

Effect of metal priming agents on bonding characteristics of an acrylic resin joined to SUS XM27 steel

Yumi Ishikawa¹⁾, Yoshikazu Kawamoto^{2,3)}, Hiroyasu Koizumi^{2,3)},
Mika Furuchi^{2,3)}, Hideo Matsumura^{2,3)} and Naomi Tanoue⁴⁾

¹⁾Nihon University Graduate School of Dentistry, Tokyo, Japan

²⁾Department of Fixed Prosthodontics, Nihon University School of Dentistry, Tokyo, Japan

³⁾Division of Advanced Dental Treatment, Dental Research Center, Nihon University School of Dentistry, Tokyo, Japan

⁴⁾Department of Specialized Dentistry, Nagasaki University Hospital of Medicine and Dentistry, Nagasaki, Japan

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Abstract: The purpose of the current study was to evaluate the effect of functional monomers contained in the primers on adhesive bonding of a steel alloy. SUS XM27 steel was primed with one of the following materials; Alloy Primer, Estenia Opaque Primer, and V-Primer. The functional monomers in the primers were a phosphate (10-methacryloyloxydecyl dihydrogen phosphate; MDP) and a thione (6-(4-vinylbenzyl-*n*-propyl) amino-1,3,5-triazine-2,4-dithione, -dithiol tautomer; VTD) for Alloy Primer, MDP alone for Estenia, and VTD alone for V-Primer. The steel disks were bonded with an acrylic resin (Unifast Trad), and bond strength was determined. Of the three primers, both the Alloy Primer (33.3 MPa) and Estenia Opaque Primer (33.9 MPa) materials exhibited far better post-thermocycling bond strength than V-Primer (0 MPa). It can be concluded that the phosphate MDP is effective, whereas the thione VTD is ineffective for bonding SUS XM27 steel. (*J. Oral Sci.* 48, 215-218, 2006)

Keywords: bonding; keeper; magnet; primer; steel.

Correspondence to Dr. Hideo Matsumura, Department of Fixed Prosthodontics, Nihon University School of Dentistry, 1-8-13 Kanda-Surugadai, Chiyoda-ku, Tokyo 101-8310, Japan
Tel: +81-3-3219-8145
Fax: +81-3-3219-8351
E-mail: matsumura@dent.nihon-u.ac.jp

Introduction

A number of magnetic attachment systems have been introduced for retaining prostheses and removable dentures (1-11). Both the magnetic assembly and keeper are currently bonded to the denture base and coping materials with resin-based materials. The cap, yoke, and keeper components of dental magnetic attachments are generally made of stainless steel to prevent corrosion of magnetized alloys (2,4,6). Several types of steels with different chromium content are used in magnetic attachment systems.

The attachment and denture base material should be bonded strongly to avoid detachment of the magnetic assembly in prostheses. Bonding magnetic assemblies and keepers with resin-based material is substantially the same as bonding stainless steel with adhesive resin. While various adhesive systems have been introduced for bonding both noble and base metal alloys (12-15), limited information is available concerning bonding of steels for magnetic systems (16-20). In particular, comparative evaluation of functional monomers contained in the priming and bonding agents has not been performed. This study evaluated the bond strength of a self-polymerizing acrylic resin to SUS XM27 steel (XM27), using three priming agents with different functional monomer ingredients.

Materials and Methods

SUS XM27 steel (XM27, 26% Cr, Hitachi Metals Ltd., Tokyo, Japan) designed for dental magnetic attachment systems was selected as the adherend material. Three

metal priming agents were used; Alloy Primer (Kuraray Medical Inc., Tokyo, Japan), Estenia Opaque Primer (Kuraray Medical Inc.), and V-Primer (Sun Medical Co., Ltd., Moriyama, Japan). All primers had a single liquid and contained at least one adhesive functional monomer in the solvent. A self-polymerizing methacrylic resin (Unifast Trad, GC Corp., Tokyo, Japan) was selected as the resin luting material. Information regarding the materials is summarized in Table 1.

Sixty-four steel disk pairs (10 and 8 mm in diameter and 2.5 mm thick) were prepared, wet-ground with 1,500 grit silicon-carbide abrasive paper, and ultrasonically cleaned in acetone. The 64 disks were divided into four sets (three primers and an unprimed control) of 16 specimens each. A piece of 50- μ m-thick tape with a circular hole 5 mm in diameter was placed on the 10 mm disk specimen surface to define the bond area and the thickness of the luting agent. Three sets consisting of 16 pairs each were primed with one of the three primers, whereas the remaining 16 pairs were left unprimed and considered as the controls. Each pair of 10-mm- and 8-mm-diameter specimens was bonded together with Unifast Trad self-polymerizing resin using a brush-dip technique.

After 30 minutes, the bonded specimens were stored in distilled water at 37°C for 24 hours. This state was defined as 0 thermocycle, and half of the specimens (eight specimens each in four priming conditions) were tested at this stage. The remaining half of the specimens (four sets of eight specimens) were subsequently thermocycled between 5°C and 55°C in a water bath for 20,000 cycles with a dwell time of 60 seconds per bath (Thermal Shock Tester TTS-1 LM, Thomas Kagaku Co. Ltd., Tokyo, Japan). Each specimen was placed in a steel mold and seated in a shear test jig (ISO TR 11405) (21). Shear bond strengths were determined by means of a mechanical testing device (Type 5567, Instron Corp., Canton, MA,

USA) at a crosshead speed of 0.5 mm/minute. After the shear bond testing, the debonded surfaces were observed through an optical microscope (8 \times ; SZX9, Olympus Corp., Tokyo, Japan).

For each group of eight replications, the average shear bond strength, median value, and standard deviation were calculated. The results were primarily analyzed by Levene test for evaluation of equality of variance (SPSS 12.0, SPSS Japan Inc., Tokyo, Japan). When the results of the Levene test did not show homoscedasticity in at least one category, Kruskal-Wallis test was performed separately for both pre- and post-thermocycling groups to evaluate the difference among primer variations at $P = 0.05$. On the basis of the results of Kruskal-Wallis test, Steel-Dwass multiple comparisons (KyPlot 4.0, KyensLab Inc., Tokyo, Japan) were further applied to compare the difference among the four priming conditions for each of 0- and 20,000-thermocycling conditions with the value of statistical significance also set at 0.05. Difference between the pre- and post-thermocycling bond strengths within an identical priming condition was analyzed with Mann-Whitney U test at $P = 0.05$ level.

Results

Kruskal-Wallis test revealed that χ^2 values were 26.189 for the pre-thermocycling group and 25.476 for the post-thermocycling group. The P -value was less than 0.05 for both pre- and post-thermocycling bond strengths, hence the pre- and post-thermocycling results were separately analyzed with the Steel-Dwass multiple comparison intervals.

Results of the shear bond testing are summarized in Table 2. The median bond strength varied from 0 to 50.4 MPa. Mann-Whitney U test run on the bond strength results showed that there was a statistically significant reduction in bond strength after thermocycling for all four priming

Table 1 Materials assessed

Material/Trade name	Manufacturer	Lot number	Composition
Steel alloy			
SUS XM27	Hitachi Metals Ltd., Tokyo, Japan		Fe 72, Cr 26, Others 2, mass%
Primer			
Alloy Primer	Kuraray Medical Inc., Tokyo, Japan	0214AA	MDP, VTD, Acetone
Estenia Opaque Primer	Kuraray Medical Inc.	0140AA	MDP, Solvent
V-Primer	Sun Medical Co. Ltd., Moriyama, Japan	LR1	VTD, Acetone
Self-polymerizing acrylic resin			
Unifast Trad	GC Corp., Tokyo, Japan	0507122 0508051	Powder: PMMA, PEMA Liquid: MMA, <i>N,N</i> -dimethyl- <i>p</i> -toluidine

VTD: 6-(4-vinylbenzyl-*n*-propyl) amino-1,3,5-triazine-2,4-dithione, -dithiol tautomer; MDP: 10-methacryloyloxydecyl dihydrogen phosphate; PMMA: Poly(methyl methacrylate); PEMA: Poly(ethyl methacrylate); MMA: Methyl methacrylate.

Table 2 Shear bond strength (MPa) to SUS XM27 steel of the Unifast Trad acrylic resin with/without priming

Primer	0 thermocycle				20,000 thermocycles				M-W <i>U</i> test
	Median	Category	Mean	SD	Median	Category	Mean	SD	
None (Control)	20.2	c	20.5	2.2	5.4	e	4.0	3.4	Significant
Alloy Primer	48.2	a	48.3	1.9	33.3	d	33.4	3.6	Significant
Estenia Opaque Primer	50.4	a	50.6	1.4	33.9	d	32.9	3.5	Significant
V-Primer	32.1	b	29.7	6.5	0.0	e	0.0	0.0	Significant

SD: Standard deviation. Identical lower case letters under category indicate that they are not statistically different (Steel-Dwass test, $P > 0.05$).

The term "Significant" under Mann-Whitney *U* test indicates that the difference between the pre- and post-thermocycling bond strengths is significant (Mann-Whitney *U* test, $P < 0.05$).

conditions (Table 2). The unprimed control group resulted in the lowest bond strength both before (category c) and after (category e) thermocycling. There was no significant difference between the Alloy Primer and Estenia Opaque Primer groups in bond strength, regardless of the application of thermocycling (category a, before; and category d, after). Overall, the Alloy Primer and Estenia Opaque Primer groups exhibited statistically identical and the greatest bond strengths within the limitation of the current experimental settings, although there was remarkable reduction in bond strength after thermocycling for both groups. Observation of the debonded surfaces revealed that adhesive failure between the metal surface and the resin material was predominant for all specimens.

Discussion

This study used a benzoyl peroxide-tertiary amine redox-initiated methyl methacrylate (MMA) resin as the luting agent. This material (Unifast Trad) is frequently used for placement of magnetic assemblies as well as keepers in the proper location of prostheses. Bond strength results clearly demonstrated effectiveness of the Alloy Primer and Estenia Opaque Primer materials. Both materials contain a hydrophobic phosphate monomer (MDP), hence the authors speculate that the improved bond strength to XM27 steel is derived from interaction between the dihydrogen phosphate in the MDP and the passive chromium oxide film on the XM27 steel (22). Effectiveness of the MDP monomer in bonding stainless steel has been reported previously (12,16,17,20), and the present results agree with these findings, although the composition of resins and steels were not identical.

The influence of VTD on the bonding to XM27 steel was next evaluated. Comparison between the Alloy Primer and Estenia Opaque Primer groups is beneficial for this evaluation because the former contains both MDP and VTD in a single liquid, whereas the latter contains MDP alone. Bond strength results showed no significant difference in bonding effect between the two priming agents. The result

suggests that VTD does not interfere with the adhesion promoting effect of the MDP monomer in bonding the XM27 steel.

Finally, the influence of VTD on bonding XM27 was evaluated using the V-Primer material. Bond strength to XM27 steel of the MMA resin was not particularly improved with the use of V-Primer. The V-Primer material was originally introduced for conditioning noble metal alloys (13,14). The VTD monomer in the V-Primer material is categorized as either a thione or a thiol. These compounds are capable of bonding noble metals and copper (22,23). This may explain the ineffectiveness of the V-Primer material in bonding the XM27 steel, which does not contain any noble metal elements.

In summary, the use of two priming agents that contain a hydrophobic phosphate monomer (MDP) effectively enhanced bond strength to SUS XM27 steel with an MMA-based self-polymerizing resin.

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