TENSILE BOND STRENGTH OF TWO VENEERING RESINS TO METAL SURFACES BONDED VIA EITHER MECHANICAL RETENTION, SILICOATER TREATMENT OR A COMBINATION OF THE TWO

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- ABSTRACT: This investigation evaluated the bond strength of two composite resin veneer systems to Nickel-Chromium (Ni-Cr) castings using three methods of promoting bonding of the resin to metal (mechanical retention, Silicoater treatment or a combination of the two). The three resin-to-metal bonding systems used were mechanical bonding (S_1), Silicoater system (S_2) and mechanical bonding with the Silicoater system (S_3). Two veneering resin materials were evaluated Chromasit – (M_1); Dentacolor – (M_2). The tensile tests were made on specimens after 7 days immersion in distilled water at a constant temperature of 37°C. The M_2/S_3 combination had significantly higher bond strength than any of the other combinations. Mechanical bonding system (S_1) provided better retention than the other bonding systems for material M_1. The bonding system S_2 gave the lowest bonding strength values for both resins.
- KEYWORDS: Fixed partial denture; crown veneer; composite resins.

Introduction

Mechanical retention, commonly using beads, has been the traditional method for bonding resins to the surface of metal. The beads are the most common technique that has been used to bond the resin veneer to the metal frameworks. Although there is a range of bead sizes available,

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microbeads are often the retention method of choice because the microbeads are inexpensive and readily available. The technique is relatively simple and is equally applicable to precious and nonprecious alloy frameworks.[9] However, microleakage between the resin and the alloy and subsequent discoloration has accompanied the use of these retention devices. Also, this method requires both more space for the metal structure and more tooth reduction in order to provide enough thickness of aesthetic material. To resolve these problems, various treatments of metal substructures have been introduced. Electrolytic etching and acid etching of castings to create microretention over the surface of the metal show promising results[1] with the advantage that for the same veneering resin thickness, the microretention features allow more resin depth for light refraction.

The application of a thin layer of tin oxide to the bonding areas of the castings can improve the resin-to-metal bond strength. With the development of an alternative bonding system, tin can be electroplated onto metal. Van der Veen et al.,[14] reported that the clinical results of 85 resin bonded fixed partial dentures with tin electroplated metal bonding areas showed a one-year success rate of 98%.

The Silicoater technique was developed to chemical bonding of resin veneers to metal. This method promotes resin bonding to metals via an intermediate layer of silica applied to the metal surface followed by a silane coupling agent. This technique has demonstrated enhanced bond strengths than the mechanical methods.[7, 8]

This study evaluated the influence of three bonding systems (mechanical retention, Silicoater treatment or a combination of the two) on tensile bond strength between two resin veneers and Ni-Cr castings.

Material and method

Three resin-to-metal bonding systems were evaluated: mechanical bonding (S_1), Silicoater system (S_2) (Heraus Kulzer, Wehrheim/TS, Germany) and mechanical bonding combined with Silicoater system (S_3). Two representative composite veneering materials – Chromasit (M_1), (Ivoclar Schaan, Liechtenstein, Germany), and Dentacolor (M_2), (Heraus Kulzer, Wehrheim/TS, Germany) – were used with the three bonding systems.

Ninety-six half-metal disks (10 mm in diameter) were cast in a nonprecious alloy Durabond (Odonto Comercial, Manaus, Amazonas, Brasil) according to the manufacturer's instructions. These were divided randomly amongst the three groups, S_1, S_2 and S_3. In the S_2 the wax patterns were smooth and in S_1 and S_3 an adhesive was applied to the wax surface of the specimens disks. Acrylic resin microbeads were then sprinkled onto the wax surface. The specimens were divested and air abraded with 250 μm grit aluminium oxide. Two half-specimens were cemented together to form a complete specimen.

Opaque application

When system S_1 was used, the metal samples with the microbeads were immersed in boiling water for 5 minutes, ultrasonically washed in distilled water for 10 minutes, and air-dried. For material Chromasit (M_1), the adhesive Chroma Link was applied onto the test surface. After 4 minutes, the Chromasit opaque was prepared and the mixture was brushed onto the metal specimens and cured in the hydropneumatic pressure polymerizer, for 5 minutes at 120°C and at a pressure of 85 pounds. For material Dentacolor (M_2), the opaque was applied and polymerised for 90 seconds in the Dentacolor XS unit (Heraus Kulzer, Wehrheim/TS, Germany). In system S_2, the flat metal specimens were immersed in ethyl acetate (Siliclean, Heraus Kulzer, Wehrheim/TS, Germany) for 12 minutes of ultrasonic cleaning and air-dried. Prior to application of the adhesive (Siliseal, Heraus Kulzer, Wehrheim/TS, Germany) the metal surfaces were brushed with Sililink (Heraus Kulzer, Wehrheim/TS, Germany). The specimens were then mounted in the Silicoater MD machine adjusted for the time required for nonprecious alloys at 320°C. The silane coupling agent (Siliseal) was immediately applied to the test surfaces and dried in the air prior to the application of the opaque and veneering resins (M_1 and M_2). In the group S_3, after the test surfaces with the microbeads had been abraded with aluminium oxide, all specimens were treated, as described above, with system S_2.

Veneering resin application

A device was used to align the metal specimens and provide a standard 2-mm space between the test surface for placement of the veneering resins. For material M_1, a half-specimen was mounted in the alignment device and dentin resin was applied in layers on the test surface.

The second half-specimen was inserted into the device and the Chromasit resin was incrementally built up in layers until the 2-mm space between the two halves was filled to obtain the complete specimen. Chromasit Fluid was applied in a thin even coating the surface of the veneering resin and polymerization was carried out in the hydropneumatic pressure polymerizer, for 7 minutes at 120°C and at air pressure of 85 pounds. After the polymerization process was finished, the specimens were removed from the device and stored in distilled water at 37 C ± 1 C for 7 days. For Material M_2, Dentacolor dentin resin was applied in layers on the test surfaces, light polymerized intermittently for 90 seconds in the Dentacolor XS unit, and then the half-specimens were placed on the alignment apparatus. The 2-mm space between the test surfaces was filled with the Dentacolor veneering resin and a thin coat of the ADS – Gel (Heraus Kulzer, Wehrheim/TS, Germany) was brushed onto the resin surface. The entire assembly, test specimens, and resin were placed in the Dentacolor XS for a 180-second polymerization cycle. The specimens were then removed from the device and placed in 37 C ± 1 C distilled water for a week. The complete specimens were divided into six groups of eight specimens.

Tensile bond strength specimen testing

The mechanical strength tests were performed using a universal testing machine (Sintech 6, MTS Systems Corporation, Eden Praire, MN, USA) at a crosshead speed of 0.5 mm/min. The bond strength was calculated in MPa based on maximum force and specimen bond area. In addition, the nature of the failure was noted as adhesive or cohesive. Examination of the specimens for adhesive or cohesive failures was made by naked eye. One investigator made all examinations.

The difference in mean tensile bond strengths among the three resin-to-metal bonding systems was evaluated by use of one-way analysis of variance (Anova), followed by Duncan's test to determine whether significant differences existed between the means. Statistical analysis was conducted at the 95% level of confidence.

Results

The Anova showed that interactions among the veneering resins and the bonding systems were all significant (Table 1). The mean bond strengths and standard deviations for the material by bonding system interaction are illustrated in Figure 1. The material M_2 (Dentacolor) had significantly higher bond strength than the material Chromasit (M_1) in all resin-to-metal bonding systems. The Dentacolor/resin-to-metal bonding system S_3 combination had significantly higher bond strength. However, the material Chromasit (M_1) showed the highest mean value in resin-to-metal bonding system S_1. The weakest tensile bond strength for both materials was obtained in resin-to-metal bonding system S_2. The failure mode data are given in Table 2.

Table 1 – Analysis of variance for tensile bond strength

Source	Degree of freedom	Sum of squares	Mean square	F value
Bonding system (S)	2	337.1072	168.5536	627.63*
Material (M)	1	183.4369	183.4369	683.05*
S X M	2	147.9693	73.9847	275.49*
Error	42	11.2793	0.2686	
Total	47	679.7927		

Table 2 – Percentage of failure (%)

*p<0.05

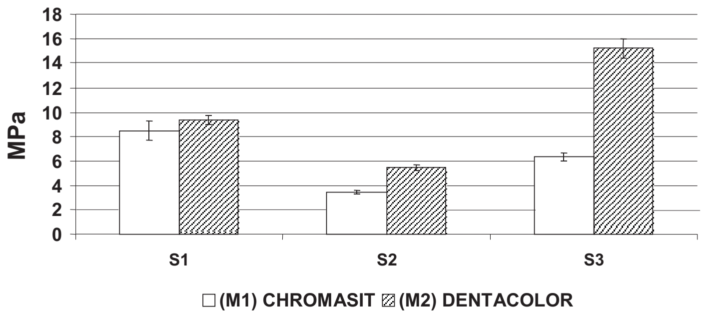

FIGURE 1 – Mean Bond strength and standard deviation of all combinations of bonding system and resin veneer groups.

Material X Resin-to-metal bonding system	Mode of bond failure	
	Adhesive	Cohesive
M_1 S_1	62.5	37.5
M_2 S_1	62.5	37.5
M_1 S_2	75	25
M_2 S_2	75	25
M_1 S_3	87.5	12.5
M_2 S_3	0	100

Discussion

In this study, the bond strength between the two resin veneers and the Ni-Cr castings was measured by using a tensile test. This test has been widely used by the investigators in order to determine the bond strength of different resin-to-metal bonding systems.[2, 6, 9, 10, 13]

Jones et al.[5] stated that when resins were attached to the alloy with retentive beads, higher shear bond strengths were evident than with chemical bonding techniques. Although a direct comparison of this study and the one cited above cannot be made because of the different research protocols used, our results also showed that bond strength for both veneering resins using retention beads (S_1) was higher than with the silicoating technique (S_2).

In this article, the specimens were tested for tensile bond strength after immersion in water at 37°C for a week. Shue et al.[12] reported that immersion in 37°C distilled water significantly increased the tensile bond strength for small beads. Herf et al. [4] found that the bond strength provided by the silicoating technique was higher than that with retention beads when tested in the dry condition. However, storing in water at 37°C for 90 days reduced the bond strength of the silicoated alloys by about 30 to 40%. No significant effect on bond strength was observed due to water storage for specimens with mechanical beads. According to the authors, in the retention bead system, the amount of composite around the undercuts of each bead was too large to be noticeably affected by the reaction to water. Faulkner and Harcourt[3] also compared the bond strength between metal rods coated with silanes and polymerized resins when the specimens were left in air and were immersed in water.

They discovered that silane treatment increased the bond strength in immediate testing and in specimens allowed to stand in air at room temperature for 4 weeks and 3 months. However, specimens immersed in water at 37°C for 1 week showed marked decreases in strength. Similar data were also obtained by Ruyter & Waarli,[11] who had observed that the water storage resulted in a reduction of 12-45% in the bond strength provided by the silicoating technique. Both water and changes in temperature appear to influence the bond strength of silicoated specimens. According to Vojvodic et al.[15] adhesive failure were observed for silicoated specimens after immersion in water at 37°C, especially after thermocycling.

The greatest mean tensile bond strength was recorded when the veneering resin Dentacolor (M_2) was bonded to the alloy by using the resin-to-metal bonding system S_3 (mechanical bonding associated to Silicoater system). The surfaces of the metal framework to be coated with resin may be prepared by a sandblasting process increasing the effective bonding surface and improving the wettability of the metal surface by the development of energy-rich structural defects and chemically active groups on the surface. In addition to the mechanical bond with the roughened metal surface, the silica treatment of the metal surfaces creates a potential for generating a chemical bond between the metal and the resin veneer. Therefore, the bond strength increased in resin-tometal bonding system S_3 for material M_2 (Dentacolor) as a result of combined chemical adhesion and increased surface from beads.[2] However, for material M_1 (Chromasit) this effect was not observed when the beaded surface was coated with the Silicoater system. This may be due to the product's opaquing medium, which appears to be critical to the success of bonding the composite resin to the metal.[4] The M_1 (Chromasit)/resin-to-metal bonding system S_2 combination showed significantly lower tensile bond strength than the other combinations. This suggests that the Chromasit's opaque resin demonstrated no affinity to the silicoater system. Analysis of the fracture sites showed that, for material M_1 (Chromasit), most of the test specimens exhibited adhesive fractures between metal and opaque resin in all resin-to-metal bond systems evaluated whereas material M_2 (Dentacolor) failed adhesively only in resin-to-metal bonding systems S_1 and S_2. The M_2 (Dentacolor)/S_3 combination samples all fracture cohesively revealing that the composite resin diametric strength was exceeded by the retentive force created by the mechanical and chemical retention.

Conclusions

- For material M_2, the system S_3 provided the highest bond strength followed by system S_1 and S_2. In the case of material M_1, system S_1 gave the highest bond strength, than system S_3 and S_2.
- For all systems, material M_2 gave higher bond strength than material M_1.

GIAMPAOLO, E. T. et al. Estudo da resistência de união ao metal de duas resinas para revestimento estético. Influência de retenção mecânica, sistema Silicoater ou a combinação de ambos os sistemas. Rev. Odontol. UNESP (São Paulo), v.30, n.1, p.87-95, jan./jun. 2001.

- RESUMO: O objetivo deste estudo foi avaliar a resistência de união de duas resinas compostas para revestimento estético de coroas e próteses fixas (SR Chromasit-M_1 e Dentacolor-M_2) a uma liga de níquel-cromo (Durabond). Os sistemas de união utilizados foram: retenção mecânica (S_1), sistema Silicoater (S_2) e associação retenção mecânica–sistema Silicoter (S_3). Os corpos-de-prova foram armazenados em água destilada a 37°C durante 7 dias antes dos ensaios de resistência à tração. Os resultados demonstraram que a associação M_2/S_3 apresentou maiores valores de resistência de união. O sistema S_1 proporcionou maior retenção para o material M_1, enquanto o sistema de união S_2 apresentou os menores valores de resistência de união para as duas resinas.

- PALAVRAS-CHAVE: Prótese parcial fixa; resinas compostas; coroas.

References

1 BARZILAY, I. et al. Mechanical and chemical retention of laboratory cured composite to metal surfaces. J. Prosthet. Dent. (St. Louis), v.59, n.2, p.131-7, Feb. 1988.

2 CAEG, C. et al. Effectiveness of a method used in bonding resins to metal. J. Prosthet. Dent. (St. Louis), v.64, n.1, p.37-41, July 1990.

3 FAULKNER, K. D. B. HARCOURT, J. K. Silane coupling agents in stainless steel nd polymethyl methacrylate systems. Aust. Dent. J. (Sydney), v.20, n.2, p.86-8, Apr. 1975.

4 HERϕ, H. et al. Adhesion of resins to Ag-Pd alloys by means of the silicoating technique. J. Dent. Res. (Washington), v.66, n.8, p.1380-5, Aug. 1987.

5 JONES, R. M. et al. Microleakage and shear bond strength of resin and porcelain veneers bonded to cast alloys. J. Prosthet. Dent. (St. Louis), v.65, n.2, p.221-8, Feb. 1991.

6 KOHLI, S. et al. The effect of three different surface treatments on the tensile strength of the resin bond to nickel-chromium-beryllium alloy. J. Prosthet. Dent. (St. Louis), v.63, n.1, p.4-8, Jan. 1990.

7 KOLODNEY, H., PUCKETT, A. D., BROWN, K. Shear strength of laboratory-processed composite resins bonded to a silane-coated nickel chromium-beryllium alloy. J. Prosthet. Dent. (St. Louis), v.67, n.3, p.419-22, Mar. 1992.

8 LAUFER, B.-Z., NICHOLLS, J. I., TOWNSEND, J. D. SiO_x-C coating: a composite-to-metal bonding mechanism. J. Prosthet. Dent. (St. Louis), v.60, n.3, p.320-7, Sept. 1988.

9 LEE, C. F., PIERPONT, H. P., STRICKLER, E. R. The effect of bead attachment systems on casting patterns and resultant tensile bond strength of composite veneer cast restorations. J. Prosthet. Dent. (St. Louis), v.66, n.5, p.623-630, Nov. 1991.

10 NICHOLLS, J. I., SHUE, S. L. Effect of bead spacing on the tensile bond strength of resin veneers to cast alloys. Quintessence Dent. Technol. (Chicago), v.10, n.8, p.511-5, Sept. 1986.

11 RUYTER, I. E., WAARLI, M. The adhesion mechanism of the silicoating technique. J. Dent. Res. (Washington), v. 68, sp. iss., p.891, 1989. (Abstract 195).

12 SHUE, S. L., NICHOLLS, J. I., TOWNSEND, J. D. The effect of metal retentive designs on resin veneer retention. J. Prosthet. Dent. (St. Louis), v.58, n.3, p.297-305, Sept. 1987

13 TENJOMA, L. T. et al. Chemical retention of composite resin to metal. Int. J. Prosthont. (Lombard), v.3, n.1, p.78-88, Jan./Feb. 1990.

14 VAN DER VEEN, H. et al. Resin bonding of tin electroplated precious metal fixed partial dentures: one-year clinical results. Quintessence Int. (New Malden), v.17, n.5, p.299-301, May 1986.

15 VOJVODIC, D. et al. Bond strength of silicoated and acrylic bonding resin systems to metal. J. Prosthet. Dent. (St. Louis), v.81, n.1, p.1-6, Jan. 1999.