Shear and micro-shear bond strengths of four self-etching adhesives measured immediately and 24 hours after application

Choltacha HARNIRATTISAI¹, Panitta ROENGRUNGREANG², Utumporn RANGSISIRIPAIBOON¹ and Pisol SENAWONGSE¹

¹ Department of Operative Dentistry and Endodontics, Mahidol University, 6 Yothee Road, Rajthwee, Bangkok 10400, Thailand

² Kamphaeng Hospital, Ministry of Public Health, Nakhonprathom province, Thailand

Corresponding author, Choltacha HARNIRATTISAI; E-mail: dtchn@mahidol.ac.th

This study measured the immediate and 24 h shear (SBS) and micro-shear bond strengths (MSBS) to dentin of four self-etching adhesives. A resin composite was bonded using each adhesive to the area of 5-mm diameter for SBS test or 0.75-mm diameter for MSBS test of flat bovine dentin. The bond strengths of all adhesives at 10 min were lower than at 24 h for both tests. The mean SBS (MPa, 10 min, 24 h) were similar in ranking order at both time periods that is: Clearfil SE Bond (21.2, 25.3) > Clearfil TriS Bond (12.7, 19.5) = i Bond (11.7, 19.5) = G Bond (11.1, 16.6). For the MSBS test, G Bond provided equivalent mean bond strength (35.0) to Clearfil SE Bond (36.9) and higher than the other adhesives at 24 h [i Bond (26.3), Clearfil TriS Bond (28.5)]. In conclusion, the MSBS test was slightly more discriminating than the SBS test.

Keywords: Micro-shear bond strength, Shear bond strength, Immediate bond strength, Self-etching adhesives

INTRODUCTION

Bond strength tests are commonly used to evaluate the bonding ability of new dental adhesives. Most laboratory bond strength tests are performed at 24 h after finishing the bonding process and water storage of the specimens. However, in clinical situations, the bonded interface is subjected to various kinds of stress immediately after restoration. These stresses are polymerization shrinkage of the resin composite (which has been reported to occur approximately 80% during the first 15 min after light curing^{1,2}) and stress from occlusal adjustment and polishing procedures of the restoration. Many studies have reported that the bond strengths of dentin adhesives to dentin tested at 10 min were lower than those tested after 24 h storage in water^{3,4}.

Currently, self-etching adhesives are increasingly used and possess some advantages compared to total-etching adhesives such as simplified bonding procedures, less technique sensitivity, and less postoperative sensitivity^{5,6}. Self-etching adhesives can be classified as 2-step, self-etching primer/adhesives and one-step, self-etching adhesives. One-step, self-etching adhesive is manufactured as two bottles, which require mixing before use, or one bottle (all-in-one) system. Previous studies have reported lower bond strengths at 24 h of some one-step, self-etching adhesives compared to two-step self-etching primer/adhesives⁷⁻⁹. However, the data concerning early bond strengths is limited for the more recently marketed all-in-one self-etching adhesives¹⁰.

Several bond strength tests have been used to evaluate the adhesive performance of dentin adhesives^{6,11-13}. The most commonly used are the shear and tensile tests¹⁴. Even though the validity of the shear test has been questioned^{15,16}, this test is frequently used due to its reproducible and relatively uncomplicated

method. Micro bond tests such as micro-tensile and micro-shear tests have been introduced and are useful methods to test the bond strength of the adhesives to small areas of substrates¹².

This results in reducing the number of teeth employed and the subsequent reduction of inter-teeth variables such as age and type of the tooth, surface preparation and amount of adhesive coverage. It has been suggested that the micro-shear bond strength test has many advantages over the micro-tensile test which is difficult to conduct and is time consuming¹⁷. Preparation of the specimens for the micro-shear bond test is relatively easy and multiple samples can be made without trimming of the sample after the bonding procedure as in the micro-tensile test. Many studies have compared the efficiency of micro-tensile tests with that of conventional shear and tensile tests^{18,19}. However, so far, the only published papers comparing the shear and micro-shear bond strength test have been one study using a finite elemental analysis²⁰ and one critical literature review¹³. There is limited information on direct comparison of micro shear and shear bond strength tests in the same study¹¹.

The purpose of this *in vitro* study was to compare the bond strengths of 4 self-etching adhesives measured immediately and after 24 h using a shear and a micro shear bond strength test. The null hypotheses tested were: (1) there is no difference between early and 24 h bond strengths to dentin of all self-etching adhesives used; (2) the bond strengths of the same time periods of adhesives used are equivalent regardless of the test methods and (3) shear bond strength test and micro-shear bond strength test are comparable methods.

MATERIALS AND METHODS

The shear bond strength test

One hundred and twenty bovine lower incisors which were stored in a frozen condition (-70°C) were used within 3 months after extraction. The teeth were embedded in chemically cured acrylic resin before the flat superficial dentin surfaces were exposed by grinding the labial enamel surfaces with a model trimmer. The exposed dentin surface of each tooth was finished with 600-grit silicon carbide paper (Struers, Ballerup, Denmark) under running water and at constant weight

for 20 s in order to standardize the resulting smear layers. A rectangular silicone mold with a cylindrical-shaped perforation with a height of 4 mm and a 5 mm internal diameter was fixed on the middle of the dentin surface by applying cyanoacrylate adhesive at the outer rim of the mold to demarcate the bonding area. The adhesive systems, compositions, batch numbers and manufacturers are shown in Table 1. All adhesive systems were applied strictly according to the manufacturers' instructions in the area delimited by the silicone mold. Before light-curing, a dry small brush was used to clear the adhesive resin that wicks up the

Table 1 Adhesives used, composition, batch number and manufacturers

Material	Composition	Lot No.	Manufacturer
Clearfil SE Bond ^a	Primer 10-Methacryloyloxydecyl dihydrogen phosphate (MDP) Hydrophilic demethacrylate Water, Camphorquinone, N,N-Diethanol p-toluidine	81114	Kuraray Co Ltd, Okayama, Japan
	Bond 10-Methacryloyloxydecyl dihydrogen phosphate (MDP) Bis-Phenol A diglycidylmethacrylate(Bis-GMA) 2-Hydroxyethyl methacrylate(HEMA) Hydrophobic dimethacrylate Camphorquinone, N,N-Diethanol p-toluidine Silanated colloidal silica		
Clearfil Tri-S Bond ^b	MDP, Bis-GMA, HEMA, Hydrophobic dimethacrylate dl-Camphorquinone, Ethyl alcohol, Water Silanated colloidal silica	51116	Kuraray Co Ltd, Okayama, Japan
G-Bond ^c	Acetone Distilled Water 4-Methacryloxy ethyltrimellitate anhydride Phosphoric ester monomer Urethane dimethacrylate Triethyleneglycol dimethacrylate	0509201	GC Co, Tokyo, Japan
i-Bond ^d	Acetone Distilled Water 4-Methacryloxy ethyltrimellitate anhydride Urethane dimethacrylate glutaraldehyde Photo initiators stabilizers	010076	Kulzer, Germany
Light-activated restorative materials Filtek Z250 ^e	Zirconia&silica filler TEGDMA UDMA Bis-EMA	20050627	3M ESPE, St Paul, MN, USA

^a Composition from manufacturer's instruction

^b Composition from manufacturer's instruction

^c Composition from Spreafico D *et al.* The effect of the air-blowing step on the technique sensitivity of four different adhesive systems. J Dent 2006; 34: 267-244

^d Composition from Landuyt *et al.* Monomer-solvent phase separation in one-step self-etch adhesives. J Dent Res 2005; 84: 183-188

^e Composition from manufacturer's instruction

wall of the mold during the air-blowing step to make a uniform adhesive thickness. Light polymerization of the adhesive was then performed with a light-curing unit (Curing Light XL 3000, 3M ESPE, St Paul, MN, USA) with 800 mW/cm² intensity. After finishing light curing, a resin composite (Filtek Z 250, 3M ESPE, St. Paul, MN, USA) was used to fill the mold. Two increments of 2 mm thickness were applied, each one cured for 40 s. Before the bond strength test, a razor blade was used to remove the remaining cyanoacrylate adhesive and the silicone mold was removed by longitudinal cutting into halves.

The early shear bond strengths were tested at 10 min after completion of light-curing of the resin composite. A universal testing machine (Instron 5566 series 5000, Instron, Canton, Mass., London, UK) with a cross head speed of 0.5 mm/min was used. Shear testing was performed with a mono-angled chisel, with the edge closely aligned to the bonding interface and perpendicular to the longitudinal axis of the resin composite cylinder (Fig. 1).

The 24-h samples were stored in water at 37 °C prior to the shear bond strength test. A mean value, standard deviation and coefficient of variation were calculated for the fifteen specimens in each group and each time period.

The micro-shear bond strength test

Forty bovine teeth from the same storage as above were used. The teeth were embedded in acrylic resin and the flat superficial dentin surfaces were exposed and polished with 600-grit silicon carbide paper in the same manner as for the shear bond strength test. Each adhesive was applied on the middle area of the exposed dentin surface at the same position as in the shear bond

strength test. Then, the irises that were cut from micro bore tygon tubing (TYG-030, Small Parts Inc, Miami Lakes, FL, USA) with an internal diameter and a height of approximately 0.75 and 0.50 mm respectively were positioned randomly on the uncured bonding surface at 3 locations which covered the same areas as in the shear bond strength test. Each tygon tube was placed 2 mm apart from the other (Fig. 1) before light polymerization of the adhesive. The same resin composite was used to fill the tube and light-cured. The tubing was then removed from the composite cylinder by longitudinal cutting with a razor blade. In each group, 5 teeth with 3 composite cylinders were performed resulting in 15 composite cylinders for micro-shear testing. Before the bond strength test, all specimens were inspected under an optical microscope (30×). Specimens with defects such as interfacial gap defects and bubble inclusions were excluded and replaced. The composite cylinders were now ready for the micro-shear bond strength test.

The micro-shear bond strength test was performed using the micro bond strength test apparatus (Bencor-Multi-T, Danville Engineering Co, San Ramon, CA, USA) attached to the universal testing machine as described by Shimada and others²¹. The specimen was placed on the apparatus with a cyanoacrylate adhesive (Zapit, Dental Venture of America, Corona, CA, USA). A thin wire with a diameter of 0.2 mm was looped around the small resin composite cylinder. This procedure makes the lower half of the cylinder contact the wire which is gently held flush against the resin-dentin interface. The resin cylinder and the center of the load cell were aligned as straightly as possible. A shear force was applied to each cylinder specimen at a cross-head speed of 0.5 mm/min until fracture.

Fig. 1 Specimen preparation for the micro-shear and shear bond tests.

The micro-shear bond strengths were tested at 10 min after completion of light-curing of the resin composite and after 24-h storage of the specimens in water. A mean value, standard deviation and coefficient of variation were calculated for the 15 specimens in each group and each time period.

Mode of failure after shear and micro-shear bond tests

The fracture modes of all de-bonded specimens from shear and micro-shear bond strength tests were observed under a SEM (S-2500, Hitachi Science Systems.Ltd.,

Ibaraki, Japan). The fracture modes were classified as follows: adhesive failure at the resin-dentin interface, cohesive failure in dentin or cohesive failure in the resin. The surface area of each fracture mode was recorded as a percentage of the total bonding area.

Statistical analysis

The mean shear and micro-shear bond strengths as well as mode of failure were analysed by Three-way ANOVA (adhesive, time, test method) and the comparison of each variable was subjected to one-way and Duncan Multiple comparison test. The data of bond strength results at 10 min and 24 h were pooled for each test method and the different of CV values between the test methods were analyzed using a one-way ANOVA. Statistical significance was considered as $p < 0.05$. All data were analysed using the SPSS program.

RESULTS

The results of the bond strength test at both 10 min and 24 h and statistical analysis of three-way ANOVA are shown in Table 2, 3 and in Fig. 2. The homogeneity of variance were analyzed with Levene's test, which indicated p value=0.05. The three-way ANOVA demonstrated a significant effect of three factors on bond strength ($p < 0.01$). The interaction between factors was found only between test methods and adhesive materials ($p < 0.001$), indicating that the effect of test method on the bond strength was dependent upon the adhesive material used (Table 2). The Duncan multiple

Fig. 2 Graphs representing the bond strengths (MPa±SD) at 10 min and 24 h of the adhesive system according to the bond strength test method.

Table 2 Statistical analysis of three-way ANOVA

Source	Statistics Values				
	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	12813.541 ^b	15	854.236	42.621	0.000
Intercept	122768.695	1	122768.695	6125.423	0.000
TIME	2718.247	1	2718.247	135.624	0.000
TEST	6988.252	1	6988.252	348.672	0.000
ADHESIVE	2291.696	3	763.990	38.119	0.000
TIME *TEST	19.494	1	19.494	0.973	0.325
TIME *ADHESIVE	44.783	3	14.928	0.745	0.526
TEST *ADHESIVE	527.421	3	175.807	8.772	0.000
TIME *TEST *ADHESIVE	223.376	3	74.459	3.715	0.012
Error	4489.517	224	20.042		
Total	140071.8	240			
Corrected Total	17303.06	239			

Dependent variable: bond strength

Table 3 Results of shear and micro-shear bond strengths (MPa) at 10 min and 24 h

Adhesive systems	Mean bond strength (SD) (CV)			
	Shear bond (<i>n</i> =15)		Micro -shear bond (<i>n</i> =15)	
	10 min	24 h	10 min	24 h
Clearfil Tri S Bond	12.7(2.3) ^h (18%)	19.5(2.2) ^{f,g} (11%)	23.8(3.9) ^{d,e} (16%)	28.5(7.2) ^b (25%)
G Bond	11.1(2.7) ^h (24%)	16.6(6.1) ^g (37%)	24.3(4.1) ^{c,d,e} (17%)	35.0(5.1) ^a (15%)
i Bond	11.7(1.6) ^h (14%)	19.5(2.9) ^{f,g} (15%)	21.7(4.1) ^{e,f} (19%)	26.3(6.4) ^{b,c,d} (24%)
Clearfil SE Bond	21.2(3.9) ^{e,f} (18%)	25.3(4.2) ^{b,c,d} (17%)	27.7(4.9) ^{b,c} (18%)	36.9(5.6) ^a (15%)

CV: coefficient of variation

Different letter in the same line indicates significant difference of the same material at different time periods and test methods.

Different letter in the same column indicates significant difference between the test adhesives at the same time periods of each test method.

Table 4 Mean percentage of failure mode after shear bond test

Adhesive system	Failure (%)					
	10 min			24 h		
	Adhesive	Cohesive		Adhesive	Cohesive	
		Dentin	Resin		Dentin	Resin
Clearfil Tri-S Bond	84.53	—	15.47	66.04	—	33.96
G Bond	97.44	—	2.56	93.42	—	6.58
i Bond	84.31	—	15.69	76.71	—	23.29
Clearfil SE Bond	53.05	22.41	24.54	32.29	53.64	14.07

Table 5 Mean percentage of failure mode after micro-shear bond test

Adhesive system	Failure (%)					
	10 min			24 h		
	Adhesive	Cohesive		Adhesive	Cohesive	
		Dentin	Resin		Dentin	Resin
Clearfil Tri-S Bond	52	7.33	40.67	49.27	7.66	43.07
G Bond	69.87	1.60	28.53	60.27	1.47	38.26
i Bond	55.87	—	44.13	38.40	2.53	59.07
Clearfil SE Bond	82.40	13.33	4.27	63.20	35.33	1.47

comparisons demonstrated a significant difference between groups. The bond strengths of all adhesives at 10 min were significantly lower than those at 24 h for both tests. At each time period, the results of shear and micro-shear test were different for all materials tested. The bond strengths of all adhesives at 10 min were significantly lower than those at 24 h for both tests. At each time period, the results of shear and micro-shear bond strength test were different for all materials tested.

For the shear bond strength test, Clearfil SE Bond provided higher bond strengths than the 3 all-in-one adhesives at 10 min and 24 h. No significant difference in bond strength was found among the all-in-one adhesives. However, for the micro-shear bond strength test, variations in the bond strength among the materials at both time periods were found. At 10 min, three overlapping groups of the micro-shear bond strengths were observed. Clearfil SE Bond showed higher bond strength than i Bond and Clearfil Tri S Bond but it was not different from G Bond. G Bond and Clearfil Tri S Bond recorded equivalent intermediate bond strengths and were not different from i Bond which provided the lowest bond strength. At 24 h, Clearfil SE Bond and G Bond showed micro-shear bond strengths which were not significantly different from each other but higher than those of Clearfil Tri S Bond and i Bond. These latter two adhesives also exhibited no differences in bond strength.

For the shear bond strength test at 10 min and 24 h, the failure mode of the all-in-one adhesives revealed significantly higher adhesive failure (66.04–97.44%) than that of Clearfil SE Bond. No cohesive failure in dentin was found in any specimen of the all-in-one adhesives whereas a significantly high number of cohesive failures in dentin were found for Clearfil SE Bond (22.41% at 10 min and 53.64% at 24 h) (Table 3).

For the micro-shear bond strength test of the all-in-one adhesives at 10 min and 24 h, fewer adhesive failures and higher cohesive failures in resin were found when compared to the shear test. Cohesive failure in dentin was not different between shear and micro-shear test of the all-in-one adhesives at both time periods and Clearfil SE Bond at 10 min. Dentin cohesive failure was found to be lower in the micro-shear specimens of Clearfil SE Bond at 24 h than for the shear test specimens (Table 4).

The overall data of the bond strength results at 10 min and 24 h were pooled for each test method and the differences of CV values between the test methods were analyzed using a one-way ANOVA. The results showed that mean CV of the micro-shear bond strength test ($28\pm 7\%$) was significantly higher than that of the shear bond strength test ($17\pm 6\%$) ($p < 0.01$).

DISCUSSION

Bovine teeth were used as a substitute for human teeth since previous studies have shown similar bond strengths results when comparing human and bovine

teeth²²⁻²⁴. Bovine teeth are usually the substrate of choice for the shear bond strength test due to their size and availability. Even though the micro-shear bond strength test allows the use of human teeth owing to the lower number of teeth required, for the purpose of comparing the two tests, bovine teeth were used in this study.

Most of the in vitro bond strength tests have been done at 24 h or longer time periods. However, several studies have also emphasized the significance of determination of the “early” or “immediate” bond strengths of the adhesives^{3,24,25}. From the literature reviews, most of the “early” bond strengths were evaluated within 10 min after completion of the bonding procedure using the conventional shear or tensile tests^{3,25}. Micro-tests of small-sized specimens, such as micro-tensile or micro-shear testing, are increasingly used to allow more even distribution of the loading stress²⁶. However, for the determination of the early bond strength, micro tensile bond strength testing is more time consuming and technically demanding. Sadek *et al.* reported that about one hour is needed for preparation of the non trimming stick to determine the “immediate” micro tensile bond strength since the test requires the process of serial cutting of the specimens¹⁰. The micro-shear test is likely to be a suitable method for testing the early bond strength, since the specimens could be prepared within the limited time of 10 min.

In this study, the early and 24 h bond strengths of four self-etching adhesives were evaluated using shear and micro-shear tests. For both test methods, the 24 h bond strength of each adhesive was significantly higher than that of the 10-min bond strength. The results also suggested that the bond strengths obtained from the micro-shear test of all adhesives were higher than those obtained from the shear bond strength test. All the three null hypotheses were thus rejected. Comparing these two methods of testing, it is rather easier to prepare the specimens for the shear bond strength test due to the size of the bonding area and the mold used for resin composite filling. For the micro-shear bond strength test, filling a tygon tube with the resin composite is a difficult task which resulted in a number of specimens of the all-in-one adhesives failing during specimen preparation. These specimens, however, were not included as pre-test failures since it is obvious that the specimens failed due to problems in the specimen preparation such as interfacial gap defect and bubble inclusion or problems in the removal of tygon tube with a razor blade. The latter procedure would introduce stress to the adhesive joint for such small specimens and if was not done carefully would result in failure of the specimen.

The coefficient of variation for the pooled data of the micro-shear bond test ($28\pm 7\%$) was higher than that of the shear bond strength test ($17\pm 6\%$). The actual number of teeth employed in the micro-shear bond strength test was less than that for the shear bond strength test since 3 specimens were prepared from a single tooth. The scattered data of the shear bond strength test seem to be due to the inter tooth variation whereas those of the micro-shear bond strength test were caused by the

intra-tooth variation (*i.e.* superficial vs. deep dentin or central vs. periphery dentin)²⁷. The higher coefficient of variation found in the micro-shear bond strength test thus supports a previous comparative study of tensile and micro-tensile bond strength tests which suggested that the effect of intra-tooth variation was larger than that of inter tooth variation²⁸. For the micro-test, there are, however, some questions concerning the interdependence of multiple specimens from the same tooth which may overstate the statistical significance levels for comparison between materials²⁷. It is highly probable that the measurements originating from one tooth would be biased by the individual characteristics of the tooth which the test was carried on.

From the three-way ANOVA results indicated the interaction between the test methods and the adhesives. This can be seen from the ranking orders of the bond strength from each test which were slightly different. The ranking of the bond strength for the shear test at 10 and 24 h was: Clearfil SE Bond > Clearfil Tri S Bond = i Bond = G Bond while the ranking order for the micro-shear bond strengths at 10 min and 24 h were similar, except for the G Bond which provided an indifferent bond strength from Clearfil SE Bond and the remaining adhesives at 10 min but similar bond strength to Clearfil SE Bond and higher bond strength than the others at 24 h. Thus, G Bond was the only adhesive that was affected by the test method. G Bond is the only adhesive in this study that is sensitive to the light intensity used for polymerization. The manufacturer's instruction emphasizes the use of light intensity of 700 mW/cm² from halogen light source for G Bond. The lower amount of adhesive used for the micro-shear test may yield a higher degree of polymerization when exposed to the same light intensity compared to when a greater amount of adhesive is used for the shear test. This may contribute to significantly increasing the micro-shear bond strength of G Bond at 10 min and 24 h.

A previous study has reported that a new adhesive provides higher bond strength and often results in dentin cohesive failure for the shear test²⁹. Our study confirmed that for the adhesives with modest adhesive strengths, such as some of the newer all-in-one self etching adhesives, most failures were adhesive. This may be due to the stress-to-failure occurring along the weaker resin-dentin interface before being deflected into the dentin substrate. This study also revealed that for the adhesive with a high bond strength (*i.e.* Clearfil SE Bond), dentin-pull-out was found more often at 10 min and increasing to 50% of the total bonding area at 24 h as the bonding developed more completely. It should be noticed that inclusion of the data with cohesive failure will lead to underestimation of the actual bond strength especially for the group of Clearfil SE Bond.

The differences found between the shear and micro-shear bond tests from our study were: 1) the higher bond strengths obtained for the micro-shear test and; 2) the higher cohesive failure found in the stressed micro-shear specimens. The reason that higher micro-shear bond strengths were obtained is due to a smaller

bonding area^{30,31}. Failure of the bonded interface occurs when a crack propagates from a critical size flaw in the bonding area. The smaller the bonding area, the lower chance of encountering a flaw and the higher the bond strength of the specimen. Many studies, using both the static-load-to-failure test and the finite element test, have reported that a wire-loop method of loading leads to smaller stress concentration effects on the dentin substrate than knife blade loading^{32,33}. In this study, the higher percentage of cohesive failures in resin of the micro-shear test, in which wire loop loading was used, was thus unexpected. However, a finite element analysis study reported that stress distribution was non-uniform and differed between shear and micro-shear models even though the wire loop loading was used in both tests²⁰. It has also been suggested that the relatively thicker adhesive layer found for the micro-shear test may lead to relevant stress intensification²⁰. This may be a reason for the higher resin cohesive failure of the micro-shear test as well as the greater number of adhesive failure modes found in the shear bond test in our study.

The results of this study which correspond to those of previous studies are that the bond strengths of the dentin adhesives measured at 24 h were higher than at 10 min^{3,10} and that the two-step self-etching adhesives did not always provide higher bond strength than all-in-one self-etching adhesives³⁴⁻³⁶. It has been suggested that the bonding ability of the all-in-one self-etching adhesives are varied depending on their specific compositions³⁴. For the shear test, the early bond strengths of the all-in-one adhesives were approximately 60–67% of those at 24 h. However for the micro-shear test, the early bond strengths of these adhesives were 70–83% of the 24-h bond strengths. The higher early bond strengths obtained from the micro test were probably due to the lower amount of adhesive applied compared with the shear test which enhances polymerization when light curing.

Even though Clearfil SE Bond and Clearfil Tri S Bond contain the same adhesive monomer-MDP, the bond strengths of Clearfil SE Bond were higher than those of Clearfil Tri S Bond in both the shear and micro-shear tests. This result is in agreement with previous studies^{34,36}. The reason for the higher bond strength of Clearfil SE Bond is probably that in the second step of applying the non-solvent, relatively hydrophobic bonding resin a stronger interface layer was produced which could transfer the stresses across the adhesive joint better than the more hydrophilic and higher water absorptive resin of Clearfil Tri S Bond³⁷.

It has been suggested that the most important requirement for dentinal bonding agents is that they achieve a complete cure as quickly as possible after application so that the bond strength will be optimized before the composite material is added³⁸. A previous study reported that a light-cured resin composite generated a setting stress of 2.4 MPa on a flat rectangular (2.0×3.0 mm) bovine dentin surface within 30 min after light-curing¹. The results of the shear bond strengths in our study may indicate that the all-in-one adhesives possess

early bond strengths which are high enough to resist the shrinkage stress of the resin composite. Clinically, however, these early bond strengths might be too low to resist the contraction stress of the resin composite when these adhesives are bonded to the class V cavity where the C-factor is higher and the setting shrinkage stress of the resin composite has been found to be 20 MPa¹¹. A previous study suggested that, rather than the shear bond strength value, the setting shrinkage stress of the light-cure resin in a cavity plays a more important role in the formation of the marginal gaps during the initial stage of restoration³⁹. Therefore, in addition to the early bond strengths test, early marginal gap formation should also be determined to evaluate the bonding ability of the adhesives.

CONCLUSIONS

Within the limitations of this study, the MSBS test resulted in higher bond strengths and more discrimination between the adhesives than the conventional SBS test. For the SBS test, Clearfil SE Bond exhibited higher bond strengths than the all-in-one adhesives at 10 m and 24 h. For the MSBS test, however, Clearfil SE Bond and G Bond showed similar bond strengths which were higher than those of Clearfil Tri S Bond and i Bond.

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