



Bond Strength of a Universal Adhesive with Different Smear Layer Preparations Under Dynamic Pulpal Pressure

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Abstract

The purpose of this study was to evaluate the effects of different smear layer preparations on the dentin bond strength of a universal adhesive under dynamic pulpal pressure.

Twenty-eight extracted lower third molars were used in this study. The occlusal enamel was cut to exposed dentin. The smear layers were created by #600-SiC paper, coarse diamond bur, superfine diamond bur, and carbide bur. Clearfil Tri-S Bond Universal (CBU) was used in this study. The microtensile bond strength test was performed on the different smear layer preparations and adhesives (n=7) under 15 cmH₂O of pulpal pressure. Data were analyzed using one-way ANOVA and Duncan multiple comparison test at a 95% significance level with SPSS software.

According to the statistical analysis, surface preparation influenced the bond strength (p<.01). The surface prepared by superfine diamond bur demonstrated the highest bond strength. No difference in microtensile bond strength was observed among surfaces prepared by SiC paper, coarse diamond bur, and carbide bur. From this study, it could be concluded that superfine diamond bur is recommended for tooth preparation when using universal adhesive.

Keywords: Smear layer, Bond strength, Pulpal pressure, Universal adhesive

1. Introduction

Nowadays, tooth-colored restoration is very popular in dentistry. The composite restoration can be bonded to the tooth structure by using dental adhesives. Recently, a new version of one-bottle adhesive systems called universal or multi-mode adhesives was introduced in the market. Manufacturers claimed it could be used in the etch-and-rinse approach and self-etching approach (Sofan et al., 2017). However, it has been shown that acid-etching of dentin did not improve the bond strength of the universal adhesives (Nagarkar, Theis-Mahon, & Perdigo, 2019; Rosa, Piva, & Silva, 2015). Besides, the previous study demonstrated a chemical interaction of the universal adhesives to the dentin when applied in the self-etching approach (Tian et al., 2016; Yoshida et al., 2012).

Vital dentin is hydrated by an outward fluid flow from the dentinal tubules due to positive pulpal pressure, estimated to be approximately 15 cmH₂O (Ciucchi, Bouillaguet, Holz, & Pashley, 1995). Several bonding studies under a simulated pulpal pressure model reported a significant reduction in the dentin bond strength can be from dentin wetness by tubular fluid (Hosaka et al., 2007; Mahdan, Nakajima, Foxton, & Tagami, 2013; Moll & Haller, 2000).

With different surface preparations, different characteristics of the smear layer can be expected. The uses of diamond bur and carbide bur were found to be more compact and denser than that produced by SiC papers (Sattabanasuk, Vachiramon, Qian, & Armstrong, 2007). There has been a concern that a very thick or rough smear layer may buffer the acidic primer and prevent the resin infiltration into the underlying dentin and compromise the etching efficacy of the primer to the underlying dentin (Oliveira et al., 2003; Tay, Carvalho, Sano, & Pashley, 2000). However, many publications showed that there was no relation between the smear layer thickness and bond strength (Oliveira et al., 2003; Reis et al., 2005; Tani & Finger, 2002).

To date, there is little information regarding the effect of different smear layers combining with hydrostatic pulpal pressure on the bonding performance of the universal adhesives. Therefore, this study aims to evaluate the effect of different smear layer preparations with dynamic pulpal pressure on the dentin bond strengths of the universal adhesive.



2. Objectives

The objectives of this study were to evaluate the microtensile bond strength (μ TBS) test of the universal adhesive to dentin prepared with different surface preparations under dynamic pulpal pressure. The null hypothesis of this study is that there was no difference among the microtensile bond strengths of the universal adhesive to the dentin prepared with different surface preparations under simulated pulpal pressure.

3. Materials and Methods

3.1 Preparation of specimens

Twenty-eight extracted sound human mandibular third molars from the patients aged between 18 to 30 years old were collected. The teeth were stored in 0.1% thymol solution (M Dent, Bangkok, Thailand) and used within six months. The protocol was approved by the Faculty of Dentistry/Faculty of Pharmacy, Mahidol University Institutional Review Board, Thailand.

After removal of the occlusal enamel, the teeth were grounded with 600-grit SiC paper under running water. Their roots were removed at 1 mm below the cemento-enamel junction to expose the pulp chambers using a slow-speed diamond saw (Isomet, Buehler Ltd, Lake Bluff, IL, USA). The pulpal tissue was gently removed with forceps. The pulp chamber was irrigated with 2.5% sodium hypochlorite solution (M Dent, Bangkok, Thailand) for 30 seconds, followed by immersion in distilled water for 30 minutes to neutralize the effects of NaOCl (Hosaka et al., 2007).

3.2 Experimental design

The occlusal dentin discs were divided into 4 groups according to 4 different surface preparations. A single operator was trained on how to achieve approximately 100 g of pressure using an analytical balance prior to perform the surface preparation.

3.2.1 Group A: 600-grit SiC paper. The occlusal dentin surfaces were prepared with 600-grit SiC paper at a constant weight under running water for 60 seconds, $n=7$.

3.2.2 Group B: Coarse diamond bur. The occlusal dentin surfaces were grounded using a coarse diamond bur at a high speed (320,000 – 350,000 rpm) with copious water spray for 5 light-pressure strokes to make a uniform surface. A new bur was replaced every 5 surfaces, $n=7$.

3.2.3 Group C: Superfine diamond bur. The occlusal dentin surfaces were grounded using a superfine diamond bur in the same manner as group B, $n=7$.

3.2.4 Group D: Carbide bur. The occlusal dentin surfaces were grounded using a carbide bur in the same manner as group B, $n=7$.

The chemical compositions of the dental adhesive are shown in Table 1.

Table 1 Chemical compositions, pH, and manufacturer's instruction of the adhesive used in this study

Adhesives	Chemical composition	pH	Application
Clearfil Tri-S Bond Universal (Kuraray Noritake, Niigata, Japan)	MDP, Bis-GMA, HEMA, hydrophilic aliphatic dimethacrylate, colloidal silica, silane coupling agent, al-camphorquinone, ethanol, water	2.3	1. Apply the bonding and rub 10 s 2. Airflow gently 5 s 3. Light-cure 10 s

3.3 Bonding strategies

The dentin disc was attached to a Plexiglas plate form that was perforated by an 18-gauge stainless steel tube using cyanoacrylate adhesive. The specimen was connected to a custom-made pulpal chamber then connected for simulating pulpal pressure with an infusion pump (ISMATEC®, Wertheim, Germany) as shown in Figure 1. The hydraulic pressure was set up at 15 cmH₂O, and the flow rate was controlled at 0.36 μ L/min to simulate intrapulpal pressure and pulpal blood flow rate, consequently (Ciucchi et al., 1995). The tooth surface was treated with Clearfil Tri-S Bond Universal (Kuraray Noritake, Niigata, Japan) following



the manufacturer's instruction then cured by using an LED light-curing unit (LED Bluephase; Ivoclar Vivadent, Schaan, Liechtenstein) with the power intensity of approximately 1,200 mW/cm².

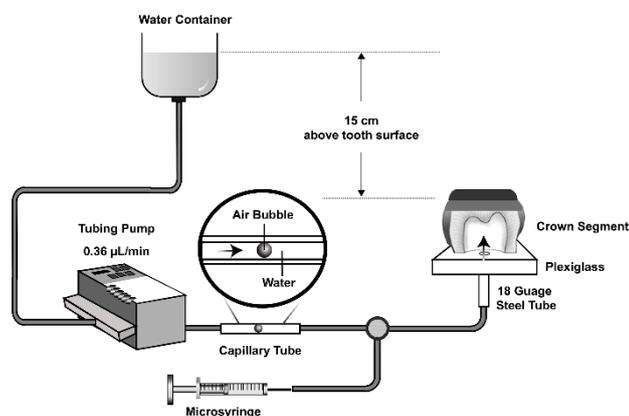


Figure 1 Schematic illustration showing the hydraulic conductance model

3.4 Resin composite built-up

After light curing, resin composite Clearfil AP-X ES-2 (Kuraray Medical, Okayama, Japan) was placed on the bonded dentin surface for two increments of 2 mm and cured by using the LED light-curing unit for 20 seconds each layer.

All bonded specimens were stored in 37°C distilled water for 24 hours. The central part of resin bonded teeth was used for the μ TBS test. Four resin-dentin beams from the central part of each tooth were prepared into approximately 1.0×1.0 mm² with a non-trimming technique using a low-speed cutting machine at a speed of 350 rpm and loading of 150 gm with constant water coolant.

3.5 Microtensile bond strength test

For evaluation of μ TBS, specimens were fixed on an experimental jig for microtensile testing using cyanoacrylate glue (Model Repair II Blue, Dentsply, SANKIN, Tokyo, Japan) as shown in Figure 1 (Armstrong et al., 2017; Nikaido et al., 2002). Then, the μ TBS test was performed using a universal testing machine (LloydTM Testing Machine, Model LR 10K, Lloyd Instruments, FarehamHanth, UK) with a cross-head speed of 1.0 mm/min. The data was recorded and expressed in MPa.

3.6 Failure mode observation

The fractured surfaces of both resin and dentin sides were stored in an incubator at 37°C for 24 hours. Then, the surfaces were coated with palladium (K500X Sputter coater; SPI Supplies, West Chester, PA, USA) and examined under a scanning electron microscope (JSM-6110 LV, JEOL, Tokyo, Japan) at 75x magnification to determine the mode of failure. The failure modes were classified into 4 types (Armstrong et al., 2017); (1) adhesive at the interface, (2) cohesive in resin either adhesive layer or resin-based composite, (3) cohesive in dentin, and (4) mixed failure.

3.7 Statistical analysis

The bond strength data were organized and analyzed for normal distribution and homogeneity of variance using the Kolmogorov-Smirnov test and Levene's test respectively. One-way ANOVA and Duncan multiple comparison tests were calculated. All analyses were performed using a statistical software system (SPSS 27.0; SPSS Inc, Chicago, IL, USA) at a 95% confidence interval.



4. Results and Discussion

4.1 Microtensile bond strength test

The μ TBS values and standard deviations of all experimental groups are demonstrated in Table 2. The normal distribution and equality of variances of all data were analyzed with the Kolmogorov-Smirnov test and Levene's test, respectively. One-way ANOVA and Duncan were used at a 95% statistical significance level.

Table 2 Exhibits the mean μ TBS value \pm standard deviations. Groups with the same superscripts are not statistically significant ($p > 0.05$).

	Microtensile bond strength (MPa)
600-grit SiC abrasive paper	23.65 \pm 0.94 ^b
Coarse diamond bur	22.56 \pm 1.69 ^b
Superfine diamond bur	34.61 \pm 2.35 ^a
Carbide bur	26.66 \pm 2.27 ^b

According to Table 2, the type of surface preparation had an influence on the bond strength ($p < .01$). The microtensile bond strength to dentin prepared with superfine diamond bur was significantly higher than other groups. However, there was no statistically significant difference among other groups.

4.2 Failure mode observation

Figure 2 gives an overview of the failure modes of all the fractured specimens. Representative images showing the different failure patterns are shown in Figure 3. The failures are mainly adhesive, irrespective of conditions of surface treatment. There are no remarkable differences in the failure patterns among all the groups.

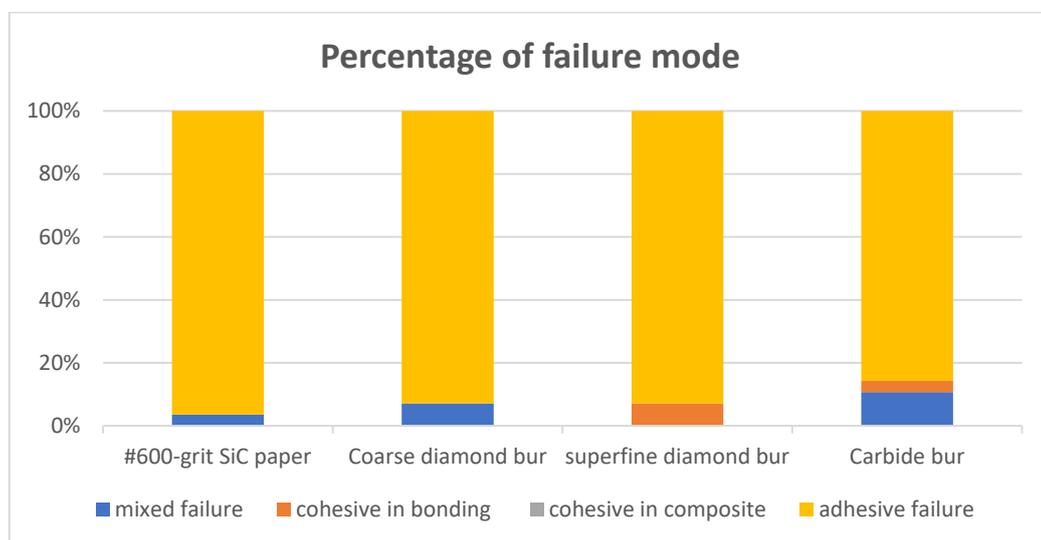


Figure 2 Percentages of failure mode distribution to different dentin surface preparations

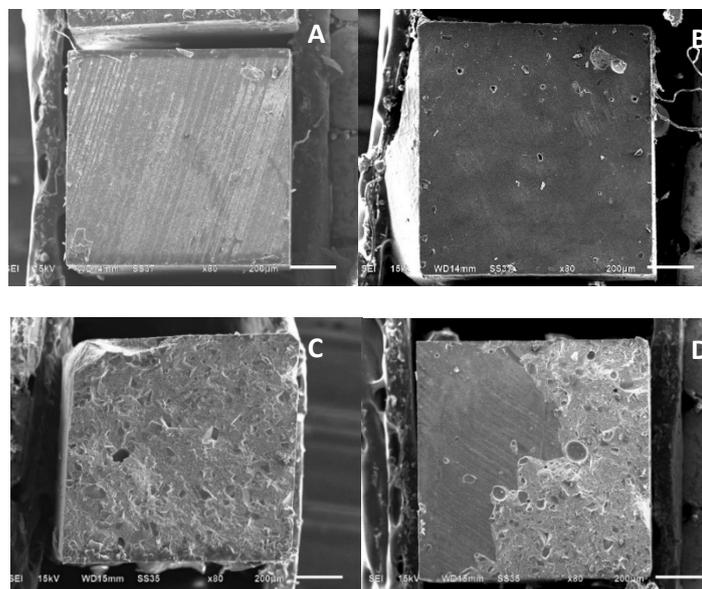


Figure 3 Representative SEM micrograph of failure mode; (A) Adhesive failure, (B) Cohesive failure in bonding, (C) Cohesive failure in resin composite, and (D) Mixed failure

4.3 Discussion

Characteristics and thickness of the smear layer are depended on the type of instrumentation used (Sattabanasuk et al., 2007; Tani & Finger, 2002). Most *in vitro* dentin bond strength studies were performed on the dentin surfaces prepared with SiC paper which is not clinically relevant. As the smear layer created by SiC paper is thicker but more loosely organized (Sattabanasuk et al., 2007) whereas diamond burs produced a thinner and more compact smear layer (Oliveira et al., 2003). For carbide bur, the smear layer was less condensed when compared to diamond bur. The thickness of the smear layer also varies by the abrasive grit size. With increasing abrasive grit size, more thickness of the smear layer was observed.

According to the bond strength test, one-way ANOVA revealed that surface preparation is the factor that influences the microtensile bond strength. Therefore, the null hypothesis that the dentin bond strength was not influenced by the type of smear layer was rejected ($p < 0.05$). The surface prepared by superfine diamond bur demonstrated the highest bond strength. Other groups such as carbide bur, #600-grit SiC paper, and coarse diamond bur group showed no statistical differences. It could be explained by the smear layer characteristic. Firstly, the bond strength of the self-etching adhesive was influenced by the thickness of the smear layer (Koibuchi, Yasuda, & Nakabayashi, 2001; Ogata et al., 2001). A recent study demonstrated that the smear layers created by coarse diamond bur and SiC paper were thicker than those prepared by superfine diamond bur and carbide bur (Saikaew et al., 2020). The thick smear layer might buffer the acidic monomer, resulting in lower bond strength whereas the thin smear layer was easily dissolved by the acidic monomer, resulting in better resin penetration. Besides, from the same study, it demonstrated that the particles of dentin chips remained on the surface prepared by carbide bur. Though the smear layer created by carbide bur might be thin, these dentin chips might act as a contaminant of the bonding surface. Therefore, the bond strength of the dentin surface prepared by these instruments was significantly lower than that of the superfine diamond bur.

Further study comparing to 2-step self-etch adhesives might be required for more information.



5. Conclusion

In conclusion, the characteristic of the smear layer is depended on the instrument used for the preparation of the dentin surface. To achieve favorable bond strength, superfine diamond bur is recommended for tooth preparation when using universal adhesives.

6. Acknowledgements

Major advisor: Asst. Prof. Dr.Pipop Saikaew

Co-advisor: Asst. Prof. Vanthana Sattabanasuk, Assoc. Prof. Dr. Pisol Senawongse

Equipment: Research Center, Faculty of Dentistry, Mahidol university

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