CA. USA). The metal disks were first polished with No. 600 SiC abrasive paper and then uniformly sand-blasted with 50 µm-sized alumina grits. Finally, they were cleaned ultrasonically with ethyl alcohol. The specimens obtained were randomly divided into two major groups of 12 specimens each. For surface treating purposes, two different methods were used. For half of the specimens, Group I, a slurry layer of opaque porcelain (Ceramco, Inc. E. Windsor, NJ 08520) was added and for the second half, Group II, the disk surfaces were treated with a metal primer (Metal Primer II; GC, Tokyo, Japan).

All the specimens in Group I first underwent an oxidation cycle, following manufacturer recommend-

ations. Then, a thin layer of opaque porcelain (1gr powder in 0.5cc liquid) was applied to the metal surface and fired up to the fusing temperature recommended by the manufacturer. To control the amount of opaque porcelain, a custom-made transparent plastic sheet (6 mm in diameter) was prepared and used for delineation of the bonding area during porcelain application. The opaque fired surface was then carefully etched for 1 min. with a 0.9% HF acid gel (Ultradent Porcelain Etch, USA). Each disk was then rinsed thoroughly and dried with oil-free air. A silane-coupling agent (Ultradent Silane; Ultradent, Salt Lake City, UT, USA) was then used to condition the surface for the composite resin material. A laboratory-cured composite resin (Gradia, GC, Tokyo, JAPAN) was built up to each pre-conditioned surface according to manufacturer instructions. A custom-made Teflon mold with an internal diameter of 5mm and 2.5mm length was utilized for this purpose.

For Group 2, after sandblasting and ultrasonic cleaning, the metal specimens were covered with a plastic sheet (as described above) and then treated with a metal primer (Metal Primer II; (Need edition). GC, Tokyo, Japan). The conditioned surface was then built up using the same laboratory composite resin (Gradia, GC, Tokyo, JAPAN) and the same Teflon tube as described for Group I. The materials used in this study are listed in Table 1.

Table 1 Materials used in the present study

Bonding Systems	Metal Primer (Metal Primer II; GC, Tokyo, Japan) Component: methacrylate with thiophosphoric acid moiety Opaque Porcelain (Ceramco, Inc. E. Windsor, NJ 08520)
Veneering Material	Gradia (GC, Tokyo, Japan)
Alloy	Ni-Cr (Supercast 1251 S.LU Cienega Blvd. Los Angeles, CA. USA) Component: Ni 75%, Cr 14%, Mo 5%
Etching Gel	0.9% HFaci gel (Ultradent porcelain etch, USA)
Silane coupling agent	(Ultradent silane; Ultradent, salt Lake City, UT, USA)

To prepare the specimens for the shear strength bonding test, each specimen was first embedded in an acrylic resin poured in a 15mm X 15mm sized Teflon tube (Fig. 1a, b). All the specimens were then immersed in tap water and incubated at 37C⁰ for 15 days. After this period, each specimen was

thermocycled about 1200 times in a water bath between 5C^o and 55C^o with a dwell time of 10 seconds. The specimens were then placed in a universal testing apparatus (Roell/ Zwick Z.20, Germany) for shear bond testing. A shear force at the cross head speed of 0.5mm/min was applied to the interface of the composite resin and conditioned surface until a fracture occurred at the interface. Finally, the fractured specimens were carefully evaluated by scanning electron microscope (CamScan-MV2300, Cambridge, England) at 200xmagnification. Statistical analysis of the shear bond strength values was performed by the Kolmogorov-Smimov test to carefully analyze the normal distribution of the data. T-test was then applied with the metal treatment as an independent factor ($P < 0.116$).

Results

All of the data obtained from the testing machine were recalculated according to the surface area of the

disk specimens and expressed in Mpa. The mean shear bond strength values and standard deviations were 17.53±3.33 Mpa for the porcelain group (Group I) and 15±4.25 Mpa for the metal primer group (Group II), respectively (Table 2). The results of T-test showed no statistical difference between the two groups in the mean values for shear bond strength ($P < 0.116$). Nevertheless, the mean bond strength for group I was higher than that for group II (Table 2).

Evaluation of failure modes in both groups revealed that in all specimens a mixed (combination) type of failure had occurred (Table 3). Although the mode of failure for group I was mixed in nature, a form of cohesive failure was predominately shown in comparison with group II in which the failure was predominately adhesive (Fig 2a I, 2a II). Scanning electron microscope (SEM) observations are presented in Figs 2b, and the energy dispersive spectroscopy (EDS) analysis of specific sites is presented in tables shown in Figs 3 and 4.

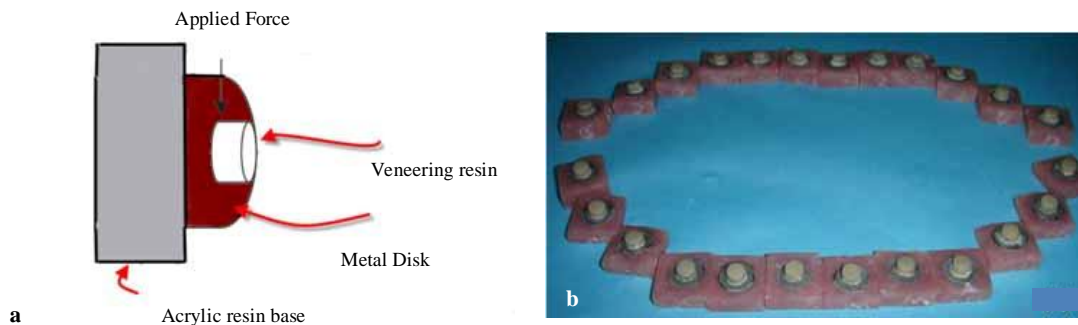


Figure 1 (a) Schematic representation of the shear testing assembly. (b) The specimens prior to testing.

Group	No. of specimens	Mean shear bond strength (±SD)
Mean Primer	12	15±4.25
Opaque Porcelain	12	17.53±3.33

Bonding Method	Failure Mode
Metal primer	Mixed (predominately adhesive)
Opaque Porcelain	Mixed (predominately cohesive)

Discussion

The use of reinforced composite resins for the fabrication of veneered restorations has recently received attention, mainly as a result of their improved mechanical properties, good handling, favorable esthetics and response to abrasion similar to that of natural teeth [13, 14]. Although the clinical performance of these restorations has improved

significantly, the major concern is associated with the durability of the metal–resin bond. A strong and stable bond between veneering material and metal framework contributes both to esthetic appearance and the clinical durability of a restoration, which must withstand a combination of mechanical, chemical and thermal stresses [2,15].

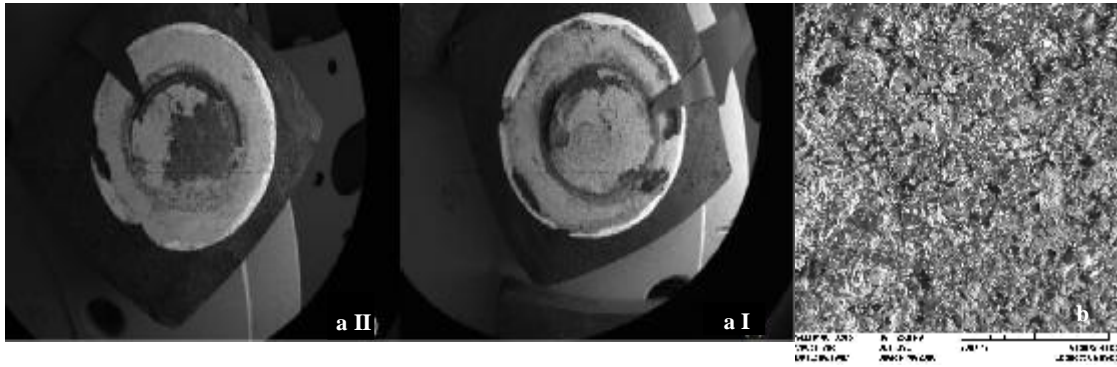
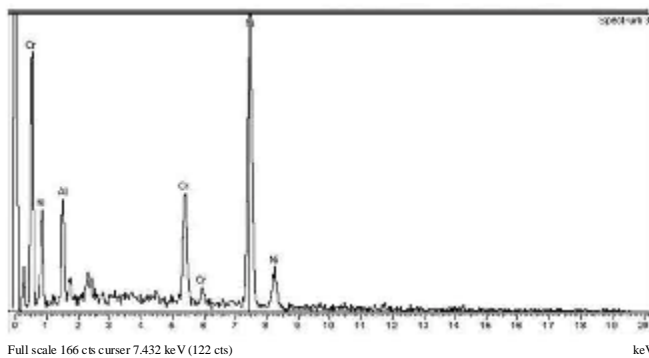


Figure 2a Representative images from the scanning electron microscope at low magnification, illustrating the fractured surfaces of metal primer (I), opaque porcelain (II). **b.** Scanning electron microphotography of opaque surface (original magnification x320) exhibiting high surface roughness promoting micromechanical interlocking with the resinous material.

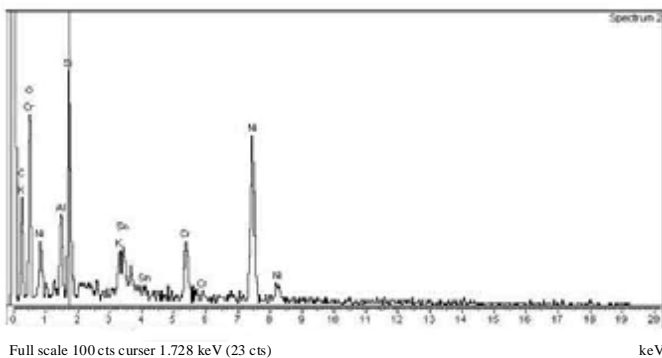


Element	App Conc.	Intensity Corr.	Weight %
Al	7.02	0.3805	14.54
Cr	17.98	1.0372	13.65
Ni	88.09	0.9658	71.81
			Total 100.00

Figure 3 Diagram of the debonded alloy surface of a metal primer specimen and EDS analysis results in discriminated areas.

Although several methods have been introduced for bonding composites to metal casting frameworks, their main disadvantage is their low bond strength, when compared with ceramic materials [16]. It has been proposed that the most significant factor in resin/metal bonding is pre-treating of the metal surface [11]. In one study, Watanabe *et al.* [12] showed that the use of primers may improve

the bonding durability of a laboratory-cured composite of different alloys. However, these authors concluded that there is no significant difference in bonding strength between chemically primed surfaces and those that have been sandblasted. The mean values for bond strength reported in their study are the same as those obtained in our research.



Element	App Conc.	Intensity Corr.	Weight %
C	713.40	0.6220	76.99
O	67.88	0.2969	15.38
Al	6.27	0.8018	0.53
Si	16.44	0.8838	1.25
K	4.48	1.0617	0.28
Cr	9.73	0.8264	0.79
Ni	46.68	0.8057	3.89
Sn	11.04	0.5335	0.89
			Total 100.00

Figure 4 Diagram of the debonded alloy surface of an opaque porcelain specimen and EDS analysis results in discriminated areas.

In another study, Matsumer *et al.* [17] found that shear bond strength greater than 10 Mpa would be satisfactory for veneering metal surfaces, being higher than the values reported by ISO 10477 (5 Mpa). The inherent mismatch between thermal expansion of composite resins, metals and polymerization shrinkage are two further problems which have been shown to be a trigger for bonding failures [18-20]. The various brands of composite resins have also been studied. Almilhatti, *et al.* [21] found that the value of shear bond strength of composite materials used is not so different, being 10-12 Mpa. However, in our study this value was 15-17 Mpa which may be regarded as reflecting the different materials and methods used. On the other hand, in-vitro studies and clinical data have indicated that silicoating can form a relatively strong metal-resin bond, which is less affected by thermal changes than other bonding systems [19,20]. The Siloc method is the most recent evolution of Silicoater system and essentially uses the same mechanism as the original method. Recent studies have shown that the shear bond strength of composite veneering materials bonded to a siloc-treated metal surface is over 17 Mpa [19]. This value is in accordance with our study in shear bond value for porcelain-treated metal surfaces.

This high degree of strength values may be the result of a good match of the coefficient of thermal expansion (CTE) between metals and porcelain as well as the silicoating materials. It has been well documented that all restorations in the oral environment are continuously subjected to temperature changes and that this aqueous hot/cold environment has the potential to have a deteriorating effect on the metal-composite bond [2,15]. The method described in this paper is the first report which attempts to improve the metal-resin-bond strength through the use of opaque porcelain. It seems that the bonding enhancement achieved by this simple and sophisticated method has the potential to be used as a routine clinical pre-treatment mechanism.

Conclusion

Under the limitations of this study, the following conclusions may be drawn:

- 1) The shear bond strength values of surface treatment combinations tested well exceeded the requirements of ISO 10477.
- 2) The etched opaque porcelain layer exhibited good bond strength values in comparison to the primed surface.
- 3) The failure modes for opaque porcelain treated surfaces are more favorable than for the metal primer alone.
- 4) Both surface treatments are appropriate for clinical uses.

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