Improved wear resistance of indirect composite-titanium joint on application of a metal priming system

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Purpose: The aim of this study was to evaluate the effect of a metal priming system on the wear resistance of composite-titanium interface.
Materials and Methods: Two different types of plate specimens were prepared: composite-titanium (Estenia C&B and T-Alloy H) joint without primer, and composite-titanium joint bonded with a priming system (Alloy Primer and Estenia Opaque Primer). Toothbrush wear test was performed using the plate specimens, toothbrushes (Bee King), and a dentifrice (Crest).
Results: Bonded specimens with priming exhibited less wear depth (3.5 μm) than the specimens joined without priming (8.0 μm).
Conclusion: It can be concluded that the use of a metal priming system at the composite-titanium interface effectively enhanced the wear resistance of the joined area under repeated brushing.
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Key Words: composite, primer, titanium, toothbrush, wear.

Introduction

The use of indirect composites in fabrication of restorations and partial dentures has increased substantially. This trend could be attributed to the improvement in the properties of materials.[1-9] The incisal edge or buccal cusp of composite-veneered restoration consists of an indirect composite material and a casting alloy.[10] The composite and casting should be adequately bonded in the joints to ensure long-term survival of the restorations. One of the problems associated with veneered restorations is unpredictable wear of the facing materials as a result of toothbrushing. Application of non-wear resistant materials on the facial surface or buccal cusp will cause loss of anatomic form of the restoration within a short period. Although wear of composite materials has been evaluated extensively using either simulated occlusal contact wear or toothbrush abrasion,[2-9] limited information is available about the wear characteristics of the interface between casting alloys and tooth-colored materials.[2,9] This study evaluated the wear resistance to toothbrush-dentifrice abrasion of a composite-titanium joint bonded with or without a metal priming system.

Materials and Methods

A light-activated composite system designed for indirect restorations and fixed partial dentures (Estenia C&B, Kuraray Medical Inc., Tokyo, Japan) was employed. The Estenia C&B composite consisted of approximately 8% urethane tetramethacrylate (UTMA) and another methacrylate monomer, and 92% inorganic filler. The E1 and OA3 shades for incisal edges and opaque materials were used for specimen preparation. A high-purity titanium (T-Alloy H, GC Corp., Tokyo, Japan) was selected for the framework. A two-step metal priming system (Alloy Primer and Estenia Opaque Primer, Kuraray Medical Inc.) was used to assess the interfacial integrity of the alloy-composite joint. Information on the materials is summarized in Table 1.

Table 1. Materials used.

Material / Trade name	Manufacturer	Lot number	Composition (mass%)
Casting alloy			
T-Alloy H	GC Corp., Tokyo, Japan	0706111	99.2 Ti, 0.3 Fe
Indirect composite			
Estenia C&B E1	Kuraray Medical Inc., Tokyo, Japan	0014AA	UTMA, Methacrylate, Photo initiator, Pigment, 92 filler (Glass, Alumina)
Estenia C&B OA3	Kuraray Medical Inc.	0051AA	Bis-GMA, Photo initiator, Pigment, Filler
Primer			
Alloy Primer	Kuraray Medical Inc.	0202AA	MDP, VTD, Acetone
Estenia Opaque Primer	Kuraray Medical Inc.	00135B	MDP, Monomer solvent
Polymerizing unit			- -
α-Light II	J. Morita Corp., Suita, Japan	0040	Halogen lamp, 360 W×1, 400-600 nm
KL-310	J. Morita Corp.	9108	Heat oven
Toothbrush			
Bee King	Bee Brand Medico Dental Co., Ltd., Osaka, Japan		
Dentifrice			
Crest Tartar Protection	The Procter & Gamble Co., Cincinnati, OH, USA		Regular Paste

UTMA, Urethane tetramethacrylate; MDP, 10-methacryloyloxydecyl dihydrogen phosphate; VTD, Triazine dithione monomer.

A total of 12 rectangular specimens (18.0x12.5x2.0 mm) were cast from the titanium and polished according to the manufacturer's specifications. The surface to be joined (18.0x2.0 mm) was air-abraded with 50-70-μm alumina (Hi-Aluminas, Shofu Inc., Kyoto, Japan) for 15 s (Jet-Blast II, J. Morita Corp., Suita, Japan). The air pressure was 0.5 MPa, and the distance between the orifice and the titanium surface was approximately 20 mm. Six specimens were primed with the Alloy Primer and Estenia Opaque Primer, whereas the remaining six specimens were left unprimed. A thin layer of opaque material was applied to the titanium surface and light-exposed for 90 s with a polymerizing unit (α-Light II, J. Morita Corp.). The specimens were placed in a steel mold (18.0x25.0x2.0 mm), and the vacant space in the mold was filled with Estenia C&B composite paste. The surface of the composite-titanium specimen was covered with a piece of glass plate (0.12-0.17 mm thick, Micro Cover Glass, Matsunami Glass, Osaka, Japan), and the specimen was placed in a polymerizing unit and irradiated for 5 minutes. After light exposure, the glass plate was removed. An oxygen barrier agent (Air Barrier, Kuraray Medical Inc.) was applied to the composite surface, and the specimen was polymerized at 110°C in a heated oven (KL-310, J. Morita Corp.) for 15 minutes. All of the specimens were then wet-ground with a series of silicon carbide (SiC) paper (up to 2,000 sheets, WetorDry Tri-M-ite, 3M Corp., St. Paul, MN, USA), followed by polishing with felt and alumina (0.3 μm, Baikalox 0.3CR, Baikowski International Corp., Charlotte, NC, USA). After polishing, the specimens were stored in distilled water at 37˚C for 14 days.

Each specimen was fixed on a specimen holder attached to a toothbrush abrasion-testing machine (K236, Tokyo-Giken Co., Ltd., Tokyo, Japan). A dentifrice with silica abrasives (Crest Tartar Protection Regular Paste, RDA-Value 136, The Procter & Gamble Co., Cincinnati, OH, USA) was used as a slurry with a paste-water ratio of 1:1. The vessel of the machine was filled with 150 g of slurry. A nylon toothbrush (Bee King, Bee Brand Medico Dental Co., Ltd., Osaka, Japan) was fixed in the brush holder of the machine, and moved over the specimen at 140 strokes per minute. A load (3.4 N) was applied vertically to the top of the toothbrush holder with a stainless steel weight. The specimens were abraded with a total of 20,000 reciprocal strokes. The toothbrush and slurry were replaced before each specimen testing. Six specimens were tested for each condition.

After the abrasion testing, specimens were removed from the machine, ultrasonically cleaned in distilled water for 10 minutes, and air-dried.

The vertical loss in μ m of each specimen was determined with a confocal scanning laser microscope (1LM21W, Lasertec Corp., Yokohama, Japan). The distance from the original specimen surface to the deepest point was defined as wear depth. Statistical analysis was carried out using SPSS software (Version 12.0.J for Windows, SPSS Japan Inc., Tokyo, Japan). Average values, medians, and standard deviations for wear depth were calculated from six replications. The result was analyzed with Mann-Whitney U test with the value of statistical significance set at p=0.05. Selected specimens after wear testing were sputtered with osmium and observed with a scanning electron microscope (SEM; S-4300, Hitachi High-Technologies Co. Ltd., Tokyo, Japan) operated at 15 kV.

Results

Table 2 shows the wear depths of the abraded specimens. Average wear depth at the joint between the Estenia C&B composite and titanium was 3.5 μm for the primed group and 8.0 μm for the unprimed group. Wear depth of the primed group was significantly smaller than that of the unprimed group (p<0.01). Figures 1 and 2 show the scanning electron micrographs of the specimens after wear testing. The composite-titanium specimens treated with the primer (Fig. 1) show a smoother surface as compared with the composite-titanium specimens without priming (Fig. 2). Fracture and detachment of filler particles can be observed from the worn surface of the unprimed group (Fig. 2).

Table 2. Wear depths of abraded specimens.

Group	Wear (μm)	Mean	Median	Minimum	Maximum	SD	Z-value	P-value
Primed		3.5	3.6	2.5	4.1	0.5	-3.36	0.001
Unprimed		8.0	7.7	5.7	10.0	1.4		

SD, Standard deviation. Significant difference was observed between primed and unprimed specimens (Mann-Whitney U test).

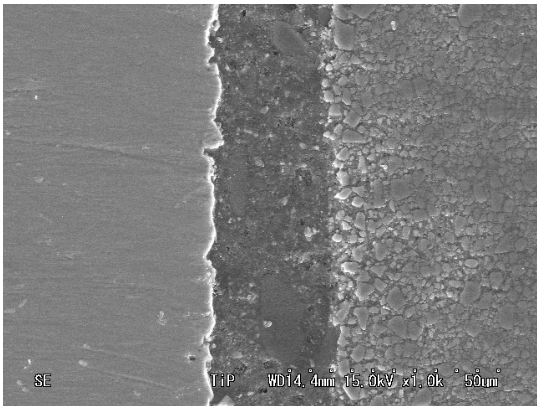

Fig. 1. Electron micrograph of the surface of a primed specimen after wearing.

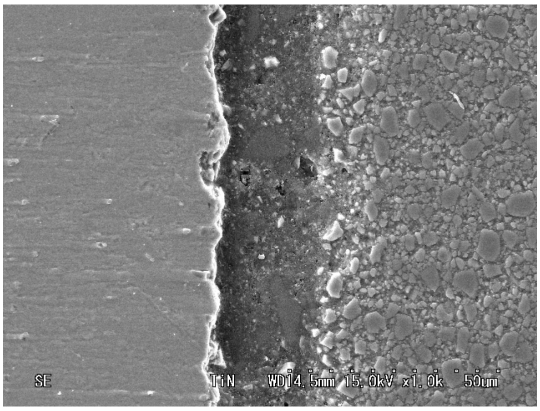

Fig. 2. Electron micrograph of the surface of an unprimed specimen.

Discussion

This study evaluated the wear and integrity of the composite-titanium interface with and without adhesive treatment. Wear testing results demonstrated that the metal priming system was effective in improving the interface integrity between the composite and titanium. As shown in Table 1, the composite-to-alloy bonded group with the Estenia priming system exhibited less wear depth as compared with the unprimed group. In addition, scanning electron micrographs demonstrated typical microfractures along the interface of the unprimed group. The disparity in integrity at the interface probably arose from the difference in fracture resistance between the two groups to cycled loading from the toothbrush and dentifrice. Both the Alloy Primer and Estenia Opaque Primer materials contain a hydrophobic phosphate monomer MDP (Table 1). Effectiveness of the MDP monomer in bonding titanium or titanium alloy has been evaluated through bond strength tests in metal-to-metal bonded specimens[10,11] and composite-to-metal bonded specimens.[12] It was therefore reasonable to consider that the bonding capability of MDP monomer in the Alloy Primer and Estenia Opaque Primer materials reduced microfracturing of the Estenia C&B composite at the composite-titanium interface during wear testing. Ishii et al. recently reported that the VTD monomer contained in Alloy Primer was effective for bonding gold alloy and ineffective for bonding titanium.[11] Based on this report, the Estenia C&B composite could be bonded to titanium without application of the Alloy Primer material, because the Estenia Opaque Primer material also contains MDP monomer in its single liquid composition.

In conclusion, dental clinicians and laboratory technicians should take extra care when designing the structure of composite-veneered restorations and super-structures of implant-supported prostheses. The use of the Estenia C&B Priming system is indispensable for the long-term survival of composite-titanium joints.

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