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Bond Strength of Luting Cement to Casting and Soldering Alloy

O Kumbuloglu*, LVJ Lassila†, A User*, S Toksavul* and PK Vallittu‡

Abstract - *Adjustment of metal alloy framework of the porcelain-fused-to-metal crown by soldering minor marginal deficiences prior insertion may sometimes be needed. The aim of this study was to compare shear bond strengths of four luting cements to casting metal alloy and soldering metal alloy. A total of 64 flame cast non-precious metal alloy and flame soldered metal alloy samples were used. Durelon, Panavia F, RelyX Unicem Applicap and RelyX ARC stubs were bonded to the alloy substrate surface. After stored in water at 37°C for 1 week, shear bond strength of the cement to the alloy was measured. Differences were analyzed using one way ANOVA ($p<0.05$). There were no difference between the cast metal alloy and soldering metal alloy substrate.*

KEY WORDS: Shear Bond Strength, Luting Cement, Solder

INTRODUCTION

Soldering is used to add proximal contacts, repair casting voids, and connect retainers and/or pontics in fixed partial dentures. It is defined as the joining of metal components by a filler material, or solder, which is fused to each of the parts being joined[1]. Technically, soldering is performed at temperatures below 425ºC and brazing at temperatures above 425ºC. In dentistry, the latter procedure is commonly called soldering[2]. It has been stated that the addition of solder alloy to porcelain-fused-to-metal crowns decreases the porcelain failure load and may potentially decrease the longevity of the restoration[3,4].

Numerous composite resin cements available consist of an adhesive for bonding to the tooth structure and polymerizing particulate filler composite resin cement for bonding to the restoration. Their performance has been evaluated by several researchers[5-8].

Adjustment of metal alloy framework of the porcelain-fused-to-metal crown by soldering minor marginal deficiencies may sometimes be needed. The crown margins are affected by high stresses in function. Therefore, bonding of the luting cement to crown margin is of importance. The aim of this study was to compare shear bond strengths of four luting cements to casting metal alloy and soldering metal alloy.

MATERIALS AND METHODS

The materials used in this investigation (Table 1) were all prepared and handled in accordance with their manufacturers' instructions. Sixty-four test specimens for metal substrates were prepared in discs with 10 mm in diameter and 2 mm in thickness. They were fired at conventional firing temperatures according to manufacturer's directions. The specimens were randomly divided into two groups as metal and solder substrates. The procedure for preparing the solder substrates involved perforation of the metal specimens in the center with a round carbide bur (HP-2, SS White Burs, Inc, Lakewood, NJ). The perforation measured 3,6 mm in diameter and min. 0.2 mm in depth, in accordance with ISO 9333. Fabrication procedures of the solder substrates were performed according to the protocol described by Shillingburg et al[1]. A No. 2 pencil was used to outline the area and limit the solder flow around the perforation. The specimens were warmed slightly, and flux was placed on the surfaces to be soldered. Fluxes may provide surface protection, reduce oxides or dissolve oxides[1]. Flux was to be displaced by solder, which then can form an interface with and bond to the surface being soldered. Fluorides were used on base metal alloys to dissolve the stabile oxides of chromium, cobalt and nickel. In addition to acting as solvents, these fluxes also serve a protective role[1]. Several pieces of solder were placed over the perforation and the specimens were heated until solder flowed in the area. The substrates were embedded in acrylic resin blocks ensuring that the surface of discs remained uncovered for surface treatment.

All specimens were wet ground with 500 grit silicone carbide abrasive, followed by 1200 grit silicone carbide abrasive using a grinding device (Struers RotoPol 11, Struers A/S, Rodovre, Denmark). The surfaces were then air-abraded with 50 µm grain sized aluminum oxide particles with a pressure of 250 kPa from a distance of approximately 10 mm for 14 s. All stubs were cleaned for 10 min in an ultrasonic bath (Quantrex 90 WT, L&R Manufacturing, Inc., Kearny, NJ, USA) containing distilled water and air-dried. Polycarboxylate cement Durelon (3M ESPE), composite resin cements Panavia F (Kuraray), RelyX Unicem Applicap and RelyX ARC (3M ESPE) stubs (diameter: 3.6mm, height 5mm) were applied and bonded to the alloy substrate surface (n=8/group).

*DDS, PhD
†DDS, MSc
‡DDS, PhD, CDT.

Table 1. *Materials Used in the Study (Compositions from Manufacturer's Information)*

Brand	*Type*
Durelon (3M ESPE, St Paul, Minnesota)	Carboxylate cement*
RelyX ARC (3M ESPE, St Paul, Minnesota)	Dual-curing or autopolymerizing composite resin cement†
Panavia F (Kuraray Co Ltd, Osaka Japan)	Dual-curing or autopolymerizing composite resin cement‡
RelyX Unicem Applicap (3M ESPE, St Paul, Minnesota)	Dual-curing or autopolymerizing composite resin cement§
Wirobond C (Bego, Bremen, Germany)	Alloy¶
Wirobond Solder(Bego, Bremen, Germany)	Solder**

* Contains powder (zinc oxide) and liquid (polyacrylic acid).
† Contains adhesive resin cement (RelyX ARC: Bisphenol-A-glycidyldimethacrylate [Bis-GMA] and triethylene glycol dimethacrylate [TEGDMA]).
‡ Contains adhesive resin cement (Panavia F: Paste A [Silanated and colloidal silica, dimethacrylate] and Paste B [Silanated barium glass, titanium oxide, dimethacrylate and sodium fluoride]).
§ Contains adhesive resin cement (RelyX Unicem: Powder [Glass powder, initiator, silica, substituted pyrimidine, calcium hydroxide, peroxy compound and pigment] and Liquid [Methacrylated phosphoric ester, dimethacrylate, acetate, stabilizer and initiator]).
¶ Cobalt-chrome metal-to-ceramic alloy (principal elements by wt%: Co 61, Cr 26, Mo 6, W 5, Si 1, Fe 0.5, Ce 0.5, C max. 0.02).
** Soldering rods (principal elements by wt%: Co 60.5, Cr 28.5, Si 4.5, Mo 3, Mn 1.5, Fe 1.5, B 1.5, C 0.5).

Panavia F (Kuraray, Osaka, Japan) composite resin luting cement system was used for this study. K-Etchant gel was applied on the substrate surface for 5 s. After water rinse and air-drying, a mixture of Clearfil Porcelain Bond Activator and the primer of Clearfil SE Bond was applied for silane treatment and left for 5 s before drying with mild air-flow. Panavia F pastes A and B were mixed for 20 s and applied by using a composite filling instrument to the conditioned ceramic substrate using translucent polyethylene molds. It was light cured (Optilux 501, Kerr, Orange, CA; light intensity 1.000 mW/cm²) for 20 s for each section. Before light curing, Oxyguard 2 was applied to all margins and rinsed off after 3 min.

RelyX Unicem Aplicap (3M ESPE, St. Paul, Minnesota) self adhesive universal composite resin luting cement was used. The cement capsules were inserted into the activator and activated by pressing down and holding the handle for 4 s. The capsules then were inserted in the mixing device (Silamat Plus, Ivoclar-Vivadent, Schaan, Liechtenstein) and mixed for 15 s at highest speed. The capsules were applied into the translucent polyethylene molds using the applier. They were light cured (Optilux 501, Kerr, Orange, CA; light intensity 1.000 mW/cm²) for 20 s for each section.

RelyX ARC (3M ESPE, St. Paul, Minnesota) adhesive composite resin luting cement system was used. Ultradent Porcelain Etch (9.5 % hydrofluoric acid, Ultradent, South Jordan, UT) was applied on the substrate surface for 60 s. After water rinse and air-drying, RelyX Ceramic Primer silane coupling agent was applied and dried for 5 s. Single Bond adhesive was applied and dried for 5 s. RelyX ARC resin cement was mixed for 10 s and applied to the ceramic substrate by using a composite filling instrument, using translucent polyethylene molds. It was light cured (Optilux 501, Kerr, Orange, CA; light intensity 1.000 mW/cm²) for 40 s for each section.

After setting or polymerization by light activation of the cement, the samples were stored in water at 37°C for one week. Shear bond strength of cements to alloy was measured. The stubs were mounted in a jig (Bencor Multi-T shear assembly, Danville Engineering Inc., San Ramon CA, USA) of a universal testing machine (Lloyd LRX, Lloyd Instruments Ltd, Fareham, UK). Schematic drawing of the test setup is given in Fig 1. The cross-head speed of continuous loading was 1.0 mm/min until fracture or debonding occurred and the load deflection curve was recorded with Nexygen 4.0 software (Lloyd LRX, Lloyd Instruments Ltd, Fareham, UK). Differences were analyzed using one way analysis of variance ANOVA ($p<0.05$). Multiple comparisons were made by Tukey Post-Hoc test.

Fracture surfaces were analyzed with scanning electron microscope (JSM 5500, Jeol Ltd., Tokyo, Japan). For the analysis, the substrate surfaces were coated with a layer of carbon, thickness 10–15 nm, using a sputter coater (Model BAL-TEC SCD 050 Sputter Coater, Liechtenstein). SEM micrographs were carried out using a standardized method with an accelerating voltage of 20 kV in a vacuum using a working distance of 20 mm.

RESULTS

There were differences between luting cements ($p<0.001$) but no difference between the metal alloy substrates was found ($p<0.05$) (Fig 2). The highest shear bond strengths in cast metal subgroups and soldering alloy subgroups were obtained with the Panavia F composite resin cement (24.8 Mpa and 26.2 Mpa, respectively). The lowest values in both cast metal (2.1 MPa) and soldering alloy (2.0 MPa) subgroups were observed with Durelon carboxylate cement.

It was observed on the micrographs that debondings from substrate surface were adhesional. The SEM photomicrographs of the substrate are given in Fig 3 and Fig 4.

DISCUSSION

Efficiency and predictability are important in the production of porcelain-fused-to-metal restorations. Solder materials routinely are used to repair casting defects and to join pontics and retainers in fixed partial dentures fabrication[3]. In some studies[3,4] which were carried out assuming soldering alloys might have negatively affected metal-porcelain bonding, no statistical significances were found. In this study, which was generated from the idea that there might

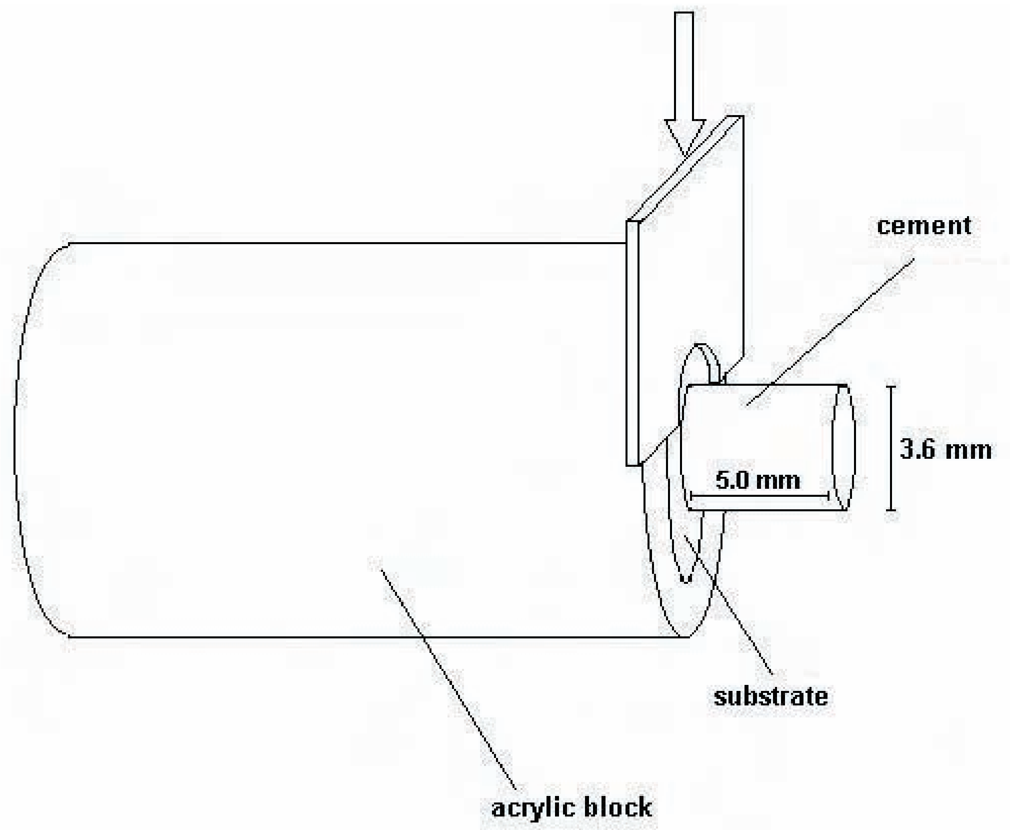
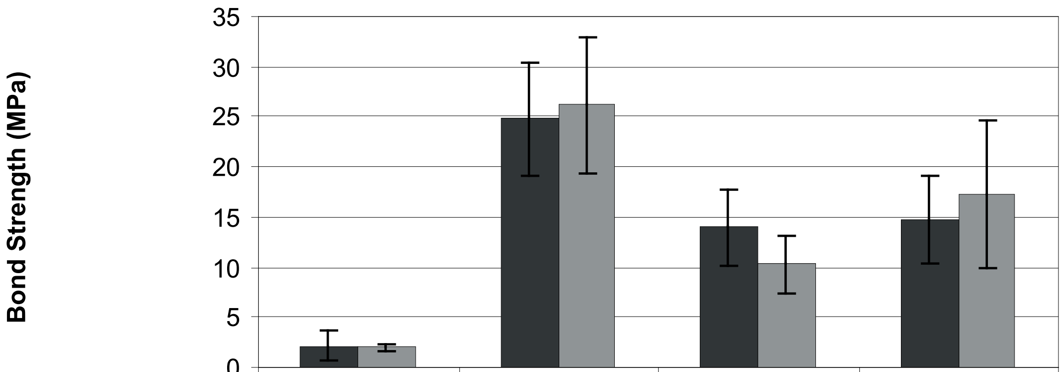


Figure 1. *Schematic drawing of the test setup.*



	Durelon	Panavia F	RelyX Unicem	RelyX ARC
■ Cast Metal	2,1	24,8	14	14,7
■ Soldering Alloy	2	26,2	10,3	17,2

Figure 2. *Shear bond strengths of the materials tested.*

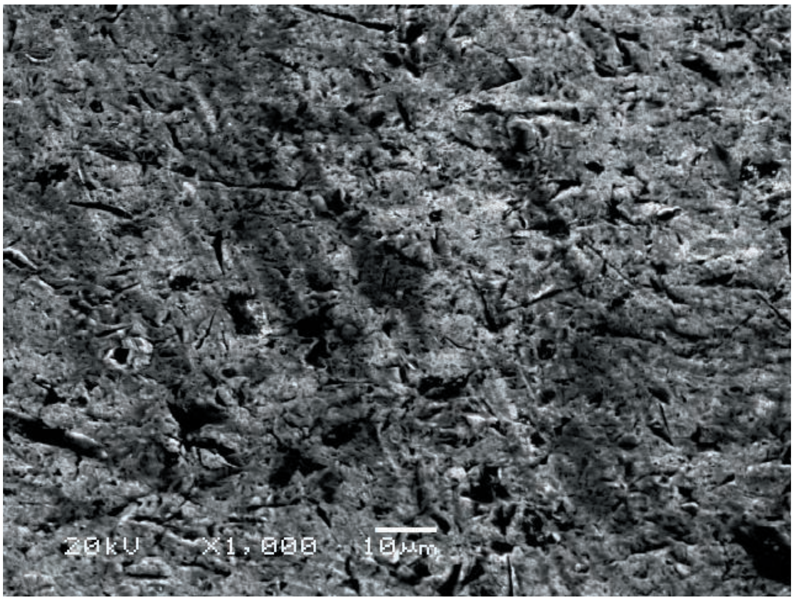


Figure 3. *SEM photomicrograph of the soldering alloy surface examined following the shear bond strength test (original magnification x 1000).The substrate surface completely uncovered indicates adhesive failure.*

Figure 4. *SEM photomicrograph of the cast metal surface observed after shear bond strength test (original magnification x 100). Similarly with the solder surface, the failure was adhesive on the surface.*

be differences in the bond strength of four different commercially available luting cements to both soldering and casting alloys, no statistical differences between the metal alloy substrates in terms of bond strengths were found, where there were statistical differences among the bond strengths of luting cements.

Properties of the luting cement and cementation procedure are keys to the clinical success of crowns and fixed partial dentures (FPDs). Loss of crown retention is reported to be the second leading cause of failure for traditional crowns and FPDs by Schwartz et al[9]. The choice of a luting agent is depent on the clinical situation combined with its physical, biologic, and handling properties[8]. The result of this study showed that Panavia F composite resin cement had the highest bond strength whereas Durelon carboxylate cement were the lowest bond strength in both cast metal and soldering alloy subgroups. Because of their thixotopic nature, polycarboxylate cements exhibit different behaviors from resin-based cements under pressure [8] and phosphate monomer of Panavia F composite resin cement had a greater attraction to basic metals[10].

CONCLUSION

It was concluded that different luting cements varied considerably with respect to their bond strengths. There were no difference between the cast metal alloy and soldering metal alloy substrate on the bond strength.

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ADDRESS FOR CORRESPONDENCE

Ovul Kumbuloglu DDS, PhD. Ege University School of Dentistry, Department of Prosthodontics, 35100 Bornova Izmir, Turkey. E-mail: kumbuloglu@hotmail.com

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