Research Paper: The Comparison of Shear Bond Strength of Self-cured and Light-cured Composite Restorations to Dentin, Using a Universal Bonding System

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ABSTRACT

Introduction: To evaluate and compare shear bond strength of self-cure and light-cure composites using a universal bonding system.

Materials and Methods: Superficial coronal dentin of 62 intact extracted premolars was exposed and bonding agent (All-Bond Universal) was applied over the dentin surface according to the manufacturer instruction (self-etch mode). Then samples were distributed in 2 groups (n=31), and composite cylinders were built using AELITE All-purpose Body Light-cure composite (group I) and MasterDent Self-cure composite (group II). Samples were kept in distilled water at room temperature for one week and then were thermocycled (500 cycles, 5 º C to 55º C). Finally, samples were mounted in acrylic molds and shear bond strength was assessed using a Universal Testing Machine at the crosshead speed of 0.5 millimeter per minute. Stereomicroscope was used to determine the failure mode. Bond strength data were analyzed using sample t-test and frequencies of failure types analyzed using Chi-square test.

Results: Mean shear bond strength in group I (34 ± 3.56Mpa) was higher than group II (32±3.24Mpa). In addition, the prevalence of adhesive failure in group II (74.2%) was higher than group I (67.7%). However, these differences were not statistically significant.

Conclusion: Our findings showed that the application of All-Bond Universal followed by a self-cured composite without using a separate self-cure activator on dentin, provides bond strength values comparable to that of a light-cured composite.

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Introduction

Due to the high aesthetic demands of patients, the use of tooth color restoration materials has increased significantly.(1) Since the success of these restorations depend on bonding to dental structures, it is very important to evaluate the bond strength of the adhesive to enamel and dentin.(2) In-vitro experimental researches are useful in assessment of new products.(3) The effectiveness of bonding agents is generally assessed by bond strength tests.(4) Universal adhesives are the latest adhesive systems. These single-bottle adhesives make it possible for the dentist to choose one of the two-step etch-and-rinse (ER), one-step self-etch(SE), or selective enamel etching approaches based on the clinical situation or his/her preference.(5-8) This adhesives has showed favorable bonding performance regardless of the bonding procedure.(9) They can be used, not only on dental tissues and resin composite, but also on different substrates, such as silica-based glass ceramics, metal alloys, and zirconia.(10) Almost all universal adhesives use phosphate esters (R-O-PO3H2), mostly 10-MDP[1] ,(8) as their primary functional monomer, which has positive properties such as chemical bonding to metals, zirconia, and dental tissues. In addition, because of their acidic nature, these monomers can demineralize dental tissues.(7, 11) Universal adhesives have higher pH than phosphoric acid (pH= 2.2 to 3.2)(12) and therefore they demineralize dentin more superficially(13) and significant amount of hydroxyapatite crystals remain around collagen fibers. Calcium ions released from the incomplete decomposition of hydroxyapatite disperse inside the hybrid layer and bond to the 10-MDP molecules, forming stable calcium salts due to the process of nano-layering. This results in the formation of a stronger phase on the surface of adhesive agent which increase the mechanical strength of the bonding agent in SE approach.(7, 13-17)

In addition to the adhesive system, the polymerization mechanism of composite resin is also important in bond strength.(18) There is incompatibility between self/dual-cured composite resins and resin cements with some simplified adhesive systems.(19-23) This incompatibility is because of the reaction between acidic monomers presented in oxygen inhibited layer of adhesive and aromatic tertiary amines in self/dual cure composite resins which results in the insufficient polymerization of these materials through preventing the production of free radicals.(7, 20, 22, 24) The hypertonic environment of the oxygen inhibited layer is another reason for this incompatibility since it results in osmotic pressure which leads to liquid transfer via the permeable layer of adhesive.(25, 26) Therefore, when using the simplified adhesive systems with self/dual-cure composite resins it is necessary to use a separate activator solution such as aromatic sodium sulfonate salts.(27, 28) Since universal adhesives should be acidic enough to be effective in a SE mode, the use of a separate activator is required when these systems are used with self/dual-cure composite resins.(7, 23, 29)

Gutierrez et al., investigated the effects of self-curing activators and the method of curing on the properties of universal adhesives bonded to dual-cure composite resins and concluded that these effects were material-dependent.(25) Silva et al., studied the bond strength of a dual-cure resin cement to dentin using different bonding systems. They reported no significant difference in the mean bond strength of the universal adhesive(Single Bond Universal) and other adhesive systems(3 step E&R, 2 step E&R, 1 step SE).(30) Michaud et al., used three adhesive agents including two-step E&R, three-step E&R, and Scotchbond Universal to investigate the compatibility between dental adhesives and dual-cure composite resins. They concluded that although light-cure composite resins showed better bond strength, dual-cure composite resins can also have a bond strength as good as light-cure composite resins. However, all dual-cure composite resins were not compatible with all adhesive systems and it is material dependent.(18) Raimondi et al., showed that

10-methacryloyloxydecyl dihydrogen phosphate monomer except for Clearfil Universal, universal bonding agents resulted in significantly lower shear bond strength of the resin cement to dentin than the two-step, self-etching bonding agents (Clearfil SE Bond or Clearfil SE Bond 2) .(31) Chen et al. investigated the dentin bond strength of dual-cure resin cements using universal adhesives. They concluded that the bond strength of some universal adhesives (even with the dual-cure activator) in self-cured group was significantly lower than dual-cured group.(32) Zuffa et al. reported that All-Bond Universal has high bond strength with self-cure resin cements (without the need for a self-cure activator).(33) All-Bond Universal, a product of BISCO Inc. is the only universal adhesive that claims to be compatible with self- and dual-cured composites (without the need for a separate activator) and to provide a bond strength that is approximately equal to that of light-cured composite resins.

Since there are few studies in this regard, the present study was undertaken to compare the shear bond strength of self- and light-cured composites to dentin, using All-Bond universal.

Materials and Methods

In this in vitro experimental study, 62 caries free human premolars which were extracted because of orthodontics reasons or periodontal disease were used. The teeth were cleaned from debris and remnant soft tissue and were disinfected in 0.5% chloramine T, stored in distilled water and used within 3 months after extraction. To remove enamel and obtain a flat surface on the dentin, the crown of the teeth was cut horizontally from 1/3 occlusal, using a diamond cylindrical fissure bur (012, Teeskavan, Iran) under water-air cooling. The samples were wet ground with 600-grit Silicon Carbide paper for 60 s. Then, the teeth were mounted in a wax mold so that the cut surfaces were 2 mm above the wax level. The teeth surfaces were washed and the excess water was removed by a cotton pellet. All-Bond Universal (BISCO, Inc., Schaumburg, IL, USA) was applied on the teeth surface by self-etch approach according to the manufacturer's instructions (table 1). The self-etch approach was used to take advantage of the simplified bonding procedure. In the next step, the adhesive was irradiated by a Bluedent LED Smart light curing unit (D and A Electronics, Bulgaria) for 10 s. The light intensity of the device was measured (600 mW/cm2) using a digital radiometer (Digirate, MONITEX CO., Taiwan). Plastic molds (3 ×3 mm) were fixed on the center of the teeth using glue wax. The samples were randomly divided into two groups (n=31), based on the type of composite resin. In group I, light-cure composite (AELITE All-Purpose Body (BISCO, Inc., Schaumburg, IL, USA)), shade A2 was used. According to the manufacturer's instruction (table 1), 1.5 mm layers of the composite were placed within the fixed molds located on the teeth surfaces. Each layer was separately irradiated for 30 s. Finally, the molds were removed from the teeth surfaces and the teeth were placed in distilled water at room temperature for one week.

In group II, self-cure composite (MASTER-DENT (Dentonics, Inc., Monroe, NC, USA)) was used. This self-cure composite is radiopaque and is present in universal shade. The composite was placed on the surface of the teeth according to the manufacturer's instruction (table 1). After the initial setting of composite) 5 min) the molds were removed. The samples were placed in distilled water at room temperature for one week. (all procedures were done by one clinician) To simulate the clinical conditions, all teeth were incubated in a thermocycler (500 cycles at 5 and 55º C with a transfer time of 10 s and dwell time of 30s). The shear bond strength of the samples was assessed by a universal testing machine (STM–20, Santam company, Tehran, Iran) equipped with a load cell of 50 kg at the speed of 0.5 mm/min. The samples were mounted in acrylic molds that were compatible with universal testing machine. The molds were placed in the universal testing machine so that the path of the blade was parallel to the dentin-composite interface. The maximum load until fracture was recorded for all samples using STM Controller software. The force at the moment of failure (in newton) was obtained from the diagrams. Then, bond strength values in megapascal (MPa) were calculated for each sample by dividing the force imposed at time of failure by the bond area(mm2).

To determine the type of failure (adhesive, cohesive, or mixed), the dentin surface of debonded area of each sample was assessed by a stereomicroscope with x40 magnification.

Data were analyzed using version 22.0 of SPSS. The normality of the data was assessed by Shapiro-Wilk test. To compare the means of bond strength in the studied groups, Independent sample t-test was applied. To compare the frequencies of the failure types in the studied groups, Chi-square test was used. A p-value less than 0.05 was considered statistically significant.

Table 1. The compositions and manufacturers' instructions of material used in the present study

Materials	Manufacturer	Grouping	Compositions	Manufacturer's Instructions
All-Bond Universal	BISCO	Universal Adhesive	Phosphate monomer 5-15 wt%, HEMA 5-15 wt%, ethanol 30-60 wt%, bis-GMA 10-40 wt%, water, photoinitiator	1.Apply two separate coats of ALL-BOND UNIVERSAL, scrubbing the preparation with a microbrush for 10-15 seconds per coat. 2.Evaporate excess solvent by thoroughly air-drying with an air syringe for at least 10 seconds, there should be no visible movement of the adhesive. The surface should have a uniform glossy appearance; otherwise, apply an additional coat of ALL-BOND UNIVERSAL and repeat steps 1 and 2. 3.Light cure for 10 seconds. 4.Continue with placement of the restorative material according to the manufacturer's instructions
AELITE All-Purpose Body	BISCO	Light-cured Micro-hybrid Resin Composite	Ethoxylated bisphenol A Dimethacrylate 10-30 wt%, TEGDMA* 5-10 wt%, Glass filler(76% w/w), Amorphous silica	1.Use the required amount of the composite. 2. Place 1-2 mm layers of the composite on the surface and light cure for 30 seconds. 3.For final layer, light cure each surface for 30 s.
MASTER -DENT	Dentonics	Self-cured Resin Composite	Bis-GMA/ TEGDMA	1.Mix the same amounts of base and catalyst pastes by a plastic spatula on a paper pad for 20 s (1-2 movements per second). 2.After 2 min, place the mixture on the desired surface. 3.After the placement, wait 2 min to allow the composite to set and wait 2 more min for the setting completion.

* Triethyleneglycol dimethacrylate

Results

Shapiron-Wilk test showed that the data were normally distributed in both light cured (p=0.564) and self-cured (p=0.581) groups.

The mean bond strength of the studied groups is shown in table 2. As seen, the mean dentin bond strength in light-cured composite group (34 ± 3.56) was higher than self-cured composite group (32 ± 3.24), this difference was not statistically significant (p=0.284)

Table 2. The comparison of bond strength between the studiedgroups

Groups	No	Mean± SD	0.95 CI*	t	p-value
Light-cured	31	34 ± 3.56	33.3-35.9	1.081	0.28
Self-cured	31	32 ± 3.24	32.4-34.8		

* Confidence interval

The failure modes in the studied groups are indicated in table 3. No cohesive failure was observed in both groups. Although, adhesive failure in group II (74.2%) was higher than group I (67.7%), this difference was not statistically significant (p=0.58).

Table 3. The comparison of the failure types between the studied groups

Failure type	Groups			p-value
	Light-cured n (%)	Self-cured n (%)	Total n (%)	
Adhesive	21 (67.7)	23 (74.2)	44 (77.0)	0.58
Mixed	10 (32.3)	8 (25.8)	18 (29)	

Discussion

The rapid evolution of bonding technology has led new products to be available in the market before being evaluated clinically. Although clinical assessment is the best method to evaluate the effectiveness of dental materials, in vitro experimental researches are also important.(18) Bond strength tests are useful tools to assess new bonding products and investigate the experimental variables.(3, 18) The effectiveness of adhesive agents is generally assessed by bond strength tests.(4) Reducing the application steps and shortening the clinical application time are the reasons for widespread acceptance of simplified systems among the clinicians.(11, 34) In addition, the main advantage of universal bonding systems in comparison with other simplified systems is that they can be used in more various restorative procedures and bonding strategies.(19)

Although the application of light-cure composite resins is more common in restorative dentistry, self-/dual-cured composite resins and resin cements are still used for cementing indirect restorations and endodontic posts, core build-up, and restorations in areas where light penetration is difficult.(21, 35-37) Some studies reported an incompatibility between self-/dual-cure composite resins and simplified light-cure adhesive agents, in which adhesive and primer are presented in the same bottle.(19-21) The main reason of this incompatibility is related to the neutralization reaction between acidic monomers presented in oxygen inhibited layer of adhesive agent and aromatic tertiary amines of self-/dual-cure composite resins, which results in preventing the formation of free radicals in levels that are required to the sufficient composite polymerization.(20, 24, 38) This incompatibility depend on the acidity and permeability of the adhesive agent.(7, 38) There are evidence on the direct relationship between the pH of adhesive agent and the mean of bond strength.(19) Since the self-cure composite resins only depend on the presence of aromatic tertiary amines to initiate polymerization and have no photo-initiators in their compositions, they are more sensitive to the acidity of simplified adhesive systems than dual-cure composites. To overcome this limitation, co-initiators such as aromatic sodium sulfonate salts as “activator solution” should be used. These ingredients react with acidic resin monomers to produce phenyl or benzene sulfonyl free radicals which result in the initiation of polymerization reaction(27)

Universal adhesives are single-bottle adhesive systems with no need for mixing. Since these adhesives have functional acidic monomers (such as MDP) they can bond with different substrates. Universal adhesives can be used as two-step E&R, one-step SE, or selective enamel etching approaches based on the clinical conditions or the user’s preference.(5-7) These adhesives should be acidic enough to be effective in self-etch mode. Therefore, when these systems are used with self/dual-cure composite resins, the use of a separate activator is required. However, All-Bond Universal adhesive agent does not need a separate activator because of its relatively lower acidity (pH=3.2, based on the manufacturer’s claim) compared to other universal adhesives. In addition, the acidity is enough to bond through self-etch strategy.

Because of the presence of 10-MDP molecules the universal adhesives are more hydrophobic than the earlier generations. This hydrophobicity is because of the long carbonyl chain of 10-MDP molecules.(7, 25) Hydrophobic adhesives dose not wet the hydrophilic dentin well. Although All-Bond Universal adhesive system is more hydrophobic than earlier generations, it provides high dentin bond strength values. This is probably because of the manner that the adhesive agent is applied on the surface (the adhesive is applied on the surface using a micro-brush with active and dynamic movements). Chen et al., in a study on one-bottle simplified adhesives showed that the more hydrophilic adhesive agents were less compatible with dual-cure materials. (38) Furthermore HEMA may inhibit interfacial Nano-layering of 10-MDP with hydroxyapatite, so the chemical bonding potential of universal adhesives may be affected by the amount of HEMA content of adhesive agents.(26)

In the present study, the shear bond strength of self- and light-cure composite resins using a universal bonding system were compared.

Michaud et al., used three adhesive agents, including two-step E&R, three step E&R, and a universal adhesive system (Scotchbond Universal using E&R approach with separate dual-cure activator) to investigate the dentin bond strength of three composite resins, including a light-cure resin composite (Filtek Supreme Ultra A2B) as control and two dual-cured resin composites (CompCore AF White and Core paste XP White) which are used for core build-up. One of the dual-cure composites showed higher bond strength with the universal adhesive than the other two adhesive systems. However, the other dual-cure composite showed a high bond strength with the three-step E&R. Therefore, the bond strength values in addition to the chemical structure of the adhesive system is also depend on the composition of the composite. It can be concluded that, the above-mentioned incompatibility between self- and dual-cure composite resins and simplified systems depend on the composition of the composite resin, and some composites are more sensitive to this incompatibility. Therefore, the vulnerability to pH is material-dependent.(18) In addition, Gutierrez et al., concluded that although the curing method and the use of self-cure activator affect the dentin bond strength, this effect is material-dependent(25) Silva et al., concluded that the system and technique used for the hybridization of dentin affect the dentin bond strength of dual-cure resin cements(30) According to the findings of these studies(18, 25, 30), it can be stated that the compatibility between universal adhesives and self/dual cure composites is material dependent. Therefore, further studies are required to determine the compatibility of universal adhesives with self-/dual-cure composite resins and resin cements. Raimondi et al., showed that the dentin bond strength of dual-cure resin cement with universal adhesive (except for Clearfil Universal) was less than two-step self-etch adhesives. (31) In contrast, in the present study, when the universal adhesive agent was used with self-cure composite, the bond strength was as good as light-cure composite. This discrepancy can be explained, at least in part, by the material dependency of bond strength of universal bonding systems with dual-cure composite resins, which was found in previous studies(18, 25, 30) In line with the finding of the present study, Silva et al., reported no statistically significant difference in the mean bond strength of dual-cure resin cement (Duo-Link) using universal adhesive agent (Single Bond Universal) and other dentin adhesives, including three systems of three-step E&R (Adper Scotchbond Multi-purpose, Optibond FL, and All-Bond 3), one system of two-step E&R (Adper Single Bond 2) and one system of one-step SE (Bonde Force)(30) Chen et al., reported that the bond strength of Scotchbond Universal adhesive (using dual-cure activator) and Adhese Universal with self-cure resin cement was lower than light-cure resin cement. However, in accordance with our findings, they reported that All-Bond Universal adhesive system showed a high dentin bond strength with both dual- and light-cured resin cement.(32)

Moosavi et. al. reported that conventional light-cure composite had higher bond strength than self- and dual-cure composite resin.(39) The reason of this contrast may be the lower pH of the universal adhesive (G-Premio Bond, pH=1.5) that was used in their study. Higher acidity increases the incompatibility between simplified adhesives and self-cured composite.(19)

Zuffa et al., reported that when All-Bond Universal adhesive agent was used with self-cure resin cements and composite resins without a separate self-cure activator provided a high dentin bond strength as light-cure cements (control group). In addition, the bond strength of most groups was higher than control group (Scotchbond Universal, with a dual-cure activator).(33) These findings are in line with our observations. In the present study, the mean dentin bond strength in light-cure group was higher than self-cure group. However, this difference was not statistically significant. Therefore, it can be stated that the All-Bond Universal adhesive system is compatible with self-cure composite and provides a bond strength as light-cure composites without the need for separate self-cure activator. Thus, All-Bond Universal adhesive agent can be used along with self- and dual-cured cements to cement indirect restorations and endodontic posts. This adhesive can also be used along with self- and dual-cured composites for Core build-ups or to perform direct restorations in areas where the light penetration is difficult. However, since some studies showed the incompatibility between universal adhesives and self- and dual-cured composites is material-dependent, it is recommended that one be cautious in the use of these bonding agents with self-cure and dual-cure composites.

In the present study, no cohesive fracture was observed. The frequency of adhesive fractures in self-cured group (74.2%) was higher than light-cured group (67.7%). However, this difference was not statistically significant. In addition, no statistically significant difference was observed in the type of failures between the groups. These findings are in accordance with the study of Gutierrez et al.(25) In contrast, Chen et al., reported that the most frequent fracture were adhesive fracture and in All-Bond Universal group the most frequent fractures were mixed and cohesive fractures.(32) Similarly, in the study of Silva et al., the most frequent fractures were cohesive, adhesive, and mixed, respectively(30) Piwowarczyk et al. also reported that adhesive fracture were the most frequent type of fracture.(40) These differences in the frequency of the fracture types in our study and the previously published studies can be attributed with the differences in the cohesive strength of the different restoration materials that have been used, the possible presence of fractures and structural defects in dentin, and different types of devices that have been used to determine the bond strength in these studies.

Conclusions

Our findings showed that All-Bond Universal adhesive system is compatible with self-cured composites and provides a dentine bond strength as light-cured composites without the need for separate self-cure activator. Therefore, this bonding agent can be used with self- and dual-cured resin materials.

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Authors'contributions

Seyedeh Maryam Tavangar: Conceptualization, Methodology, Writing - Review & Editing **Yasaman Sadeghi:** Resources, Investigation, Visualization **Reza Tayefeh Davalloo:** Methodology, Visualization **Farideh Darabi:** Writing - Original Draft, Data Curation **Zahra Atrkar Roushan:** Funding acquisition, Project administration, Supervision **Hanieh Dadashi:** Writing - Review & Editing Resources

Conflict of Interests

The authors declare no conflict of interest.

Ethical declarations

Not applicable

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None

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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