Original Article

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Effect of pulpal pressure simulation on dentin bonding of a universal adhesive

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Objective: This study evaluated the dentin adhesion of a universal adhesive (Single Bond Universal; SBU) applied in either etch-and-rinse (E&R) or self-etch (SE) mode in the situations where 15 cm.H2O hydrostatic pulpal pressure (PP) was simulated during difference bonding and/or storage time.

Materials and methods: Crown segments of 90 extracted third molars were used, in which direct communication between the PP simulation model and pulp chamber was created. They were divided into 2 groups according to application modes of SBU. Each group was divided into nine subgroups according to three bonded and stored condition (0/0 bonded and stored at 0 pressure, 0/15 bonded at 0, stored at 15 cm.H2O pressure, and 15/15 bonded and stored at 15 cm.H2O pressure) and three storage time (0 min-immediate measurement, 24 h and 3 months), then restored with resin composite. In all groups after storage in water, stick-shaped specimens from each tooth were prepared for micro-tensile bond strength (μTBS) test. Data were analyzed using Kruskal-Wallis and Mann-Whitney U tests ($p<0.05$).

Results: Regardless of the application mode and PP simulation, μTBS values at 24 h were the highest and those at 3 months were the lowest ($p<0.05$). Generally, the group SE15/15 presented lower μTBS than groups SE0/0. However, the group E&R15/15 showed lower μTBS than group E&R0/0, but not different from that group E&R0/15. Different modes of application revealed similar μTBS at immediate measurement, irrespective of PP simulation ($p>0.05$). But for longer storage periods, SBU with SE mode seemed to show higher or at least similar μTBS to that with E&R mode.

Conclusion: In conclusion, SBU bonded using SE mode provided similar or better dentin adhesion than that bonded using E&R mode. Simulation of PP during bonding procedure impaired the bond of SBU with SE mode, while PP simulation during storage seemed to have a negative impact on that with E&R mode.

Keywords: microtensile bone strength, simulated pulpal pressure, universal adhesive

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Introduction

At present, dental adhesives can be mainly classified into two different strategies regarding to the interactions with enamel/dentin substrate [1]. The etch-and-rinse approaches utilize 30-40% phosphoric acid to pretreat the dental hard tissues in a total-etch manner [1, 2]. On the other hand, the self-etch approaches contain acidic monomers and other polymerizable monomers, which can etch and prime or even bond to the tooth substrates without rinsing [3, 4]. The selection between etch-and-rinse and self-etch approaches is a matter of personal preference. Due to the current trends toward simpler and fewer clinical steps, a new family of dental adhesive has been introduced as "universal adhesives". The so-called "universal" adhesive is a single-bottle, multi-purpose, multi-mode adhesive, which can be either used as etch-and-rinse or as self-etch adhesive [5-7]. Such versatility advocates the use of the simplest option of the abovementioned adhesive strategies, that is, two-step etch-and-rinse or one-step self-etch adhesive.

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Dentin is a permeable structure where the dentinal tubules extend from the pulp to the enamel-dentin or cementum-dentin junction. The tubules contain odontoblastic process and dentinal fluid under positive pressure, at approximately 15 cm. H2O, from dental pulp [8]. Once the dentin is exposed, fluid within the tubules can move and hence affect the bonding properties of dental adhesives. It has been reported that water droplet can disturb the polymerization of dental adhesives [9, 10].

For dental adhesion study, evaluation of adhesive performances can be conducted immediately after bonding, at 24 hours or longer period of storage [11-13]. Nevertheless, the experimental setting does not exactly reflect the clinical situations where the bonding surface might be interfered with the seepage of dentinal fluid during adhesive manipulation. Furthermore, even though long-term adhesive evaluation can be done laboratorial by immersion of the bonded teeth or even the specimens in several storage media [14-16], such conditions, however, could not represent the outwardly directed flow of dentinal fluid.

The aim of this laboratory study, therefore, was to investigate the dentin bonding performances of a universal adhesive – Single Bond Universal (SBU) when employed in etch-and-rinse (E&R) and self-etch (SE) modes of application. The adhesive procedures were conducted with or without simulated pulpal pressure and the bonded teeth were also subsequently stored in the presence or absence of pulpal pressure over the period of 3 months prior to the bonding evaluations. Micro-tensile bond strength and micro morphological analysis of fracture surfaces under scanning electron microscopy were observed.

Materials and methods

Materials

Materials used in this study are presented in Table 1 Single Bond Universal is one step self-etching universal adhesive system that can be used in etch-and-rinse and self-etching mode. The resin composite that was used is a nanohybrid resin composite (Filtek Z250 XT).

Methods

Tooth specimen preparation

Ninety extracted non-carious and non-defect third molars were used in this study. The teeth were stored in 0.1 % thymol solution for no more than one month before being used. For each tooth, occlusal enamel was removed using a low-speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA) and grinding with 600 – grit SiC paper under water cooling to prepare flat coronal dentin surfaces. The root part was cut by means of a low-speed diamond saw under water cooling to remove the roots below the cemento-enamel junction and expose the pulp chamber. Excavation of the pulpal tissues was done by a small pair of forceps, be careful not to touch pulp chamber walls and then rinsed with distilled water. A high-speed diamond bur was used to bevel the surrounding enamel margins. A pincer – type caliper was used to measure the remaining dentin thickness (RDT) that should be in the range between 0.9-1.0 mm.

Each specimen was fixed to an acrylic plate (2x2x0.3 cm) with cyanoacrylate adhesive (Model Repair II blue: SANKIN, Tokyo, Japan), which inserted by an 18-gauge stainless steel tube at a center hole of the plate. This tube protrudes 1 mm from the top of the acrylic plate and allowed communication with the pulp chamber and was attached to Model simulated pulpal pressure filled with distilled water in order to produce a hydrostatic pressure of 15 cm.H2O at the dentin surface that was bonded (Figure 1).

Table 1 The materials used in this study

Material	Composition	pH	Type	Application
Single Bond™ Universal (3M ESPE, St. Paul, MN, USA)	10-MDP, HEMA, silane, dimethacrylate resins, Vitrebond™ copolymer, filler, ethanol, water, initiater	2.7	Self- etch mode	1. Apply bonding agent and rub 20s. 2. Air dry gently for 5s. 3. light cure 10s.
			Etch-and-rinse mode	1. Acid etch 15s., rinse 15s. and air-dry 10s. kept dentin moist 2. Apply bonding agent 20s. 3. Air dry gently for 5s. 4. light cure 10s
Scotchbond™ etchant (3M ESPE, St. Paul, MN, USA)	Water, phosphoric acid, synthetic amorphous silica	0.6	Etchant gel	As above
Filtek™ Z250xt (3M ESPE, St. Paul, MN, USA)	Filler (81.8 wt%) : silica (20nm.), zirconia/silica cluster (0.1-10 µm.) Resin Bis-GMA, UDMA, Bis-EMA, PEGDMA, TEGDMA		Nanohybrid resin composite	1. Apply resin composite in a layer of 2 mm. 2. Light cure for 40s. each layer

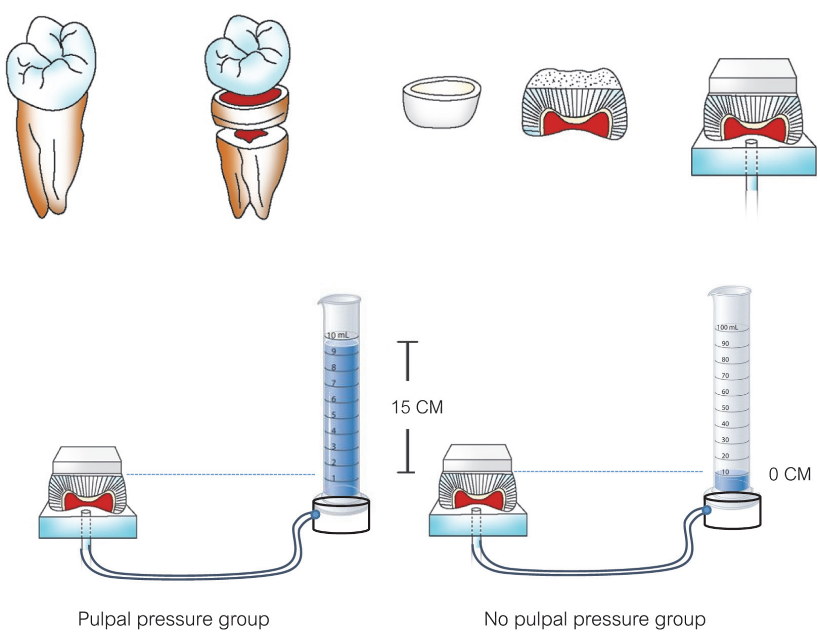

Figure 1 Diagram of specimen preparation.

Bonding procedure

The teeth were randomly divided into 2 groups according to the mode of application of Single bond universal and each group was further divided into subgroups according to different bonding and storage conditions. Each subgroup was stored at 3 different storage times (immediate measured, 24 h, 3 months) (Table 2)

Dental adhesive, principal components, instruction and manufacturer are demonstrated in Table 1

Dentin surfaces were rinsed with water and selected for bonding with Single bond universal in either etch-and-rinse mode or self-etching mode, following the manufacturer's instruction. After light curing the bonding resin, Z250XT nanohybrid resin composite (3M Dental Products Inc., St. Paul. USA) was built up to a height of 6 mm, with three 2 mm increments and light cured for 40 seconds on each increment at light intensity of 1,100 mW/cm2 using a Polywave LED featuring halogen-like light-curing unit (Bluephase Style, Ivoclar Vivadent Schaan, Principality of Liechtenstein). All the procedures were done under a hydrostatic pressure of 15 cm.H2O or 0 cm H2O pulpal pressure according to different experiment groups.

The group which immediately measured the bond strength, after completely light-curing the resin composite, the bonded specimens of the control and experimental groups were prepared to test for the micro-tensile bond strength. Since the preparation of specimens for the micro-tensile bond strength testing being time consuming and technically demanding, the immediate micro-tensile bond strengths of all groups in this study were thus the bond strengths measured at 1 h. after the restorations were completed.

For the remaining groups, the bonded specimens were stored under simulated pulpal pressure or without pulpal pressure at 37 C for 24 h and 3 months before testing. The bonding assembly as well as the restored tooth specimens were immersed in water during storage. The level of water in water bath was just above the tooth specimens. Hydrostatic pressure of 15 cm. H2O was maintained throughout the storage times for the groups with simulated pulpal pressure. The total of 90 teeth were used in this study as in Table 2.

Specimens preparation for micro-tensile bond strength test

The specimens in each subgroup were tested for microtensile bond strength. The teeth were vertically sectioned perpendicularly to the bonded interface buccolingually using non-trimming technique, with the diamond saw under water cooling to prepare resin-dentin sticks. Each specimen stick had a cross-sectional area of approximately 1.0 mm^2. Six sticks from each tooth were used which 5 for microtensile bond strength test. Only the sticks from the central area of each tooth were used. The sticks from the most peripheral area were excluded.

Table 2 The number of teeth in each procedure

Mode of adhesive systems	Bonded	Stored	Immediate	24 hr	3 mo
Etch-and-rinse modes	0 cm H_2O	0 cm H_2O	5	5	5
	0 cm H_2O	15 cm H_2O	5	5	5
	15 cm H_2O	15 cm H_2O	5	5	5
Self-etch modes	0 cm H_2O	0 cm H_2O	5	5	5
	0 cm H_2O	15 cm H_2O	5	5	5
	15 cm H_2O	15 cm H_2O	5	5	5
Total 90 teeth			30	30	30

Micro-tensile bond testing

The specimens were subjected to the micro-tensile bond strength test (μ TBS) using a universal testing machine (Instron Model 5566, Instron corp., Buckinghamshire, UK) and loaded in tension and at a crosshead speed of 1 mm/min. until failure. After microtensile testing, debonded specimens were mounted on brass stubs, sputter coated with gold (SPI Supplies, West Chester, USA), and observed with a scanning electron microscope (Model JSM 5410 LV, JEOL Company, Tokyo, Japan) for failure modes. The modes of failures for each group were classified and recorded as percentage of these followings [17]:

1) Adhesive failure: the fracture within interface between resin composite and dentin.

2) Cohesive failure in dentin: the fracture within dentin.

3) Cohesive failure in resin composite: the fracture within resin.

Calculating the failure mode from the SEM image divides the SEM image into a 10X10 grid. The failure patterns were counted as specified in every specimen. The values were obtained to find the mean in each experiment group.

Statistical analysis

Normal distribution of bond strength data was confirmed using the Kolmogorov Smirmov test. Since the bond strength data for all groups were not normally distributed, the results were then statistically analyzed using a nonparametric test (Kruskal-Wallis Analysis of Variance test). Pair-wise differences between means μTBS of experimental groups were analyzed using the Mann-Whitney U test and the significance values have been adjusted by the Bonferroni correction for multiple tests. For all analyses, statistical significance was set at α = 0.05.

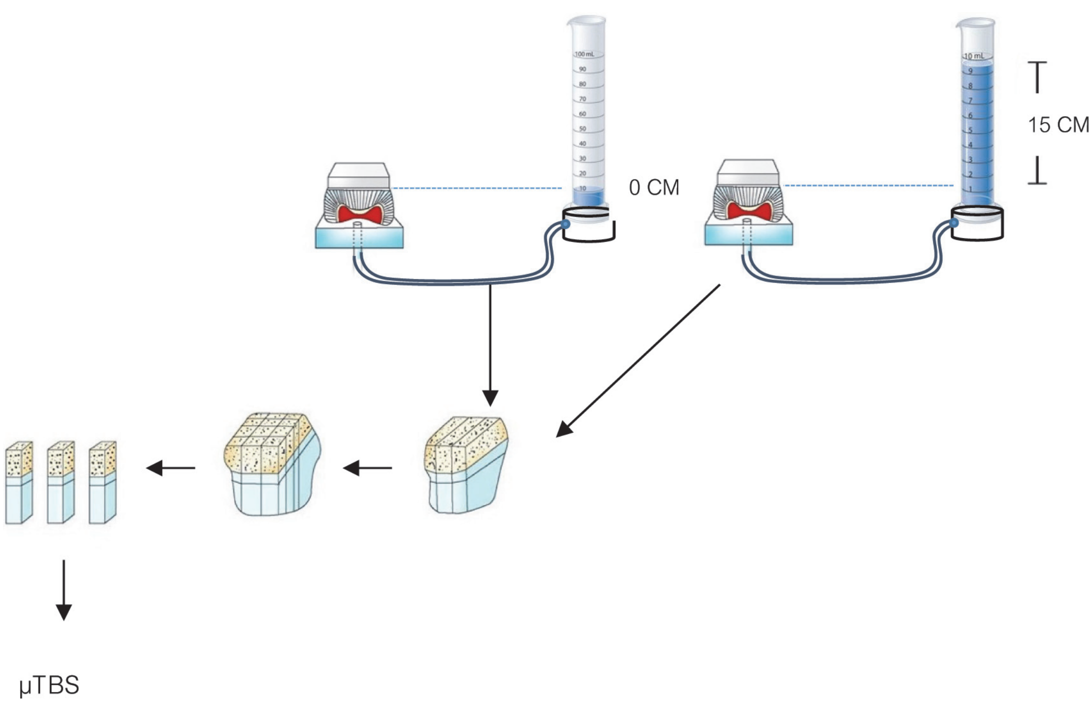

Figure 2 Diagram of specimen preparation for micro-tensile bond strength tests (μTBS).

Results

Micro-tensile bond strength (μTBS)

The micro-tensile bond strength results of the current study are summarized in Table 3

Overall, dentin bond strength values were influenced by all three tested factors, namely mode of application, bonding/storage pulpal condition, and storage time. The highest bond strength was found when Single Bond Universal (SBU) was applied in self-etch (SE) mode at 0/0 condition after 24 h water storage (32.17±1.98 MPa). For the etch-and-rinse (E&R) mode of application, the highest bond strength was also detected at 24 h storage in 0/0 condition (28.12±2.75 MPa). The lowest bond strengths for both application modes were found at 3-month storage in 15/15 condition (14.96±1.91 MPa for SE mode, and 16.09±2.33 MPa for E&R mode).

The storage time influenced the μTBS data regardless of the application mode or bonding/storage pulpal condition ($p \leq 0.001$). The highest bond strengths were shown at 24 h ($p \leq 0.031$), followed by the values at immediate measurement and at 3-month storage, respectively ($p \leq 0.021$). Figures 3 showed whisker box plots of the bond strength values for each storage time. When accounting for the bonding/storage pulpal condition, the bond strengths of 0/0 groups were not statistically different from 0/15 groups ($p \geq 0.093$), except for the SE mode measured at 3-month storage where the significance level was detected at $p = 0.040$. Regarding the application modes of SBU, the μTBS values of SE mode in 15/15 condition were significantly lower than those of 0/0 and 0/15 groups for all storage times ($p \leq 0.022$). For E&R mode, however, bond strength values of 15/15 group were significantly lower than those of 0/0 group ($p \leq 0.001$) but not when compared with 0/15 groups ($p \geq 0.053$), except those measured at 3-month storage where the significance level was detected at $p = 0.046$.

Table 3 Micro-tensile bond strengths (mean ± SD, median, minimum and maximum values) in MPa.

Material Group	Time											
Pressure (cm.H_2O)	Immediate				24 hours				3 months			
Bonded / Stored	Mean±SD	median	Min.	Max.	Mean±SD	median	Min.	Max.	Mean±SD	median	Min.	Max.
Etch-and-rinse modes												
Group 1. 0 / 0	24.80±2.66^{a,A}	25.4	17.6	28.2	28.12±2.75^{a}	27.9	24.3	33.3	18.46±2.03^{a}	18.8	14.5	21.9
Group 2. 0 / 15	23.09±2.80^{a,b,A}	22.9	18.6	28.1	26.54±2.13^{a,b}	26	23.8	30.5	17.64±1.67$^{a,+,A}$	18.2	13.3	19.8
Group 3. 15 / 15	20.30±4.07^{b,A}	20.3	11.8	25.8	24.54±2.30^{b}	24.7	20.3	28.7	16.09±2.23$^{+,§}$	15.8	11.8	20.3
Self-etch modes												
Group 4. 0 / 0	24.68±3.46^{a,A}	25.9	17.8	28.6	32.17±1.98^{a}	32.1	28.4	35.6	20.33±2.31*	20.8	15.5	23.4
Group 5. 0 / 15	23.12±3.20^{a,A}	23.3	17.7	28	31.01±1.82^{a}	30.8	28.4	34.9	18.32±1.94^{*,A}	18.9	15	20.5
Group 6. 15 / 15	20.39±1.96^{bA}	20.3	16	24.3	26.53±2.49^{b}	26.1	23.3	31.5	14.96±1.91§	14.5	12.8	19.8

Values among three storage times are statistically significant difference ($p<0.001$)

Same lowercase superscript letters indicate statistical similarity of the data among different bonding/storage pulpal conditions for each application mode and storage time. + indicates statistical difference at $p=0.046$ and * indicates statistical difference at $p=0.040$.

Same uppercase superscript letters indicate statistical similarity of the data between different application modes for each pulpal condition and storage time. § indicates statistical difference at $p=0.044$

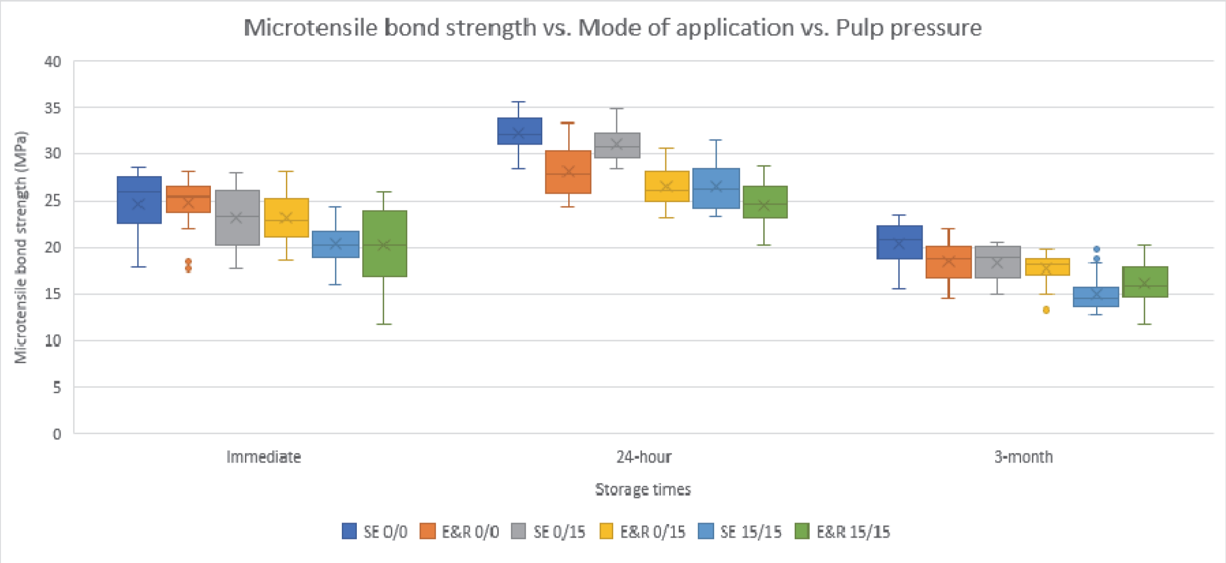

Figure 3 Box-whisker plot (min- [lower quartile-median-upper quartile] -max) of the immediate μTBS of Single Bond Universal in self-etch (SE) mode and etch-and-rinse (E&R) to dentin in different storage conditions. Mean±SD is also presented for each group. Different uppercase letters indicate significant differences between groups in SE mode. Different lowercase letters indicate significant differences between groups in E&R mode. * indicates no significant difference between SE and E&R mode in similar storage conditions.

When comparing the μTBS between two application modes, statistical similarities were detected for all bonding/storage pulpal conditions at immediate measurement ($p \geq 0.662$). After storage for 24 h and 3 months, The μTBS of SE mode group was higher than E&R mode for all bonding/storage conditions ($p \leq 0.015$), except for the 0/15 group measured at 3-month storage where statistical similarity was observed ($p = 0.107$) and the 15/15 group measured at 3-month storage where higher bond strength was detected for the E&R mode ($p = 0.044$).

Mode of failure evaluation

The percentage distributions of failure patterns are revealed in Table 4. All fractured specimens were in mixed type of failure mode – combination of adhesive failure, cohesive failure in resin and cohesive failure in dentin. Overall, the area of adhesive failure was found to be more than 50% for all groups, except when SBU was applied in SE mode and measured immediately where adhesive failure was found to be lower than 50% with higher percentage of cohesive failure.

The representative figure of each failure pattern is shown in Figure 4

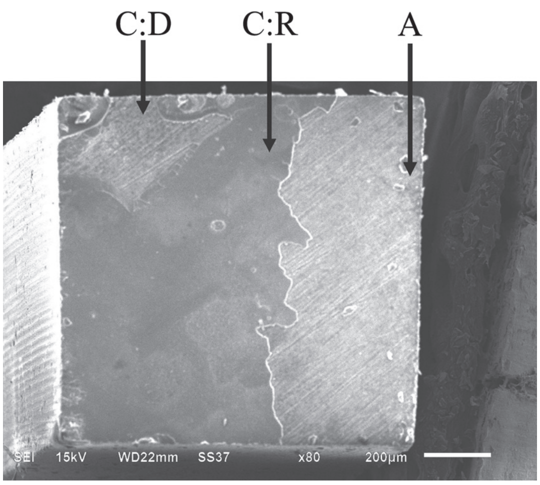

Figure 4 Scanning electron micrograph of the fractured surface at 80x magnification
A represents adhesive failure
C: R represents cohesive failure in resin
C: D represents cohesive failure in dentin

Table 4 Percentage surface area of fracture patterns of micro-tensile specimens as analyzed by a SEM in each experimental group.

Materials	Time								
Pressure (cm. H_2O) Bonded / Stored	immediate			24 hours			3 months		
	Failure Mode (%)								
	A	C - R	C - D	A	C - R	C - D	A	C - R	C - D
Etch-and-rinse modes									
Group 1. 0 / 0	87.7	10	2.3	90.8	4.5	4.7	72.1	26.2	1.7
Group 2. 0 / 15	86.8	12	1.2	79.3	15.7	5.0	64.5	24.3	11.2
Group 3. 15 / 15	52.2	39.6	8.2	62	22.5	15.5	51.7	31.2	17.1
Self-etch modes									
Group 4. 0 / 0	45	31	24	68.3	29.7	2.0	62.0	24.7	13.3
Group 5. 0 / 15	43	32.3	24.7	77.5	17.0	5.5	61.7	29.0	9.3
Group 6. 15 / 15	48.7	37.2	14.1	62.8	30.4	6.8	72.3	25.0	2.7

Discussion

The current study aimed to investigate the long-term micro-tensile bond strength (μTBS) of Single Bond Universal when applied in either etch-and-rinse (E&R) or self-etch (SE) mode under three different laboratory bonding/storage pulpal conditions as to simulate the situations found in clinical practices. In order to investigate the influence of simulated pulpal pressure and water storage on adhesive performance, Hosaka *et al* evaluated the resin-dentin bond strengths of two all-in-one adhesives at 24 h, 1 month and 3 months in the condition of bonding and storage under simulated pulpal pressure compared to those bonded and stored without pulpal pressure [18]. In their study, however, there was no representative group of specimens that bonded under zero pulpal pressure and stored under simulated pulpal pressure. This situation was included in the present study to mimic the clinical situation where the injection with local anesthetic containing vasoconstrictor was done – represented as the 0/15 bonding/storage pulpal condition. In the 0/15 condition, the specimens were bonded after connection to the simulated pulpal pressure device but without any actual delivery of pulpal pressure.

The results of this study indicated that the μTBS of SBU at immediate measurement, 24 h, and 3 months were statistically different, irrespective of bonding strategies or bonding/storage conditions with the highest at 24 h storage and the lowest at 3-month storage. A previous study comparing the dentin bond strength at 24 h and at 1-year water storage of SBU applied in E&R and SE modes [19]. revealed that 1-year water storage decreased bond strengths on both bonding strategies with more effect on etch-and-rinse mode was observed. The decrease in bond strength was approximately 60% for etch-and-rinse strategy. In the current study, however, the reduction of bond strength was only 30-46% for both bonding strategies after 3-month water storage with or without pulpal pressure. The differences may be due to the long-term storage under pulpal pressure in addition to water aging employed in this study.

Such findings are in agreement with the results reported in an updated systematic review and meta-analysis of bonding performances of universal adhesives [20]. The current μTBS results at 24 h and 3-month measurement are in agreement with previous studies [19, 21, 22] that long-term water storage decreased the bond strength of most universal adhesives. The reason for using water storage under pulpal pressure for only 3 months in this study is that the decreasing dentin permeability occurs in vivo after cavity preparation. The previous pulpal responses studies reported that sclerotic dentin as well as reparative dentin are formed following operative procedure with decreased pulpal fluid movement which subsequently reduce dentin permeability [23, 24].

Generally, regardless of storage period, dentin bond strengths in groups of 0/0 bonding/storage pulpal condition were not different from those of groups 0/15 condition for both application modes. Moreover, the bond strengths of groups 15/15 condition were lower than those of 0/0 and 0/15 conditions for SE mode, but were lower than only 0/0 condition for E&R mode. The results of groups 0/0 and 15/15 seem to be in agreement with the previous study of Hosaka et al which showed that all-in-one adhesives are susceptible to both pulpal pressure and water storage [18]. Their results were product-dependent and the μTBS was lowered more by simulated pulpal pressure than by storage time. The particular results of the groups 0/15 and 15/15 bonding/storage condition may further indicate that simulated pulpal pressure during the bonding and resin composite built-up had more influence on dentin bond strengths of SBU in SE mode. For E&R mode, however, simulated pulpal pressure during the bonding and resin composite built-up showed less influence, but pressure during storage did. The possible explanation may be due to the E&R mode employing the wet-bonding technique. In addition, Single Bond Universal consists of methacrylate-modified carboxylic acid copolymer, also known as Vitrebond copolymer, in its composition which might facilitate the dentin bonding under various degrees of hydration such as found in the wet surfaces of etched dentin following acid etching [25].

There are two studies which measured the 1-h and 24-h micro-bond strengths of different generations of adhesive including the all-in-one system [16, 26]. In their studies, there were no significant differences between the 1-hour and 24-hour bond strengths of several 2-step E&R adhesives and four all-in-one adhesives evaluated without simulated pulpal pressure during the bonding and water storage. They concluded that clinicians may immediately perform contouring, finishing and polishing procedures or occlusal adjustments of the bonded composites without adversely affecting the integrity of the restorations that were initially established. Our current study showed that the immediate bond strengths of Single Bond Universal were lower than those of 24 h, irrespective of application strategies and bonding/storage conditions. Such findings are different from those of the previous studies. The reason may possibly be due mainly to the different adhesive used. Even though the immediate bond strengths in this study were lower than those at 24 h, the bond strengths obtained immediately were approximately 84% to those of 24 h in E&R mode and 75% to those of SE mode. It is interesting that such a high bond strength of adhesive which developed over a short period of time after restoration, even though slightly lower than at 24 h measurement, may be strong enough to allow immediate occlusal adjustment and finishing procedure. Unfortunately, there is still no literature concerning the minimum immediate bond strength which can withstand stress from finishing procedure or occlusal stress right after restoration.

In contrast, another immediate microtensile bond strength study using all-in-one adhesives bonded to dentin in a zero simulated pulpal pressure before delivered pulpal pressure during resin composite built-up, reported that the bond strengths were less than 7 MPa for two all-in-one adhesives [27]. A previous study showed the degree of conversion of Single Bond Universal as high as 84% when measured immediately as thin film on a mylar strip. The degree of conversion for Single Bond Universal is probably greater when applied on dentin substrate as it was found that buffering effect of dentin could even increase the degree of conversion of acidic self-etch adhesive. In addition, there is a study reported that the degree of conversion of contemporary universal adhesives positively correlated with the bond strength to dentin [28]. This may be one explanation to the high immediate bond strength of Single Bond Universal found in this study.

Immediate bond strengths of Single Bond Universal applied in SE mode were similar to those in E&R mode in the same bonding/storage pulpal condition. For longer storage time, the μTBS of Single Bond Universal in SE mode were greater than, or at least still equal to those in E&R mode. Exception was detected for 15/15 condition where higher bond strength for E&R mode was found with p = 0.044. Explanation for the nearly non-significant result might be noted as previously described and increase of sample size should be aware of in further observations. To compare the bond strengths between 1 h and 24 h measurement, the increase in bond strengths was detected more in SE mode (35% increasing) than E&R mode (16% increasing). In E&R mode, the wet-bonding technique is used to prevent the collapse of collagen fibrils; remaining water at the adhesive interface may affect the continued polymerization over a 24 h period. Further study to determine the degree of conversion at 24 h of Single Bond Universal applied on dentin in E&R and SE mode is needed to clarify this postulation.

At 3 months, the bond strengths of SBU for both application modes declined approximately 35-40%. The greatest reduction in dentin bond strength was found in the group of SE mode in 15/15 bonding/storage pulpal condition. This may again confirm that simulated pulpal pressure during the bonding and restorative procedure is critical to this adhesive when manipulated in self-etch mode. If we consider that the degree of conversion is an important factor for long-term bond stability of universal adhesive, as suggested in one study [28], the greatest reduction in bond strength of SBU applied in SE mode in 15/15 group may reflect to the inferior degree of monomer conversion of the adhesive under fluid permeation. Without the effect of simulated pulpal fluid during bonding and storage, the long-term bond strengths of Single Bond Universal applied in SE mode is generally greater than that applied in E&R mode. This result is in agreement with a previous in vitro study which indicated that bonds created by universal adhesives in the SE mode are more resistant to deterioration when compared with those in the E&R mode [19]. However, the results at 3-month storage of Single Bond Universal confirmed the previous studies that degradation of the bond interface could be found in both E&R and SE modes.

CONCLUSION

In conclusion, Single Bond Universal bonded using self-etch mode provided similar or better dentin adhesion than that bonded using etch-and-rinse mode. Pulpal pressure simulation and storage time affected the bonding performance of Single Bond Universal. Simulation of pulpal pressure during bonding procedure impaired the bond of Single Bond Universal with self-etch mode, while pulpal pressure simulation during storage seemed to have a negative impact on that with etch-and-rinse mode.

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