Results: For light-activated restorative materials during early setting (<3 min), application of Adper Prompt L-Pop exhibited generally superior marginal adaptation to most system adhesives. But there was no additional benefit from double application. The marginal-gaps in tooth cavities and the marginal-gaps in Teflon cavities were highly correlated ($r=0.86$–0.89, $p<0.02$–0.01). For enamel and dentin shear bond-strengths, there were no significant differences between single and double applications, for all materials tested except Toughwell and Z 250 with enamel.

Significance: Single application of a self-etch adhesive was a feasible and beneficial alternative to system adhesives for several classes of restorative. Marginal gap-widths in tooth cavities correlated more strongly with free shrinkage-strain magnitudes than with bond-strengths to tooth structure.

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Immediate performance of self-etching versus system adhesives with multiple light-activated restoratives

Masao Irie* Kazuomi Suzuki†
David C. Watts‡

*Okayama University, mirie@md.okayama-u.ac.jp
†Okayama University
‡University of Manchester

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Immediate performance of self-etching *versus* system adhesives with multiple light-activated restoratives

M. Irie[1]*, K. Suzuki[1], D.C. Watts[2]

[1]Department of Biomaterials, Okayama University Graduate School of Medicine and Dentistry, Okayama, JAPAN

[2]University of Manchester Dental School, Manchester, United Kingdom.

Short Title: Marginal-gap formation of light-activated restoratives

***Corresponding Author details**:

Masao Irie,

Department of Biomaterials, Okayama University Graduate School of Medicine and Dentistry, 2-5-1 Shikata-cho, Okayama 700-8525, JAPAN

Phone: +81-86-235-6668, Fax: +81-86-235-6669,

E-mail: mirie@md.okayama-u.ac.jp

Abstract

Objectives: The purpose of this study was to evaluate the performance of both single and double applications of (*Adper Prompt L-Pop*) *self-etching* dental adhesive, when used with three classes of light-activated restorative materials, in comparison to the performance of each restorative *system* adhesive. Evaluation parameters to be considered for the adhesive systems were (a) *immediate* marginal adaptation (or gap formation) in tooth cavities, (b) free setting shrinkage-strain determined by the *immediate* marginal gap-width in a non-bonding Teflon cavity, and (c) their *immediate* shear bond-strengths to enamel and to dentin.

Methods: The maximum marginal gap-width and the opposing-width (if any) in the tooth cavities and in the Teflon cavities were measured immediately (3 min) after light-activation. The shear bond-strengths to enamel and to dentin were also measured at 3 min.

Results: For light-activated restorative materials during early setting (< 3 min), application of *Adper Prompt L-Pop* exhibited generally superior marginal adaptation to most system adhesives. But there was no additional benefit from double application. The marginal-gaps in tooth cavities and the marginal-gaps in Teflon cavities were highly correlated ($r=0.86 – 0.89$, $p < 0.02 – 0.01$). For enamel and dentin shear bond-strengths, there were no significant differences between single and double applications, for all materials tested except Toughwell and Z 250 with enamel.

Significance: Single application of a self-etch adhesive was a feasible and beneficial alternative to system adhesives for several classes of restorative. Marginal gap-widths in tooth cavities correlated more strongly with free shrinkage-strain magnitudes than with bond-strengths to tooth structure.

Keywords: Marginal gap formation; Bond strength; Adhesive technique, Resin composite; Compomer.

INTRODUCTION

Marginal adaptation and bonding of restorative filling materials to the tooth cavity may not be secure in the initial stage. It has been suggested that restoration failure might occur immediately after setting or during the initial stage of restoration [1] and early gaps may lead to bacterial penetration and pulpal damage [2, 3]. Therefore protocols for measuring marginal gap formation were developed to evaluate the marginal adaptation of resin composite restorations [1, 4, 5]. When a resin composite is used to restore a dental cavity, any gap resulting at the cavity margin may be the result of an interaction between its' setting shrinkage, bond strength and material flow during the setting period [4].

Contemporary self-etching adhesives and the recently introduced all-in-one adhesives are attractive additions to the clinician's bonding procedures. They are user-friendly in that the number of steps required in the bonding protocol is reduced. As the smear layer is not removed prior to the application of the adhesive, the potential for post-operative sensitivity that is caused by incomplete resin infiltration of patent dentinal tubules can be substantially reduced. Moreover, as water is an essential component of these systems to enable ionization of the acidic monomers for demineralization of hard dental tissues, the technique sensitivity associated with variations in the state of hydration of a demineralized collagen matrix is also eliminated. These self-etching adhesives vary in their acidity by differences in the composition and concentration of polymerizable acids and/or acidic resin-monomers in these systems. Moreover, self-etching adhesives are generally less technique sensitive compared with systems that utilizes separate acid conditioning and rinsing steps [6-8]. Clinically, self-etching adhesives not only simplify the bonding process by eliminating steps, but also eliminate some of the technique-sensitivity of total-etch systems [9].

The version of *Adper Prompt L-Pop* (3M ESPE, Seefeld, Germany) designed for use with compomer or resin composite contains methacrylated phosphoric acid esters as the acidic components and is an all-in one, self-etching adhesive. Strong self-etch adhesives, such as *Adper Prompt L-Pop* have been documented as producing an interfacial ultra-morphology at dentin resembling that produced typically by total-etch adhesives [8]. Consequently, the mechanism of bonding strong self-etch adhesives *to dentin* is more like that of total-etch adhesives. This means that nearly all apatite minerals are removed from surface layers of collagen and thus any chemical interaction between apatite minerals and functional monomers is excluded. These strong self-etch adhesives exhibit the typical hybridization features of total-etch adhesives along with the formation of abundant resin tags. Concern is often raised however regarding the bonding effectiveness of self-etch adhesives *to enamel*. Numerous recent laboratory studies provide data that suggest either equal or reduced enamel bonding effectiveness as compared to conventional phosphoric acid etching [6, 10].

Previous studies have evaluated the effect of multiple applications of self-etching or self-priming adhesives. Although manufacturers suggested a double application technique of the adhesives to improve their bonding ability, no significant benefit was reported from this application technique [11, 12]. For *Clearfil Liner Bond 2V*, bond strengths increased significantly as the thickness of bonding layer increased ($p<0.05$) whereas bond strengths of *Single Bond* decreased significantly with increased thickness of the bonding layer ($p<0.05$). Thus the effect of the thickness of the adhesive layer on bond strength was evidently material-dependent [13].

All light-activated resin-based biomaterials shrink upon photo-polymerization and this is a major problem in light-activated restorative procedures [14, 15], such that the restorative /tissue bond may be disrupted [16]. Previous studies have suggested that setting shrinkage-strain has a greater effect on the marginal adaptation than two other factors, namely: bond strength or flow of the restorative material [13-19]. Our method for measuring the relative setting shrinkage-strain, for comparison with marginal gaps in tooth cavities, was described previously [18-20]. This method is based upon determining marginal gap-widths in non-bonding Teflon cavities. These showed a significant correlation with marginal gap-widths in tooth cavities [18, 19]. The effect of water-storage on gap-widths in both Teflon and tooth cavities was also studied [20].

This investigation was, therefore, carried out with multiple types of light-activated restorative materials to evaluate their system adhesives *versus* both single and double applications of a self-etching adhesive (*Adper Prompt L-Pop*). Performance was to be assessed with regard to: (a) their *immediate* marginal adaptation (or gap formation) in tooth cavities; (b) their *immediate* free setting shrinkage-strain, determined by the marginal gap-width in a non-bonding Teflon cavity; (c) their *immediate* shear bond strengths to enamel and to dentin. The first hypothesis to be tested was that the single or double application of *Adper Prompt L-Pop* would have no adverse effect on marginal integrity, compared to the system adhesives. The second hypothesis to be tested was that, amongst the set of materials studied, trends in one or more of properties (b) and (c) would correlate with trends in property (a).

MATERIALS AND METHODS

Seven light-activated restorative materials, including three compomers, one giomer and three composites, used in this study are listed in Table 1. This range of materials was not only representative of major clinical types but provided a range of values for the parameters under investigation. Tooth preparation procedures, mixing and handling were carried out according to the manufacturers' recommendations (Table 2). A visible-light curing unit (New Light VL-II, GC, Tokyo, Japan; irradiated diameter: 8 mm) was used for light-activated materials with an irradiation time of 30 sec. The light intensity was checked immediately before each application of the adhesive resin and restorative material, using a radiometer (Demetron/Kerr, Danbury, CT, USA). During the experiment the light intensity was maintained at 450 mW/cm^2. Human premolars, extracted for orthodontic reasons, were used throughout this study. After extraction and cleaning, teeth were immediately stored in cold distilled water at 4 ^{o}C for 1-2 months before testing, then mounted in a holder using a slow setting epoxy resin (Epofix Resin, Struers, Copenhagen, Denmark).

Marginal gap in the tooth cavity

A flat enamel surface was obtained by grinding the tooth with a wet 220 grit silicon carbide paper, until at least a 4 mm diameter area was exposed. With the tooth held rigidly in a custom-made drill press, a cylindrical cavity was prepared to a depth of approximately 1.5 mm, with a diameter of 3.5 mm, using a tungsten carbide bur (200,000 rpm) and a custom bur rotating at 4,000 rpm under wet conditions. One cavity preparation was made in each tooth in the coronal region and on the mesial surface. A total of 210 cavities were prepared in 210 teeth for this study. The cavity walls and surrounding enamel margin were pretreated according to the manufacturers' instruction as described in Table 2. Each cavity was filled with various restorative materials using a syringe tip (Centrix C-R Syringe System, Centrix, Connecticut, USA). The slightly overfilled cavity was covered with a plastic strip and allowed to harden. Excess filling material and approximately 0.1 mm of enamel were removed by wet grinding on carborundum paper #1000, followed by polishing with linen using an aqueous slurry of Alfa Micropolish (0.3 μm) (Buehler Ltd., Chicago, USA) immediately after setting. Each restoration margin was inspected under a traveling microscope (400 ×) (XY-B, D-Type, Nikon, Tokyo, Japan) for the presence, location, and extent of marginal gaps. The maximum gap-width and the opposing width (if any) between the material and the cavity wall were measured using the optical microscope, as previously described [5, 11, 12, 17, 18], *at a time of 3 minutes from start of light-activation*. The sum of these two measurements was defined as the marginal gap in the tooth cavity. For each material, 10 specimens were prepared.

Marginal gap in the Teflon cavity

Since the Teflon material does not react with the restorative materials, it was used as a mold to measure the degree of shrinkage-strain (immediately after setting). For direct comparison with the width of the marginal gap in the tooth cavity, a Teflon cavity of the same diameter as the tooth cavity was used. The prepared Teflon mold was placed on a glass plate covered with silicone oil, so that the glass plate did not react or bond to the filled material. Making and measuring a specimen involved the same procedure as described above, but without adhesive application, again *at a time of 3 minutes* *from start of light-activation*. The sum of two measurements was expressed as the marginal gap-width in the Teflon cavity. For each material, 10 specimens were prepared.

Shear bond strength to enamel and to dentin

Wet grinding of the buccal surfaces was performed with up to 1000 grit silicon carbide abrasive paper until a flat enamel or superficial dentin area of at least 4 mm in diameter was exposed. The surface was pretreated as described above. A split Teflon mold with a cylindrical hole (diameter, 3.6 mm; height, 2 mm) was clamped to the prepared enamel or dentin surface. The Teflon mold was filled with various restorative materials using a Centrix syringe tip (Centrix C-R Syringe System, Centrix, Connecticut, USA). It was covered with a plastic strip and the material was hardened by light irradiation, as described above. This prepared specimen was secured in a mounting jig. At a time of *3 minutes from start of light irradiation*, the shear force was transmitted by a flat (blunt) 1 mm broad shearing edge making a 90° angle to the direction of the load (or the back of the load plate). The shear force was applied using a testing machine (Autograph DCS-2000, Shimadzu, Kyoto, Japan) at a cross-head speed of 0.5 mm/min [19]. For each material, 10 specimens were prepared. The stress at failure was calculated and recorded as the shear bond strength. The failed specimens were examined under a light microscope (4 ×) (SMZ-10, Nikon, Tokyo, Japan) to determine the total number of adhesive failure surfaces [11, 18].

All procedures, except for testing, were performed in an air-conditioned room at $23 \pm 0.5\ ^{o}C$ and 50 ± 2 % R.H. The data-sets for marginal gaps in tooth cavities and shear bond strength were each subjected to one-way ANOVA to examine the influence of the adhesive techniques and the system adhesive. Significant differences at $p<0.05$ were determined using Duncan's new multiple-range test. Possible correlations between pairs of parameters were analyzed by linear regression.

RESULTS

The data for marginal gaps in the tooth and Teflon cavities are presented in Table 3. Single and double applications of *Prompt L-Pop* with all restorative materials, except Toughwell, showed significantly smaller gaps than when using the corresponding system adhesive. There was no significant difference between the single and the double applications of *Prompt L-pop* for all the materials tested. With both the single and the double applications of *Prompt L-Pop*, F 2000 showed significantly wider marginal gaps than with the other materials. The marginal-gap data for the tooth cavities separated into three groups, whereas the marginal-gap data for the Teflon cavities separated into four groups. All resin-composites showed significantly smaller marginal gaps than all compomers. For the set of restorative materials studied, the marginal-gaps in tooth cavities with each adhesive technique were highly correlated with the marginal-gaps in Teflon cavities (Table 4). These three correlation coefficients (**r**) were approximately the same for each technique. Thus, in general, a restorative material with a smaller marginal-gap in the tooth cavity showed a smaller marginal-gap in the Teflon cavity.

The values of shear bond strength to enamel are presented in Table 5. Single and double applications of *Prompt L-Pop* to enamel with all restorative materials, except Toughwell and Z 250, showed significantly higher strengths than with the corresponding system adhesive. There was no significant difference between the single application and the double application with all materials tested, except with Toughwell and Z 250. The system adhesives for Toughwell and Z 250 showed the highest values amongst the data-set (Table 5). With the single and double applications of *Prompt L-Pop*, the enamel bond-strength data separated into three groups. With the system adhesives, the strength data separated into four groups. No single or double applications of *Prompt L-Pop* showed adhesive failures. With its system adhesive, the proportion of adhesive failures of specimens using Reactmer was 40 percent. No relationship was observed between the marginal gaps in tooth cavities with each of three kinds of adhesive technique and the corresponding shear bond strength to enamel ($p>0.10$, $n=7$).

The values of shear bond strength to dentin are presented in Table 6. There was no significant difference between the single and the double applications of *Prompt L-pop* with all materials tested, except with Z 250. Single and double applications of *Prompt L-Pop* with Hytac showed significantly higher strengths than with the corresponding system adhesive. However, the system adhesive of Toughwell showed significantly higher strengths than with either single or double applications of *Prompt L-Pop*. With the single and double applications of *Prompt L-Pop*, the dentin bond-strength data separated into two groups. With the system adhesives, the strength data separated into three groups. No single or double applications of *Prompt L-Pop* showed adhesive failure. With the system adhesive, the proportion of adhesive failures using Dyract AP was only 10 percent. No relationship was observed between the marginal gaps in tooth cavities with each of three kinds of adhesive technique and the corresponding shear bond-strengths to dentin ($p>0.10$, $n=7$).

DISCUSSION

With the aim of simplifying restorative procedures, a new self-etching all-in-one adhesive (*Adper Prompt L-Pop*) was developed, with the ability to completely solubilize the smear layer and smear plugs, even with thick smear layers. Thus hybrid layers could be formed with a thickness approaching those of phosphoric-acid-conditioned dentin [7]. A similar difference in aggressiveness could also be seen on unground enamel.

This self-etching adhesive was studied with both compomer and resin-composite restorations [8]. It was demonstrated that a double application of *Adper Prompt L-Pop* did not improve performance, relative to single application, when evaluated by marginal-gaps in the tooth cavities, and by enamel and dentin shear bond-strengths. *Clearfil Mega Bond*, the least aggressive system had a pH value of 2.0, while *Non-Rinse Conditioner/Prime & Bond NT* that produced moderate etching, had a pH value of 1.2. *Adper Prompt L-Pop*, the most aggressive system at etching unground enamel, had a pH value of 1.0 [8]. Dental adhesive resins penetrate the subsurface microporosity created in etched enamel and the underlying layer of hybridized enamel tissue has been credited with producing the strong resin-enamel bond. It is possible that the more hydrophilic resins that are employed in contemporary adhesive systems produce deeper penetration into the interprismatic substance of the etched enamel tissue.

The present data, concerning gap-formation in enamel margins and enamel and dentin bond-strength values, showed that in most cases when using *Adper Prompt L-Pop* significant improvements occurred in comparison with the performance of system adhesives. An exception occurred with *One-up Bond F*, where the action of the self-etching system primer resulted in the formation of a thin hybridized complex, consisting of a surface zone of hybridized smear layer and a subsurface authentic hybrid layer [7, 21]. Under such circumstances, the strength of the resin-dentin bond would depend on the strength of the polymerized resin components.

This study demonstrated that double-applications of *Adper Prompt L-Pop* caused no additional improvement in performance. However, manufacturers of other adhesive systems often advise double primer applications, which may be entirely appropriate. For example, the manufacturer (Dentsply/Caulk, Milford, DE) of *Prime & Bond NT* states that if the first application of the adhesive does not leave a uniform glossy appearance, a second application is indicated. The manufacturer of *OptiBond Solo Plus* Self-Etch Adhesive system (Kerr, Orange, CA) recommends the use of two coats of adhesive. However, multiple applications of one-bottle adhesives had little effect on composite shear bond-strength to dentin [11]. Double applications had no effect with *OptiBond Solo* (Kerr, Orange, CA) or with *One-step* (Bisco, Schaumburg, IL) adhesives [12]. The effect of the adhesive-layer thickness on bond-strength is evidently material-dependent, and care should be taken to avoid excess adhesive [13]. Increase in the adhesive-layer thickness by double application of *Adper Prompt L-Pop* may affect its stress distribution during polymerization, since shrinkage-stresses may be concentrated at the interface during polymerization [16, 17]. Since volatile solvents may be removed within *Adper Prompt L-Pop* by gently air-drying prior to light-activation (3M ESPE data), there may be little effect on bonding if the double adhesive-layer was not too thick. Thus we observed that the fracture patterns for both a single and double applications were the same. These were mostly of interfacial failure between dentin and adhesive.

The shrinkage behavior of a light-activated direct restorative material depends on many intrinsic factors, as well as the host temperature and environment and the irradiation regime [22]. Examples of these intrinsic factors are the monomer system, the concentration of the catalyst and/or initiating system, amount of filler, filler type, size and silane coating. All materials studied incorporated a light-activated monomer system (Table 1). Shrinkage of the polymerized restorative materials has a great effect on their marginal adaptation [14-20].

A marginal shrinkage-gap was created in the Teflon cavity mold margin during the initial setting process. The sum of the maximum marginal-gap width and the opposing width in the Teflon cavity was taken as a measure of the net setting shrinkage-strain [18,19] as was the same property measured after water-storage [20].

The *range* of marginal-gap values measured using Teflon molds was generally similar to the range of results for the same materials placed in same-size tooth cavities. However, with each material, the *actual values* for the Teflon cavities were distinctly greater than for the tooth cavities. Restorative materials in Teflon molds are not susceptible to strong interaction with the cavity walls due to the non-reactivity of Teflon. The smaller marginal-gaps observed in natural teeth than in Teflon molds, confirmed the important influence of interfacial adhesion. Nevertheless, a highly significant correlation was found (Table 4) between the Teflon marginal-gaps and the marginal-gap in the identically-sized tooth-cavities. Therefore, it appeared that the immediate shrinkage-strain of materials had a significant effect on marginal-gap formation in tooth cavities. The empirical regression approach to the magnitudes of marginal gap-widths in Teflon cavities has also been suggested as a predictor of marginal leakage in tooth cavities [18, 19].

Perhaps surprisingly, the *trends* in shear bond-strength values to enamel and to dentin were not determinative at all for the *trends* in the marginal gap-width in tooth cavities. As noted above, early adhesion probably influences the *magnitude* of marginal-gaps, making them smaller than they would otherwise be [18, 19].

The values of shear bond-strength to enamel and to dentin were significantly different for the restorative materials used this study, even though the tooth substrate was pretreated by the same self-etching adhesive system. The mechanical properties of the adhesive layers may be critical as most fractured surfaces showed interfacial failure between dentin and adhesive, and some cohesive failures in the adhesive layers. Thus the reasons betanin this result may be complex.

The Gluma-system previously showed a correlation between the marginal gap and bond strength, when the intermediate resin was changed [5]. In that study, however, bond-strength was measured after 24 h, and when there were a number of common conditions. Therefore, the test conditions were different from those of the present study.

Further studies on the formation of marginal gaps, with light-activated restorative materials, require careful analysis and comparison of the competing shrinkage and bond-formation abilities.

In conclusion, for light-activated direct restorative materials during the early stage of setting (< 3 min), application of *Adper Prompt L-Pop* exhibited generally superior performance to most system adhesives. But there was no additional benefit from double application. The free shrinkage-strain, measured, by marginal gap-widths in Teflon cavities, had a greater correlation with marginal gap-widths in tooth cavities than the bond-strengths to tooth structure.

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Table 1 Light-activated restorative materials investigated

Product(type)	Composition	Manufacturer	Batch No.
F 2000 (A)	f luoro-aluminosilicate-glass (84 wt%), CDMA oligomer, GDMA, photo initiators, stabilisers	3M ESPE, St. Paul, MN, USA	F2990825
Dyract AP(A)	strontium-fluoro-silicate glass (47 vol%, 73 wt%) polymerisable resins, TCB, strontium fluoride photo initiators, stabilisers	Dentsply/DeTrey Konstanz Germany	DA990826
Hytac(A)	Ca-Al-Zn-fluoride glass (66 wt%) organic monomers, photo initiators, stabilisers	3M ESPE AG Seefeld, Germany	FW0054808
Reactmer(B)	fluoro-aluminosilicate-glass + silica (77 wt%), F-PRG, UDMA, HEMA	Shofu, Kyoto, Japan	099900
Unifil F(C)	fluoro-aluminosilicate-glass + silica (77 wt%), UDMA, dimethacrylate, , photo initiators, stabilizer	GC, Tokyo, Japan	101181
Toughwell(C)	silica/zirconia filler (83 wt%) Bis-MPEPP, TEGDMA, UDMA, photo initiators	Tokuyama Dental Tokyo, Japan	323
Z 250(C)	zirconia/silica filler (60 vol%) TEGDMA, UDMA, Bis-EMA	3M ESPE St. Paul, MN, USA	ABJ

A: compomer, B: Giomer, C: Composite
CDMA oligomer: Dimethacrylate functional oligomer derived from citric acid. ,
GDMA: Glyceryl dimethacrylate
TCB: Butane tetracarboxylic acid and hydroxyethylmethacrylate
HEMA: 2-Hydroxyethyl methacrylate, PENTA: Dipentaerythritol pentaacrylate phosphate,
UDMA: Urethane dimethacrylate, Bis-GMA: Bisphenol A glycidyl methacrylate,
TEGDMA: Tri-ethylene-glycol dimethacrylate,
Bis-MPEPP: 2,2-Bis(4-methacryloyloxypolyethoxyphenyl)propane,
Bis-EMA: Bisphenol A polyethellene glycol diether dimethacrylate
F-PRG: full reaction type of prereacted glass-ionomer

Table 2 System adhesive and self-etching adhesive components

Adhesive	**Composition and surface treatment**	**Manufacturer**	**Batch No.**
Primer/adhesive	Side A: HEMA, Methacrylated polycarboxylic acid Water, Ethanol, Photoinitiator Side B: Maleic acid, Water Primer/Adhesive (30 s) – air – light (10 s)	3M ESPE, St. Paul, MN, USA	ALAR
Prime & Bond 2.1	PENTA, Elastomeric resin, Short chain cross-linking resins, Amine hydrofluoride, Initiator, Stabilisers, Acetone Prime & Bond 2.1 (30 s) – air – light (10 s)	Dentsply/DeTrey Konstanz, Germany	DA990826
Hytac OSB	Co-momomer, Initiator, Acetone, Stabiliser Hytac OSB (30 s) – air – light (10 s)	3M ESPE AG Seefeld, Germany	FW0054808
Reactmer Bond	A: water, acetone, F-PRG filler, FASG filler, initiator B: 4-AET, 4-AETA, HEMA, UDMA, initiator A+B (20 s) – air (5 s) – light (20 s)	Shofu, Kyoto, Japan	IB 515
UniFil Bond	Self-etching primer: ethanol, water, HEMA,4-MET, Phototoinitiator Bonding agent: UDMA, HEMA, TEGDMA, silica filler Phototoinitiator Self-etching Primer (20 s) – air – Bonding Agent – light (10 s)	GC, Tokyo, Japan	090491
One-up Bond F	Bonding A: methacryloyloxyalkyl phosphate, MAC-10, bifunctional dimethacrylate, co-catalyst One-up Bond F (20s) – air – light (10 s)	Tokuyama Dental Tokyo, Japan	454720
Scotchbond Multi-Purpose,	Echant (7EE): 10% maleic acid, water Primer (7AC): HEMA, polyalkenoic acid, copolymer, water Adhesive (7AB): Bis-GMA, HEMA, Phototoinitiator Echant (15 s) – rinse & dry – Primer (30 s) – dry – Adhesive – light (30 s)	3M, St. Paul, MN USA	
Prompt L-Pop	methacrylated phosphoric acid ester, water, phosphine oxide, stabilizer, fluoride complex Single application: Prompt L-Pop (15 s) – air – light (10 s) Double application: Prompt L-Pop (15 s) – air – Prompt L-Pop (15 s) – air – light (10 s)	3M ESPE, Seefeld, Germany	FW66757

HEMA: 2-Hydroxyethyl methacrylate,
PENTA: Dipentaerythritol pentaacrylate phosphate,
GPDM: Glycerol phosphate dimethacrylate,
UDMA: Urethane dimethacrylate,
Bis-GMA: Bisphenol A glycidyl methacrylate,
TEGDMA: Tri-ethylene-glycol dimethacrylate,
4-MET: 4—methacryloxyethyl trimellitic acid,
MAC-10: 11-methacryloyloxy-1, 1-undecanedicarboxylic acid,
F-PRG filler: full-reaction-type pre-reacted glass-ionomer filler: ,
FASG filler: fluoroaluminosilicate glass filler,
4-AET: 4-acryloxyethyltrimellitic acid, ,
4-AETA: : 4-acryloxyethyltrimellitate anhydride

Table 3 Immediate marginal gaps (μm)

Restorative	In the tooth cavity (mean (SD))[a]			In the Teflon cavity (mean (SD))[a]
	Adhesive technique			
	Single application of *Prompt L-Pop*	Double application of *Prompt L-Pop*	System adhesive	
F 2000	11.2 (1.2) * A	10.1 (1.3) * A	12.9 (1.9) A	20.7 (2.1) A
Dyract AP	7.2 (2.3) * B	7.0 (2.0) * B	11.7 (5.2) A B	18.1 (1.7) A B C D
Hytac	8.9 (2.3) * A B	7.3 (1.9) * B	12.0 (2.4) A B	18.7 (4.5) A B C
Reactmer	7.2 (2.3) * B	6.8 (2.3) * B	9.9 (2.8) A B C	14.9 (1.8) D
UniFil F	7.1 (2.1) * # B	6.4 (1.5) * B	8.6 (2.2) # B C	15.3 (2.6) C D
Toughwell	6.9 (1.7) * B	6.2 (1.5) * B	7.6 (2.4) * C	15.7 (2.2) B C D
Z 250	8.5 (1.3) * B	8.2 (2.1) * A B	11.7 (1.5) A B	18.8 (1.8) A B

[a] N=10;

With each adhesive technique and Teflon cavity, mean values designated with the same letters (A,B,C,D) were not significantly different ($p > 0.05$).
With each product, means designated with the same symbols (*,#) were not significantly different ($p > 0.05$).

Table 4 The linear regression relationships between the marginal gaps in the tooth cavities and the marginal gaps in Teflon cavities

Adhesive technique	r	p value
Single application of prompt L-Pop	0.86	<0.02
Double application of prompt L-Pop	0.86	<0.02
System adhesive	0.89	<0.01

N=7

Table 5 Immediate shear bond strength to enamel (MPa, Mean (S.D., F))[a]

Restorative	Adhesive technique		
	Single application of *Prompt L-Pop*	Double application of *Prompt L-Pop*	System adhesive
F 2000	16.1 (3.5, 0) * A	15.6 (2.9, 0) * A B C	7.7 (1.1, 2) # A
Dyract AP	10.5 (2.3, 0) * B	12.2 (2.3, 0) * B	7.1 (5.2, 0) # A
Hytac	16.9 (2.8, 0) * A	18.8 (3.0, 0) * A	10.2 (2.9, 1) # A B
Reactmer	16.8 (3.2, 0) * A	18.3 (3.4, 0) * A	11.9 (2.8, 4) # B
UniFil F	11.8 (1.4, 0) * B C	12.8 (2.3, 0) * B C	9.6 (2.3, 1) # A B
Toughwell	10.1 (1.5, 0) * B	14.0 (1.5, 0) # B C	20.1 (2.6, 0) +
Z 250	14.7 (2.9, 0) * A C	17.8 (3.3, 0) # A C	25.0 (3.0, 0) +

[a] N=10; F: Number of adhesive failure modes;
Within each adhesive technique, mean values designated with the same letters are not significantly different (p＞0.05).
With each restorative, means designated with the same symbols (*,#, +) are not significantly different (p＞0.05).

Table 6 Immediate shear bond strength to dentin (MPa, Mean (S.D., F))[a]

Restorative	Adhesive technique		
	Single application of *Prompt L-Pop*	Double application of *Prompt L-Pop*	System adhesive
F 2000	10.0 (1.6, 0) * A	11.5 (1.8, 0) * A	10.5 (2.6, 0) * B
Dyract AP	8.9 (2.0, 0) * A B	10.0 (1.6, 0) * A B	10.5 (4.5, 1) * B
Hytac	8.5 (1.9, 0) * A B	10.1 (2.1, 0) * A B	5.7 (2.6, 0) # C
Reactmer	8.9 (1.5, 0) * A B	10.5 (2.4, 0) * A	8.8 (2.0, 0) * B C
UniFil F	8.0 (1.6, 0) * A B	9.6 (1.8, 0) * # A	11.4 (2.8, 0) # A B
Toughwell	7.1 (1.9, 0) * B	7.5 (2.5, 0) * B	15.1 (3.6, 0) # A
Z 250	7.8 (1.6, 0) * A B	10.2 (2.5, 0) # A B	9.8 (1.7, 0) # B

[a] N=10; F: Number of adhesive failure modes;
Within each adhesive technique, mean values designated with the same letters (A,B,C) are not significantly different (p＞0.05).
With each restorative, means designated with the same symbols (*,#) are not significantly different (p＞0.05).