The Effect of Primers on Bond Strength of Polyacid-modified Resin Composites (Compomers)

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This study evaluated the effect of primer on shear bond strength and marginal gaps of six new compomers immediately after light-activation. A resin-modified glass ionomer cement, a conventional glass-ionomer cement and a microfilled composite were used for comparison. The marginal gap widths of each of the four compomers and a microfilled composite used with the primer were significantly smaller compared with those used without the primer. The bond strength values of five compomers used with the primer were significantly higher than those used without the primer. The bond strength of conventional glass-ionomer was not affected by the primer (or the conditioner).

Key words: Polyacid-modified resin composite, Bond strength, Primer

INTRODUCTION

Polyacid-modified resin composites (compomers) belong to a new group of restorative materials which combine technology derived from glass ionomer cement with a resin composite\(^1\). One manufacturer introduced a new one-paste restorative material as a compomer (Dyract, DY) in the early 1990s. It contained a radiopaque fluoride-silicate glass in a matrix of acidic polymerizable monomers but in insufficient amounts to promote an acid-base reaction\(^2\). In vitro evaluations have shown that the compomer exhibited high enamel and dentin bond strengths\(^3-6\). In vivo evaluations confirmed that this material has good handling characteristics and color matching\(^7-10\).

Presently, there are many commercially available compomers in the market. Many of these products have a higher flexural strength than resin-modified glass-ionomer cements, and all of these materials have lower hygroscopic expansion than resin-modified glass ionomer cements\(^11\).

However, many of the characteristics of compomers have not been evaluated. It is essential for compomers to be used with primers to get higher bond strength to tooth surfaces, in the same way that resin composites are used with bonding systems\(^2-10\). For example, DY was supplied with a self-etching primer/adhesive. Little information exists about the effectiveness of the primer on the bond strength of new commercially available compomers. It is also very important to evaluate the bond immediately after light-activation to avoid the interference of hygroscopic expansion and in the worst case scenario\(^12-14\), namely the condition of both the greatest
marginal gap in tooth cavity and the lowest bond strength\textsuperscript{15,16}).

The aim of this study was to evaluate the effect of primer on bond strength by ISO standard tests, marginal gaps in dentin cavities\textsuperscript{15} and shear bond strength to dentin\textsuperscript{16}, of new commercially available compomers immediately after light-activation. Resin-modified and conventional glass-ionomer cements and a microfilled composite were used for comparison.

\textbf{MATERIALS AND METHODS}

\textit{Materials}

Six compomers, one microfilled resin composite, one resin-modified glass-ionomer cement and one conventional glass ionomer cement as controls were used in this study (Table 1, 2). Handling was carried out according to the manufacturers' instructions. A visible light source (New Light VL-II, GC, Tokyo, Japan; Tip diameter: 8 mm) was used to cure materials, with an irradiation time of 30 seconds. Human premolars, extracted for orthodontic reasons, were used for the experiment. After extraction, each tooth was immediately stored in cold distilled water at about 4°C for one to two months before testing. Ten specimens were made from each material.

\textit{Marginal gap in dentin cavity}

The proximal surface of a tooth was ground flat on wet silicon carbide paper (#220). A cylindrical cavity was prepared with a fissure bur (8000 rpm) under wet conditions to a depth of about 1.5 mm with a diameter of 3.5 mm (SD ± 0.1 mm). The cavity walls and surrounding dentin were left untreated or treated according to manufacturer's instructions. Each cavity was filled with a test material using a syringe tip (Centrix C-R Syringe System, Centrix, Connecticut, USA) and covered with a plastic strip prior to light-activation. The surface was polished immediately after light-activation. The maximum gap space was measured by an optical microscope (1000×)\textsuperscript{15,17}.

\textit{Shear bond strength to dentin}

A human premolar was embedded in slow setting epoxy resin (Epofix Resin, Struers, Copenhagen, Denmark). A flat surface of dentin was obtained by grinding the tooth with wet silicon carbide paper (#1000). The dentinal surface was left untreated or treated according to the manufacturer's instructions. A filling material was placed into a Teflon mold (3.6-mm diameter, 2.0-mm height) set on the dentinal surface, and hardened by a light-activated unit. This assembly was mounted on a testing machine (Model 5565, Instron, Canton, USA) and shear stress was applied using a cross-head speed of 0.5 mm/min\textsuperscript{16}. Tests were carried out immediately after light-activation. All of the debonded specimens were analyzed under a light microscope (4×) (Measurescope, MM-11, Nikon, Tokyo, Japan) to check the location of fractures.

All procedures, except for cavity preparation and mechanical testing, were performed in an air-conditioned room, 23±0.5°C and 50±2% R.H. Results were analyzed
### Table 1 Restorative Materials investigated

<table>
<thead>
<tr>
<th>Code</th>
<th>Material</th>
<th>Batch No.</th>
<th>Type</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>DY</td>
<td>Dyract$^1$</td>
<td>9706001083</td>
<td>Compomer</td>
<td>UDMA, TCB, Strontium fluoro-silicate glass (72 wt%), Initiators, Stabilisers, Strontium fluoride</td>
</tr>
<tr>
<td>CG</td>
<td>Compoglass$^2$</td>
<td>812055</td>
<td>Compomer</td>
<td>Bis-GMA, UDMA, Tetraethylene glycol dimethacrylate, Cycloaliphatic dicarboxylic acid dimethacrylate, Silanized spheroidal mixed oxides, Ytterbium trifluoride, Silanized Ba-fluorosilicate glass (56 vol%, 79 wt%), Initiators, Stabilisers</td>
</tr>
<tr>
<td>HT</td>
<td>Hytac$^3$</td>
<td>016</td>
<td>Compomer</td>
<td>Organic monomers, Inorganic filling structures Ca-Al-Zn-fluoroglass (66 wt%) initiators, Stabilisers</td>
</tr>
<tr>
<td>XN</td>
<td>Xeno Paste$^4$</td>
<td>05</td>
<td>Compomer</td>
<td>Organic monomers, Fluoro-alumino-silicate-glass (59 vol%, 79 wt%), Initiators</td>
</tr>
<tr>
<td>F2</td>
<td>F 2000$^5$</td>
<td>19970916</td>
<td>Compomer</td>
<td>CDMA oligomer, GDMA, Fluori-alumino-silicate-glass (84 wt%), Photo initiators, Stabilisers</td>
</tr>
<tr>
<td>DA</td>
<td>Dyract AP$^6$</td>
<td>9706001084</td>
<td>Compomer</td>
<td>Polymerisable resins, TCB resin, Strontium-fluoro-silicate glass (47 vol%, 73 wt%), Strontium fluoride, Photo initiators, Stabilisers</td>
</tr>
<tr>
<td>SP</td>
<td>Silux Plus$^7$</td>
<td>6DG</td>
<td>Micro-filled composite</td>
<td>Bis-GMA, TEGDMA, Colloidal silica (38 vol%, 52 wt%)</td>
</tr>
<tr>
<td>FL</td>
<td>Fuji II LC$^8$</td>
<td>P: 060181 L: 221721</td>
<td>Resin-modified glass-ionomer</td>
<td>P: Fluoro-alumino-silicate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L: Copolymer of acrylic and maleic acid, HEMA, Water, Photo initiators</td>
</tr>
<tr>
<td>F1</td>
<td>Fuji II$^9$</td>
<td>P: 071161 L: 061161</td>
<td>Conventional glass-</td>
<td>P: Fluoro-alumino-silicate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L: Copolymer of acrylic and maleic acid, Polybase carboxylic acid, Water</td>
</tr>
</tbody>
</table>

$^1$ Detrey/Dentsply, Konstanz, Germany,  
$^2$ Vivadent, Schaan, Liechtenstein  
$^3$ Espe, Seefeld, Germany,  
$^4$ Sankin, Tokyo, Japan  
$^5$ 3M, St. Paul, USA,  
$^6$ Detrey/Dentsply, Konstanz, Germany  
$^7$ 3M, St. Paul, USA,  
$^8$ GC, Tokyo, Japan  
$^9$ GC, Tokyo, Japan

UDMA: Urethanedimethacrylate, GDMA: Glyceril dimethacrylate  
TCB: Butane tetracarboxylic acid and hydroxyethylmethacrylate  
CDMA oligomer: Dimethacrylate functional oligomer derived from citric acid

Statistically by one-way ANOVA, Duncan’s Multiple-Range Test and the t-Test for marginal gaps, and by one-way ANOVA and Duncan’s Multiple-Range Test and by one-way ANOVA and Duncan’s Multiple-Range Test$^a$ and t-Test for shear bond strength. The Complex Chi-Squared Test was used to determine significant differences in the analysis of fracture modes$^b$. 
Table 2  Treating agents investigated

| Code | Material                  | Batch No. | Components                                                                 
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P-PB</td>
<td>Prime &amp; Bond</td>
<td>96120001</td>
<td>PENTA, Elastomeric resin, TGDMA, Amine hydrofluoride, Initiators, Stabilisers, Acetone</td>
</tr>
<tr>
<td>P-CG</td>
<td>Compoglass SCA</td>
<td>800333</td>
<td>Dimethacrylate, Modified polyacrylic acid, Maleic acid, CQ, Water</td>
</tr>
<tr>
<td>P-HT</td>
<td>Hytac OSB</td>
<td>008</td>
<td>Co-monomer, Initiators, Acetone, Stabilisers,</td>
</tr>
<tr>
<td>P-XN</td>
<td>Xeno Bond</td>
<td>01</td>
<td>Catalyst: HEMA, Tetra-methacryloxy-ethylpyro-phosphate, CQ, Initiator</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Universal: HEMA, Catalyst, Ethanol, Water</td>
</tr>
<tr>
<td>P-F2</td>
<td>Primer/adhesive</td>
<td>07AD</td>
<td>Side A: HEMA, Methacrylated polycarboxylic acid, water, Ethanol, Photoinitiator</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Side B: Maleic acid, Water (5%)</td>
</tr>
<tr>
<td>P-DA</td>
<td>Prime &amp; Bond 2.1</td>
<td>9706001359</td>
<td>PENTA, Elastomeric resin, short chain cross-linking resin, Amine hydrofluoride, Initiator, Stabilisers, Acetone</td>
</tr>
<tr>
<td>P-SP</td>
<td>Scotchbond Multi-Purpose</td>
<td>Etchany(4AK)</td>
<td>10% Maleic acid, Water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primer(4EB)</td>
<td>HEMA, Polyalkenoic acid copolymer, 50 vol% water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adhesive resin(4DR)</td>
<td>Bis-BMA, HEMA, Photoinitiator system</td>
</tr>
<tr>
<td>DC</td>
<td>Dentin Condition</td>
<td>056371</td>
<td>Polyacrylic acid, Water</td>
</tr>
</tbody>
</table>

1 Detrey/Dentsply, Konstanz, Germany, 2 Vivadent, Schaan, Liechtenstein
3 Espe, Seefeld, Germany, 4 Sankin, Tokyo, Japan
5 3M, St. Paul, USA, 6 Detrey/Dentsply, Konstanz, Germany
6 3M, St. Paul, USA, 8 GC, Tokyo, Japan

PENTA: Dipentaerythritolpenta-acrylatmonophosphate
TGDMA: Triethylene glycoldimethacrylate diluent
HEMA: 2-Hydroxyethyl methacrylate, Bis-GMA: Bisphenol glycidylmethacrylate

RESULTS

Table 3 shows the effect of the primer on marginal gaps immediately after light-activation. All compomers except DY, DA, and SP treated with primer had significantly smaller gap widths compared with those without the primer. Although DY and DA showed smaller values when the primer was used, there was no statistically significant difference. There was no significant difference between all compomers and FI treated with the primer. There was no effect of the primer (or the conditioner) on the two glass-ionomers. There were no significant differences in gap width between DY, DA and two types of glass-ionomers when the dentin was not treated with the primer. SP treated with the primer showed the smallest gap width.

Table 4 shows the bond strength values of the test materials used with or without
Table 3 Effect of primer on the marginal gap in tooth cavities of tooth colored restorative materials immediately after setting

<table>
<thead>
<tr>
<th>Code</th>
<th>Mean±S.D. (μm)</th>
<th>Statistical difference between two values (t-Test)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With primer</td>
<td>Without primer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DY</td>
<td>12.1±3.3</td>
<td>B</td>
</tr>
<tr>
<td>CG</td>
<td>14.0±3.5</td>
<td>A</td>
</tr>
<tr>
<td>HA</td>
<td>12.0±2.4</td>
<td>A</td>
</tr>
<tr>
<td>XN</td>
<td>11.3±2.1</td>
<td>A</td>
</tr>
<tr>
<td>F2</td>
<td>12.9±1.9</td>
<td>A</td>
</tr>
<tr>
<td>DA</td>
<td>11.7±5.2</td>
<td>B</td>
</tr>
<tr>
<td>SP</td>
<td>6.3±2.6</td>
<td>C</td>
</tr>
<tr>
<td>FL</td>
<td>14.9±3.5</td>
<td>A</td>
</tr>
<tr>
<td>FI</td>
<td>13.9±2.4</td>
<td>A</td>
</tr>
</tbody>
</table>

Number of specimens=10
Means with the same letters were not significantly different by Duncan's New multiple-range test (p>0.05).
***: Significant difference at p<0.001, **: Significant difference at p<0.01
NS: No significant difference (p>0.05)

Table 4 Effect of primer on the shear bond strength to dentin of tooth colored restorative materials immediately after setting

<table>
<thead>
<tr>
<th>Code</th>
<th>Mean±S.D. (MPa)</th>
<th>Statistical difference by Mann-Whitney U-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With primer#</td>
<td>Without primer@</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DY</td>
<td>6.23±2.26</td>
<td>D</td>
</tr>
<tr>
<td>CG</td>
<td>1.15±1.05</td>
<td>F</td>
</tr>
<tr>
<td>HA</td>
<td>5.67±2.56</td>
<td>D</td>
</tr>
<tr>
<td>XN</td>
<td>4.89±3.22</td>
<td>D</td>
</tr>
<tr>
<td>F2</td>
<td>10.53±2.58</td>
<td>D</td>
</tr>
<tr>
<td>DA</td>
<td>16.96±2.61</td>
<td>A</td>
</tr>
<tr>
<td>SP</td>
<td>13.07±4.79</td>
<td>B</td>
</tr>
<tr>
<td>FL</td>
<td>3.95±1.52</td>
<td>D</td>
</tr>
<tr>
<td>FI</td>
<td>2.20±0.67</td>
<td>E</td>
</tr>
</tbody>
</table>

Number of specimens: 10
( ): Number of specimens having no bonding
#: Means with the same letters were not significantly different by Duncan's New multiple-range test (p>0.05).
@: Means with the same letters were not significantly different by Duncan's New multiple-range test (p>0.05).
***: Significant difference at p<0.001, **: Significant difference at p<0.01
NS: No significant difference (p>0.05)

The bond strengths of all compomers, except CG, were significantly higher when used with the primer. DA and F2 showed significantly higher bond values when compared with the other compomers. The mean values for CG were lower with or without primer and several specimens had no measurable bond. In each of the groups without primer, except for DA, there were some specimens having no measurable bond. Under both conditions, DA showed the
Table 5 Analysis of fracture mode corresponding to Table 4

<table>
<thead>
<tr>
<th>Code</th>
<th>With primer</th>
<th>Without primer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AF</td>
<td>MF</td>
</tr>
<tr>
<td>DY</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>CG</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>HA</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>XN</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>F2</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>DA</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>SP</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>FL</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>FI</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Number of specimens: 10, AF: Adhesive fracture at bonding site, MF: Mixed fracture, CF: Cohesive fracture, *: Complex Chi-Square Test
S: Significant difference (p<0.05), NS: No significant difference (p>0.05)

highest bond value of all the products. Although SP showed the second highest bond strength value when primer was included, the same material had no measurable bond without the bonding system. Although the bond of FL was affected by primer (or the conditioner), FI showed no effect of the primer (or the conditioner). There were no glass-ionomer specimens having no bond under either condition.

Table 5 shows the analysis of fracture modes corresponding to Table 4. The fracture modes of all products except FI showed statistically significant differences between the primer and no-primer groups. There were most common fracture modes for the compomers, and SP showed mixed fracture or cohesive fracture when the primer was used. Only a few debonded surfaces showed adhesive fracture at the bonding site treated with the primer. Adhesive fracture mode was observed more often when no primer was used. The predominant mode of fracture for the glass-ionomers under both conditions was mixed fracture or cohesive fracture.

**DISCUSSION**

Statistical analysis revealed significantly smaller marginal gap widths and greater bond values for compomers used with the primer compared with those used without the primer when tested immediately after light-activation. The results were similar to those of a microfilled composite, but different from those of glass-ionomers. The component or setting reaction of both the filling and the primer materials for compomers is similar to that of a resin composite or a bonding system (see Table 1 and 2), although the setting mechanism for a compomer differs slightly from glass-ionomer. There are insufficient amounts of material to promote acid-base reaction in the dark. There is a range of compositions, employing different properties of acid-base and free-radical reactions to bring about the cure\(^1\). For DY, the novel acid monomer of the compomer contains two acidic carboxylate groups and two
polymerizable methacrylate groups enabling free radical polymerization by light-activation\textsuperscript{2)}. It is reported that the physical properties of this compomer are similar to those of resin composites\textsuperscript{11}). In priming or bonding system, DY, F2 and DA are the same as a composite. The mechanism by which the glass ionomer bonds to the tooth structure primarily involves chelation of the carboxyl groups of the polyacids with the calcium in the apatite of the enamel and dentin. Water is a most important constituent of the cement liquid. It initially serves as the reaction medium, and then slowly hydrates the cross-linked matrix, thereby increasing the material strength\textsuperscript{20}). However, there is little water in the compomers, in contrast with the glass-ionomer material (see Table 1 and 2).

The analysis of fracture modes demonstrated adhesive fracture when primer was not used. In contrast, the two glass-ionomer-untreated dentin interfaces revealed frequent occurrence of cohesive or mixed failure modes. It appears that a compomer restorative material itself has little if any ability to bond to the tooth substrate, much like a resin composite, and unlike the two types of glass-ionomer. The findings in this study support the claim that it is essential for these compomers to be used with the primer to get the higher bond strength to the tooth substrate. It also appears that the characteristics of compomers are more similar to those of composites than glass-ionomers.

CONCLUSION

Use of the primer with the tested compomers increased the bond strength and decreased the gap significantly. The bond strength of conventional glass-ionomer cement was not affected by the use of the primer or the conditioner.

ACKNOWLEDGEMENTS

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