Sealing Ability of New Generation Adhesive Systems in Primary Teeth: An In Vitro Study

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Abstract

Purpose: This study evaluated the sealing ability of different types of restorative-adhesive combinations on deciduous molars in vitro.

Methods: Facial and lingual Class V cavities were prepared in 120 primary teeth. They were randomly divided into 8 groups of N=15, in which different adhesives were used (XE=Xeno III; LP=Adper Prompt L Pop; IB=I Bond; SB=Scotch Bond 1; EP=Etch & Prime 3.0; AS=AdheSE; OB=Optibond Solo plus self-etch primer; CS=Clearfil SE Bond). All cavities were restored with composite Z 250. After thermocycling and immersion in 2% methylene blue, the dye penetration was evaluated under a microscope.

Results: In enamel and in cementum: the best seals were obtained with XE and LP, followed by CS, AS, IB, OB, SB, and EP (P=.001). No significant differences were recorded in the microleakage degree between the cementum and the enamel margins (P=.40).

Conclusions: In this in vitro model, Xeno III and Adper Prompt L Pop provided the best seals both at the enamel and the cementum margins of Class V cavities in primary molars. (*Pediatr Dent.* 2004;26:322-328)

KEYWORDS: MARGINAL SEAL, MICROLEAKAGE, DECIDUOUS MOLARS, SELF-ETCHING ADHESIVES

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In pediatric dentistry there is an increasing demand for the esthetic benefits of adhesive dentistry.[1,2] One of the advantages of the associated minimally-invasive cavity designs—omitting the traditional "extension for prevention," is to further preserve sound dental tissues.[3] Adhesive dentistry also avoids the possible side effects of amalgam.[4-7]

Composite fillings are technique sensitive and have been documented to have a high failure rate in primary teeth.[2] This is partly due to lack of cooperation in small children, leading to inadequate tooth isolation and subsequent higher incidence of marginal leakage. Microleakage is defined as the clinically undetectable passage of bacteria, fluids, molecules, or ions between a cavity wall and the restorative material applied to it.[8] Microleakage at the tooth-restoration interface is considered to be a major factor influencing the longevity of a dental restoration. It may lead to marginal discoloration or, worse, to marginal breakdown or secondary caries.[9,10] It can be clinically difficult to distinguish between secondary caries and marginal discoloration.[11,12] Increased postoperative sensitivity has also been described,[13] particularly in the pediatric patient whose cavity floor may be close to the pulp.[14]

Three-step bonding systems are often considered to be too complicated and time consuming, especially in pediatric dentistry, and tend to be replaced by so-called "self-etching" or sixth-generation adhesives. Self-etching agents are applied directly to the tooth without rinsing or drying, thus eliminating potential problems related to collagen fiber collapse after conditioning.[15] Another advantage of the simultaneous etching and priming is the elimination of the possible contamination of an etched and unprimed dentin surface.[16] These systems were also reported to reduce the incidence of post-treatment sensitivity sometimes encountered in previous systems,[17-19] even though the bond strength to dentin and enamel was lower than with the fourth-generation and fifth-generation systems.[20]

A further modification was introduced in late 2002, combining etchant, primer, and adhesive in a single bottle, thus eliminating the additional mixing and/or placement step over the sixth-generation systems.

Even though some studies have concluded that there are few differences between bond strengths on primary and permanent teeth,[21] much less is known about the performance of dentin adhesives in primary teeth. This may

Table 1. Components and Manufacturers of the Materials Used in All Groups

Group	Material	Composition		Manufacturer
XE	Xeno III	Liquid A	2 hydroxyl ethyl methacrylate (HEMA) Purified water Ethanol Butylated hydroxyl toluene (BHT) Highly dispersed silicon dioxide	Dentsply, Detrey, Konstanz, Germany
		Liquid B	Phosphoric acid modified methacrylate resins Mono, fluoro, phosphazene modified polymethcrylate resin Urethane dimethacrylate Butylated hydroxyl toluene (BHT) Camphorquinone Ethyl-4-dimethylaminobenzoate	
LP	Adper Prompt L Pop	Liquid 1 (red blister)	Methacrylate phosphoric esters Bis-GMA Stabilizers Initiators based on camphorquinone Stabilizers	3M Dental Products, St. Paul, Minn
		Liquid 2 (yellow blisters)	Water 2 hydroxyl ethyl methacrylate (HEMA) Polyalkenoic acid	
IB	I Bond	Acetone/water based	Formulation of light-activated methacrylate-resins and glutaraldehyde	Heraeus Kulzer, Inc, New York, NY
SB	Scotch Bond 1	Etchant: Primer/adhesive	35% phosphoric acid Ethanol Diglycidyle oxyde dimethacrylate 2 hydroxyl ethyl methacrylate (HEMA) 2 hydroxy-1,3-propanediyle Bismethacrylate 2 propenoic acid Purified water	3M Dental Products, St. Paul, Minn
EP	Etch & Prime 3.0	Catalyst	Tetra-methacryloxyethyl pyrophosphate 2 hydroxyethylmethacrylateUniversal 2 hydroxyethyl methacrylate Ethanol Distilled water Stabilizer	Degussa AGG eschâflsbereich Dental, Hanau, Germany
AS	AdheSE	Primer	Phosphonic acid acrylate Bis-acrylamide Water Initiators and stabilizers Bonding Dimethacrtylate Hydroxyethylmethacrylate Highly dispersed silicon dioxide Initiators and stabilizers	Ivoclar, Vivadent Schaan, Liechtenstein
OB	Optibond Solo plus self etch	Self-etch primer Adhesive	Glycerophosphatedimethacrtlate (GPDM) Bis-GMA GDM HEMA GPDM Ethanol	Kerr, Glendora, Calif
CS	Clearfil SE Bond	Primer	MDP HEMA Hydrophilic dimethacrylate Di-camphorquinone N-N-diethanol-p-toluidine WaterBond MDP HEMA Bis-GMA Hydrophobic dimethacrylate Di-camphorquinone N-N-diethanol-p-toluidine Silanated colloidal silica	Kuraray Dental, Osaka, Japan

reflect the difficulty in obtaining sufficient primary teeth for research purposes.

This in vitro investigation evaluated microleakage in enamel and cementum margins of Class V resin-based composite restorations in primary molars, using 6 sixth-generation adhesive systems:

1. Adper Prompt-L-Pop (LP; 3M Dental Products, St Paul, Minn);
2. Xeno III (XE, Dentsply, Detrey, Konstanz, Germany);
3. AdheSE (AS, Ivoclar, Vivadent Schaan, Liechtenstein);
4. Etch & Prime (EP, Degussa AG Geschâflsbereich Dental, Hanau, Germany);
5. Optibond Solo plus self-etch primer (OB, Kerr, Glendora, Calif);
6. Clearfil SE Bond (CS, Kuraray Dental, Osaka, Japan);
7. I Bond (IB, Heraeus Kulzer, Inc, New York, NY), a first all-in-one, self-etching adhesive system;
8. Scotch Bond 1 (SB, 3M Dental Products, St Paul, Minn), a multi-step adhesive.

Methods

One hundred twenty primary teeth extracted for pulp disease or orthodontic reasons were used in this study. The samples were stored in an aqueous 1% chloramine solution[22,23] at room temperature for no more than 3 months after extraction.

Cavity preparation

Two standardized C-shape, Class V cavities were located at the cementum-enamel junction on the buccal and lingual surfaces of each tooth. Cavities were prepared with diamond burs (CF 980204.035, Komet, Lemgo, Germany) in a high-speed handpiece with water cooling. The cavities were located on the cementum-enamel junction, half in enamel and half in cementum. Occlusal (enamel) cavosurface margins were bevelled to approximately 45°, and the gingival (cementum) cavosurface margins were left at 90°C.[24,25]

Cavity dimensions were: (1) 1.5-mm depth; (2) 3-mm width; and (3) 4-mm height.[26] The length of the bur was used as a guide for the cavity depth.

Cavity restoration

To test 8 different bonding systems, the specimens were randomly assigned to 8 groups of 15 subjects each. Table 1 shows the components and manufacturers of the tested adhesives. Each cavity was cleaned with pumice using a rubber cup prior to restoration. The adhesive systems were applied strictly according to the manufacturers' instructions, and all cavities were restored with composite Z 250 (Filtek, 3M Dental Products, St. Paul, Minn).

Dye penetration

The samples were first stored for 24 hours in a saline solution at 37°C and then thermally cycled in water baths: 2,500 cycles between 5°C and 55°C, with a dwell time of 15 seconds and a 15-second transfer time between baths to simulate temperature fluctuations found in the oral cavity.[27]

After thermocycling, the teeth were covered with 2 coats of nail polish up to approximately 1 mm of the restoration margin and immersed in 2% methylene blue dye for 24 hours at 37°C.[28,29] Following removal from the dye, the teeth were cleaned, rinsed with tap water, and embedded in slow-curing [Epofix] epoxy resin (EMS; Fort Washington, Penn).

After embedding, the teeth were sectioned labiolingually through the center of the restoration using a water-cooled diamond disc. The different samples were then examined under a stereomicroscope (125× magnification) to analyze dye penetration at the marginal seal of each restoration (Catima Program, Deltalogic Automatisieruengstechnik GmbH, Schwäbisch, Germany).

The degree of microleakage was evaluated and scored as follows[30-32]:

1. 1=dye penetration along the incisal or gingival wall less than the total length of the wall;
2. 2=dye penetration along the entire length of the incisal or gingival wall;
3. 3=dye penetration along the entire length of the incisal or gingival wall as well as the axial wall;
4. 0=no dye penetration.

All the procedures were performed by the same investigator.

Statistical analysis

All data were analyzed via chi-square test or Fisher's exact test when adapted in order to determine the significant differences between groups. Results were considered significant for $P<.05$.

Results

The microleakage scores in the 8 groups at the enamel and cementum margins are shown in Tables 2 and 3. Both in enamel and cementum, the best seals were obtained with XE and LP, followed by CS, AS, IB, OB, and SB. EP provided more microleakage (scores≠0) both in enamel and cementum.

Statistical analysis

Considering all the adhesives, there is a significant association between the penetration scores and the tested adhesives (the overall chi-square test is significant; $P=.001$) for enamel and cementum).

The adhesives were also compared against each other (chi-square test or Fisher's exact test when adapted), and the results are detailed in Table 4. To simplify the table, comparison results were only reported when there was a significant difference between enamel and cementum scores. Consequently, all other comparisons were insignificant.

Even if most adhesives provided better seals at the enamel margin (except IB and SB), no significant differences were recorded in the degree of microleakage between the cementum and enamel margin ($P>.05$).

Table 2. Comparison of Microleakage Scores Between 8 Materials at the Enamel Walls of Restoration

	Enamel							
Microleakage score	XE	LP	CS	AS	IB	OB	SB	EP
Score=0	30	30	28	28	25	24	23	21
Score=1	0	0	2	2	5	6	5	9
Score=2	0	0	0	0	0	0	2	0
Score=3	0	0	0	0	0	0	0	0

Table 3. Comparison of Microleakage Scores Between 8 Materials at the Cementum Walls of Restoration

	Cementum							
Microleakage score	XE	LP	CS	AS	I B	OB	SB	EP
Score=0	30	29	26	26	25	22	24	18
Score=1	0	1	2	2	5	6	3	12
Score=2	0	0	2	2	0	2	3	0
Score=3	0	0	0	0	0	0	0	0

Table 4. Multiple Comparison Between Adhesives

	Multiple comparison	
	Enamel	Cement
XE vs OB	$P<.05$	$P<.01$
XE vs SB	$P<.05$	$P<.05$
XE vs EP	$P<.01$	$P<.001$
PL vs OB	$P<.05$	$P<.05$
PL vs SB	$P<.05$	n.s.
PL vs EP	$P<.01$	$P<.05$
AS vs EP	$P<.05$	$P<.01$
SB vs EP	n.s.	$P<.01$
CS vs EP	n.s.	$P<.01$

n.s.=Not signifigant

Discussion

Clinicians and researchers use microleakage as a measure for assessing the performance of restorative materials in the oral environment.[33] Dye penetration measured on sections of restored teeth is the most common technique for evaluating microleakage at the tooth-restoration interface.[28,29]

In this study, an in vitro model was chosen to:

1. standardize the model;
2. obtain "ideal" adhesion conditions;
3. allow thermocycling, simulating stress caused by thermal variations.[33]

Depending on the treatment of the smear layer produced during cavity preparation, 3 adhesion mechanisms are currently used in modern adhesive procedures.[34] In the first group, the smear layer is modified and incorporated in the bonding process. In the second group, the smear layer is completely removed (SB). In the third group (self-etching primers), the smear layer and the underlying dentin surface are partially demineralized without removing the dissolved smear layer remnants or unplugging the tubule orifices. In these systems, the bonding agent is either applied after the self-etching primer (CS, EP, AS, OB) or mixed together with the self-etching primer before a single application (XE, LP). Recently, an innovation was introduced combining etchant, primer, and adhesive in a single bottle (IB).

In this study, SB was chosen as a total-etch agent to allow a comparison with the self-etching systems. For SB's procedure, the acid-etching agent is first used to demineralize the dentin. Once this is completed, the clinician applies the dentin bonding agent. If the time required to allow complete diffusion of the adhesive into the denatured dentin is not respected, however, adequate penetration may not be achieved.

Obviously, there are other factors that may influence this penetration level. Overdrying the preparation and, thus, failing to leave residual water on the surface (moist bonding) can stop the primer from penetrating the dentin. Excess surface water may also prevent bonding agent influxing. Another potential source for inadequate diffusion may be related to the early evaporation of the alcohol or acetone solvent within the bonding agent.

Self-etching adhesive systems offer 2 advantages in pediatric dentistry:

1. Tooth isolation—since the use of a rubber dam is not always possible with small, sometimes uncooperative and often mouth breathing children. In this case, when the etching gel is rinsed, its unpleasant taste often causes a swallowing or a spitting reflex, leading to salivary contamination.
2. Working time reduction—even if the time saved is not that great, the easy handling of self-etching adhesive systems makes them a good choice in pediatric dentistry, since the elimination of rinsing and drying steps reduces the possibility of overwetting or overdrying, which can have a negative influence on adhesion.[35]

Furthermore, post-treatment sensitivity has been shown to be reduced when compared to previous systems.[17-19] The inherent advantage of these systems is that they etch and prime simultaneously. There is no discrepancy between the demineralization depth and resin infiltration depth, since both processes occur at the same time.[36-38] Besides simplification, the rationale is to superficially demineralize dentin and simultaneously penetrate it with monomers, which can be polymerized in situ. A continuum from the unaltered dentin to the adhesive resin is created without the formation of an unpolymerized hydrophilic monomer layer at the base of the demineralized dentin layer, which might be highly sensitive to hydrolysis.

Moreover, the results obtained in this study show that, except for EP, self-etching primers provide a similar (CS, OB, AS, IB) or even better (XE, LP) seal when compared to SB. No microleakage was observed for XE in enamel or cementum or for LP in enamel, while all the other margins exhibited some degree of dye penetration. This suggestion is supported by other studies[39-41] reporting the existence of microleakage in the evaluation of different dentinal bonding agents.

Even though there were more microleakage scores at the cementum margin, no significant differences were recorded in the degree of microleakage between both margins. This finding was in agreement with some authors,[42] but contradicted the belief that cervical margin microleakage is always severe compared with enamel margins.[43-45] One possible explanation can be found in the simplification of the procedures reducing the difference between marginal integrity in enamel and cementum.

The differences observed between the tested self-adhesives might be explained by a combination of different factors, including the presence of fillers, and action on enamel and dentin.

The solvent

IB contains acetone, while LP is based on water and XE on ethanol. Since acetone is more volatile, it evaporates rapidly from the dentin surface, and the application of several layers of IB is required, making the procedure technique more demanding.

Moreover, the resin components cannot be mixed with water, which can result in the formation of resin globules during the early evaporation of the acetone solvent in acetone-based systems.[46] EP led to the most microleakage. It contains alcohol, water, solvents, and 2-hydroxy ethyl methacrylate (HEMA). The rise in HEMA concentration lowers the water's vapor pressure, making it more difficult to remove the final quantities of water. The residual water may interfere with adhesive monomer polymerization, thereby diminishing hybrid layer quality.[47]

The presence of fillers

Another significant factor may be the presence of fillers in some of the tested adhesives, including XE, CS, OB, and AS. Because the adhesive layer obtained with these adhesives is thicker, the ability of the interfaces to maintain adhesion during the critical early stages of polymerization is better, improving the resistance to dimensional changes. Studies have shown that the use of low-rigidity resins improved the strain capacity of the restoration and significantly influenced the quality of the marginal integrity.[48-50]

The progressive loss of marginal integrity and subsequent marginal discoloration by microleakage is probably caused mainly by residual stresses from polymerization shrinkage of the composite restorative material and stresses resulting from thermal dimensional changes.[51] Incorporation of filler particles into the bonding resin may promote formation of adhesive films with appropriate thicknesses and also reduce adhesive shrinkage, even if the elasticity modulus and, thus, the adhesive rigidity will be increased.[52]

Action on enamel and dentin

Depending on the pH and etching aggressiveness, the self-etching effect can be classified as "strong," "moderately strong," and "mild."[51] LP is a "strong" self-adhesive because of the phosphoric esters in its formulation. Second only to XE, the least microleakage was obtained with LP. The lower pKa of LP is such that it etches beyond the smear layer and demineralizes the underlying intact dentin, forming an authentic hybrid layer.[47,53]

In general, "mild" self-etch systems have a pH of around 2 (CS=2.2) and demineralize the dentin to a depth of only 1 μm. This superficial demineralization occurs only partially, so residual hydroxyapatite remains attached to the collagen. The hydroxyapatite crystals that remain around the collagen are considered particularly advantageous. Enabling more intimate chemical interaction with the functional monomers on a molecular level, they may also help prevent or retard marginal leakage.[51]

Some new adhesives such as AS, OB, IB, and XE are referred to as "moderately strong" self-etch adhesives.[51] Their pH is about 1.5. These adhesives are more acidic than the "mild" self-etch adhesives, so that a better micromechanical interlocking is achieved at the enamel and the dentin. The residual hydroxyapatite at the hybrid layer base may still allow for chemical intermolecular interaction, as has been demonstrated previously for the "mild" self-etch adhesives.[51]

Conclusions

This in vitro study produced the following conclusions:

1. Among the different self-etching products used in this study, Xeno III provided the best seal in enamel and cementum.
2. Two single-step, self-etch adhesives analyzed in this study (Xeno III and Adper Prompt L Pop) presented lower microleakage scores when compared to a total-etch system (Scotch Bond 1) or elf-etch, 2-step adhesive systems .
3. Different adhesive systems can affect the sealing ability of Class V restorations.

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Abstract of the Scientific Literature

Developing a Pediatric Oral Health Therapist

In 2002, the Robert Wood Johnson Foundation commissioned a study of policy barriers to accessing health care. The study indicated that bold new solutions were needed to address the growing problem. This article describes one strategy to help address the problem. The author describes a "dental therapist" program currently operating in New Zealand. The article documents the curriculum and training received by high school graduates entering the program. The 24-month program includes 2,400 hours of curriculum—760 hours of which are spent in the clinic treating children. After graduation, the therapist must serve for 1 year with another school dental therapist who provides supervision and support. Program graduates provide comprehensive dental care to children at school-based clinics. They are certified to: (1) perform examinations; (2) develop treatment plans; (3) provide preventive services; (4) administer local anesthesia; (5) prepare and restore primary and young permanent teeth; (6) extract primary teeth. The author suggested that, despite documentation of the ability of individuals other than dentists to successfully provide quality care to children, America's dental profession has been "immovable" in its resistance to this type of allied profession. The article further suggested that the development of pediatric oral health therapists—allied professionals uniquely trained to care for the oral health of children—should be implemented in the United States to improve access to care for all.

Comments: This article is thought provoking and rather controversial among those involved in dental education**. BB**

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Nash DA. Developing a pediatric oral health therapist to help address oral health disparities among children. *J Dent Educ*. 2004;68:8-22.

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