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Research Paper: Effect of metal primer and adhesives on bond strength of composite resin to nickel-chromium alloy

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ABSTRACT

Introduction: Indirect metal-ceramic restorations can be repaired intra-orally by using composite resins. The purpose of this study was to evaluate the effect of several adhesives and metal primer on shear bond strength(SBS)of flowable composite to nickel-chromium(Ni-Cr) alloy.

Materials and Methods: In this in vitro study, 100 Ni-Cr alloy specimens were casted measuring 2x10x8 mm. The surface of all specimens was sandblasted, and they were randomly assigned to five groups (n=20) of no primer or adhesive (group 1 or control),alloy primer (AP; group 2), AP+Single Bond 2 (SB2) adhesive (group 3),AP+G-Premio Bond (group 4), and G-Premio Bond alone (group 5).Flowable composite was bonded to the surfaces in cylindrical plastic molds (3 mm in diameter and height). The specimens were stored in distilled water at room temperature for 24 hours. Thermocycling was performed for 1000 cycles. The SBS was measured by a universal testing machine. Failure mode was also evaluated under a stereomicroscope.

Results: The SBS of composite to alloy was the highest in G-Premio group (20.09±14.27MPa), and the lowest in the control group (11.11±5.35MPa). The failure mode in the four experimental groups was mainly mixed while the control specimens showed adhesive failure($P \leq 0.05$).

Conclusion: It maybe concluded that G-Premio universal adhesive can create a strong bond to Ni-Cr alloy.

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Introduction

Indirect metal-ceramic restorations are a suitable option for oral rehabilitation (1).Gold and nickel-chromium (Ni-Cr)alloys are suitable materials for the fabrication of single crowns and implant restorations due to their high modulus of elasticity (2).A previous study on fixed partial dentures fabricated from high-noble alloys reported a five-year survival rate of80% to 98% for them(3). However, the high cost of high-noble alloys led to the growing use of non-precious metal alloys for metal-ceramic restorations(4-6). The modulus of elasticity of most base metal alloys is twice that of noble and high-noble alloys (4, 7).

Some failures of indirect metal-ceramic restorations are related to ceramic failure (1, 2). When selecting a metal primer, it is important to consider the interactions of metal and functional monomers. For the base metal alloys, carboxylic, phosphoric, and phosphonic acid monomers are important (8, 9). Failure of porcelain-fused-to-metal bridges and crowns usually occurs as a result of parafunctional habits, insufficient occlusal adjustment, or inadequate tooth reduction (10). Ideally, restoration replacement is undesirable (11). Various chemical and mechanical bonding techniques have been proposed in an attempt to improve the bond strength of composite resins to alloys(12). The suggested primers for this purpose usually contain carboxylic monomer, 4-methacryloxyethyltrimellitate anhydride (4-META),10-methacryloyloxydecyl dihydrogen phosphate (10-MDP), or glycerol phosphate dimethacrylate. These monomers in the composition of metal primers improve the resin bond strength to metal alloys (1, 13, 14). Metal primers include active monomers that create chemical bonds between composite resins and metal oxides on the alloy surface(15).Another noteworthy issue is that dental materials are exposed to constant humidity and thermal alterations in the oral cavity, which adversely affect resin bond strength (15, 16). The4-META was the first monomer used to for bonding to metal (13). New monomers with carboxylate and phosphoric acid groups were introduced to improve the bond strength to metal alloys, such as 10-MDP and functional monomers containing sulfur like 6-(4-vinylbenzyl-n-propyl)amino-1,3,5-triazine-2,4-ditione (VBATDT) compounds and 6-methacryloxyhexyl-2-thiouracil-5 carboxylate. They are also effective for precious metal alloys (15, 17, 18). Primers containing carboxylic or phosphoric monomers are designed for both base metal and noble alloys. These primers contain 10-MDP, VBATDT, 6-methacryloxyhexyl-2-thiouracil-5 carboxylate,1-methacryloxy-1,1-undecanecarboxylic acid, or a combination of two functional monomers.

The newly introduced universal or multimode adhesives contain phosphate esters (R-O-PO3H2) as their main functional monomers, and 10-MDP is a commonly used phosphate ester in the composition of most universal adhesives. However, some products use other phosphate esters such as dipentaerythritol penta acrylate monophosphate, and glycerol phosphatedimethacrylate(19). The majority of the available studies on universal adhesives have focused on bonding to enamel and dentin, and only a few studies have evaluated bonding to metal alloys. The aforementioned studies showed that universal adhesives had optimal bond strength to enamel, dentin and indirect substrates comparable to that of conventional bonding agents. They also discussed that universal adhesives may be suitable for metal alloy treatment since they are easy to use and have a short working time(19-22) .Therefore, the aim of this study was to evaluate and compare the effect of several adhesives and metal primers on shear bond strength (SBS) of flowable composite to Ni-Cr alloy after thermocycling. The null hypothesis was that the effect of different adhesives and metal primers would not be significantly different on SBS of flowable composite to Ni-Cr alloy and the failure mode.

Materials and Methods

A total of 100 rectangular wax patternsmeasuring2 × 10 × 8 mm were invested and casted with Ni-Cr alloy(Verabond 2; Aalba Dental

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Inc., Fairfield, CA, USA)composed of 76.5% Ni, 11.5% Cr, and 3.5% Mo, Nb, Al, Si, and Ti, as disclosed by the manufacturer. A mold was fabricated with putty impression material (Tigre, Rio Claro, Sp, Brazil)matching the dimensions of the universal testing machine, and filled with auto-polymerizing acrylic resin (Vipi Produtos Odontológicos, Pirassununga, SP, Brazil). The casted blocks were mounted in acrylic resin such that the metal surface was exposed. The alloy surface of all specimens was polished with a 180-grit silicon carbide paper (Norton Guarulhos SP, Brazil) for 30 seconds, and was then sandblasted with 50 µL aluminum oxide particles for 10 seconds(Microetcher IITM;Danville Engineering Inc. ,San Ramon, CA,USA) with 60 Pascals pressure and 10 mm distance between the sandblaster tip and the specimen surface. The samples were randomly assigned to 5 groups (n=20)as follows:

1.Control group(no surface treatment)

2.Application of alloy primer(AP; Kuraray Noritake Dental Inc., Tokyo Japan)on the alloy surface

3. Application of AP and Single Bond2(SB2; 3M,ESPE) (Table 1)

4. Application of AP and G-Premio Bond(GC, America) (Table 1)

5. Application of G-Premio Bond

All primers and adhesives were used according to the manufacturers' instructions, and cured with the same light curing unit(Ivoclar Vivadent; Schaan, Liechtenstein). The intensity of curing light was periodically checked after 10 curing cycles.

A cylindrical plastic mold(with 3 mm diameter and 3 mm height)was mounted perpendicular to the specimen surface by sticky wax. Filtek Supreme composite resin (Ultra Flowable Restorative Resin; 3M ESPE) was injected into the mold through the syringe tip. Excess composite was removed with a plastic instrument. For easy filling of the tube, flowable composite was applied incrementally. Light curing was performed for 20 seconds, and then the cylindrical mold was carefully separated from the composite cylinder, and removed. The specimens were stored in distilled water for 24 hours at room temperature. Subsequently, thermocycling (MSCT-1, Marcelo Nucci-Me, Sao Carlos, SP, Brazil) was performed for1000 cycles between5°C to 55°C with 10 seconds of dwell time and 3 seconds of transfer time, corresponding to approximately one year of clinical service (23). The SBS of specimens was measured by a universal testing machine(Instron)with a cross head speed of 1 mm/min. Force application was documented by the STM Controller computer software for all specimens.

Table1: Characteristics of the adhesive systems

Adhesive system	composition	Treatment strategy	company
Single bond2	Bis-GMA, HEMA, ethanol, water, photoinitiator, photoinitiator, methacrylate functional copolymer	Apply 2-3 coats for 15 s Gently air dry for 10s Light polymerize for 10s	3M USA
G-permio bond	4-MET MDP MDTP	Apply using a microbrush for 10 s Leave for 10s Dry for 5 s Light cure for 10s	GC JAPAN

Statistical Analysis

Descriptive statistics including the mean, standard deviation, and range of changes were used to describe quantitative data. The normality of SBS values was analyzed by the Kolmogorov-Smirnov test, which showed non-normal data distribution (P<0.05) in all groups except for the third group. Thus, the non-parametric Kruskal-Wallis test was applied for the comparisons. In this test, the mean rank, which is equivalent to the median, was used instead of the mean. The Mann-Whitney U test was applied for pair wise comparisons and the Chi-square test was used to compare the frequency of fracture modes among the study groups.

Results

The study population included 100 Ni-Cr alloy specimens. The mean and standard deviation of SBS in the 5 groups of control, AP, AP + SB2, AP + G-Premio, and G-Premio are presented inTable2. The highest composite to alloy SBS was recorded in the G-Premio group (14.27 ± 20.09MPa)while the control group showed the lowest SBS (11.11 ± 5.35MPa). The non-parametric Kruskal Wallis test showed a significant difference in SBS among the five groups (P=0.05, Table2).

Table2:Mean and standard deviation of SBS of the study groups (MPa)

MPA(mega pascal)	N	Mean	Std. Deviation
control	20	11.11	5.35
AP	20	18.42	17.51
AP+Single bond	20	14.10	6.47
AP+GC	20	19.85	19.54
GC	20	20.09	14.27
Total	100	16.72	14.04

Asymp. sig.0.05

AP: alloy primer ,GC:G-permio bond

Pair wise comparisons of the experimental groups regarding SBS by the Mann-Whitney U test revealed no significant difference, except between the control and G-Premio groups (P<0.05), and G-Premio and AP + SB2 (P<0.05)groups (Table3).

Table 3:Pairwise comparisons of the groups regarding SBS

number	Comparison Pairwise	MPA(mega pascal)
1	Control AP/	0/09
2	AP+Single bond / Control	0/09
3	AP+GC / Control	0/09
4	GC/Control	0/00
5	AP+Single bond/AP	0/58
6	AP+GC/AP	0/89
7	AP/GC	0/29
8	AP+GC / AP+Single bond	0/68
9	GC/AP+Single bond	0/05
10	AP+GC/GC	0/16

AP: alloy primer ,GC:G-permio bond

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The highest mean SBS was found in the G-Premio group, followed by AP + G-Premio and AP groups, while the lowest SBS was noted in AP+ SB2and the control groups.

Regarding the failure mode, the results showed that the mode of failure was mainly mixed in the four experimental; groups (AP, AP + SB2, AP + G-Premio, G-Premio) and the adhesive type was less frequent.

In the control group, all specimens showed adhesive failure. In the G-Premio group, mixed failure had the highest frequency and no adhesive failure was observed. The difference in frequency of failure modes was statistically significant among the four groups of AP, AP + SB2, AP + G-Premio, and G-Premio ($P<0.05$, Table4).

Table 4:Frequency of different failure modes in the study groups

groups fracture Cross tabulation					
Count					
		fracture			Total
		adhesive	Cohesive	Mixed	
groups	control	20	0	0	20
	AP	8	0	12	20
	AP+Single bond	6	1	13	20
	AP+GC	4	1	15	20
	GC	0	1	19	20
Total		38	3	59	100

AP: alloy primer ,GC:G-permio bond

Discussion

Metal-ceramic dental restorations are famous for their optimal esthetics and high durability. Precious alloys have always been the first choice for the metal framework. However, due to financial constraints, their application has decreased. This reduction led to the widespread use of base-metal Ni-Cr or cobalt-chromium alloys for the metal framework (1). Porcelain fracture repair is often considered as an emergency treatment. Composite resin is the material of choice for intraoral repair of metal-ceramic restorations due to its easy application and optimal esthetics. Creation of micromechanical retention by sandblasting with aluminum oxide particles can increase the bond strength of resin to nonprecious alloys.

Silane can chemically bond to metal oxides on the restoration surface; however, this bond may be hydrolyzed during thermocycling, causing a reduction in bond strength(24). In vitro studies have been conducted to measure the bond strength of metal to composite resin (25).

Bonding of two different materials is always a challenge in dentistry, and often requires a combination of chemical and physical treatments to obtain a strong bond (26). Newer chemical bonding agents with acid monomers were introduced to provide a better adhesion between metal and resin or enamel. Cyanoacrylate is a type of acrylic resin with acid-basic monomer used for ceramic repair and bonding to metal with a low success rate(27). In the present study, the highest SBS was achieved between the composite and metal in the G-Pre-

mio universal adhesive group. The AP + SB2 group did not show a significant difference with the control group in SBS. The SBS of metal to composite resin depends on micromechanical retention, physicochemical bonding, or a combination of both(28). Chemical retention is provided by the function of monomers in metal primers that bond to the superficial oxide layer of dental alloys(17). Therefore, the bond strength values may change after thermocycling according to the type of metal primer and type of applied adhesive. In the present study, the alloy surface was sandblasted with 50 µm aluminum oxide particles before the application of AP on the Ni-Cr surface(12)in order to remove the superficial oxide layer and increase the bonding surface area. Also, sandblasting of the samples was performed to standardize the metal surface for precise evaluation of the pure effect of primer and adhesives on the composite SBS to Ni-Cr alloy. In the present study, flowable composite was used due to its easy application (29). The purpose of thermocycling was to induce aging at the metal-composite interface(15). A previous study showed that even after aging, mechanical and chemical treatment with10-MDP plus silane improved the bond strength of Ni-Cr alloy to a resin cement (30). Metal primers contain monomers that can be effective in increasing the bond strength to metal. AP contains a combination of VBATDT and 10-MDP in its formulation. VBATDT is a thione-thiol tautomer that is effective on the bond of noble alloys to resin materials. The thione group chemically reacts with metals while vinyl groups react with bis-methacrylate resins. Higher bond strength of AP than the control group can also be attributed to the presence of 10-MDP monomer and its composition(12, 31). ForSB2 adhesive, it is not known which component mediates bonding to metal, and according to the present results, SB2 with AP did not increase the bond strength. The highest bond strength was obtained following the application of G-Premio adhesive. The G-Premio adhesive contains 10-MDP and 4-META monomers. The 10-MDP and 1-methacryloxy-1,1-undecanecarboxylicacid monomers have phosphoric and carboxylic groups in their formulation that enable bonding to metal alloys(13). These monomers may effectively increase the bond strength to metal. Presence of two active monomers may justify the superiority of the application of G-Premio to AP in the present study. Nima and colleagues examined the effect of primers and multimode adhesives on SBS of composite to Ni-Cr alloy. They showed that after thermocycling, the highest bond strength was observed in Universal Primer + Scotchbond Universal group while the lowest SBS was observed in the control group. In their study, the SBS following the application of AP and universal adhesive was higher than that in use of AP alone. This finding was similar to the present results, and there was no significant difference between the control group and the AP group. However, application of SB with AP in the study by Nima et al. improved the bond strength, which was in contrast to the present findings. According to their study, application of SB could not improve the bond strength after thermocycling(32). Taira et al. used three types of dental alloys including silver-palladium alloy, gold-silver alloy, and cobalt-chromium alloy. Different primers were also used such as GC commercial primer which contains0.04% thiophosphoric methacrylate and methyl methacrylate as its main constituents. Four solutions with or without 0.6% benzoyl peroxide were applied on the surface of specimens. Application of thiophosphoric methacrylate with phosphoric monomer significantly increased the bonding durability, and the mean increase in bond strength was 20 MPa(25). Bulbul et al. evaluated the effect of metal primer on the acrylic resin bond strength to three types of dental alloys. The highest SBS was obtained following the application of AP on the Co-Cr metal alloy; the bond strength significantly decreased after thermocycling below the acceptable level (31). The bond strength was lower in the AP group after thermocycling. In a study by Santos et al, all samples were sandblasted with100 µm aluminum oxide particles. Application of AP resulted in higher bond strength due to MDP

chemical bonding, and the percentage of cohesive failure in this group was higher, although it was not statistically significant. Their results were in agreement with the present findings(1). Mensudar and colleagues evaluated the effectiveness of SB alone versus SB + AP. All specimens were sandblasted with 50µm aluminum oxide particles. The bond strength to Ni-Cr alloy was higher after the application of SB +AP compared with the application of SB alone(33). Klaisiri et al. evaluated the effect of universal adhesives on SBS at the composite resin/base metal alloy interface and reported that the SBS was the highest in AP and AdperSB2 group followed by Clearfil universal adhesive and G-Premio Bond, SB universal and Optibond universal andAdperSB2 alone. Adhesive failure was found in all negative control groups. G-Premio universal adhesive creates sufficiently high bond strength between composite and amalgam, and using a combination of AP with a bonding system improves the bond strength(34).Thus, universal adhesives appear to be effective and easy to use (21).Yanagida et al. reported that the bond strength of aluminum oxide air abrasion group significantly decreased after thermocycling, and application of metal primer and surface treatments were recommended to enhance the bond strength of composite resin to gold alloy(35).In the present study, only SBS was assessed while in the oral cavity, the teeth and restorations are subjected to a combination of forces, and this was a limitation of this study. Further studies with a larger sample size and longer storage time are recommended.

Conclusion

Despite the limitations of this in vitro study, it maybe concluded that G-Premio Bond universal adhesive can create a strong bond to Ni-Cr alloy and can be considered as a suitable adhesive for composite repair of metal-ceramic restorations.

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None

Authors' contributions

Yasaman Sadeghi deh baneh: Conceptualization, Methodology, Writing - Review & Editing **Seyedeh Maryam Tavangar:** Resources, Investigation, Visualization **Hoorieh Alsadat Hosseini basti:** Methodology, Visualization **Rabiollah Farmanbar:** Writing - Original Draft, Data Curation **Sogol Jafari:** Funding acquisition, Project administration, Supervision

Conflict of Interests

The authors declare no conflict of interest.

Ethical declarations

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Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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