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Microtensile bond strength of resin-based composites to Ti–6Al–4V

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ABSTRACT

Objective. The purpose of this study was to determine the microtensile bond strength of various resin composite/adhesive systems to alumina particle abraded Ti–6Al–4V substrate after aging for 24 h, 10 days, and 30 days in distilled water at 37 °C.

Methods. Four laboratory resin composite veneering systems (Gradia, GR; Solidex, SOL; Ceramage, CER; and Sinfony, SF) were bonded to 25 mm diameter machined disks of Ti–6Al–4V with their respective adhesive and methodology, according to the manufacturer's instructions. Microtensile bars of approximate dimensions 1 mm × 1 mm × 6 mm were prepared for each resin composite/adhesive system. After cutting, groups ($n = 12$) from each adhesive system were separated and either stored in water at 37 °C for 24 h (baseline) or aged for 10 or 30 days prior to loading to failure under tension at a cross head speed of 1.0 mm/min. Failure modes were determined by means of scanning electron microscopy (SEM). Statistical analysis was performed through one-way ANOVA and Tukey's test at 95% level of significance.

Results. Significant variation in microtensile bond strength was observed for the different systems and aging times. SOL and GR showed the highest mean bond strength values followed by SF and CER at baseline. Aging specimens in water had an adverse effect on bond strength for SOL and CER but not for the SF and GR groups.

Significance. In vitro bond strength of laboratory resin composites to Ti–6Al–4V suggests that strong bonds can be achieved and are stable for certain systems, making them useful as an alternative for esthetic fixed prosthetic restorations.

1. Introduction

The use of titanium and its alloys for cast restorations and fixed partial denture frameworks has increased substantially over the last years. This trend can be mainly attributed to the development of casting technology for titanium alloys, such as new casting machines and investment materials and the extensively reported advantages of titanium over other base metal alloys [1–3]. Also, excellent biocompatibility, high strength to weight ratio, low density, high corrosion resistance and low cost compared to noble metals are attractive properties which have favored the application of titanium alloys in

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Table 1 – Materials utilized in this study.

Material	Description	Manufacturer	Mode of application
Ceramage™	Light curing composite system with UDMA matrix and zirconium silicate micro ceramic filling.	Shofu Dental Corp., San Marcos, CA, USA.	Apply two thin coats of ML metal primer and allow to air dry for 10 s between layers; apply a thin coat of pre-opaque and light cure for 3 min with GC Labolight LV-III; apply two layers of opaque and light cure for 3 min each; apply cervical, body and incisal and light cure each layer for 2 min.
Gradia™	Light curing composite system with bis-(methacryloyloxy)-propoxy-carbonylaminohexane-triazine-trione, aluminoborosilicate and silica filling.	GC America Inc., Alsip, IL, USA.	Apply two thin coatings of Metal Primer II and allow them to dry for 30 s; apply three layers of opaque and light cure it for 1 min each with GC Labolight LV-III; apply opaque dentin, dentin and enamel layers and light cure each layer for 3 min.
Synfony™	Light curing composite resin with aliphatic and cycloaliphatic monomers, strontium aluminium borosilicate glass and pyrogenic silica fillers.	Pentron Laboratory Technologies, Wallingford, CT, USA.	Microblast metal surface with Rocatec Pre and silicoat it with Rocatec Plus; apply ESPE Sil and allow it to air dry for 5 min; mix opaque liquid and powder and apply a thin light curing it for two cycles of 5 s with Visio Alpha Unit; apply opaque dentin, dentin, transparent opal and enamel layers, light-curing each layer for four to six cycles of 5 s; cure with vacuum in 3M ESPE Beta Vario unit for 15 min.
Solidex™	Light-curing indirect ceramic polymeric composite system.	Shofu Dental Corp., San Marcos, CA, USA.	Microblast and silicoat metal surface with Rocatec system; apply Solidbond and allow it to dry; apply opaque liquid and light cure it in DentaColor XS for 1 min; apply two layers of flow opaque and light cure each layer for 3 min with GC Labolight LV-III; apply cervical, body and incisal layers of composite and light cure each layer for 3 min.

prosthetic restorations [4–12]. However, problems with porcelain bonding have been reported when titanium is used in metal–ceramic restorations as thick and non-adherent layers of titanium oxide are formed at the high temperatures used for porcelain fused to metal (PFM) technique [13–15]. For this reason, special low fusing porcelains have been developed [12,13,15,16]. Resin composite veneering on titanium castings has been considered as an alternative for esthetic anterior restorations [1].

Metal–composite restorations have long been used as an alternative to PFM restorations [17–19]. Indirect light-cured composite resins have been extensively used in tooth restoration because they can provide acceptable aesthetics, wear resistance similar to tooth structure, and are easy to manipulate in the laboratory and to repair [20–23]. However, durable bonding between composite resins and metal frameworks has been a challenge. Years ago, macro- or micro-mechanical retention on the metal substructures such as beads, loops and pits, or sandblasting and etching, were the only mechanisms for bonding composite materials to metallic substrates. However, recent developments resulting in chemical bonding have been achieved [20,21,24,25], including silicoating systems and functional monomers systems [2,20,23,24]. The former covers the metal surface with a thin layer of silica and is followed by a bi-functional silane-coupling agent which bonds the silanol-groups of the silica layer with monomers of the composite [24,26–28]. The latter utilizes organic sulphur and phosphoric acids (thiophosphate derivatives) that bond to the oxides of the metal surface. These monomer acids are dissolved in solvents or in methacrylate-based liquids to bond to the composites [6,19,23,29,30].

Several studies have shown that silicoating and functional monomer systems improve the composite-to-metal bond strength with noble and non-noble dental alloys [17–20,23,26,28,30] and with titanium and its alloys [1–3,28,31–33]. However, the stability of composite–titanium bond is still questionable. While studies have shown that shear bond strength results were considerably affected by thermal cycling or long-term water storage [2,6,24,34–41], other studies have demonstrated that a number of the composite/adhesive systems evaluated under various metal surface conditioning methods exhibited considerably high and durable bond strength values after thermocycling [20,23,25,30].

Such controversial and limited results concerning adhesive performance between indirect composite and titanium alloys has led to the lack of an informed design rationale for bonding composite materials to titanium alloys [1,2,35]. The current study evaluated the bond strength of four commercially available indirect composite/adhesive systems to a titanium alloy (Ti–6Al–4V) subjected to different times of water storage. The bond strength was determined by microtensile testing and