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Effect of Mode of Application on the Microtensile Bond Strength of a Self-etch and Etch-and-Rinse Adhesive System

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Clinical Relevance

All Bond 3 and All Bond Self-Etch are versatile systems, capable of being used either in the full or simplified version. Both showed adequate microtensile bond strength results in enamel and dentin after 24 hours of water storage.

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DOI: 10.2341/09-319-L

SUMMARY

This study examined the 24-hour microtensile bond strength (µTBS) of a three-step etch-and-rinse (All Bond 3 [AB3]) and a two-step self-etch system (All Bond Self-Etch [ABSE]) to dentin and ground enamel, varying the application mode. Methods: AB3 was applied according to the following procedures: A–phosphoric acid + adhesive application. The adhesive was then light-cured before resin buildup. B–similar to Procedure A, except that a thin layer of bonding resin was applied over the cured adhesive; C–similar to Procedure B, however, the adhesive was not light-cured before application of the bonding resin. ABSE was applied according to the follow-

ing procedures: A–the acidic adhesive was applied and light-cured; B–after the acidic adhesive application and light-curing, a thin layer of ABSE Liner was applied and light cured; C–similar to B, however, the acidic adhesive was not light cured before application of the ABSE Liner. Resin composite buildups (Charisma) were bonded to teeth substrates after adhesive application. The bonded specimens were sectioned into beams 0.9 mm^2 after storage in water (24 hours/37°C) and subjected to µTBS with a crosshead speed of 0.5 mm/minute. The average values (MPa) obtained in each substrate were subjected to two-way repeated measures ANOVA and the Tukey's test (α=0.05). Results: No significant difference was observed among the experimental groups either in ground enamel or dentin. Conclusions: The 24-hour microtensile bond strength of All Bond 3 and All Bond Self-Etch was similar, regardless the mode of application of the adhesive systems.

INTRODUCTION

The development of adhesive systems has completely changed the traditional concepts of dentistry. Macromechanical retention is no longer required, as long as adhesive procedures are employed. Today, adhesive systems are widely used in direct procedures as restoration of anterior and posterior cavities, fissure sealing, reattachment of fractured fragments, corrections in tooth morphology and in indirect procedures involving cementation of root-canal posts and indirect ceramic and composite crowns.

However, as the development of these materials progressed, several adhesive systems, based on different bonding strategies and numbers of steps, were launched into the marketplace.[1] Based on management of the smear layer substrate, they can be classified as etch-and-rinse (ER) and self-etch (SE) systems. Both bonding strategies are also available in a full or simplified version. When the conditioning step is followed by a priming step and application of the adhesive resin, ER adhesives are available in three steps, or they are available in a two-step procedure when the primer and adhesive resin are joined into one application. Similarly, SE adhesives can employ two steps or a single one, depending on the way the acidic primer and bonding resin are provided by the manufacturer.

An immediate consequence of reducing the number of steps is sacrificing the universality of multi-bottle adhesives.[1-2] Most simplified versions (two-step etch-and-rinse and one-step self-etch systems) are capable of bonding only to light-cured composites.[3-4] Although the adhesion of chemically-cured and dual-cured composites may be improved with adjunctive use of ternary catalysts that offset the acid-base incompatibility between acidic methacrylate monomers and terniary amines,[5] the bonding efficacy of both two-step etch-and-rinse and one-step self-etch adhesives to chemically/dual-cured composites/resin cements is hampered by the intrinsic permeability of these systems to water, which results from their increase in hydrophilicity[6-8] and this might compromise their durability over time.[9] Therefore, the unconditional use of two-step etch-and-rinse and one-step self-etch materials in any clinical procedure can result in clinical failures in the short run.

Currently, clinicians prefer these simplified adhesives,[12] and this requires them to have more than one adhesive system in their office. When chemically-cured composites, resin cements or their polymerizable versions with delayed polymerization are not involved in the clinical procedure,[3,5,13-14] two-step etch-and-rinse and one-step self-etch materials can be safely employed. In all other clinical scenarios, bonding procedures with two-step etch-and-rinse and one-step self-etch should be avoided and the full version of both bonding strategies employed. Therefore, it would be of clinical interest to have versatile systems capable of being used either in the full (three-step etch-and-rinse and two-step self-etch systems) or simplified (two-step etch-and-rinse and one-step self-etch systems) version. Recently, versatile systems of both bonding strategies were released into the marketplace. According to the manufacturer, these adhesives can be used in a simplified or full version, as they are in the last case associated with a thin layer of a bonding resin. However, these materials still lack laboratory evidence on their performance.

Unfortunately, as emphasized by Coelho Santos and others,[15] differences in the adhesive application technique can affect many properties, such as film thickness and bond strength, mainly when simplified adhesives are compared with their full version. Pre-curing the adhesive is fully compatible with the direct application of composite restorations. However, this is not as clear for indirect bonded restorations. The thickness of the adhesive layer in luting procedures plays an important role in the correct seating of indirect restorations, and this depends on the amount of adhesive used and the number of light-curing procedures needed for bonding. Light-curing the primer (for ER adhesives) or acidic primer (for SE systems) before application of the bonding resin can result in an increase in the adhesive layer thickness,[15] which, depending on the adaptation of the crown to the prepared tooth structure, might affect the setting of the indirect restoration.

Therefore, the current study evaluated the resin-enamel and resin-dentin microtensile bond strength values of an etch-and-rinse and self-etch systems in simplified and full version with or without pre-curing of the primer/acidic primer. The null hypothesis tested was that both adhesives will perform equally, regardless of the different modes of application.

METHODS AND MATERIALS

Microtensile Bond Strength Evaluation

Forty-five extracted human third molars, stored in 0.5% chloramine for up to one year, were used in the current study. The teeth were randomly assigned to one of two bonding substrates: dentin or ground enamel. For dentin, five teeth were employed for each one of the six experimental conditions. For enamel, five tooth halves were employed for each condition.

On the basis of an expected microtensile bond strength of 45 MPa for All-Bond 3 for Procedure B for dentin,[16-17] and with an α of .05, a power of 80% and a one-sided test, the minimal sample size was five teeth in each group to detect a 20% difference between groups.[18]

For dentin, 30 teeth were used. The middle dentin was exposed by sectioning the crowns in a precision slow-speed diamond saw under water-cooling. The dentin was then polished with wet 600-grit SiC abrasive paper (Buhler, Lake Bluff, IL, USA) for 60 seconds to create a standardized smear layer. Etch-and-rinse All Bond 3 (BISCO, Inc, Schaumburg, IL, USA) and self-etch All Bond Self-Etch (BISCO, Inc) were evaluated and applied according to three different modes, as depicted in Table 1.

For enamel, a total of 15 teeth were used. First, they were sectioned in a mesio-to-distal direction to obtain tooth halves. The buccal and lingual surfaces of these teeth were cleaned with slurry of pumice and water and examined under a 40x stereomicroscope (HMV-2, Shimadzu, Tokyo, Japan) to ensure that they were free of surface cracks, decalcification or any sign of previous grinding. The enamel was then demarcated to outline the flattest area for bonding. The mid-coronal third of the buccal and lingual surfaces was usually outside the bonding area, due to their inclination. The enamel surface was flattened with a fine-grit diamond bur (#2135F, KG Sorensen, Barueri, São Paulo, Brazil) attached in a high-speed handpiece under water irrigation in order to remove approximately 0.5 mm of the superficial enamel layer. The abraded surfaces were then polished with wet 600-grit SiC paper to produce a standard smear layer. All Bond 3 and All Bond-Self Etch were applied according to the modes of application depicted in Table 1.

In summary for All Bond 3, the following procedures were tested:

PROCEDURE A: 1. Application of 32% phosphoric acid (15 seconds), followed by rinsing (15 seconds) and air drying (15 seconds); 2. Mixing Part A and Part B (1:1) until a uniform color was achieved; 3. Application of one coat of the adhesive under vigorous pressure (15-20 seconds) to wet the dentin or dry the enamel; 4. Air drying of the adhesive using a gentle stream of air for 15 seconds; 5. In case the substrate was not shiny, procedures 3 and 4 were repeated; 6. Light-activation (10 seconds–500 mW/cm^2).

PROCEDURE B: 7. After steps 1 through 6 from Procedure A, a thin layer of All Bond 3 Resin was applied; 8. And light-activated (10 seconds–500 mW/cm^2).

PROCEDURE C: 6. After steps 1 through 5 from Procedure A, a thin layer of All Bond 3 Resin was applied; 7. And light-activated (10 seconds–500 mW/cm^2).

In Procedure A, All Bond 3 was used as a two-step etch-and-rinse adhesive, therefore, the All Bond 3 Resin was not applied after adhesive application. In Procedures B and C, this material was used in the three-step approach and, therefore, a thin layer of All Bond 3 Resin was applied over the adhesive. The main difference between Procedures B and C is that, in Procedure B, the adhesive was light-cured before application of All Bond 3 Resin, whereas in Procedure C, the All Bond 3 Resin was applied over the uncured adhesive (Table 1).

In summary for All Bond Self-Etch, the following procedures were tested:

PROCEDURE A: 1. Mixing Part I and Part II (1:1) until uniformly pink; 2. Application of one coat of the adhesive under vigorous pressure (15-20 seconds); 3. Air thinning of the adhesive using a strong air stream for 15 seconds; 4. In case the substrate was not shiny, procedures 1 and 2 were repeated; 5. Light-activation (10 seconds–500 mW/cm^2).

PROCEDURE B: 6. After steps 1 through 5 from Procedure A, a thin layer of All Bond SE Liner was applied; 7. Light-activation (10 seconds–500 mW/cm^2).

PROCEDURE C: 5. After steps 1 to 4 from Procedure A, a thin layer of All Bond SE Liner was applied; 6. Light-activation (10 seconds – 500 mW/cm^2).

For All Bond Self-Etch, Procedure A represents use of the material in a one-step approach. Procedures B and C represent use of the material as a two-step self-etch system. Therefore, a thin layer of All Bond SE Liner was applied after application of the acidic adhesive. As for All Bond 3, the main difference between Procedures B and C is that, in Procedure B, the acidic adhesive was light-cured before applying the All Bond SE Liner, whereas in Procedure C, the All Bond SE Liner was applied over uncured acidic adhesive (Table 1).

All the adhesives were applied in a controlled environment (24°C/75% relative humidity) by a single oper-

Table 1: *Adhesive Systems, Batch Number and Application Mode*

Adhesive Systems	Composition	Application Mode	Batch #
All-Bond 3 (BISCO, Inc)	Uni-etch–32% phosphoric acid and benzalkonium chloride; Part A–Ethanol and glycine-glycidyl methacrylate salt Part B–Bisphenol "A"diglycidil methacrylate, bisphenyl dimethacrylate, hydroxyethyl methacrylate; All Bond 3 Resin–bisphenol A diglycidylmethacrylate, urethane dimethacrylate, trieethyleneglycol dimethacrylate, glass frit	*PROCEDURE A* 1. Application of 32% phosphoric acid (15 seconds) followed by rinsing (15 seconds) and air drying (15 seconds); 2. Mixing Part A and Part B (1:1) until the achievement of an uniform color; 3. Application of one coat of the adhesive under vigorous pressure (15-20 seconds) to wet dentin or dry enamel; 4. Air drying of the adhesive using a gentle stream of air for 15 seconds; 5. In case the substrate was not shiny, procedures 3 and 4 were repeated; 6. Light-activation (10 seconds–500 mW/cm²). *PROCEDURE B* 7. After steps 1 to 6 from procedure A, a thin layer of All Bond 3 Resin was applied; 8. Light-activation (10 seconds–500 mW/cm²). *PROCEDURE C* 6. After steps 1 to 5 from procedure A, a thin layer of All Bond 3 Resin was applied; 7. Light-activation (10 seconds–500 mW/cm²).	0600011757 0600007325 0600007338
All Bond Self-Etch (BISCO, Inc)	Part I–Ethanol, sodium benzene sulfinate dehydrate. Part II–Bis(glyceryl 1,3 dimethyacrylate) phosphate; hydroxyethyl methacrylate, biphenyl dimetacrylate All Bond SE Liner: Bisphenol A diglycidyl methacrylate, urethane dimethacrylate, hydroxyethyl methacrylate, glass frit	*PROCEDURE A* 1. Mixing of Part I and Part II (1:1) until uniformly pink; 2. Application of one coat of the adhesive under vigorous pressure (15-20 seconds); 3. Air thinning of the adhesive using a strong air stream for 15 seconds; 4. In case the substrate was not shiny, procedures 1 and 2 were repeated; 5. Light-activation (10 seconds–500 mW/cm²). *PROCEDURE B* 6. After steps 1 to 5 from procedure A, a thin layer of All Bond SE Liner was applied; 7. Light-activation (10 seconds–500 mW/cm²). *PROCEDURE C* 5. After steps 1 to 4 from procedure A, a thin layer of All Bond SE Liner was applied; 6. Light-activation (10 seconds–500 mW/cm²).	0600010907 0600007324 0600007395

ator using the bonding protocols summarized in Table 1. The light-curing step was performed with a VIP unit (500 mW/cm², BISCO, Inc). Resin composite buildups (Charisma, Heraeus Kulzer, Hanau, Germany) were incrementally constructed in three 1-mm thick increments, each being light-cured for 40 seconds at 500 mW/cm² (VIP, BISCO, Inc).

After storage in distilled water at 37°C for 24 hours, the specimens were sectioned perpendicular to the adhesive-tooth interface using a Labcut diamond saw (Extec, Enfield, CT, USA) to obtain rectangular beams (0.9 mm²). The beams were prepared with the resin composite forming the upper half of the beam and the underlying enamel and dentin forming the lower half. The number of prematurely debonded beams (PD) per tooth during specimen preparation was recorded. The cross-sectional area of each stick was measured with a digital caliper to the nearest 0.01 mm and recorded for calculation of the microtensile bond strength (Absolute Digimatic, Mitutoyo, Tokyo, Japan).

The beams from each adhesive group were stressed to failure under tensile using a universal testing machine mounted with the Geraldeli Jig[19] (Emic, São José dos Pinhais, PR, Brazil) at a crosshead speed of 0.5 mm/minute. The force until fracture was measured in Newtons and the bond strength was calculated in MPa.

The bond failure modes were evaluated at 40x under a light stereomicroscope (HMV-2, Shimadzu, Tokyo, Japan) and classified as cohesive (more than 50% of failures within enamel or resin composite) and adhesive (more than 50% of failure at the resin/enamel or resin/dentin interface) or mixed (adhesive/cohesive fracture—when no predominant pattern occurred).

The bonded sticks that did not survive specimen preparation (premature debonded specimens) were recorded, but they were not included in the tooth mean for statistical analysis. Only sticks with adhesive or mixed failure modes were considered for statistical purposes.

The experimental unit in the current study was the tooth (dentin) and hemi-tooth (enamel). The mean of the microtensile bond strength values of all sticks from the same tooth/hemi-tooth were averaged for statistical purposes. As the normality (Kolmogorow-Smirnoff test) and homoscedasticity assumptions (Levene test) of the data appeared to be valid,[20] a two-way analysis of variance was used to examine the effects of the "adhesive system" and "mode of application" and the interaction of these two factors on microtensile bond strength. Post hoc multiple comparisons were carried out using the Tukey's test, with a statistical significance set at α=0.05.

RESULTS

The range of cross-sectional area was 0.82 mm^2 to 0.96 mm^2 for ground enamel and 0.87 mm^2 to 0.97 mm^2 for dentin. No significant difference among the treatment groups was detected (p>0.05). The percentage of specimens (%) according to the fracture pattern and the percentage of premature debonded (PD) specimens for each experimental condition are depicted in Table 2.

The results (Table 3) from the two-way ANOVA for ground enamel and dentin revealed that the main factors Adhesive and Mode of Application and the interaction Adhesive vs Mode of Application were not statistically significant (p>0.05) (Tables 4 and 5). The overall means and standard deviations (MPa) of the bond strength means are shown in Table 3.

For All Bond Self-Etch, the highest resin-enamel and resin-dentin bond strength values were obtained for Procedure C (24.2 ± 14.2MPa) and Procedure B (44.1 ± 11.9 MPa), respectively. However, these groups were not statistically different from the others within the same substrate.

For All Bond 3, the highest resin-enamel and resin-dentin microtensile bond strength values were obtained for Procedure A (27.1 ± 10.1) and Procedure C (43.2 ± 11.3), respectively; however, these groups were not different from the others performed in the same substrate.

DISCUSSION

The results of the current study show that the etch-and-rinse adhesive applied in either full or simplified version demonstrated similar resin-dentin and resin-enamel bond strength values. Earlier studies that compared the performance of three-step vs two-step etch-and-rinse adhesives showed controversial findings. While some authors have demonstrated that three-step etch-and-rinse materials are superior to their simplified version in terms of bond strength values,[21] other authors demonstrated that similar bond strength values can be achieved using both versions.[22] This lack of consensus suggests that one cannot make any generalized statement regarding the 24-hour performance of simplified and full versions of etch-and-rinse materials, since they may be material-dependent.[23]

The current study verified that the resin-enamel bond strength values were similar for both versions of the etch-and-rinse systems. This finding could be attributed to the fact that the same acidic conditioner was used in both cases. Enamel etched with 30%-40% phosphoric acid guarantees effective adhesion through selective demineralization of prismatic and aprismatic enamel and simple micro-mechanical interlocking upon polymerization of bonding resin *in situ*.[24] Although the ultimate strength and degree of cure of the bonding resin plays a role in the measured resin-enamel and resin-dentin bond strength,[25-27] one could conclude that the presence of solvents in simplified versions might impair the formation of a strong polymer.[28] However, as long as care is taken to allow for the appropriate evaporation of solvents, mainly ethanol-containing systems,[29] the polymer formed within created enamel porosities might be strong enough (for both

Table 2: *Number and Percentage of Specimens (%) According to the Fracture Pattern* or Premature Debonded Failures (PD) for Each Experimental Condition*

Adhesive Systems		Ground Enamel				Dentin			
		A/M	R	D	PD	A/M	R	D	PD
All Bond Self-Etch	Procedure A	43 (52.4)	0	0	39 (47.6)	80 (97.6)	1 (1.2)	0	1 (1.2)
	Procedure B	52 (74.3)	0	0	18 (25.7)	71 (98.6)	0	0	1 (1.4)
	Procedure C	45 (62.5)	0	0	27 (37.5)	81 (98.8)	0	0	1 (1.2)
All-Bond 3	Procedure A	48 (62.3)	5 (6.6)	2 (2.6)	21 (27.6)	61 (98.4)	0	0	1 (1.6)
	Procedure B	35 (44.3)	13 (16.4)	1 (1.3)	30 (38.0)	61 (98.4)	0	1 (1.6)	0
	Procedure C	45 (57.0)	13 (16.4)	4 (5.1)	17 (21.5)	83 (96.5)	0	2 (2.3)	1 (1.2)

**A/M = adhesive or mixed failure; R = cohesive failure in resin; D = cohesive failure in dentin; PD = premature debonded failure.*

Table 3: *Mean, Standard Deviation (MPa) and Statistical Significance of Bond Strength Indexes at Each Experimental Condition (*)*

Adhesive Systems		Ground Enamel	Dentin
All Bond Self-Etch	Procedure A	19.21 ± 7.12 a (43)	41.32± 10.10 b (81)
(BISCO, Inc)	Procedure B	23.62 ± 10.13 a (52)	44.13 ± 11.90 b (71)
	Procedure C	24.21 ± 12.21 a (45)	35.61 ± 12.14 b (81
All-Bond 3	Procedure A	27.14 ± 10.14 a (55)	42.44 ± 11.20 b (61)
(BISCO, Inc)	Procedure B	25.53 ± 9.20 a (49)	38.11 ± 13.10 b (62)
	Procedure C	26.92 ± 9.70 a (62)	43.20 ± 11.33 b (85)

(*) Same letters in each column indicate no statistically significant difference (p>0.05).

Table 4: *Analysis of Variance for Resin-enamel Microntesile Bond Strength Data*

	df Effect	MS Effect	df Error	MS Error	F	*p*-level
Mode of application	2	13.9893	24	101.1373	0.13832	0.871509
Adhesive	1	110.2083	24	101.1373	1.08969	0.306941
Interaction	2	25.5693	24	101.1373	0.252818	0.778652

Table 5: *Analysis of Variance for Resin-dentin Microntesile Bond Strength Data*

	df Effect	MS Effect	df Error	MS Error	F	*p*-level
Mode of application	2	17.7143	24	103.9288	0.170447	0.844300
Adhesive	1	11.7813	24	103.9288	0.113360	0.739278
Interaction	2	119.0463	24	103.9288	1.145460	0.334862

ethanol-containing etch-and-rinse versions) to allow for achievement of a strong bond.

However, the results of the All Bond Self-Etch adhesive were surprising. Several studies have consistently shown that one-step self-etch adhesives do not perform as well as two-step self-etch systems.[2,30-31] Studies that compared both versions from the same manufacturer, Clearfil SE Bond and Clearfil S3 Bond) have demonstrated superiority of the two-step version.[32-33]

The high permeability of the adhesive layer formed by one-step self-etch systems,[6,14,34-36] the phase separation between hydrophilic and hydrophobic monomers[37] that these materials are prone to, the lower hydrolytic stability of acidic monomers into low pH solutions[38] and finally, the higher amount of solvents included in these adhesive solutions[39] are usually the factors that explain the lower performance of simplified self-etch materials.

One of the factors that differentiates the adhesive All Bond Self-Etch from most one-step self-etch materials evaluated in the aforementioned studies is the fact that All Bond Self-Etch is a two-component one-step self-etch adhesive, which means that water and acidic monomers are packaged in separate bottles. This seems to be advantageous, since it was already reported that acidic methacrylates become hydrolyzed in aqueous solutions when the pH values are below 2.[38] Thus, while different from single-component self-etch systems, All Bond Self-Etch is more likely hydrolytically stable.

In enamel, no significant difference was detected between the simplified and full version of the self-etch system. As the pH of All Bond 2 is quite high (approximately 2.2 according to the manufacturer), one would expect lower bond strength values in enamel when compared to etch-and-rinse adhesives. However, this was not the case. Recent studies have demonstrated that the good performance of self-etch systems in enamel cannot solely be attributed to a retentive etching pattern. Mild self-etch systems are not capable of producing a deep, retentive etching pattern similar to that obtained with phosphoric acid,[40-41] and this does not necessarily mean that their performance is inferior to that observed with more acidic self-etch systems.[30-31] As long as a high-strength bonding resin is applied over an enamel surface conditioned with mild or strong self-etch systems, high bond strength values can be achieved.[40]

Although the current study demonstrated that both versions of the etch-and-rinse and self-etch adhesive can provide high bond strength values, this does not mean that they can be used unconditionally in all clinical scenarios. No one can deny that the adhesive layer formed by the single application of phosphoric acid + primer (etch-and-rinse approach) or acidic primer (self-etch approach) will be much more hydrophilic and permeable to water.[6-8,34] Therefore, based on previous literature findings, the authors of the current study do not advise the use of simplified adhesive versions with chemically/dual-cured composites/resin cements.[4,6,8,13-14] In addition, one can also expect that durability of the bonded interfaces formed with simplified adhesives will be shorter than that formed when the primed surfaces are covered with a hydrophobic bonding resin.

Further studies should be conducted in order to validate the above hypothesis.

When chemically- or dual-cured composites or resin cements are to be used, the primer surfaces should be covered with a hydrophobic adhesive layer. The application of All Bond 3 Resin and All Bond SE Liner for the etch-and-rinse and the self-etch adhesives, respectively, overcomes the concerns associated with the high permeability of hydrophilic adhesive layers and improves adhesive bonding to composites, regardless of their mode of cure.[2,14,37] Also, the bonding resin layers of both adhesives are HEMA-free and are likely to be less hydrophilic than other bonding resins that contain HEMA.[39]

Although it is known that the application of a hydrophobic layer prevents incompatible issues, it is not known whether the primer should be pre-cured or not and if this has any effect on the immediate microtensile bond strength values of both adhesives. When seating and cementing an indirect restoration, the application and curing of the adhesive system immediately before insertion of the indirect composite or ceramic restoration can increase the thickness of the adhesive layer and interfere with complete seating of the restoration.[15,42] According to Magne and others,[43] the thickness of the light-cured primer can vary significantly, based on surface geometry. On smooth convex surfaces, the adhesive layer can be 60-80 µm, while in concave regions, such as the marginal chamfer, the thickness of the adhesive layer might be as high as 200-300 µm.[44-45]

It is likely that thicker adhesive layers are observed in flat surfaces when the primer is pre-cured before the application of bonding resin. As both modes of application could yield high bond strength values when bonding direct composites, one can suggest that the bonding of indirect composites can be done without pre-curing the primer. Unfortunately, this issue has not been evaluated in laboratory studies and should be further investigated.

CONCLUSIONS

The use of an extra layer of Resin/Liner for All Bond 3 and All Bond Self-Etch did not improve resin-enamel and resin-dentin bond strength. The previous light-curing of the adhesive before resin/liner application also did not affect bond strength on both tooth substrates.

(Received 20 October 2009; accepted 18 February 2010)

References

1. Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P, Van Landuyt K, Lambrechts P & Vanherle G (2003) Buonocore Memorial Lecture. Adhesion to enamel and dentin: Current status and future challenges *Operative Dentistry* **28(3)** 215-235.
2. King NM, Tay FR, Pashley DH, Hashimoto M, Ito S, Brackett WW, Garcia-Godoy F & Sunico M (2005) Conversion of one-step to two-step self-etch adhesives for improved efficacy and extended application *American Journal of Dentistry* **18(2)** 126-134.
3. Sanares AM, King NM, Itthagarun A, Tay FR & Pashley DH (2001) Adverse surface interactions between one-bottle light-cured adhesives and chemical-cured composites *Dental Materials* **17(6)** 542-556.
4. Cheong C, King NM, Pashley DH, Ferrari M, Toledano M & Tay FR (2003) Incompatibility of self-etch adhesives with chemical/dual-cured composites: Two-step vs one-step systems *Operative Dentistry* **28(6)** 747-755.
5. Suh BI, Feng L, Pashley DH & Tay FR (2003) Factors contributing to the incompatibility between simplified-step adhesives and self-cured or dual-cured composites Part III. Effect of acidic resin monomers *Journal of Adhesive Dentistry* **5(4)** 267-282.
6. Tay FR, Pashley DH, Yiu CK, Sanares AM & Wei SH (2003) Factors contributing to the incompatibility between simplified-step adhesives and self-cured or dual-cured composites Part I. Single-step self-etch adhesive *Journal of Adhesive Dentistry* **5(1)** 27-40.
7. Tay FR & Pashley DH (2003) Have dentin adhesive become too hydrophilic? *Journal of the Canadian Dental Association* **69(11)** 726-731.
8. Tay FR, Suh BI, Pashley DH, Prati C, Chuang SF & Li F (2003) Factors contributing to the incompatibility between simplified-step adhesives and chemical-cured or dual-cured composites Part II. Single-bottle, total-etch adhesive *Journal of Adhesive Dentistry* **5(4)** 91-106.
9. De Munck J, Van Meerbeek B, Yoshida Y, Inoue S, Suzuki K & Lambrechts P (2004) Four-year water degradation of a resin-modified glass-ionomer adhesive bonded to dentin *European Journal of Oral Science* **112(1)** 73-83.
10. van Dijken JW (2004) Durability of three simplified adhesive systems in Class V non-carious cervical dentin lesions *American Journal of Dentistry* **17(1)** 27-32.
11. Loguercio AD, Costenaro A, Silveira AP, Ribeiro NR, Rossi TR & Reis A (2006) A six-month clinical study of a self-etching and an etch-and-rinse adhesive applied as recommended and after doubling the number of adhesive coats *Journal of Adhesive Dentistry* **8(4)** 255-261.
12. CRA newsletter. Single-bottle self-etch adhesives April, 2005. http://www.cranews.com/additional_study/2005/05-04/index.htm. Visited in February 24, 2006.
13. Tay FR, Pashley DH & Peters MC (2003) Adhesive permeability affects composite coupling to dentin treated with a self-etch adhesive *Operative Dentistry* **28(5)** 610-621.
14. Carvalho RM, Pegoraro TA, Tay FR, Pegoraro LF, Silva NRFA & Pashley DH (2004) Adhesive permeability affects coupling of resin cements that utilise self-etching primers to dentine *Journal of Dentistry* **32(1)** 55-65.
15. Coelho Santos MJ, Navarro MF, Tam L & McComb D (2005) The effect of dentin adhesive and cure mode on film thickness and microtensile bond strength to dentin in indirect restorations *Operative Dentistry* **30(1)** 50-57.

16. Hashimoto M, Ohno H, Kaga M, Sano H, Endo K & Oguchi H (2002) Fractured surface characterization: Wet versus dry bonding *Dental Materials* **18(2)** 95-102.

17. Tay FR, Pashley DH, Suh BI, Carvalho RM & Itthagarun A (2002) Single-step adhesives are permeable membranes *Journal of Dentistry* **30(7-8)** 371-382.

18. Pocock SJ (1993) The size of a clinical trial In: Pocock SJ *Clinical Trials: A Practical Approach* Chichester, England, Wiley 123-141.

19. Perdigão J, Geraldeli S, Carmo AR & Dutra HR (2002) *In vivo* influence of residual moisture on microtensile bond strengths of one-bottle adhesives *Journal of Esthetic & Restorative Dentistry* **14(1)** 31-38.

20. Montgomery DC (1991) *Design and Analysis of Experiments* 5th edition John Wiley & Sons, Inc, New York.

21. Tjan AH, Castelnuovo J & Liu P (1996) Bond strength of multi-step and simplified-step systems *American Journal of Dentistry* **9(6)** 269-272.

22. Wilder AD Jr, Swift EJ Jr, May KN Jr & Waddell SL (1998) Bond strengths of conventional and simplified bonding systems *American Journal of Dentistry* **11(3)** 114-117.

23. Inoue S, Vargas MA, Abe Y, Yoshida Y, Lambrechts P, Vanherle G, Sano H & Van Meerbeek B (2001) Microtensile bond strength of eleven contemporary adhesives to dentin *Journal of Adhesive Dentistry* **3(3)** 237-245.

24. Buonocore MG (1955) A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces *Journal of Dental Research* **34(6)** 849-853.

25. Takahashi A, Sato Y, Uno S, Pereira PN & Sano H (2002) Effects of mechanical properties of adhesive resins on bond strength to dentin *Dental Materials* **18(3)** 263-268.

26. Kanehira M, Finger WJ, Hoffmann M, Endo T & Komatsu M (2006) Relationship between degree of polymerization and enamel bonding strength with self-etching adhesives *Journal of Adhesive Dentistry* **8(4)** 211-216.

27. Reis A, Grandi V, Carlotto L, Bortoli G, Patzlaff R, Accorinte MLR & Loguercio AD (2005) Effect of smear layer thickness and acidity of self-etching solutions on early and long-term bond strength to dentin *Journal of Dentistry* **33(7)** 549-559.

28. Ikeda T, De Munck J, Shirai K, Hikita K, Inoue S, Sano H, Lambrechts P & Van Meerbeek B (2005) Effect of evaporation of primer components on ultimate tensile strengths of primer-adhesive mixture *Dental Materials* **21(11)** 1051-1058.

29. Nunes TG, Garcia FC, Osorio R, Carvalho R & Toledano M (2006) Polymerization efficacy of simplified adhesive systems studied by NMR and MRI techniques *Dental Materials* **22(10)** 963-972.

30. De Munck J, Van Meerbeek B, Satoshi I, Vargas M, Yoshida Y, Armstrong S & Lambrechts P (2003) Microtensile bond strengths of one- and two-step self-etch adhesives to bur-cut enamel and dentin *American Journal of Dentistry* **16(6)** 414-420.

31. Inoue S, Vargas MA, Abe Y, Yoshida Y, Lambrechts P, Vanherle G, Sano H & Van Meerbeek B (2003) Microtensile bond strength of eleven contemporary adhesives to enamel *American Journal of Dentistry* **16(5)** 329-334.

32. Perdigão J, Gomes G, Gondo R & Fundingsland JW (2006) *In vitro* bonding performance of all-in-one adhesives Part I—microtensile bond strengths *Journal of Adhesive Dentistry* **8(6)** 367-373.

33. Sadr A, Shimada Y & Tagami J (2007) Effects of solvent drying time on micro-shear bond strength and mechanical properties of two self-etching adhesive systems *Dental Materials* **23(9)** 1114-1119.

34. Tay FR, Pashley DH, Suh BI, Carvalho RM & Itthagarun A (2002) Single-step adhesives are permeable membranes *Journal of Dentistry* **30(7-8)** 371-382.

35. Grégoire G, Joniot S, Guignes P & Millas A (2003) Dentin permeability: Self-etching and one-bottle dentin bonding systems *Journal of Prosthetic Dentistry* **90(1)** 42-49.

36. Tay FR, Pashley DH, Suh BI, Hiraishi N & Yiu CKY (2005) Water treeing in simplified adhesives—déjà vu? *Operative Dentistry* **30(5)** 561-579.

37. Van Landuyt K, De Munck J, Snauwaert J, Coutinho E, Poitevin A, Yoshida Y, Inoue S, Peumans M, Suzuki K, Lambrechts P & Van Meerbeek B (2005) Monomer-solvent phase separation in one-step self-etch adhesives *Journal of Dental Research* **84(2)** 183-188.

38. Nishiyama N, Suzuki K, Yoshida H, Hideki T & Nemoto K (2004) Hydrolytic stability of methacrylamide in acidic aqueous solution *Biomaterials* **25(6)** 965-969.

39. Yiu CK, Pashley EL, Hiraishi N, King NM, Goracci C, Ferrari M, Carvalho RM, Pashley DH & Tay FR (2005) Solvent and water retention in dental adhesive blends after evaporation *Biomaterials* **26(34)** 6863-6872.

40. Pashley DH & Tay FR (2001) Aggressiveness of contemporary self-etching adhesives Part II: Etching effects on unground enamel *Dental Materials* **17(5)** 430-444.

41. Moura SK, Pelizzaro A, Dal Bianco K, de Goes MF, Loguercio AD, Reis A & Grande RH (2006) Does the acidity of self-etching primers affect bond strength and surface morphology of enamel? *Journal of Adhesive Dentistry* **8(2)** 75-83.

42. Haller B, Hassner K & Moll K (2003) Marginal adaptation of dentin bonded ceramic inlays: Effects of bonding systems and luting resin composites *Operative Dentistry* **28(5)** 574-584.

43. Magne P (2005) Immediate dentin sealing: A fundamental procedure for indirect bonded restorations *Journal of Esthetic & Restorative Dentistry* **17(3)** 144-155.

44. Pashley EL, Comer RW, Simpson MD, Horner JA, Pashley DH & Caughman WF (1992) Dentin permeability: Sealing the dentin in crown preparations *Operative Dentistry* **17(1)** 13-20.

45. Magne P & Douglas WH (1999) Porcelain veneers: Dentin bonding optimization and biomimetic recovery of the crown *International Journal of Prosthodontics* **12(2)** 111-121.