Resin bonding to wet substrate. I. Bonding to dentin

John Kanca III*

An in vitro study was undertaken to evaluate the ability of a dentin-enamel bonding system to bond to wet, as well as to dry, dentinal substrate. The All-Etch/All-Bond system was used to bond to wet and dry dentin using 10% and 37% phosphoric acid surface conditioning. The wet dentinal surfaces exhibited significantly higher bond strengths than did the dry surfaces. It is suggested that, because of the unique behavior of the resin-primer mixture, the dentinal surface is adapted to much more thoroughly and intimately when the surface is wet. (Quintessence Int 1992;23:39–41.)

Introduction

The All-Bond dentin-enamel bonding system (Bisco Dental) is available in two forms. One system includes, according to the manufacturer, a 32% phosphoric acid enamel etchant, a dentinal conditioner containing a hydroxyethyl methacrylate-related compound, a primer A consisting of N(p-tolyl)glycine-glycidyl methacrylate in acetone, a primer B consisting of biphenyl dimethacrylate in acetone, and an unfilled resin adhesive containing a hydrophilic monomer. The second form of the system is derived from a bonding system described by Kanca.1-3 It is composed of a 10% phosphoric acid conditioner for both the enamel and dentin, primer A, primer B, and the unfilled resin adhesive. It is referred to by the manufacturer as the All-Etch system.

Manufacturers of dentinal bonding systems today almost universally indicate that dentinal dryness is critical for the proper functioning of their products. But vital dentin is inherently wet and thorough desiccation is very difficult to achieve clinically.4 Studies simulating physiologic conditions indicate that dentinal bond strengths are frequently diminished in the presence of dentinal wetness.5-9 McGuckin et al10 and Tao and Pashley11 have shown that the wetness of dentin can have a detrimental effect on the in vivo bond strength of a dentinal bonding system. Brännström12 has reported that dentinal fluid passes through dentinal tubules at a rate sufficient to empty the tubules ten times in one day.

Although dentinal wetness may not be readily discernable on a clinical basis, it may still be present and have an effect on bonding systems when placed in vivo. A dentin-enamel bonding system that would function well in the presence of moisture would have a great advantage. The purpose of this report is to examine the effect of variable dentinal drying on the shear bond strength of the All-Etch version of the All Bond dentinal bonding system.

Method and materials

Sixty extracted human molars were selected for this study. They were free of obvious defects and were used within 2 weeks of harvest. They were stored in tap water at 4°C.

For the experiment, the teeth were embedded in autopolymerizing acrylic resin in a stainless ring with an inside diameter of 1 inch. Fifty of the teeth were ground on a model trimmer to expose adequate dentinal surface for bonding. The exposed dentinal surfaces were wet-sanded with 320-grit sandpaper and the teeth were left in water for 24 hours at 4°C to assure full hydration of the teeth. Following storage, the teeth were warmed to body temperature for the ex-
The teeth were randomly divided into five groups.

A sixth group of ten molar teeth was mounted as described, except that the teeth were ground to expose occlusal enamel surfaces for bonding.

**Group 1.** The dentinal surfaces were dried with oil-free, dried, compressed air for 5 seconds. Ten percent phosphoric acid gel (All-Etch) was applied to the dentinal surface for 20 seconds. The gel etchant was then rinsed off with an air-water spray for 10 seconds. The dentinal surface was then dried for 10 seconds at the maximal pressure of the air syringe while the tip of the syringe was approximately 2 cm from the dentinal surface. One drop of primer A and one drop of primer B were then mixed in a well and applied to the dentinal surface. Four coats were applied consecutively without drying between applications. The primed surface was allowed to remain undisturbed for 10 seconds. The primer surface was then thoroughly air dried for 5 seconds to remove any remaining volatiles.

A uniform layer of the unfilled resin was then applied to the dentinal surface and was light polymerized for 20 seconds. It was not air thinned. A Teflon mold, 2.5 mm in thickness and with a cylindrical matrix 4 mm in diameter, was then clamped to the embedded tooth so that the matrix was above the treated dentin. The matrix was filled with a single increment of Bisfil composite resin (universal shade, Bisco Dental), and the composite resin was light activated for 40 seconds.

**Group 2.** The teeth in this group were treated similarly to those in group 1, except that, following rinsing of the etchant, the dentin was wiped with a damp facial tissue to remove only the excess water from the surface. Efforts were made not to disturb the fluid present in the tubules. The surface of the dentin was intentionally left wet; ie, the surface of the dentin was shiny with moisture, as opposed to the matte surface present when the wetness was blown away. The mixture of primers A and B was immediately applied in four consecutive coats. The surface was not dried between applications. Composite resin cylinders were bonded to the teeth as in group 1.

**Group 4.** The teeth in this group were treated as described for teeth in group 1, except that a 37% gel acid etchant was used on the dentin for 15 seconds, and the drying time was 10 seconds. Composite resin cylinders were bonded to the teeth as in group 1.

**Group 5.** The teeth in this group were treated the same as those in group 4, except that the dentinal surface was wiped with a damp facial tissue, to remove the excess water only, following rinsing of the gel etchant. The dentinal surface remained obviously moist. Composite resin cylinders were bonded to the teeth as in group 1.

**Group 6.** The tooth surfaces were wet-sanded with 320-grit sandpaper. The enamel surfaces were treated with a 37% phosphoric acid gel for 15 seconds, rinsed, and dried. A drop each of primers A and B was mixed in a well and applied to the etched enamel surface in four consecutive coats. This was allowed to sit for 15 seconds and then the primed surfaces were gently air dried to remove the remaining volatiles. Then a uniform layer of unfilled dentin-enamel bonding resin was applied to the primed surface and was light polymerized for 20 seconds. Composite resin cylinders were bonded to the teeth as in Group 1. This set of enamel specimens was included to compare with the strengths of the dentinal specimens.

**Results**

The mean bond strength of each group is listed in Table 2. Group 1 had one cohesive dentinal failure. Group 3 exhibited cohesive dentinal failure nine times similarly, except that, following acid treatment and rinsing of the dentin, the dentin was wiped with a damp facial tissue to remove only the excess water from the surface. Efforts were made not to disturb the fluid present in the tubules. The surface of the dentin was intentionally left wet; ie, the surface of the dentin was shiny with moisture, as opposed to the matte surface present when the wetness was blown away. The mixture of primers A and B was immediately applied in four consecutive coats. The surface was not dried between applications. Composite resin cylinders were bonded to the teeth as in group 1.

**Group 2.** The teeth in this group were treated similarly to those in group 1, except that, following rinsing of the etchant, the dentin was wiped with a damp facial tissue to remove only the excess water from the surface. Efforts were made not to disturb the fluid present in the tubules. The surface of the dentin was intentionally left wet; ie, the surface of the dentin was shiny with moisture, as opposed to the matte surface present when the wetness was blown away. The mixture of primers A and B was immediately applied in four consecutive coats. The surface was not dried between applications. Composite resin cylinders were bonded to the teeth as in group 1.

**Group 4.** The teeth in this group were treated as described for teeth in group 1, except that a 37% gel acid etchant was used on the dentin for 15 seconds, and the drying time was 10 seconds. Composite resin cylinders were bonded to the teeth as in group 1.

**Group 5.** The teeth in this group were treated the same as those in group 4, except that the dentinal surface was wiped with a damp facial tissue, to remove the excess water only, following rinsing of the gel etchant. The dentinal surface remained obviously moist. Composite resin cylinders were bonded to the teeth as in group 1.

**Group 6.** The surfaces were wet-sanded with 320-grit sandpaper. The enamel surfaces were treated with a 37% phosphoric acid gel for 15 seconds, rinsed, and dried. A drop each of primers A and B was mixed in a well and applied to the etched enamel surface in four consecutive coats. This was allowed to sit for 15 seconds and then the primed surfaces were gently air dried to remove the remaining volatiles. Then a uniform layer of unfilled dentin-enamel bonding resin was applied to the primed surface and was light polymerized for 20 seconds. Composite resin cylinders were bonded to the teeth as in Group 1. This set of enamel specimens was included to compare with the strengths of the dentinal specimens.

**A summary of surface treatments is presented in Table 1.**

The matrices were removed from the teeth, and the teeth were stored for 24 hours in water at 37°C. Shear bond strength was measured on an Instron universal testing machine No. 1123 (Instron Corp) with a crosshead speed of 5 mm/min.

**Results**

The mean bond strength of each group is listed in Table 2. Group 1 had one cohesive dentinal failure. Group 3 exhibited cohesive dentinal failure nine times similarly, except that, following acid treatment and rinsing of the dentin, the dentin was wiped with a damp facial tissue to remove only the excess water from the surface. Efforts were made not to disturb the fluid present in the tubules. The surface of the dentin was intentionally left wet; ie, the surface of the dentin was shiny with moisture, as opposed to the matte surface present when the wetness was blown away. The mixture of primers A and B was immediately applied in four consecutive coats. The surface was not dried between applications. Composite resin cylinders were bonded to the teeth as in group 1.
out of ten. Group 5 had four cohesive dentinal failures. All specimens in group 6 failed adhesively.

Two-way analysis of variance showed that the mean shear bond strength of group 4 was significantly lower than those of groups 1 and 2. Mean bond strengths of groups 1 and 2 were not significantly different from one another, but both were significantly lower than those of groups 3, 5, and 6. Mean bond strengths of groups 3, 5, and 6 were not significantly different from one another. Groups 3 and 5 also showed bond strengths with lower coefficients of variation than were found in groups in which the dentin was dried.

### Discussion

The difference in bond strength between the air dried samples and the wet samples is rather startling. It has been generally assumed that bonding to dentin will be severely compromised by the presence of moisture. The data presented here suggested that, with the described bonding system, the presence of moisture or wetness was not only allowable, it was desirable. The data also indicated that the bond strength of the resin to dentin could exceed the cohesive strength of the dentin itself.

The explanation for these results seems to lie in the properties of acetone-water interactions. The addition of acetone to water raises the vapor pressure of the water and causes some of it to become volatile. In addition, acetone reduces the surface tension of the water and allows spreading of the mixture along the surfaces that are coated with water. Thus the acetone and resin mixture "chases" the water present. The acetone will seek out the water until an equilibrium is established, carrying with it the resin primer. Presumably, this includes the dentinal surface and the dentinal tubule lumina. If there is good adaptation to the tubule walls to any depth, this could greatly enhance retention. The remaining acetone is then dried, leaving a layer of primer on the dentinal substrate.

When the surfaces are thoroughly dried, there is no interaction with water, and the primer mixture is deposited on the surface, apparently without the same intimacy of adaptation. The primer mixture no longer retains the same wettability characteristics as when there is a layer of water present.

The implications of these results may be clinically significant. In the past, great emphasis has been placed on the need to assure dryness of the dentinal substrate. However, dentin is inherently a wet tissue. The ability to work with the substrate in its natural state may prove to facilitate clinical placement of this resin bonding material. Of course, it would be difficult to dry the enamel without drying the dentin. The ability of this resin system to bond to wet enamel has been investigated, and the data have been submitted for publication.

A scanning electron microscopic study is currently underway to investigate the possible mechanism of these results.

### Table 2 Mean shear bond strengths (MPa)

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>CV*</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16.38</td>
<td>6.59</td>
<td>39.6%</td>
<td>9.75-31.21</td>
</tr>
<tr>
<td>2</td>
<td>16.11</td>
<td>6.42</td>
<td>39.9%</td>
<td>5.07-26.53</td>
</tr>
<tr>
<td>3</td>
<td>29.34</td>
<td>4.09</td>
<td>13.9%</td>
<td>23.02-37.84</td>
</tr>
<tr>
<td>4</td>
<td>3.35</td>
<td>2.14</td>
<td>63.9%</td>
<td>1.17- 9.36</td>
</tr>
<tr>
<td>5</td>
<td>25.01</td>
<td>6.50</td>
<td>26.0%</td>
<td>9.75-33.55</td>
</tr>
<tr>
<td>6†</td>
<td>30.43</td>
<td>5.11</td>
<td>16.1%</td>
<td>22.63-40.57</td>
</tr>
</tbody>
</table>

* Coefficient of variation.
† Enamel.

### References