INTRODUCTION

Metal ceramic restorations have been used for a long time, largely because of their esthetic benefits and satisfactory mechanical properties. Noble metal alloys have been used for the fabrication of metal ceramic restorations. Regarding the luting materials for metal ceramic restorations, diverse luting cements have been used. Resin-modified glass ionomer cement (abbreviated as RMGIC) was developed for the intent of overcoming the highly brittle nature of conventional glass ionomer cements. This was achieved by replacing part of the water content by water soluble or compatible vinyl monomer (e.g., 2-hydroxyethyl methacrylate and crosslinking monomers). Hereby mechanical properties such as flexural strength and fracture toughness, those of RMGICs excel those of conventional glass ionomer cements. Furthermore, RMGICs are easier to remove than conventional glass ionomer cements; clinical reports have demonstrated that RMGICs maintained durable bonding. Therefore the use of RMGICs as the luting material of metal ceramic restorations is expected to increase.

In terms of bond strength of RMGICs to dentin, it has been improved by the following means. Either a specific acidic functional monomer is added to the liquid component or that a dentin conditioning agent contains at least one bonding promoter. On the other hand, the bond strength of RMGICs to restorative materials has not been thoroughly and comprehensively evaluated. This is because restorations have been mechanically retained in the cavity preparation. Unlike the RMGICs, bond strength of resin materials to noble metal alloys is improved by applying metal priming agents which consist of a volatile solvent and an organic sulfur compound. In addition, metal priming agents contain a polymerizable group, which consists of a methacryloyl group or vinyl group to be copolymerized with resin materials.

RMGICs also contain resin components such as HEMA. This component can copolymerize with the polymerization group of metal priming agents. Therefore, the bond strength between RMGICs and noble metal alloys is expected to improve by the application of metal priming agents. However, limited information is available regarding the bond strength of RMGICs in combination with metal priming agents.

The aim of this study, therefore, was to evaluate in vitro the shear bond strength to a gold alloy of RMGICs combined with three metal priming agents. Gold alloy was primed with one of the following materials: Alloy Primer, Metal Primer II, or Metaltite. Non-treated group was considered as the control. Specimens were bonded with one of the following luting agents: Super-Bond C&B, Vitremer Luting Cement, Fuji Lute, or Xeno Cem Plus. Shear bond strength was then determined.

The bond strengths of resin-modified glass ionomer cements primed with the metal priming agents were greater than that of non-treated group, except for the Vitremer Luting Cement-Alloy Primer combination. It was thus concluded that the priming agents employed in this study were substantially effective in improving the bonding of resin-modified glass ionomer cements to gold alloy.

Keywords: Bonding, Priming agent, Resin-modified glass ionomer cement

Effect of Metal Priming Agents on Bond Strength of Resin-modified Glass Ionomers Joined to Gold Alloy

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Keywords: Bonding, Priming agent, Resin-modified glass ionomer cement

MATERIALS AND METHODS

Materials used

A gold alloy for metal ceramic restorations (Degudent U, Degudent, Hanau, Germany) was used as the substrate material. Three single-liquid metal priming agents for noble metal alloys (Alloy Primer, Kuraray Medical Inc., Tokyo, Japan, VTD; Metal
Primer II, GC Corp., Tokyo, Japan, MEP; Metaltite, Tokuyama Dental Corp., Tokyo, Japan, MTU) were selected for priming in this study. Each priming agent contained an organic sulfur compound; VTD, MEP, and MTU-6 contained 6-(4-vinylbenzyl-n-propyl)amino-1,3,5-triazine-2,4-dithiol, or -2,4-dithione tautomer (VTD), methacryloyloxyalkyl thiophosphate derivative (MEPS), and 6-methacryloyloxyhexyl 2-thiouracil-5-carboxylate (MTU-6), respectively.

Three resin-modified glass ionomer cements (Vitremer Luting Cement, 3M ESPE, Seefeld, Germany; Fuji Lute, GC Corp., Tokyo, Japan; Xeno Cem Plus, Dentsply-Sankin K.K., Tokyo, Japan) and a resin adhesive (Super-Bond C&B, Sun Medical Co. Ltd., Moriyama, Japan) were selected as the luting agents. Table 1 summarizes the information of the materials used in this study.

### Material assessed

<table>
<thead>
<tr>
<th>Material</th>
<th>Abbreviation</th>
<th>Component</th>
<th>Lot number</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold alloy</td>
<td>Degudent U</td>
<td></td>
<td></td>
<td>Au 77.3, Pt 9.8, Pd 8.9, Others 4.0 (mass%)</td>
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</tbody>
</table>

#### Metal priming agents

<table>
<thead>
<tr>
<th>Material</th>
<th>Abbreviation</th>
<th>Component</th>
<th>Lot number</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloy primer</td>
<td>VTD</td>
<td></td>
<td>00156A</td>
<td>VTD, MDP, Acetone</td>
</tr>
<tr>
<td>Metal Primer II</td>
<td>MEP</td>
<td></td>
<td>0410251</td>
<td>MEPS, MMA</td>
</tr>
<tr>
<td>Metaltite</td>
<td>MTU</td>
<td></td>
<td>01403</td>
<td>MTU-6, Ethanol</td>
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</tbody>
</table>

#### Luting agents

Resin-modified glass ionomer cements (RMGICs)

<table>
<thead>
<tr>
<th>Material</th>
<th>Abbreviation</th>
<th>Component</th>
<th>Lot number</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitremer Luting Cement</td>
<td>VI</td>
<td>Powder</td>
<td>20041030</td>
<td>Fluoroaluminosilicate glassa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Liquid</td>
<td>20041030</td>
<td>Water, HEMA, Copolymer of alkenoic and itaconic acid</td>
</tr>
<tr>
<td>Fuji Lute</td>
<td>FL</td>
<td>Powder</td>
<td>0405181</td>
<td>Fluoroaluminosilicateglass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Liquid</td>
<td>0405181</td>
<td>Polyalkenoic acid, HEMA, Water, UDMA</td>
</tr>
<tr>
<td>Xeno Cem Plus</td>
<td>XC</td>
<td>Powder</td>
<td>385022</td>
<td>Fluoroaluminosilicate glass, Photochemical initiatorsa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Liquid</td>
<td>385022</td>
<td>UDMA, HEMA, Polyalkenoic acid, Chemical initiatorsa</td>
</tr>
</tbody>
</table>

Resin adhesive

<table>
<thead>
<tr>
<th>Material</th>
<th>Abbreviation</th>
<th>Component</th>
<th>Lot number</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super-Bond C&amp;B</td>
<td>SB</td>
<td>Catalyst</td>
<td>LE11</td>
<td>TBB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monomer</td>
<td>GG2</td>
<td>4-META, MMA</td>
</tr>
<tr>
<td>Opaque Ivory powder</td>
<td></td>
<td></td>
<td>KF1</td>
<td>PMMA</td>
</tr>
</tbody>
</table>

* Begazo et al.13*  

VTD: 6-(4-vinylbenzyl-n-propyl)amino-1,3,5-triazine-2,4-dithiol; MDP: 10-methacryloyloxydecyl dihydrogen phosphate; MEPS: Methacryloyloxyalkyl thiophosphate derivative; MMA: Methyl methacrylate; MTU-6: 6-methacryloyloxyhexyl 2-thiouracil-5-carboxylate; 4-META: 4-methacryloyloxyethyl trimellitate anhydride; TBB: Tri-n-butylborane; PMMA: Poly(methyl methacrylate); HEMA: 2-hydroxyethyl methacrylate; UDMA: Dimethacryloxyethyl 2,2,4-(or 2,4,4-) trimethylhexamethylene diurethane

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### Specimen preparation

Two disk sizes (10 mm or 8 mm in diameter by 2.5 mm in thickness) were cast from the alloy. All disks were ground with #1500 silicon carbide abrasive paper and ultrasonically cleaned in acetone. A piece of tape with a circular hole 5 mm in diameter was positioned on the surface of 10 mm disks to control the bonding area.

Disks of both sizes were divided into four groups. Thirty-two pairs of disks were prepared for each of the three priming agents and for non-treated group (abbreviated as N) as a control. Thus, eight pairs of metal disks were bonded with one of the three RMGICs or resin adhesive. The three RMGICs were spatulated according to the manufacturers’ instructions. The resin adhesive was applied using the brush-dip technique.
Shear bond strength test
Immediately after bonding procedure, a 5.0 N constant load was applied vertically to the specimens for 30 minutes. Bonded specimens were then immersed in 37°C distilled water for 24 hours. Then shear bond strength was measured with a mechanical testing device (Type 5567, Instron Corp., Canton, MA, USA) at a crosshead speed of 0.5 mm/minute. For each set of specimens, the mean shear bond strength and standard deviation (SD) of the eight specimens were calculated.

Statistical analysis
Data distributions were evaluated by Kolmogorov-Smirnov test. Levene’s test was used to study the equality of variances prior to Dunnett’s T3 test with the value of statistical significance set at 0.05.

RESULTS
Kolmogorov-Smirnov test run on the shear strength test results revealed a normal distribution. Levene’s test showed inhomogeneity of variance. Therefore, the results were analyzed by Dunnett’s T3 multiple comparison test at 0.05 level of significance.

Figure 1 shows the shear bond strength results as well as the statistical categories of non-treated groups. Among the four luting agents without priming agent, the bond strength of the SB resin adhesive was significantly higher than those of VI, FL, and XC RMGICs. No significant differences were found among these three cements.

Figures 2a through 2d summarize the shear bond strengths of four luting agents as well as their statistical categories to compare the effect of priming agents. All primed groups with one exception produced greater bond strength than the non-treated groups. Bond strengths of the SB primed groups were significantly higher than that of the non-treated SB resin adhesive. The bond strengths of the
VI RMGIC primed with the MEP or MTU material were significantly higher than that of the non-treated group. However, the bond strength of the VI RMGIC primed with the VTD material was lower than that of the non-treated VI RMGIC (Fig. 2b). The bond strengths of the FL RMGIC primed groups were significantly higher than that of the non-treated FL RMGIC (Fig. 2c). The bond strengths of the XC RMGIC primed groups were also significantly higher than that of the non-treated XC RMGIC (Fig. 2d).

For all the luting agents, the MTU material was most effective in improving bond strength. On this score, the bond strengths of four luting agents with the MTU material were compared (Fig. 3). Although SB yielded the highest bond strength, the other RMGICs rendered shear bond strengths equal to or greater than 26.5 MPa.

**DISCUSSION**

This study evaluated the effect of priming agents on the shear bond strength of RMGICs to a gold alloy. The results showed that for almost all the luting agents, the primed groups yielded higher bond strengths than the non-treated groups.

In terms of composition, RMGICs contain the components of conventional glass ionomers (fluoroaluminosilicate glass in powder and polyalkenoic acid in liquid) and resins (monomers such as HEMA and/or UDMA, and initiators). During the setting reaction of RMGICs, an acid-base type of setting reaction and a polymerization reaction occur independently. Water is essential for the acid-base reaction.

As for the metal priming agents of noble metal alloys, they contain functional monomers. The VTD material contains two kinds of functional monomers: VTD for noble metal alloy and MDP for base metal alloy. The MEP material contains MEPS for both noble and base metal alloys. The MTU material contains MTU-6 for noble metal alloys. A functional monomer consists of three parts; functional group, hydrophilic intermediate chain, and polymerization group. The functional group of priming agents for noble metal alloys contain a thione compound and are expected to improve the bond strength between resin adhesives and noble metal alloys. The polymerization group consists of a methacryloyl group or vinyl group, to be copolymerized with resins. In the present study, the bond strength of RMGICs to gold alloy was affected by the application of priming agents. This suggested that the use of priming agents was effective in enhancing bonding to the gold alloy. The priming agents were probably copolymerized with the resin components of RMGICs, and thus yielded higher bond strengths than the non-treated groups.

Amano et al. recently reported on the bond strength between RMGICs and a noble metal alloy primed with metal priming agents. Results of their study concluded that the application of metal priming agents improved bond strength. Chen et al. also compared the bond strength of RMGICs to gold alloy primed with metal priming agents. Their results indicated that the bond strength of the VI RMGIC primed with the VTD material was slightly greater than that of the non-treated VI RMGIC. On the other hand, the VI RMGIC primed with the MEP material was considerably greater than that of the non-treated VI RMGIC. In the current study, the bond strength of the VI RMGIC primed with the VTD material was lower than that of the non-treated VI RMGIC. This indicated that bond strength was affected by the combination between a metal priming agent and a RMGIC.

Although RMGICs as well as conventional glass ionomer cements require water during the setting reaction, metal priming agents have a hydrophobic component. Therefore, metal priming agents can act as a separating medium between ionomer components and the alloy, thereby resulting in lower bond strengths. In the present study, the compositions of the three RMGICs examined were similar, as declared by the manufacturers. Differences in the contents of glass ionomers (fluoroaluminosilicate glass and polyalkenoic acid) and resins played a critical role in influencing the bond strength between RMGICs and gold alloy. In cases where the properties of RMGIC conform well with those of resin, the priming agents seemed to function effectively. In contrast, in cases where the cement had strong properties of ionomer, the function of priming agents seemed to be inhibited.

Within the limitations of this *in vitro* study, it was found that priming agents were substantially effective in improving the bonding of RMGICs to gold alloy.
gold alloy. Especially the bond strengths of all RMGICs in combination with MTU exceeded 25 MPa. However, some combinations of RMGIC and priming agent seemed to render a negative effect on bond strength, such as that between the VI RMGIC and the VTD material in this study.

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REFERENCES