In vitro effect of cavity disinfectants on the bond strength of dentin bonding systems

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Objective: To evaluate the effect of two cavity disinfectants, a 2% chlorhexidine and a 1% benzalkonium chloride solution, on the shear and tensile bond strengths of dentin bonding systems to dentin. Method and materials: Superficial dentin was exposed from 84 freshly extracted human third molars. The teeth were randomly assigned to two main groups according to the bonding agent used, either One Step or Optibond Solo. Each dentin bonding system had six test groups (three for shear, three for tensile testing), and each test group had a control and two cavity disinfectant groups. In the control groups, dentin bonding systems were applied after etching the dentin, whereas in the cavity disinfectant groups, dentin was conditioned and treated for 20 seconds with the disinfectants before applying the dentin bonding systems. A hybrid resin composite then was applied to all treated samples. After storage in distilled water at 37°C for 24 hours, shear and tensile tests were performed. Data were analyzed using Kruskall-Wallis and Mann-Whitney U tests. Results: The mean shear and tensile bond strengths of One Step and Optibond Solo were not significantly different from each other, and the cavity disinfectants also had no significant effects on shear and tensile bond strength values versus the controls. Conclusion: The results indicate that the use of 2% chlorhexidine and 1% benzalkonium chloride solutions as cavity disinfectants after etching the dentin did not affect the shear and tensile bond strengths of One Step and Optibond Solo. (Quintessence Int 2004;35:56-60)

Key words: benzalkonium chloride, cavity disinfectant, chlorhexidine, dentin bonding

CLINICAL RELEVANCE: Chlorhexidine- and benzalkonium chloride-based cavity disinfectants can be used with acetone- and alcohol-based dentin bonding systems without compromising the bond strength to dentin.

One of the most important factors determining the success of a restoration is the adhesion between tooth structure and the restorative material. If a proper adhesion cannot be achieved, microleakage, defined as the passage of bacteria, fluids, chemical substances, molecules, and ions between the tooth and its restoration, can occur, which would threaten clinical performance and longevity of the restoration. The problems associated with microleakage can be magnified by incomplete sterilization of the preparation from all infected enamel and dentin. Inadequate removal of all cariously affected dentin has been demonstrated to be the reason for secondary or residual caries. Moreover, even when the cavity is sealed completely, bacteria existing in the smear layer, can multiply, and their toxins and degradation products can diffuse into the pulp, resulting in irritation and inflammation. Therefore, during preparation of a carious tooth for restoration, all infected dentin should be removed.

Cariously affected dentin is most commonly diagnosed through visual and tactile examinations and radiographs. However, studies have shown that this is a subjective assessment based on the color and texture of the dentin and often inadequate for evaluating whether removal of caries is complete. Alternative procedures for the detection of cariously altered...
dentin have been developed. A number of investigators have advocated the use of caries-disclosing dyes, either 1% acid red or 0.5% basic fuchs in propylene glycol, that enhance visual recognition of carious dentin. However, histobacteriologic studies showed that 20%, 15%, and 25% of the teeth still contained bacteria at the deepest portion of the carious lesions even after removal of the stained dentin. Anderson et al indicated that the cariously affected dentin contained 1,300 times more colony-forming units per milligram (CFU/mg) than the dentin that did not take up the dye. However, the dentin containing less than 10,000 CFU/mg was not disclosed by the dye. The use of caries-disclosing dyes will greatly decrease but not completely eliminate viable bacteria remaining in a cavity preparation. Therefore, a possible solution to reduce secondary or residual caries and postoperative sensitivity, would be to treat the cavity with a disinfectant solution.

This study evaluated the effect of two commercially available cavity disinfectants, 2% chlorhexidine- and 1% benzalkonium chloride-based solutions, on the shear (SBS) and tensile (TBS) bond strengths of an acetone dentin bonding system (One Step, Bisco) and an alcohol dentin bonding system (Optibond Solo, Kerr) to dentin.

**METHOD AND MATERIALS**

The materials used in the study are shown in Table 1. Eighty-four noncarious human third molars were hand scaled to remove all soft tissue and were stored in distilled water with thymol crystals at 4°C until required. After embedding the teeth in self-cure acrylic resin (Vertex, Dentimex Zeist), the occlusal enamel of each tooth was ground flat using 180-grit silicon carbide abrasive paper (Atlas Abrasives) to expose dentin, and the superficial dentin surface was polished with 600-grit silicon carbide paper to standardize the smear layer. The bonding area was demarcated by placing a piece of vinyl tape having a 3-mm-diameter hole, over the prepared dentin surface. The teeth were randomly assigned to two main groups according to the bonding agent used, either One Step or Optibond Solo. Each dentin bonding system had six test groups (three for shear and three for tensile testing), and each test group had a control and two cavity disinfectant groups (n = 7).

**One Step (control).** Dentin was etched with 32% phosphoric acid (Uni-etch, Bisco) for 15 seconds, rinsed with water for 15 seconds, and gently air dried, leaving the surface visibly moist. Two consecutive coats of One Step were applied to the dentin surfaces, thoroughly air dried for 10 seconds to evaporate the solvent, and light cured for 10 seconds with a conventional light curing unit (Hilux 350, Benlioglu). If the surface was not shiny, two additional coats were applied as above, and the surface was air dried for 10 seconds and light cured for 10 seconds.

**One Step + Consepsis.** Consepsis (Ultradent) was applied with a mini-brush tip to the damp dentin surface for 20 seconds after acid etching. Excess moisture was gently removed with compressed air, leaving the surface visibly moist. One Step was applied as mentioned in the One Step control group.

**One Step + Ultracid F.** Ultracid F (Ultradent) was applied with a mini-brush tip to the damp dentinal surface for 20 seconds after acid etching. Excess moisture was gently removed with compressed air, leaving the surface visibly moist. One Step was applied as mentioned in One Step (control).

**Optibond Solo (control).** Dentin was etched with 37.5% phosphoric acid (Kerr etchant, Kerr), rinsed with water for 15 seconds, and gently air dried leaving the surface visibly moist. Optibond Solo was applied to the dentin surface with a light brushing motion for 15 seconds, gently air thinned, and polymerized for 20 seconds.

**Optibond Solo + Consepsis.** Consepsis was applied with a mini-brush tip to the damp dentin surface for 20 seconds after acid etching. Excess moisture was gently removed with compressed air, leaving the surface visibly moist. Optibond Solo was applied as mentioned in Optibond Solo (control).

**Optibond Solo + Ultracid F.** Ultracid F was applied with a mini-brush tip to the damp dentin surface for 20 seconds after acid etching. Excess moisture was gently removed with compressed air, leaving the surface visibly moist. Optibond Solo was applied as mentioned in Optibond Solo (control).

For shear testing, a plexiglass mold 5 mm in diameter and 3 mm in height was seated securely perpendicular against the bonded surface, and a hybrid resin composite (Valux Plus, 3M ESPE) was applied in two layers. Each layer was light cured for 40 seconds, and the plexiglass mold was removed after light curing was completed (Fig 1).

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**TABLE 1** Materials used in study

<table>
<thead>
<tr>
<th>Material</th>
<th>Composition</th>
<th>Manufacturer</th>
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<tbody>
<tr>
<td>One Step</td>
<td>BPDM, bis-GMA, HEMA, acetone</td>
<td>Bisco</td>
</tr>
<tr>
<td>Optibond Solo</td>
<td>bis-GMA, HEMA, GPDM, ethanol, silica, barium glass, sodium hexafluorophosphate</td>
<td>Kerr</td>
</tr>
<tr>
<td>Consepsis</td>
<td>2% chlorhexidine</td>
<td>Ultradent</td>
</tr>
<tr>
<td>Ultracid F</td>
<td>EDTA, benzalkonium chloride, 1% sodium fluoride</td>
<td>Ultradent</td>
</tr>
</tbody>
</table>

BPDM = biphenyl dimethacrylate; bis-GMA = dimethacrylate; HEMA = hydroxyethyl methacrylate; GPDM = glycerophosphoric acid dimethacrylate; EDTA = ethylenediaminetetraacetic acid.
For tensile testing, resin composite was applied into another plexiglass mold 3 mm in diameter and 3 mm in height, which was left on the specimen to be mounted to the testing machine (Fig 2). After storage in distilled water at 37°C for 24 hours, the specimens were mounted to a mechanical testing device (Amsler) with a crosshead speed of 1 mm/minute for the measurement of the shear and tensile bond strengths until fracture occurred. The failure loads were recorded, and failure modes were evaluated with a stereomicroscope. The location of each failure was recorded as either cohesive failure in composite or in dentin, adhesive failure at the resin-dentin interface, or a combination (mixed) of cohesive and adhesive failures.

Bond strength data were subjected to Kruskall-Wallis and post hoc Dunn's multiple comparison test. For the comparison of the independent groups, Mann-Whitney U test was performed.

**RESULTS**

The mean shear and tensile bond strengths of the control and disinfectant groups are shown in Tables 2 and 3. Kruskall-Wallis test (*P* < .05) showed no significant differences among the control and the disinfectant groups of the dentin bonding systems regarding the shear and tensile bond strengths. Mann-Whitney U test showed no significant differences between the control and the disinfectant groups of the two dentin bonding systems. Surface analysis of the debonded specimens revealed mostly mixed failures after shear and tensile bond tests. Cohesive failures in dentin were not observed.

**DISCUSSION**

Chlorhexidine-containing solutions and benzalkonium chloride-containing etchants have been found to be effective against *Streptococcus mutans* and *Streptococcus sobrinus.* The use of these products as cavity cleansers after tooth preparation could help in reducing residual caries and postoperative sensitivity. Some clinicians also recommended the use of chlorhexidine as a rewetting agent prior to the application of hydrophilic dentin primers. Applying a 2% chlorhexidine solution before etching reduced the shear bond strength of a smear layer modifier dentin bonding system, Syntac (Vivadent), while it had no adverse effect on the smear layer remover system, Tenure (Dent-Mat). Gürgan et al. indicated that using chlorhexidine prior to or after etching the dentin without rinsing could affect the shear bond strength of Permagen. However, el-Housseiny and Jamjoum showed that applying chlorhexidine before acid etching did not significantly affect the bond strength of Scotchbond Multipurpose Plus to enamel and dentin. The use of cavity disinfectants appeared to
be material specific regarding their interactions with various dentin bonding systems' ability to seal dentin. Therefore, in the current study, one acetone- and one alcohol-based total etch dentin bonding system (One Step and Optibond Solo) and a chlorhexidine- (Consepsis) and a benzalkonium chloride-based (Ultracid F) disinfectant were used to examine their interactions. Among the control groups of One Step and Optibond Solo, Optibond Solo produced higher shear and tensile bond strength values than One Step although this difference was not statistically significant. This may be attributed to the filled adhesive of Optibond Solo. The filler particles have been reported to create a flexible intermediate resin layer that could resist the polymerization shrinkage stress of the resin composite. However, the effect of filler incorporation into adhesives is still controversial. Although Cardoso et al. reported that filled adhesives had advantages over unfilled adhesives of similar composition, Braga et al. suggested that the use of filled adhesives was not considered to be a determining factor for achieving high bond strengths to dentin.

The present in vitro study showed that Consepsis did not affect the shear and tensile bond strengths of the acetone-based dentin bonding system One Step after etching the dentin. This result is consistent with the research data of Perdigao et al. and Cao et al. who have shown that Consepsis did not reduce the shear bond strength of the acetone-based All Bond 2. Regarding the shear and tensile bond strength values, the alcohol-based dentin bonding system Optibond Solo also was not affected by the use of the chlorhexidine solution Consepsis. Chlorhexidine has a strong affinity for tooth surfaces, which has been shown to increase with acid etching. Theoretically, it can improve the bond strengths of the adhesive to dentin. It has a strong positive ionic charge, so it easily binds to phosphate groups. However, the presence of the chlorhexidine residue on the dentin surface has been indicated to negate these effects. Recently, Pilo et al. indicated that Consepsis, when applied after etching and washed off, could increase the shear bond strength of One Step. Washing off the chlorhexidine that contains a surfactant might only partially drive away the chlorhexidine molecules, and the bound molecules might serve as a cosurfactant on the conditioned dentin before resin is applied.

There is little information in the literature on how the benzalkonium chloride-based disinfectants affect the bond strength to dentin. In this study, the use of Ultracid F, containing 1% benzalkonium chloride, disodium ethylenediaminetetraacetic acid (EDTA) dihydrate, and 1% sodium fluoride, with the acetone- and alcohol-based dentin bonding systems, yielded bond strength values very similar to the control groups. Benzalkonium chloride has been shown to cross link to collagen but does not impair hybridization. Regarding similar bond strength values of the disinfectant-treated groups and the control groups, it may be concluded that the use of benzalkonium chloride-based Ultracid F did not interfere with the dentin bonding systems One Step and Optibond Solo. Tubicilid red label (Global Dental), which has the same composition as Ultracid F has been shown not to reduce the tensile bond strengths to root dentin of a smear layer modifier dentin bonding system. Cao et al. reported that Tubulicid decreased the shear bond strength of All Bond 2 (Bisco) and Amalgambond (Parkell), while it had no adverse effect on Permagain after the etching process. When Tubulicid was used and rinsed after etching the dentin, it did not affect the shear bond strength of One Step and Prime&Bond 2.1 to dentin. Based on the results of these studies, the application sequence of the disinfectant is also an important factor to be considered. While some clinicians prefer to apply the disinfectants after cavity preparation prior to the bonding procedure, others prefer to apply them after etching. The manufacturer recommends the use of Consepsis and Ultracid F after etching, followed by removal of excess moisture and applying the primer/adhesives. Although information is lacking on the efficacy of disinfectants when applied over the smear layer or smear layer-free dentin surface, the use of the cavity disinfectants would be much more preferable after etching the dentin as the removal of the smear layer leads to the elimination of most of the microorganisms. Then the use of the cavity cleansers would be much more beneficial for those microorganisms and their toxins that remain viable in the dentinal tubules. Therefore, in the current study, the effect of cavity disinfectants on the bond strength of the dentin bonding systems was evaluated after removal of the smear layer.

Although the results of the current study showed no reduction in dentin bond strength, dentin-bonding agents and disinfectants vary dramatically in composition from manufacturer to manufacturer, which should be taken into consideration. Especially during the treatment of patients who use immunosuppressive drugs or have immunodeficiency syndromes, the use of cavity disinfectants may provide additional protection against microorganisms when the right disinfectant and dentin bonding combination has been selected. Particularly chlorhexidine, which is actually adsorbed by hydroxyapatite and produces a prolonged antimicrobial effect in low concentrations, might be beneficial. However, in such special cases, whether the use of cavity disinfectants will prove to be an effective method for reducing the incidence of residual or secondary caries still needs to be examined with in vivo studies. The effectiveness of disinfectants below restorations bonded...
with self-etching primer systems also should be determined, as these systems only modify or dissolve the smear layer.

**CONCLUSION**

The results of this in vitro study indicate that the use of 2% chlorhexidine and 1% benzalkonium chloride solutions after etching the dentin did not reduce the shear and tensile bond strengths of the acetone-based One Step and alcohol-based Optibond Solo to dentin.

**ACKNOWLEDGMENT**

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**REFERENCES**