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Composite Resin Bond Strength to Zirconia and Base Metal Alloys Using Two Types of Intraoral Porcelain Repair Systems

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ABSTRACT

Objectives: This study aimed to evaluate the shear bond strength (SBS) of two repair composites (Crea.lign vs. PermaFlo) to a base metal alloy and zirconia ceramic.

Materials and Methods: Sixty-four discs (12mm diameter, 1mm thickness) were fabricated using Wirobond base metal alloy and zirconia. They were then bonded with their respective composite resins (N=16) in each of the two porcelain chipping repair kit subgroups consisting of PermaFlo and Crea.lign. All specimens were stored in 37°C distilled water for 24 hours. Half of them were subjected to 10,000 thermal cycles (5-55°C, 30s). All specimens were tested for SBS with a universal testing machine. Failure types were analyzed using a digital camera. Analysis of the data was done by two-way ANOVA and Bonferroni post-hoc tests.

Results: SBS was significantly affected by the type of composite resin. PermaFlo had a significantly higher SBS than Crea.lign to base metal alloy ($P<0.001$) and zirconia ceramic ($P<0.001$). Thermocycling decreased the SBS of both composites to base metal alloy ($P<0.001$) and zirconia ($P<0.001$).

Conclusion: A universal adhesive could provide higher shear bond strength of zirconia and base metal alloy to composite resin than Crea.lign composite and the MKZ primer supplied by its manufacturer.

Keywords: Composite Resins; Metal Ceramic Alloys; Shear Strength; Zirconia

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INTRODUCTION

Modern dentistry requires an eye for aesthetics when creating fixed restorations. Ceramics were first used with metal substructures as reinforcement, and they were referred to as porcelain-fused metal restorations or metal-ceramic restorations. A number of disadvantages with these restorations including decreased light transmission, discoloration of the gingiva around the abutment teeth, allergic reactions, and metallic ions released into the gingival tissue led to the introduction of metal-free ceramic restorations. Zirconia crowns typically consist of a zirconia framework layered with feldspathic ceramic [1]. Compared to monolithic zirconia crowns, they are more often used due to their aesthetic advantages [2,3]. However, the veneering ceramic on bi-layered zirconia crowns is prone to chipping due to differences in coefficients of thermal expansion, poor shear bond strength (SBS), and poor tensile strength. [4]. Ni-Cr (nickel-chromium) alloys are characterized by a high modulus of elasticity, making them ideal for making prosthetic frameworks [5,6]. They contain 70-80% nickel and 15% chromium to resist corrosion and small amounts of aluminum, beryllium, and manganese [7].

Repairing the fractured or chipped veneering porcelain in these restorations represents a unique and potentially difficult clinical challenge [5]. Laboratory error in surface treatment of the framework, incorrect treatment planning, inadequate inter-occlusal space resulting in an inadequate thickness of framework and porcelain, inadequate tooth preparation, trauma, parafunctional habits, insufficient occlusal adjustment, inadequate support of the veneer by the framework, and incorrect framework design represent the most common causes of porcelain fracture [3, 8]. In the event of porcelain chipping, restoration replacement is the best option. Nevertheless, this is not always possible, and intraoral repair of restorations using composite resin is a faster and simpler procedure that carries a lower cost [9]. Restoring restorations on the chairside can save time and money while enhancing patient satisfaction [10]. Several composite resins and bonding agents can be used to repair porcelain and manufacture artificial gingiva. However, the physical properties of the materials, as well as their bond strength to metal and zirconia frameworks, need to be investigated. Several methods have been proposed to enhance the bonding strength between composite resins and metal or zirconia [7].

Among these techniques is the use of specific primers such as 4-methacryloyloxy ethyl trimellitate anhydride [11]. The phosphate ester monomers have been proven to chemically bond to metal-oxide substrates [12, 13]. One of these products is Perma Flo, which contains Peak Universal Bond as an adhesive. This universal adhesive contains an organic phosphorus oxide monomer, a form of phosphate ester monomer with a unique affinity to bond chemically to metal oxide substrates [14]. The Crea.lign light-curing composite from Bredent is supplied with a specific MKZ primer. The manufacturer claims that it can be used to veneer a wide range of cores, including polyether ether ketone, zirconia, titanium, noble, and base metal alloy cores with identical aesthetic appearance and color on a wide range of framework types.

Limited information is available about the bond strength of Crea.lign composite to metal and zirconia ceramic frameworks. Hence, this study sought to evaluate the SBS of Crea.lign versus PermaFlo repair composites to a base metal alloy and zirconia ceramic. The null hypothesis was that the shear bond strength of Crea.lign composite and MKZ primer to zirconia ceramic and base metal alloy is not significantly different from Ultradent repair composite and a universal adhesive.

MATERIALS AND METHODS

Ethical approval was obtained from the ethics committee of Tehran University of Medical Sciences (IR.TUMS.DENTISTRY.REC.1398.023, and IR.TUMS.DENTISTRY.REC.1398.024). PASS 11's two-sample t-test power analysis feature was used to calculate the minimum sample size in this in vitro experimental study, which was 11 in each subgroup, according to An et al. [15]. To minimize errors, 16 specimens were included in each subset.

Fabrication and bonding of base metal alloy discs

As specified by the manufacturer, 32 discs with a diameter of 12mm and a thickness of 1mm were made from Wirobond base metal alloy (Bego, Bremen, Germany) and sandblasted with 50µm alumina particles (CYKY, Henan, China) at both surfaces with 35 Psi pressure at a distance of 10mm from the nozzle [16]. The specimens were then placed in an ultrasonic cleaner for 5 minutes (Treedental, Guangdong, China) [17]. The discs were randomly divided into two groups (N=16) for bonding using the chipping repair kit, containing Crea.lign composite resin (Bredent, Senden, Germany), and the porcelain repair kit, containing PermaFlo composite resin (Ultradent Products, Cologne, Germany). In the Crea.lign composite group, MKZ primer (Bredent GmbH & Co.KG, Witzighausen, Germany) was applied to the disc surface by a micro brush (TPC Advance Technology, City of Industry, USA) and allowed to dry at room temperature for 30s [18].

The bonding area was standardized using a cylindrical plastic mold with a diameter of 4mm and a thickness of 2mm [19,20]. The Crea.lign composite was applied in incremental 2mm thicknesses to the disc mold and cured for 40s with a LED wireless dental curing device

(Woodpecker, ZZlinker, Henan, China). After removing the plastic mold, the composite cylinder was cured for another 40s. Alloy primer (Kuraray, Tokyo, Japan) was applied in the PermaFlo composite subgroup using a micro brush (TPC Advance Technology, City of Industry, USA) and allowed to dry at room temperature for 30s. Next, Peak Universal Bond (Ultradent, Germany) was applied and light-cured for 20s. A cylindrical plastic mold with 4mm diameter and 2mm thickness was used to standardize the bonding area [20]. PermaFlo composite was applied into the mold on the disc in 2-mm-thick increments and cured for 40s using the same curing unit. After removing the plastic mold, the composite cylinder was cured for another 40 seconds. To ensure maximum curing depth, the curing unit was positioned vertically as close to the composite surface as possible without touching it.

Fabrication and bonding of zirconia ceramic discs

Zirconia discs (ICE Translucent; Zirconzahn, Gais/South Tyrol, Italy) were fabricated, sandblasted, and cleaned in the same manner described above for Wirobond discs [16, 21].

The zirconia discs were fabricated using partially sintered zirconia blocks (with a diameter of 12 mm and a thickness of 1 mm) using a CAM milling machine (Cercon; Degudent, Hanau, Germany) followed by sintering in Cercon heat furnace (Degudent, Hanau, Greece) at 1350°C for 7 hours for final production.

The ceramic model was milled 25% larger to account for 25% shrinkage during sintering. Crea.lign composites were bonded in the same way as Ni-Cr alloys. For the PermaFlo composite subgroup, one coat of Peak Universal Bond (Porcelain Repair Kit, Ultradent Products, Cologne, Germany) was rubbed on the surface for 15 seconds. Following the manufacturer's instructions, it was air-thinned until it lost its creamy appearance and then light-cured for 20 seconds. A plastic mold measuring 4mm in diameter and 2mm thick was used to standardize the bonding area [20]. A 20-gauge micro-tip was then carefully connected to the PermaFlo syringe (Porcelain Repair Kit, Ultradent Products, Cologne, Germany).

The first composite layer was applied in 1-mm thickness and cured for 20 seconds. Afterward, a second layer was applied and cured for 20 seconds.

Storage of specimens and SBS testing

All specimens were then stored in distilled water for 24 hours. Following this, half of the samples from each of the two subgroups were exposed to 10,000 thermal cycles between 5-55°C, with a dwell time of 30 s and a transfer time of 10 seconds [22]. Assuming that 20 to 25 thermal cycles are performed every day, 10,000 thermal cycles would be the equivalent of about one year of clinical service [22]. The thermocycled specimens were incubated at 37°C for 24 hours [7]. A 1kN load was applied with a flat-end tip, and a crosshead speed of 0.5mm/min to each specimen in a universal testing machine (Instron 3345, Instron Corp., Norwood, MA, USA) according to International Organization for Standardization (ISO) standards ISO/TS 11405:2015(E) and ISO 29022:2013(E) [23-26]. Loads were laid parallel to the bonding interface (composite-porcelain/alloy interface) as much as possible [21]. The load at failure was measured in megapascals (MPa) and indicated the SBS. A digital camera (Nikon D850, Nikon Corporation, Tokyo, Japan.) was used to photograph the specimens and determine the failure mode, classified as adhesive, cohesive, or mixed [21].

Statistical analysis.

The data were analyzed using ANOVA to determine the difference between the subgroups in SBS. Pairwise comparisons were performed with the Bonferroni posthoc test. $P<0.05$ was set as the significance level.

RESULTS

SBS of composites to base metal alloy

The mean SBS of PermaFlo and Crea.lign composite resins to base metal alloy discs with and without thermocycling is presented in Table 1. SBS was not significantly influenced by the interaction effect of composite type and thermocycling, according to two-way ANOVA ($P=0.085$). Composite type significantly impacted SBS, with PermaFlo's mean SBS significantly higher than Crea.lign's ($P<0.001$). Thermocycling significantly reduced the SBS in both groups ($P<0.001$). A disc-composite interface failure mode was identified in all specimens (Figure 1).

Table 1. Measurements of the shear bond strength (SBS) of PermaFlo and Crea.lign composites to base metal alloy discs with and without thermocycling (TC)

Composite (N=8)	TC	SBS (MPa)			SD
		Min	Max	Mean	
Crea.lign	No	4.49	6.45	5.49	0.69
	Yes	3.82	5.28	4.52	0.57
PermaFlo	No	11.68	20.63	14.21	3.01
	Yes	8.13	13.55	10.95	1.83

Min: minimum; Max: maximum; SD: standard deviation

Table 2. Measurements of the shear bond strength (SBS) of PermaFlo and Crea.lign composites to zirconia ceramic discs with and without thermocycling (TC)

Composite (N=8)	TC	SBS (MPa)			SD
		Min	Max	Mean	
Crea.lign	No	1.49	2.97	2.03	0.53
	Yes	0.32	1.73	1	0.53
PermaFlo	No	6.53	9.28	7.88	0.83
	Yes	4.74	7.46	5.98	0.89

Min: minimum; Max: maximum; SD: standard deviation

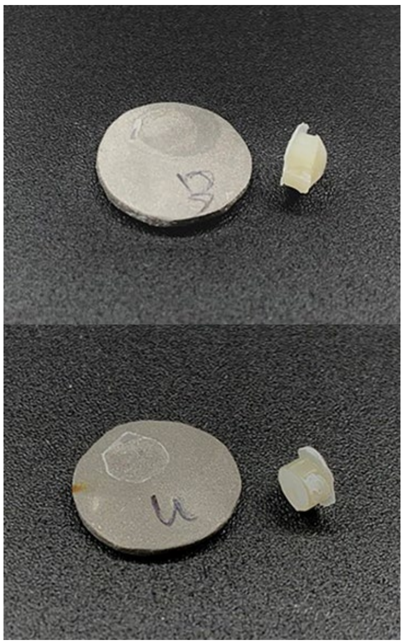

Fig. 1. Adhesive failure in one representative sample of Crea.lign (upper) and PermaFlo (lower) subgroups to base metal alloy after thermocycling

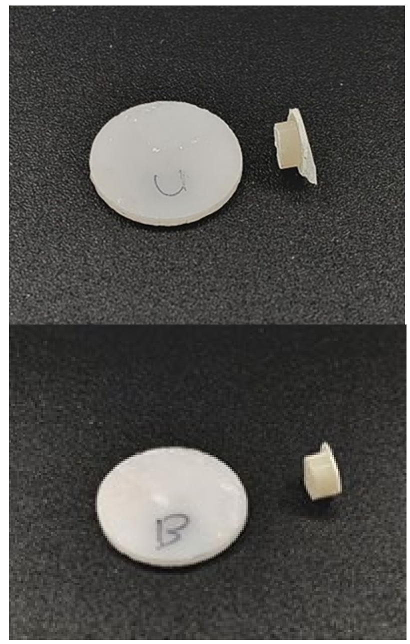

Fig. 2. Adhesive failure in one representative sample of Crea.lign (upper) and PermaFlo (lower) subgroups to zirconia ceramic after thermocycling

SBS of composites to zirconia ceramic

The mean SBS of PermaFlo and Crea.lign composite resins to zirconia ceramic discs with and without thermocycling are presented in Table 2. According to two-way ANOVA, the interaction effect of the composite type and thermocycling on SBS was statistically insignificant (P=0.1). The type of composite made a significant difference on SBS, with PermaFlo being significantly higher than Crea.Lign (P<0.001). A significant decrease in SBS was observed after thermal cycling (P<0.001). All specimens failed due to adhesive failure at the disc-composite interface (Figure 2).

DISCUSSION

Metal-ceramic and all-ceramic restorations are prone to porcelain chipping. Researchers have explored the possibility of repairing the restoration with composite without removing it. Additionally, composite can be used to imitate gingiva in metal-ceramic and all-ceramic restorations to improve color. However, their durability is questionable [27]. This study evaluated the SBS of Crea.Lign with MKZ primer versus PermaFlo repair composite with a universal adhesive containing phosphate esters monomer for zirconia and base metal alloy under the same surface preparation procedure. The results showed that the type of composite and bonding agent significantly affected the mean SBS. Therefore, the null hypothesis, was rejected.

Ozel et al. compared the SBS values of three types of repair composites to Ni-Cr and feldspathic porcelain (Ceramco) frameworks. Kuraray's Ceramic Repair System/Tetric Ceram led to the highest SBS to ceramic and metal after 1000 thermal cycles. Furthermore, 60% of the Ceramic Repair System/Tetric Ceram's bonding failures were cohesive, and 40% were adhesive. In contrast, the other groups had 100% adhesion failures. The use of an alloy primer and the presence of 10-MDP in Clearfil SE Bond contributed to this finding. Similarly, in our study, the phosphorate ester monomer in universal adhesive led to a stronger bond strength for alloy primer to metal than the other groups. A silane coupling agent was used in bonding ceramic to porcelain, which explained why the bond strength between porcelain and composite was higher in all their study groups [28]. It is likely that the difference in failure modes between the two studies is due to the method of fabrication and surface treatment of the discs. According to Almilhatti et al. feldspathic porcelain (EX-3 Noritake) had a stronger bond to Ni-Cr alloy than three light-cure composite resins (Artglass, Solidex, Targis). They found that the failure mode was adhesive in both Artglass and Solidex composite resins. Targis exhibited both adhesive and cohesive failures. The mean SBS of the three composite resins in their study was close to the value in our PermaFlo composite and higher than that in Crea.lign, which indicates a weak bond between Crea.lign and base metal alloy [16].

Sarafianou et al. compared the bond strength of indirect composite resin to a base metal alloy using different adhesive primers. They showed that abrasion of metal surfaces with 50 μ aluminum oxide particles enhanced the bond strength of metal to composite, irrespective of the primer used. Metal Primer II (GC Corp, Tokyo, Japan) and SR Link (Ivoclar Vivadent, Schaan, Liechtenstein), which are both metal primers, showed no significant difference in bond strength. Metal Primer II and Tender Bond had a lower mean bond strength than PermaFlo and similar bond strengths compared to Crea.lign in our study. In the other two groups, the bonding strength was higher than the values in our study, probably due to differences in bonding agents, surface treatments, and frequency of thermal cycling [10]. Since phosphate ester monomers are reported to exhibit superior bond strength to metal oxide substrates, the higher bond strength for PermaFlo than Crea.lign in the current study is likely because of the presence of organophosphine oxide monomer in its composition [13].

Mahgoli et al. [29] studied the effect of two types of zirconia primers on the bond strength of composites to zirconia. They reported that Mono Bond Plus did not bond to zirconia as well as Zirconia Primer Plus plus Porcelain Bonding Resin. They believed this difference was caused by the addition of MDP phosphate monomers to Zirconia Primer Plus. All bond strength values in their study were higher than those obtained in our research in the Crea.lign plus MKZ primer subgroup. PermaFlo's mean SBS before thermocycling in our study was similar to Porcelain Bonding Resin's in their research. After thermocycling, however, its SBS value was comparable to that of Mono Bond Plus. Since all groups of subjects underwent thermocycling in their study, it can be assumed that PermaFlo's SBS value to porcelain is comparable to Mono Bond Plus's SBS value. Like us, all failures in their study were adhesive in the Porcelain Bonding Resin group.

Zakavi et al. [30] assessed the SBS of composite resin to zirconia using universal and conventional adhesives and zirconia primer. They reported maximum SBS in Futurabond U followed by Clearfil Universal Bond. They concluded that universal adhesives yield a stronger SBS than zirconia primers due to the 10-MDP monomer in their composition. The SBS of PermaFlo to porcelain in our study was comparable to the reported value in their study, probably due to the composition of phosphate ester monomer in Peak Universal Bond; however, the SBS of Crea.lign in our study was lower than the value reported in their study. It should be noted that they only performed 5000 thermal cycles, which may explain the higher mean SBS in their research. Celik et al. [1] also assessed the SBS of composite to zirconia. They indicated that specimens repaired with universal adhesive had higher SBS than those repaired with a porcelain repair kit due to the presence of 10-MDP monomer in universal adhesives. They also demonstrated that thermocycling caused a maximum reduction in SBS, which was in line with our findings. Scaminaci Russo et al. [31] performed a systematic review on bonding to zirconia and reported that physicochemical preparation of zirconia surface could increase the adhesion. They also showed that sandblasting with alumina particles, tribochemical silicoating, and chemicals containing phosphate ester monomers such as 10-MDP base would yield higher bond strength values. De Mello et al. [32] also reported that surface treatment by sandblasting increases the SBS of Y-TZP to ceramic veneers.

Thermocycling is intended to simulate the thermal stress to which the restorative materials would be exposed to get years of aging in a short period of time. During this process, thermal changes are created in water baths between 5-55°C in order to create strain at the bonding interface. It has been reported that repeated thermal changes can weaken the bond between resin matrix and filler [33]. According to Ozcan et al. [23] thermocycling is more accurate than other methods for simulating composite aging. Consequently, this profile is thought to better simulate clinical temperature variations.

Assuming an average of 20 to 25 heat cycles per day, 10,000 thermal cycles would simulate one year of clinical practice [10]. In accordance with several other studies, the current study indicated thermocycling significantly reduced the shear bond strength between resin-metal and resin-ceramic systems [15,17,24,33].

The results of this study should be interpreted with caution in clinical applications. This is because the present study did not account for factors existing in the oral environment, such as dynamic fatigue loading and pH fluctuations. The mode of failure was adhesive at the disc-composite interface in all specimens. A digital camera was used rather than a stereomicroscope. Therefore, a more detailed investigation of the mode of failure will be needed. Future research, including long-term clinical studies, is required to confirm the efficacy of the tested technologies in providing reliable bond strength.

CONCLUSION

The present study showed that the use of universal adhesive resulted in higher bond strength for zirconia and base metal alloys compared to Crea.lign and MKZ primer

CONFLICT OF INTEREST STATEMENT

None declared.

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