Microshear Bond Strength of Different Adhesive Systems to Dentin

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INTRODUCTION
Use of composite resin restorations has significantly increased due to their optimal esthetic properties and non-invasive tooth preparation design. Long-term success of composite resin restorations depends on the durability and strength of the bond between the tooth structure and composite resin [1]. Bonding durability is critical for the longevity of restorations. Degradation of the bonding interface can lead to gap formation at the interface. The success of adhesion in dentistry...
depends on several factors, such as the type of substrate, type of adhesive, moisture, and operator’s experience and skills [2]. Effective bonding to substrates with different properties is an important aspect in dentin adhesion [3]. Resin-dentin bonds are less durable than resin-enamel bonds, because dentin is a more complex substrate composed of both mineral and organic phases. Moreover, dentin moisture should be preserved to avoid collapse of the collagen matrix; thus, it is essential for successful bonding, but it also adversely affects the long-term bonding results [3,4].

According to the bonding substrate (enamel or dentin), dental adhesive systems are used in three clinical steps of etching, priming, and bonding [5]. Dental adhesives are classified into three major categories based on their clinical application mode. The first system is referred to as the etch-and-rinse system and can be employed in three-step and two-step approaches [6]. The second system is the self-etching primer system. The third system is known as all-in-one or one-step self-etching system [7].

The ultimate goal of adhesive dentistry is to enable simple and fast adhesive application with durable bonding to enamel and dentin. The manufacturers are constantly introducing new adhesive systems with claims of simple use, improved composition and the ability to bond to tooth structure [8]. One of the most recent novelties in adhesive dentistry is the introduction of ‘universal’ or ‘multi-mode’ adhesives. These are simplified adhesives, usually containing all bonding components in one single bottle. Universal adhesives may be applied either in etch-and-rinse or self-etching bonding modes, according to the manufacturers’ claims. Besides, universal adhesives can be used with different restorative materials [9]. The manufacturers claim that there is no compromise on bonding effectiveness when either bonding strategy is used. Nevertheless, it is known that simplified adhesives are often associated with lower in vitro bond strength results and poorer in vivo longevity of restorations. These findings are probably due to the complex formulation of simplified adhesives and their high content of solvents, which may impair complete solvent volatilization and consequently lead to inadequate adhesive polymerization [10].

Based on all the above, the aim of the current study was to evaluate the microshear bond strength (μSBS) of different adhesive systems to dentin. The null hypothesis was that no significant difference in bond strength exists between the universal adhesives and other adhesive systems.

MATERIALS AND METHODS

After obtaining approval from the Ethics Committee in Research of the Health Sciences of Tehran University of Medical Sciences (6087), 60 sound extracted human third molars without any cracks or defects were collected, cleaned and disinfected in 0.5% chloramine solution for 1 week. Then, they were embedded in acrylic resin cylinders. The root of each tooth was cut and the occlusal enamel was removed by means of a diamond disc (Extec; Enfield, CT, USA). Dentin discs with 2 mm height were obtained from the middle part of the tooth crowns. The specimens were ground wet using 100, 400 and 1000-grit abrasive papers (Carborundum Abrasives; Recife, PE, Brazil) and incubated at 37°C for 48 hours.

They were then randomly divided into four groups (n=15) according to the adhesive system and the application protocol of adhesives on dentin surfaces:

**Group A:** Scotchbond Universal (3M ESPE, St. Paul, MN, USA) in self-etch mode: No acid-etching gel was used. The adhesive was rubbed on dentin surface with a microbrush for 20 s, followed by gentle air drying for 5 s and light curing for 10 s (woodpecker D; Guilin Woodpecker Medical Instrument Co., Guilin, Guangxi, China).

**Group B:** Adper Single Bond 2 (3M ESPE, St. Paul, MN, USA): 37% phosphoric acid gel (Etch Royale; Pulpdent, Watertown, USA) was used to etch dentin surfaces for 15 s. The etched dentin surfaces were then rinsed for 10 s to completely remove the etching gel. Then, the adhesive was applied on the wet dentin with a
microbrush and rubbed for 20 s followed by gentle air drying for 5 s, and the second layer was applied and gently air-dried and light cured for 10 s.

**Group C**: Clearfil SE Bond (Kuraray Co. Ltd., Osaka, Japan): The self-etching primer was applied on dentin using a microbrush and was left in place for 30 s. Air drying for 5 s was done to remove excess solvent. Then, bonding was used with a microbrush and after that gentle air drying and light curing were performed for 5 and 20 s, respectively.

**Group D**: Scotchbond Universal (3M ESPE, St. Paul, MN, USA) in etch and rinse mode: First, 37% phosphoric acid gel (Etch Royale, Pulpdent) was used to etch the dentin surface for 15 s. Next, the etched dentin surfaces were rinsed for 10 s to completely remove the etching gel and then the adhesive was agitated on dentin with a microbrush for 20 s followed by gentle air drying for 5 s and light curing for 10 s. Detailed information on chemical composition of the adhesive systems is presented in Table 1. Following adhesive applications, Tygon tubes 1 mm in height and 1.2 mm in diameter were fixed on the surface. Composite resin (Vit-l-escence, Ultradent, USA) was incrementally applied into the tubes. Each increment was polymerized for 20 s using a LED curing unit (Woodpecker D; Guilin Woodpecker Medical Instrument Co., Guilin, Guangxi, China) with an intensity of 1000 mW/cm². The bonded specimens underwent thermocycling and were subjected to 1,000 thermal cycles between 5°C and 55°C with a dwell time of 20 s and a transfer time of 10 s. Specimens were loaded with shear force until fracture in a universal testing machine (Instron 3220; Instron Corporation, Canton, Massachusetts, USA) at a crosshead speed of 1.0 mm/min using a knife-edged chisel. The SBS in megapascals (MPa) was calculated by dividing the maximum load in Newtons by the cross-sectional area of the bonded surface in square millimeters.

**Statistical analysis**

Data were statistically analyzed using one-way ANOVA with bond strength data as dependent variable and adhesive type and application mode as factors. One-way ANOVA and the Tukey’s post-hoc test were used to find groups with significant differences. The level of significance was set at 0.05 for all tests. SPSS version 21.0 (SPSS Inc., IL, USA) was used for statistical analyses in this study.

**Table 1**: Chemical composition of adhesives

| Dentin Bonding Agent | Composition | Manufacturer | Batch No. |
|----------------------|-------------|--------------|-----------|
| Adper Single Bond 2  | Ethyl alcohol (25-30), silane treated silica (nanofiller) (10-20), bis-GMA (10-20), HEMA (5-10), glycerol, 1,3-dimethacrylate (5-10), copolymer of acrylic and itaconic acids (5-10), water (5), diurethane dimethacrylate (1-5) | 3M ESPE, St Paul, MN, USA | N300780BR |
| Scotchbond Universal | MDP, bis-GMA HEMA, DMA, methacrylate functional copolymer, filler, ethanol, water, initiators, silane | 3M ESPE, St Paul, MN, USA | 502226 |
| Clearfil SE Bond Primer | 2-hydroxyethyl methacrylate, 10-methacryloyloxydecyl dihydrogen phosphate, hydrophilic aliphatic, dimethacrylate dl-camphorquinone, water, accelerators, dyes and others | Kuraray, Osaka, Japan | 00147A |
| Clearfil SE Bond adhesive | 2-hydroxyethyl methacrylate (25–35), 10-methacryloyloxydecyl dihydrogen phosphate (MDP) Expose to a gentle air stream Bisphenol A diglycidyl methacrylate Cure 10 s 2-Hydroxyethyl methacrylate Hydrophobic dimethacrylate dl-Camphorquinone N,N-diethanol-p-toluidine Silanated colloidal silica | Kuraray, Osaka, Japan | 00114A |
Table 2. Mean and standard deviation of μSBS in different groups

| Adhesive                      | Mean  | Std. deviation | Maximum μSBS | Minimum μSBS |
|-------------------------------|-------|----------------|--------------|--------------|
| Scotchbond Universal in self-etch mode | 15.80 a | 6.08           | 26.37        | 8.05         |
| Adper Single Bond 2           | 11.24 b | 3.75           | 18.93        | 6.63         |
| Clearfil SE Bond              | 15.24 ab | 4.06           | 22.38        | 6.28         |
| Scotchbond Universal in etch and rinse mode | 11.68 ab | 4.07           | 21.59        | 6.99         |

Similar superscripted letters indicate no significant difference in μSBS values.

RESULTS
The mean and standard deviation of μSBS values are shown in Table 2. As shown, Scotchbond Universal in self-etch mode showed the highest mean μSBS value followed by the Clearfil SE Bond and Scotchbond Universal in etch and rinse mode; Adper Single Bond demonstrated the lowest mean μSBS value. One-way ANOVA showed significant differences in bond strength values among the groups (P=0.015). Thus, the Tukey's test was applied for pairwise comparisons.

One-way ANOVA showed significant differences (P=0.015) in bond strength values between groups. Thus, Tukey's test was performed for pairwise comparisons. The results showed that there was a significant difference in μSBS between Scotchbond Universal in self-etch mode and Adper Single Bond 2 (P=0.04); but there were no statistically significant differences between Scotchbond Universal in self-etch mode and Clearfil SE Bond and Scotchbond Universal in etch and rinse mode, and also between Adper Single Bond 2 with Clearfil SE Bond and Scotchbond Universal in etch and rinse mode (P>0.05, Table 2).

DISCUSSION
Dentin adhesion is a difficult challenge, while good adhesion to enamel is easy and predictable [11,12]. Therefore, a new type of adhesive known as “universal” or “multi-mode” adhesive was recently introduced to enhance dentin adhesion. Universal adhesives are recommended by dental material manufacturers for use with/without acid pretreatment of enamel surfaces [13,14]. There is limited information as to whether the different etching modes provide equal bond strength to dentin [15]. Bond strength is one of the most important factors that affects the bonding durability [16].

Our study investigated the μSBS by use of a universal adhesive in etch and rinse and self-etch modes compared with other adhesive types with the same application modes. Thus, the aim of this study was to evaluate the μSBS of different adhesive systems to dentin. We found that Scotchbond Universal in self-etch mode resulted in higher μSBS to dentin compared with other adhesives. Thus, the null hypothesis was rejected.

In this study, Scotchbond Universal in self-etch mode showed the highest mean μSBS value (15.80±6.08 MPa) followed by the Clearfil SE Bond (15.24±4.60 MPa) and Scotchbond Universal in etch and rinse mode (11.68±4.07 MPa), and Adper Single Bond 2 demonstrated the lowest mean μSBS value (11.24±3.75 MPa). The μSBS in self-etch mode was higher than that in etch and rinse mode in use of universal adhesive, but there was no significant difference between them. Studies have shown that there is no significant difference in dentin bond strength of universal adhesives in etch and rinse or self-etch modes of application. However, there is presently a preference for self-etch adhesive systems for application on dentin due to shallower demineralization compared with 35% phosphoric acid, and elimination of the rinsing step after etching with phosphoric acid; this is one of the most critical steps during etch-and-
rinse adhesive system application [17]. In addition, 35% phosphoric acid removes calcium from the dentin surface, leaving a network of collagen fibers surrounded by water [18]. The removal of calcium from the dentin surface might avoid any potential ionic bonding between the calcium and phosphate and/or carboxylate groups present in the adhesive, decreasing the bonding ability to dentin, especially after aging [19].

Okada et al. [20] compared the bonding efficacy of two self-etch one-step adhesives, one self-etch two-step adhesive and one etch and rinse two-step adhesive. According to their findings, the μSBS of self-etch adhesive was higher to dentin compared with others. But in contrast to our findings, Yousry et al. [21] concluded that etch and rinse adhesive compared with self-etch adhesive, had better results in μSBS to dentin.

Since the application protocols of adhesive systems on dentin substrate and dentin moisture play a significant role in mechanical and biological behavior of the adhesive interface, in the present study, we investigated the μSBS of Scotchbond Universal adhesive system applied on wet and dry dentin following etch and rinse and self-etch bonding modes. According to our results, the application of Scotchbond Universal on dry dentin by the self-etch technique resulted in the highest μSBS value, with no significant difference with Clearfil SE bond. Our study showed that self-etch universal adhesive showed almost similar results to self-etch adhesive in μSBS [22]. In our study, self-etch mode yielded superior bond strength results to dentin in comparison with etch and rinse and self-etch bonding modes. Generally, when the dentin surface is pre-etched with phosphoric acid, the resin components of the self-etch adhesive are prevented from penetrating into the exposed collagen network, leading to a reduction in bond strength [26,27]. Adper Single Bond had the lowest μSBS among the adhesive groups in our study. One reason for significantly lower dentin bond strength of etch and rinse systems is the suboptimal infiltration of resin into the demineralized collagen network and subsequently poor adaptation of the bonding resin to the collagen fibrils. The lower bond strength of Adper Single Bond could be explained by the absence of MDP functional monomer in its composition [28].

**CONCLUSION**

Within the limitations of this in vitro study, we may conclude that universal adhesive in self-etch mode may yield a μSBS superior or almost equal to that of universal adhesive in etch and rinse modes. Moreover, the universal adhesive showed lower μSBS to dentin in etch and rinse mode in our study.
rinse mode and two-step self-etching adhesive when using dentin as substrate. Also, an etching step prior to universal adhesive application insignificantly decreases the SBS to dentin.

CONFLICT OF INTEREST STATEMENT
None declared.

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