One year in vivo dentin bond durability of an all-in-one adhesive system in wedge-shaped cervical defects

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Purpose: To evaluate the in vivo long-term dentin bond durability of resin composite restorations in wedge-shaped defects using an all-in-one adhesive system.

Materials and Methods: Fifteen non-caries cervical wedge-shaped defects of fifteen patients were restored with a fluoride-releasing adhesive system (Reactmer Bond) and a resin composite (Reactmer Paste). The restored teeth were extracted after 1 day, 1 month and 1 year and then subjected to micro-tensile bond strength (μ-TBS) testing. After the μ-TBS test, the fracture modes of the debonded specimens were observed using a scanning electron microscope. The data of the tensile bond strengths were analyzed using one-way analysis of variance (ANOVA) and Fisher’s PLSD test at a 95% level of confidence.

Results: No restorations failed during the observation periods. The μ-TBSs after 1 day, 1 month, and 1 year were 13.2 MPa, 10.5 MPa and 4.7 MPa, respectively. There was no significant difference in the μ-TBS between 1 day and 1 month, however, the μ-TBS significantly decreased over 1 year.

Conclusion: The tensile bond strengths of the all-in-one adhesive decreased over 1 year.

Key Words: all-in-one adhesive, dentin bond durability, wedge-shaped defect.

Introduction

Wedge-shaped cervical defects are caused by toothbrush abrasion and/or abfraction that is generated by the tensile stresses of occlusal loading.1,2 The surface of the wedge-shaped cervical defect is composed of sclerotic dentin that has undergone hypermineralization with the tubules occluded by mineral crystals.3 Therefore, the bonding of an adhesive resin to a wedge-shaped cervical defect is different from that to unaffected normal dentin. In vitro research has shown that the bond strengths of adhesives to sclerotic dentin are lower than those to normal dentin.1 The dentin bond durability of the recent dentin bonding systems has also yet to be clarified. Moreover, the long-term durability of an adhesive system in vivo may be different from that in vitro.

Previous in vitro studies have indicated dentin bond strengths gradually decreased over time in water storage.4,5 On the other hand, Okuda et al.6 reported that the bond strength of a fluoride-releasing adhesive system, Fluoro Bond, (Shofu Inc., Kyoto, Japan) did not reduce after 9 months water storage. While Sano et al.7 has reported relatively stable bond strengths to dentin over one year despite increased porosity of the hybrid layer, Hashimoto et al.8 reported a significant reduction in bond strengths over time in vivo. However, there is little information on long-term in vivo dentin bond durability to natural wedge-shaped cervical defects.

Recently, the remarkable improvement in dentin bonding systems has led to the development of fluoride-releasing all-in-one adhesive systems. The all-in-one adhesive system “Reactmer Bond” contains fully pre-reacted glass-ionomer fillers which exhibits sustained fluoride-ion release. The resin composite “Reactmer Paste” contains fully pre-reacted glass fillers (Shofu Inc.).9 The new restorative system, Reactmer Bond and Reactmer Paste can reduce technique sensitivity and manipulation time.10 In addition, a restoration, which combines a fluoride-releasing adhesive and fluoride-releasing restorative material may inhibit secondary caries.
on cervical dentin.\textsuperscript{11,12} Sonoda et al.\textsuperscript{13} evaluated the pulpal response to the Reactmer system using monkey teeth, which was reported to be biologically compatible with vital pulps. However, there have been few in vivo studies on the bond durability of an all-in-one bonding system to human sclerotic dentin. Thus, the purpose of this study was to evaluate the dentin bond durability of this new restorative system in wedge-shaped defects over 1 year.

**Materials and Methods**

**Restoration of the cavities**

Fifteen human premolars with cervical wedge-shaped defects were restored in fifteen patients at Nishimura Dental Clinic from November 2000 to May 2001. The restored teeth were scheduled for extraction due to periodontitis. Informed consent and agreement were obtained from all the patients before treatment and extraction. The restorative materials and their procedures are shown in Table 1 and Fig. 1, respectively.

**Table 1.** Materials used for bonding.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Ingredients</th>
<th>Lot number</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactmer Bond</td>
<td>Fluoroaluminosilicate glass, F-PRG, Water, Solvent, Initiator</td>
<td>040001</td>
<td>Shofu Inc.</td>
</tr>
<tr>
<td>Adhesive A</td>
<td>4-AET, 4-AETA, 2-HEMA, UDMA, Solvent, Initiator</td>
<td>040001</td>
<td>Shofu Inc.</td>
</tr>
<tr>
<td>Adhesive B</td>
<td>F-PRG filler, glass filler, 2-HEMA, UDMA, Initiator</td>
<td>040001</td>
<td>Shofu Inc.</td>
</tr>
<tr>
<td>Reactmer Paste</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F-PRG, Full-reaction type pre-reacted glass ionomer filler; 4-AET, 4-acryloxyethyltrimellitate; 4-AETA, 4-acryloxyethyltrimellitate anhydride; 2-HEMA, 2-hydroxyethyl methacrylate; UDMA, Urethane dimethacrylate.


**Fig. 1.** Specimen preparation procedure for the micro-tensile bond test.

The teeth with non-caries cervical wedge-shaped defects were cleaned using the Prophy Brush (0213, Young Dental Mfg., Earth City, MO, USA) without pumice mounted in a low speed micro-motor handpiece. Reactmer Bond A and B were mixed together and applied to surface each cavity for 20 s using a micro-brush, and light-cured for 20 s. The cavities were then bulk-filled with Reactmer Paste and light-cured for 30 s. A curing unit (Optilux 500, Demetron, Danbury, CT, USA) was used for light curing. The restored cavities were finished and polished with a superfine-grit diamond bur (Smoothcut, C16ff, GC Corp., Tokyo, Japan) and a silicone point (Compomaster, Shofu Inc.) under a stream of water. The teeth were then extracted following the patients’ consent at 1 day, 1 month and 1 year after restoration.

**Micro-tensile bond strength test**

Immediately after extraction of the teeth, an additional 4 mm-thick layer of resin composite was placed on the
restorations. The resin-bonded teeth were then serially sectioned into three to four slices approximately 0.7 mm thick, parallel to the long axis of the tooth, using a low-speed diamond saw (Leitz 1600 Microtome, Leica Instruments GmbH, Heidelberg, Germany) under water coolant. These sections were then trimmed and shaped to form a gentle curve with the narrowest portion at the adhesive interface at the deepest central part using a superfine diamond point (c16ff, GC Corp.) mounted in a high-speed handpiece under copious water spray. The bonded surface area, which ranged from 0.95 to 1.05 mm², was calculated before testing by measuring the diameter and thickness of each specimen. These specimens were then attached to the testing device with a cyanoacrylate adhesive (Zapit, Tokyo Dental Industry, Tokyo, Japan) and placed in a universal testing machine (EZ-test, Shimadzu Corp., Kyoto, Japan) for tensile testing at a crosshead speed of 1 mm/minute.

**Microscopic observation**

After microtensile bond testing, all the fractured specimens were fixed in 10% neutral buffered formalin solution for at least eight hours, then placed on scanning electron microscope (SEM) stubs, desiccated, gold sputter-coated, and observed with a SEM. The failure modes were classified as: A, cohesive failure in composite or adhesive; B, fracture between the deepest portion of the adhesive resin and the top layer of the demineralized dentin (interface); C, mixed failure (resin and interface); D, mixed failure (interface and beneath the hybrid layer); and E, cohesive failure beneath the hybrid layer.

**Statistical analysis**

Statistical analysis of the tensile bond strengths was performed using one-way ANOVA and Fisher’s PLSD test at a 95% level of confidence.

**Results**

No restoration debonded from the cavities during the observation period. The results of the µ-TBS test are shown in Table 2. The µ-TBSs of the specimens at 1 day, 1 month, and 1 year were 13.2 MPa, 11.0 MPa, and 4.7 MPa, respectively. There was no significant difference in the µ-TBS between 1 day and 1 month. However, the µ-TBS after 1 year was significantly lower (p<0.05). For the specimens after 1 day, no specimens failed during specimen preparation for µ-TBS. On the other hand, three of sixteen specimens failed after 1 month, while nine of seventeen specimens failed after 1 year. If the specimens debonded during the specimen preparation, the µ-TBSs of the debonded specimens were calculated as 0 MPa.

**Table 2. Micro-tensile bond strengths (µ-TBS) of Reactmer to dentin in wedge-shaped cavities.**

<table>
<thead>
<tr>
<th>µ-TBS Category</th>
<th>µ-TBS (MPa)</th>
<th>SD (MPa)</th>
<th>Range (MPa)</th>
<th>Debonded (n)/ Specimen size</th>
<th>Fracture mode (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>13.2</td>
<td>a</td>
<td>4.7</td>
<td>6.0-23.4</td>
<td>0/17</td>
</tr>
<tr>
<td>1 month</td>
<td>11.0</td>
<td>a</td>
<td>7.4</td>
<td>0-22.1</td>
<td>3/16</td>
</tr>
<tr>
<td>1 year</td>
<td>4.7</td>
<td>b</td>
<td>6.3</td>
<td>0-19.8</td>
<td>9/17</td>
</tr>
</tbody>
</table>

A, Cohesive failure in composite or adhesive; B, Mixed (resin cohesive and interface) failure; C, Interface failure; D, Mixed (interface and beneath the hybrid layer) failure; E, Cohesive failure beneath the hybrid layer.

Category: Identical letters indicate that they are not significantly different (p>0.05).

SEM images of the fractured surfaces are shown in Fig. 2. Cohesive failures in the bonding resin and mixed failures including resin cohesive and interface were predominant in the 1-day specimens. For one month, mixed (resin cohesive and interface) failures were frequently observed. On the other hand, mixed (resin cohesive and interface) failures and interface failures were mainly observed after 1 year.
Discussion

A wedge-shaped defect consists of occlusal and gingival walls. The dentinal tubule orientation of the occlusal wall is generally parallel to the surface, whereas that of the gingival wall is perpendicular to the surface. Inoue et al.\(^{14}\) reported that the ultimate tensile strength of human dentin is different according to the direction of the dentinal tubules. Yoshiyama et al.\(^{3}\) reported that there was no statistically significant difference between the strengths of resin bonds made to occlusal vs. gingival margins in either natural or artificially created wedge-shaped lesions in cervical root dentin. On the other hand, Ogata et al.\(^{15}\) reported that tensile bond strength to the gingival wall was lower than that to the occlusal wall in artificial wedge-shaped defects.

In this study, the $\mu$-TBSs were measured on the deepest part of the wedge-shaped defect, because the shape and the size of natural wedge-shaped defects are various. The natural wedge-shaped defect is different from normal dentin often used in vitro studies, which is sound, flat and polished. As a result of the aging process and in response to mild irritations like cervical abrasion or chemical erosion, there is continued deposition of intratubular dentin, resulting in a gradual reduction of the tubule diameter.\(^{16,17}\) This continued deposition often leads to complete closure of tubule, so-called sclerotic dentin.\(^{16,17}\) These sclerotic surfaces are reported to be difficult to condition by adhesive systems, resulting in the creation of a thin hybrid layer or relatively lower bond strengths.\(^{3,15-17}\) The natural wedge-shaped defect may be a more difficult bonding substrate compared with sound dentin and enamel, because it is covered with a hypermineralized layer that is acid-resistant.\(^{18,19}\)

The all-in one adhesive, Reactmer Bond, has a relatively mild acidity of pH 2.3. It has been reported that the sclerotic dentin surface is less permeable than young caries-free dentin\(^{20}\) and in general, the dentin bond strengths of all-in-one systems are less than two-step systems.\(^{21,22}\) Okuda et al.\(^{6}\) reported that the bond strength of a fluoride-releasing adhesive system was relatively stable during nine months (in vitro) water storage, and indicated that hydrolytic degradation of the resin-dentin interface did not progress due to the effect of fluoride release. More than half of the specimens after 1 year failed during specimen preparation for the $\mu$-TBS test. In vivo, bond strengths are gradually reduced by occlusal stresses.\(^{23,24}\) However, no secondary caries occurred and no restoration de-bonded from cavities during the observation period. Clinically, Reactmer Bond demonstrated

\[\text{\fig{2}}\]
good durability during one year of observation. Tsuchiya et al.25 reported that a thick acid-base resistant zone adjacent to a restoration using Reactmer Bond could be clearly observed by SEM. This suggests that Reactmer Bond might inhibit secondary caries formation.

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References

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