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-carious 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.
(Int Chin J Dent 2006; 6: 65-69.)
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.[11,12] Sonoda et al.[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.

Materials	Ingredients	Lot number	Manufacturer
Reactmer Bond			Shofu Inc.
Adhesive A	Fluoroaluminosilicate glass, F-PRG, Water, Solvent, Initiator	040001	
Adhesive B	4-AET, 4-AETA, 2-HEMA, UDMA, Solvent, Initiator	040001	
Reactmer Paste	F-PRG filler, glass filler, 2-HEMA, UDMA, Initiator	0400	Shofu Inc.

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.
Procedure: 1) Mix adhesive A and B. 2) Apply adhesive (20 s). 3) Mild air blowing. 4) Light curing (20 s). 5) Place restoration, light-cure, and polish.

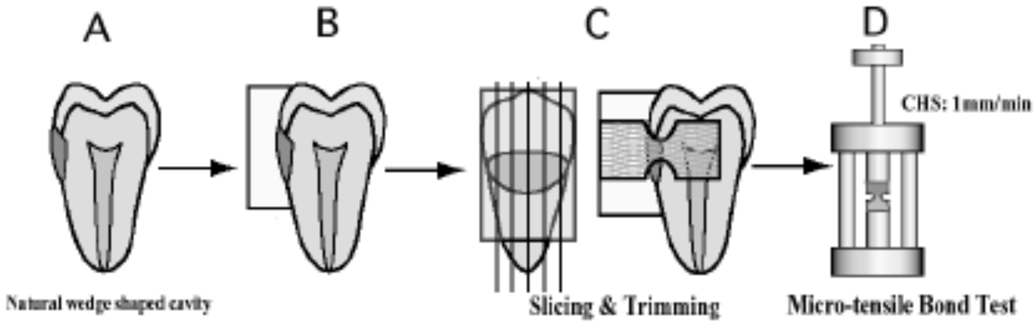


Fig. 1. Specimen preparation procedure for the micro-tensile bond test.

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 mm^2, 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

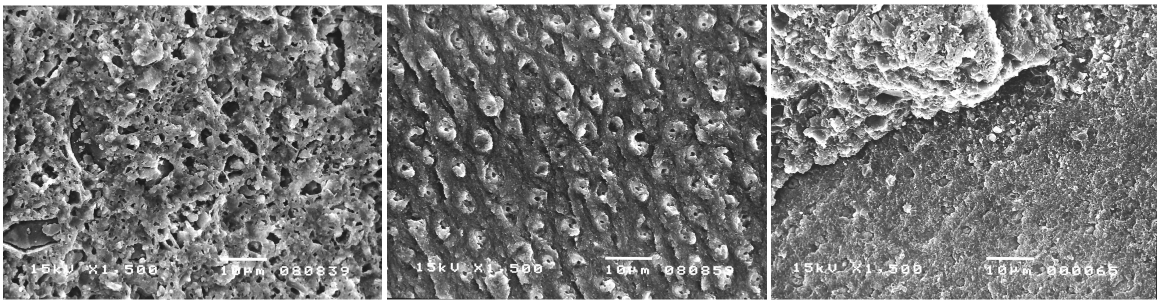
No restoration debonded from the cavities during the observation period. The results of the μ-TBS test are shown in Table 2. The μ-TBSs of the specimens at 1 day, 1 month, and 1 year were 13.2 MPa, 11.0 MPa, and 4.7 MPa, respectively. There was no significant difference in the μ-TBS between 1 day and 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.

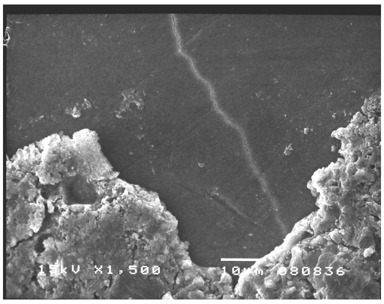
	μ-TBS (MPa)	Category	SD (MPa)	Range (MPa)	Debonded (n)/ Specimen size	Fracture mode (%)				
						A	B	C	D	E
1 day	13.2	a	4.7	6.0-23.4	0/17	41	29	18	12	0
1 month	11.0	a	7.4	0-22.1	3/16	19	50	25	0	6
1 year	4.7	b	6.3	0-19.8	9/17	0	56	44	0	0

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.



A B C



D

Fig. 2. SEM images of the fractured surfaces.
A, Cohesive failure in composite (1 day in vivo).
B, Cohesive failure beneath the hybrid layer (1 day in vivo).
C, Mixed (resin cohesive and interface) failure (1 month in vivo).
D, Mixed (resin cohesive and interface) failure (1 year in vivo).

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 μ-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 μ-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 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.

Acknowledgment
This research was supported by a grant from the Center of Excellence Program for Frontier Research on Molecular Destruction and Reconstruction of Tooth and Bone at Tokyo Medical and Dental University, Japan.

References

1. Lee WC, Eakle WS. Possible role of tensile stress in the etiology of cervical lesions of teeth. J Prosthet Dent 1984; 52: 374-80.
2. Grippo JQ. Abfractions: A new classification of hard tissue lesions. J Esthet Dent 1991; 3: 14-9.
3. Yoshiyama M, Sano H, Ebisu S, et al. Regional strengths of bonding agents to cervical sclerotic root dentin. J Dent Res 1996; 75: 1404-13.
4. Burrow MF, Tagami J, Hosoda H. The long term durability of bond strengths of dentin. Bull Tokyo Med Dent Univ 1993; 40: 173-91.
5. Tanaka Y, Sugaya T, Kawanami M. Durability of adhesion between 4-META/MMA-TBB resin and cementum. Dent Mater J 2004; 23: 265-70.
6. Okuda M, Pereira PNR, Nakajima M, Tagami J, Pashley DH. Long-term durability of resin dentin interface: nanoleakage vs. microtensile bond strength. Oper Dent 2002; 27: 289-96.
7. Sano H, Yoshikawa T, Pereira PNR, et al. Long-term durability of dentin bonds made with a self-etching primer, in vivo. J Dent Res 1999; 78: 906-11.
8. Hashimoto M, Ohno H, Kago M, Endo K, Sano H, Oguchi H. In vivo degradation of resin-dentin bonds in humans over 1 to 3 years. J Dent Res 2000; 79: 1385-91.
9. Ikemura K, Tay FR, Kouro Y, et al. Optimizing filler content in an adhesive system containing pre-reacted glass-ionomer fillers. Dent Mater 2003; 19: 137-46.
10. Meerbeek BV, Landuyt KV, Munck JD, et al. Technique-sensitivity of contemporary adhesives. Dent Mater J 2005; 24: 1-13.
11. Itota T, Nakabo S, Iwai Y, Konishi N, Nagamine M, Torii Y. Inhibition of artificial secondary caries by fluoride-releasing adhesives on root dentin. J Oral Rehabil 2002; 29: 523-7.
12. Okuda M, Pereira PNR, Nikaido T, Tagami J. Evaluation of in vitro secondary caries using confocal laser scanning microscope and X-ray analytical microscope. Am J Dent 2003; 19: 191-6.
13. Sonoda H, Sasafuchi Y, Kitasako Y, Arakawa M, Otsuki M, Tagami J. Pulpal response to a fluoride-releasing all-in-one resin bonding system. Oper Dent 2002; 27: 271-7.
14. Inoue S, Pereira PNR, Kawamoto C, et al. Effect of depth and tubule direction on ultimate tensile strength of human coronal dentin. Dent Mater J 2003; 22: 39-47.
15. Ogata M, Nakajima M, Sano H, Tagami J. Effect of dentin primer application on regional bond strength to cervical wedge-shaped cavity walls. Oper Dent 1999; 24: 81-88.
16. Fuks AB, Chosack A, Eidelman E. Two-year evaluation in vivo and in vitro of class 2 composites. Oper Dent 1990; 15: 219-23.
17. Duke ES, Lindemuth J. Polymeric adhesion to dentin: Contrasting substrates. Am J Dent 1990; 3: 264-70.
18. Duke ES, Lindemuth J. Variability of clinical dentin substrates. Am J Dent 1991; 4: 241-6.
19. Meerbeek BV, Braem M, Lambrechts P, Vanherle G. Morphological characterization of the interface between resin and scrlerotic dentin. J Dent 1994; 22: 141-6.
20. Tagami J, Hosoda H, Burrow MF, Nakajima M. Effect of aging and caries on dentin permeability. Proc Finn Dent Soc 1992; 88(Suppl 1): 149-54.
21. Tay FR, Sano H, Tagami J, et al. Ultrastructural study of a glass ionomer-based, all-in-one adhesive. J Dent 2001; 29: 489-98.
22. Ogata M, Takada T, Harada N, Nakajima M, Tagami J. Micro-shear bond strengths of a newly developed fluoride releasing all-in-one adhesive. Adhes Dent 2003; 21: 74-81.
23. Kubo S, Yokota H, Sata Y, Hayashi Y. The effect of flexural load cycling on the microleakage of cervical resin composites. Oper Dent 2001; 26: 451-9.
24. Nikaido T, Kunzelmann KH, Chen H, et al. Evaluation of thermal cycling and mechanical loading on bond strength of a self-etching primer system to dentin. Dent Mater J 2002; 18: 269-75.
25. Tsuchiya S, Nikaido T, Sonoda H, Foxton RM, Tagami T. Ultrastructure of the dentin-adhesive interface after acid-base challenge. J Adhes Dent 2004; 6: 183-90.

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Received February 14, 2006. Accepted April 19, 2006.