

EFFECT OF PRIMERS ON THE SHEAR BOND STRENGTH OF TWO TYPES OF ACRYLIC RESIN TO CO-CR PARTIAL DENTURE ALLOY

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ABSTRACT

The absence or poor chemical bonding of acrylic resin to Cobalt-Chromium metal frameworks, often introduces microleakage and bond failure at the interface.

The aim of this study was to compare the shear bond strength of sandblasted cast and ingot cobalt-chromium alloy to heat-cured and self-cured acrylic resins primed with four different metal primers.

Fifty Co-Cr Ingot and fifty cast specimens were fabricated and embedded in resin. Their surfaces were sandblasted and primed with four primers except for the control group. 4 x 5 mm discs of self-cure and heat-cured resins were processed against the alloy and stored in distilled water for 24 hours. Specimens were de-bonded in shear using a Universal testing machine. The data were analyzed statistically using ANOVA, and Fisher's PLSD test.

In general, primed alloy specimens showed greater bond strength than the non-primed controls and heat-cured resin bonded better than the auto-polymerized resin. ZP primer demonstrated the highest bond strength regardless of type of alloy and resin. Monobond P demonstrated the lowest bond strength. The bond strength of primed specimens improved significantly compared to the control group.

Within the limitation of this study, it is shown that primers enhanced the bond strength of acrylic resin and cast Co-Cr alloy. Therefore, metal primers such as ZP Primer and SR Primer are recommended for routine use in the process of fabrication of removable partial denture to increase its longevity.

Key words: Removable Partial Denture Alloy, Acrylic Resin, Primers, Shear Bond Strength

INTRODUCTION

The growing size and changing demographics of aging adults place a significant demand for removable and fixed dental prosthesis. Optimizing shear bond strength at the resin-metal interface of a removable partial denture is one of the key factors for clinical longevity of the prosthesis.¹⁻³ The absence of chemical bonding between poly(methyl methacrylate) (PMMA) and cobalt-chromium (Co-Cr) alloy can lead to clinical problems such as micro-leakage.⁴ The differences in the coefficients of thermal expansion between acrylic resins and alloys, and the polymerization shrinkage of acrylic resin, may result in separation of these materi-

als.⁵ Various methods had been introduced for improving the bond strength between acrylic resin and removable partial denture casting alloy.⁶ In lieu of emerging trends for fabricating implant-supported fixed or removable prosthesis using cobalt-chromium metal frameworks, this aspect of dental materials is important for prosthodontic research.

Current methods for bonding acrylic resin to metal alloy can be categorized as mechanical, chemical or a combination of both. Macromechanical retentive features reduce the bulk of acrylic resin thus compromising retention and esthetics. Micromechanical retention can be achieved with acid and electrolytic

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etching, sandblasting or by using beads, post, open lattice or mesh. Chemical bonding is considered necessary to overcome interface denture failures especially in situations such as limited interridge space, short span area and where excessive functional forces are anticipated. Absence of chemical bonding may result in microleakage of oral fluids in the finish lines, which causes an accumulation of oral debris, microorganisms, and stains.⁷⁻⁹ This can result in soft-tissue irritation and consequently, reduced longevity of the metal-resin bond.^{10,11}

Many authors have suggested that use of primers enhances the bond strength of metal resin interface.¹²⁻¹⁵ Yoshida, et al (1997)¹⁶ suggested that the functional monomers present in the primers have an affinity to chromium oxide layer that is formed at room temperature. Most of these studies were done using ingots of Co-Cr alloy as supplied by manufactures.¹²⁻¹⁷ and suggested that primers should be selected depending on the type of metal alloys used.

The aim of this study was to compare the shear bond strength of sandblasted cast and ingot cobalt-chromium alloy treated with four metal primers to heat-cured and self-cured repair resin.

METHODOLOGY

The materials used included cast and ingot cobalt-chromium (Super Cast, Pentron), heat-cured and auto-polymerized acrylic resin (Dentsply) and four metal primers consisting of different functional monomers [Z Prime Plus (ZP) by Bisco Dental Products, SR Link (SR) by Ivoclar Vivadent, Metal Primer II (MetP) by GC lab, Monobond Plus (MBP)] by Ivoclar Vivadent .

The diagrammatic representation of the assembly used to make self-cured and heat-cured resin specimens are shown in Figure 1 and Figure 2 respectively. In order to produce cast alloy specimens, 50 cylinder shaped wax pattern (9 mm diameter and 13 mm height) were invested and cast using a Co-Cr alloy following manufacturer's instructions. Fifty cobalt-chromium alloy ingots, 9 mm diameter and 13 mm in height were provided by the manufacturer. The ingots are normally extracted from a continuously cast bar pulled directly from the molten pool of the alloy. All alloy specimens were embedded in orthodontic resin (Dentsply) using a cylinder mold ensuring that one of the flat sides

remains exposed for bonding. All specimens were ground with 600-grit silicon carbide discs under water. Half of each alloy specimens (25) were used for bonding with auto-polymerized resin normally used for repairs and the other half were bonded to heat-cured resin.

Preparation of auto-polymerized specimens: Airborne-particle abrasion of alloy specimens was performed with 50 µm aluminum oxide for 5 seconds at 0.5psi pressure, at 45-degree angle with a 5-mm nozzle to metal surface distance. All specimens were cleaned with distilled water and dried using oil-free air. The specimens were then primed with one of the four metal primers following manufacturer's instructions using a micro brush (Centrex Incorporated). The control groups (5 specimens in each group) were not primed. Auto-polymerized resin discs of 4 mm diameter and 5 mm in height were fabricated using a polytetrafluoroethylene mold and a jog to hold the assembly (Figure 1). The sprinkle on technique was used to avoid entrapment of air bubbles at the interface. The specimens were cured in a pressure pot at 20 psi for 15 minutes.

Preparation of heat-cured specimens: Wax cylinders (4mm diameter and 5mm length) of sticky wax were fabricated using addition silicone putty (Reprosil, Dentsply Caulk, Milford DE) matrix. They were attached perpendicular to the alloy surface. The alloy specimens were then invested in Type III dental stone in the bottom half of a dental flask (Hanau Varsity, Whip Mix Corp). Silicone putty was used as the second pour in the flask at the cope to the height of the wax cylinder. This assured ease of deflasking and also prevented separation of the resin specimens from alloy. The final pour of flasking procedure was done with Type III dental stone. After dewaxing, any wax remnants were cleaned off with steam and by sandblasting. A separating medium was then applied and Heat-cured resin was mixed and trial packed three times at 1500, 2500 & 3500 lb pressure to remove flash. Primer was applied to metal surface before the final packing at 3500 lb pressure. Specimens were cured at 165°F for eight hours and at 210°F for one hour. Flasks were bench cooled before deflasking.

The bonded specimens were stored in distilled water for 24 hours at 37°C in a humidor (100% relative humidity). They were then mounted in a loading jig and debonded in shear using a universal testing machine

(Instron model 8501, Instron Corp., Canton, MA) at a cross-head speed of 0.05 mm/min. The forces at which the bond failed were noted, and bond strengths were calculated in Mega Pascals (MPa) by dividing the force by the bonding area. The failure mode of each specimen was also evaluated under a low-power optical microscope at magnification (10X).

Five replications (n=5) for each experimental condition were tested. The data were analyzed statistically using ANOVA (Statview 5.0, Cary, NC) with a factorial model. The comparison of means by Fisher's PLSD Post-Hoc test at the 0.05 level of significance was performed.

RESULTS

The means and standard deviations of shear bond strength recorded for various groups tested are given in Table 1. Generally, higher shear bond strength values were recorded when ZP Plus was used as a surface treatment and the lowest values were observed for no primer groups. The statistical analysis of data using three-way ANOVA is given in Table 2. Statistically significant differences were found (p<0.05) between interactions of metals, resins and various surface treatments.

The main effects of alloy (cast vs. ingot), primers (no primer vs. primer) and resin type (self cure vs. heat cure) as shown in the Table 2 were also statistically significant (p<0.0001). A graphical comparison of bond strength of the groups (Graph 1) shows that (a) Heat-cured resin specimens exhibited higher bond strength compared to self-cured resin except for the no primer group where self-cured resin showed higher bond strength, and (b) ingot specimens had higher bond strength compared to cast specimens irrespective of the primer used (p<0.0001).

Fisher's PLSD (Table 3) for comparisons of means of bond strength at the 0.05 significance level for all variables tested were <0.0001. Differences between two means greater than the appropriate Fisher's PLSD intervals were considered statistically significant.

Generally, primed specimens showed greater bond strength than the non primed specimens. For non-primed group the values recorded for both Ingot and cast alloys were very low, however, the cast alloy showed slightly higher mean values.

In all of the primed groups, the heat cured specimens had significantly higher bond strength compared to self-cured specimens irrespective of metal type. However, for non-primed groups, the self-cured group showed statically higher bond strength.

Among all primers tested in this study, ZP showed highest bond strength irrespective of resin. In descending order, the mean bond strengths recorded for cast alloy and self-cured resin specimens were ZP SR, MBP and MetP. Slightly different ranking of these primers in descending order (ZP, SR, MetP and MBP) was observed for cast alloy and heat-cured resin specimens.

Similar results were also recorded for Ingot specimens. Mean bond strengths for ingot alloy and self-cured resin specimens in descending order were ZP, SR, MBP and MetP and that recorded for heat-cured resin was ZP, SR, MetP and MBP.

TABLE 1: THE MEANS AND STANDARD DEVIATIONS OF SHEAR BOND STRENGTH RECORDED FOR VARIOUS GROUPS TESTED IN THIS STUDY

Group	Count	Mean	Dev. Std.	Std. Err.
Cast, SC, None	5	3.303	1.097	0.491
Cast, SC, ZP	5	12.990	1.686	0.754
Cast, SC, SR	5	9.727	1.342	0.600
Cast, SC, MBP	5	6.920	0.682	0.305
Cast, SC, MetP	5	5.386	0.538	0.241
Cast, HC, None	5	2.060	0.312	0.140
Cast, HC, ZP	5	23.611	1.373	0.614
Cast, HC, SR	5	19.526	0.421	0.188
Cast, HC, MBP	5	9.626	0.879	0.393
Cast, HC, MetP	5	13.926	1.998	0.893
Ingot, SC, None	5	3.144	0.695	0.311
Ingot, SC, ZP	5	14.855	0.715	0.320
Ingot, SC, SR	5	12.076	0.275	0.123
Ingot, SC, MBP	5	8.155	1.348	0.603
Ingot, SC, MetP	5	7.050	0.604	0.270
Ingot, HC, None	5	1.727	0.619	0.277
Ingot, HC, ZP	5	27.272	0.681	0.304
Ingot, HC, SR	5	23.862	0.526	0.235
Ingot, HC, MBP	5	12.174	0.803	0.359
Ingot, HC, MetP	5	19.859	1.676	0.750

TABLE 2: ANALYSIS OF VARIANCE (ANOVA TEST) TABLE FOR SHEAR BOND STRENGTH, MPa

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Type	1	133.366	133.366	124.903	<.0001	124.903	1.000
Resin	1	1226.288	1226.288	1148.478	<.0001	1148.478	1.000
Primer	4	3489.410	872.352	817.000	<.0001	3268.000	1.000
Type * Resin	1	21.136	21.136	19.795	<.0001	19.795	0.997
Type * Primer	4	50.978	12.745	11.936	<.0001	47.744	1.000
Resin * Primer	4	654.637	163.659	153.275	<.0001	613.099	1.000
Type * Resin *Primer	4	12.823	3.206	3.002	0.0231	12.009	0.778
Residual	80	85.420	1.068				

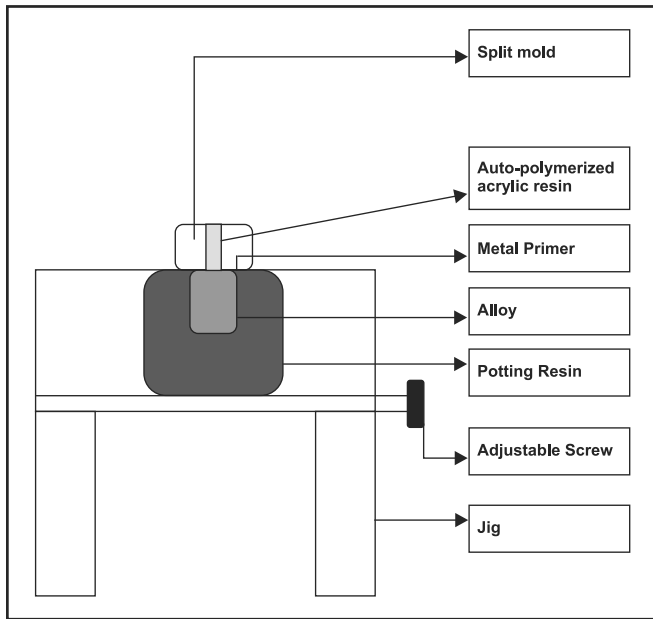


Fig 1: Diagrammatic representation of assembly used to prepare Self cured specimens

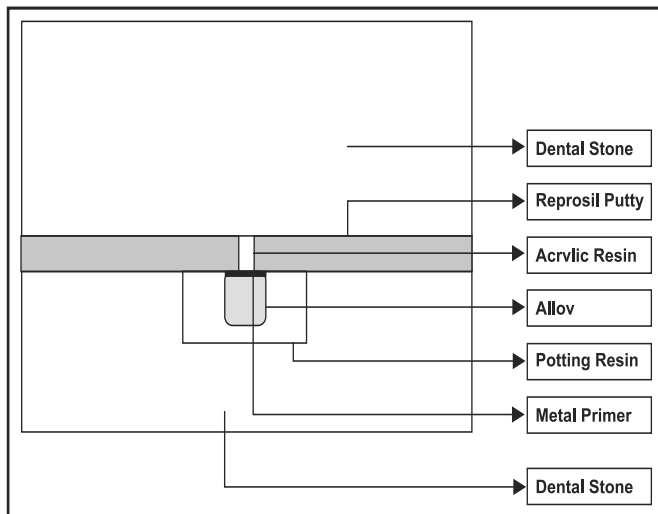


Fig 2: Diagrammatic representation of assembly used to prepare heat-cured specimens

TABLE 3: FISHER'S PLSD FOR BOND STRENGTH, MPa

Significance Level: 5 %
Effect: Primer

	Mean diff.	Crit. diff.	P-value
None, ZP	-17.124	0.650	<.0001 S
None, SR	-13.740	0.650	<.0001 S
None, MBP	-6.660	0.650	<.0001 S
None, MetP	-8.997	0.650	<.0001 S
ZP, SR	3.384	0.650	<.0001 S
ZP, MBP	10.464	0.650	<.0001 S
ZP, MetP	8.127	0.650	<.0001 S
SR, MBP	7.079	0.650	<.0001 S
SR, MetP	4.743	0.650	<.0001 S
MBP, MetP	-2.337	0.650	<.0001 S

Effect: Type of metal

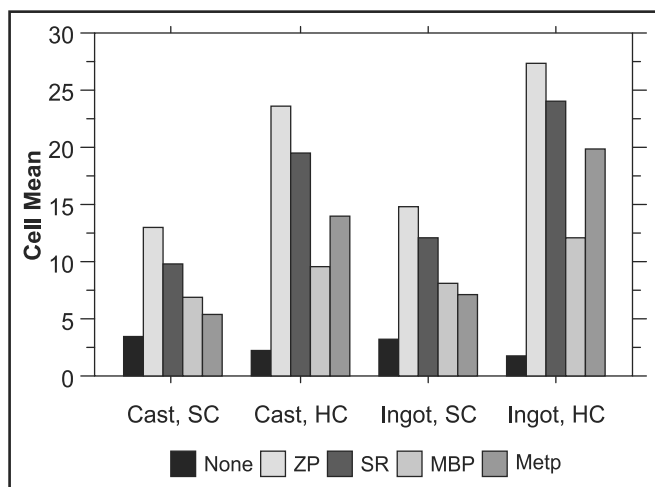
	Mean diff.	Crit. diff.	P-value
Cast, Ingot	-2.31	0.411	<.0001 S

Effect: Resin

	Mean diff.	Crit. diff.	P-value
SC, HC	-7.004	0.411	<.0001 S

FAILURE MODE

The failure mode data was recorded from observations of each specimen under a low-power optical microscope at 10X magnification. All of the non-primed (control) groups showed a dominantly adhesive type of failure indicating poor bonding. Among the primed groups, both ingot and cast Co-Cr alloy treated with ZP, SR and Met P showed high cohesive failure.



Graph 1: Interaction Bar Plot for Bond Strength, MPa. Effect: Metal * Resin (HC: heat cure; SC: self cure)* Primer

DISCUSSION

This study was designed to compare the shear bond strengths of sandblasted cast and Ingot Co-Cr alloy to heat-cured and self-cured repair acrylic resin after treating with four metal primers. The tests for cast alloy is clinically relevant, and ingot alloy was used for comparison to previous research studies.^{12,17} The four primers used had different chemical composition as well as functional monomers and are recommended by manufacturers for bonding base metal alloy to acrylic resin.

The interface between metal substructure and acrylic resin of the removable partial denture prosthesis has often been held responsible for many clinical problems¹⁰ including the potential for microleakage and accumulation of oral debris, microorganisms, and stains.^{4,15} Strong bonding at the interface of the two surfaces improves the strength of the repaired unit and reduces stress concentration.¹⁸ The composition and integrity of the metal surface oxide layer is considered critical for bonding¹⁹ and for base metals preconditioning such as air abrasion and ultra sonic cleaning can further increase the bond strength.^{20,21} The preparation of specimens in this study included all these recommended steps.

The results showed that ingot alloy exhibited greater bond strength than cast alloy. Unlike ingot alloy, the cast specimens were produced under routine laboratory conditions and may have an oxide layer that is

different in composition than that of the ingot metal. The cast metal may have a different grain configuration as well that could affect its properties.

Generally the shear bond strengths of the control specimens were significantly lower than the primed specimens regardless of alloy. The mode of failure observed for these two groups was entirely adhesive, indicating a failure along the metal-resin interface due to poor bonding. The cast specimens showed 57 % greater bond strength to self-cured resin than the heat-cured resin meaning that repair of RPDs should be done with self-cured resin. The results for the primed specimens in this study are consistent with previous studies where primer treated specimens were found to have significantly higher bond strengths.^{4,6,12,16,22,22-24}

Among all specimens tested, ZP treated groups had the highest bond strength regardless of type of alloy and resin. ZP contains both phosphate monomer and carboxylate monomer. The strong bond could be due to the presence of phosphate monomer, which is a chemical with methacrylate group at one end and phosphoric acid group at the other.

Clinically, the use of any of the 4 primers tested in this study will produce more durable bond between Co-Cr and acrylic resin than non-primed RPD frameworks; however use of ZP and SR primers is recommended. Careful interpretation in the clinical application of these results is suggested, as the design of the present study did not consider factors existing in the oral environment, such as dynamic fatigue loading metal framework design, and pH changes.

CONCLUSIONS

Within the limitation of this in-vitro study, the following conclusions were drawn:

1. The metal primers promoted a significant increase ($p < .0001$) in the adhesive bonding of acrylic resins to base metal alloy. ZP demonstrated the highest bond strength among all primers tested.
2. Among the metal alloys tested, primed ingot alloy showed the higher shear bond strength, than the cast alloy. However, data for ingot specimens is not clinically relevant.

3. Shear bond strength of primed metal to heat-cured acrylic resin was significantly ($p < .0001$) higher than auto-polymerized resin group, suggesting the use of primers with heat-cured resin at the time of resin processing of RPDs for better bond at the metal-resin interface.

CLINICAL SIGNIFICANCE

The result of this in-vitro study suggest that metal primers be routinely used in the process of fabrication of removable partial dentures to increase metal to resin bonding, thus enhancing the longevity of the partial dentures. This study recommends the use of ZP and SR primers for enhanced bonding.

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