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EFFECT OF SONIC APPLICATION ON MICROSHEAR BOND STRENGTH OF SELF-CURE UNIVERSAL ADHESIVE SYSTEM TO DENTIN: IN VITRO STUDY

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ABSTRACT

Objective: To assess the effect of sonic application on microshear bond strength (μSBS) of self-cure universal adhesive system to dentin. **Materials and methods:** A total of 48 specimens were obtained from 16 extracted molars after the occlusal surfaces were ground to expose the occlusal dentin. The samples were categorized into two primary groups (n=24) according to the application mode (manual and sonic). Afterwards, each main group was divided into 2 subgroups (n=12) based on universal adhesive system type; self-cure group (Palfique universal bond) and light-cure group (Single bond universal adhesive). Each subgroup was subsequently subdivided into two divisions based on storage time (three-months and six-months). A custom-made silicon sheet was seated over the tooth and the two adhesive systems were applied observing the manufacturer's guidelines (manual group) or sonic agitation for 20s (sonic group), then the nanofilled composite (Palfique lx5 composite) was added and packed into the holes. The μSBS was evaluated through a universal testing device after two water storage periods (three-months and six-months). **Results:** The sonic application mode showed a statistically significantly higher μSBS than manual application in both adhesives. There were no significant variances among the two types of adhesive systems or between the storage periods. However, the light-cure adhesive displayed a non- significantly higher μSBS than self-cure adhesive and there was a non-significant decrease in the μSBS with time in both adhesives. **Conclusions:** Sonic application may be considered an effective technique that can improve the dentin bonding strength of self-cure and light-cure adhesive systems.

KEYWORDS: Sonic application; Microshear bond strength; Dentin; Self-cure universal adhesive.

INTRODUCTION

Patient desire for esthetic restorations that mimic the natural tooth color, has made composites crucial in restorative procedures, with bonding being a key factor affecting intraoral performance and long-term success of composite restorations [(1)]. Currently, the one-step universal adhesive systems are popular because of its less sensitive approaches and easier application processes, allowing clinicians for utilizing them in self-etch, etch and rinse, or selective enamel etch approaches [(2)]. Self-etch adhesive systems can include a smear layer in the hybrid layer, which reduces postoperative pain brought on by the resin monomers' partial entry of the dentin [(3)].

Furthermore, the majority of adhesive polymerization that occurs today is photoinitiation based, meaning that the dentists have total control throughout the initiation process. The light cure adhesive systems were revealed to be troublesome when light supply was hampered, like in endodontic and deep cavity preparations [(4)]. The most recent technology available right now is self-cured bonding

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agents, which is an 8th generation of bonding agent that was developed to counteract this major drawback. Eliminating the light cure step augments the benefit of saving time. It also chemical curing in areas inaccessible to light curing[5].

Dentin bonding is difficult than to enamel since the enamel has a lesser water content and a greater mineral concentration than dentin[6]. However, dentin structure and adhesive system performance are both important factors in dentin bonding, also because of the heterogeneous substrate and histology of dentin have made adherence to it difficult[7]. In actuality, it is crucial to achieve both a strong bonding at the resin–dentin interface and optimal interdiffusion of the bonding resins inside collagen fibrils[8].

It becomes sense to give careful thought to improve the description of the gold standard method for placing the bonding agents to dentin. As such, a variety of techniques, such as active bonding application, multiple-layer application, and prolonged application duration, may be implemented by dentists in their routine practice to enhance the dentin bond strength. However, there is no perfect approach to achieve consistent and optimum adhesion of bonding agents to dentin [9].

The adhesives' micromechanical contact with the underneath hard tissues and the bond strength are both enhanced by the active application [10]. However, the force from the dentist can be applied to the active application, this if not standardized, might compromise the approach's effectiveness. Various adhesive application tools were used, and they are all capable of standardizing the process [11]. Sonic device use is superior to manual active application in clinical settings due to its ability to reduce finger pressure variations, ensure homogeneous adhesive vibration, and require no calibration procedure, making it less sensitive to operator experience [12].

Thus, from the previous review, it was important to determine how sonic application affects microshear bond strength (μSBS) of self-cure universal adhesive system to dentin at different water storage periods (3 months and 6 months). The null hypothesis was that the sonic treatment expected to greatly enhance the μSBS, and there is no significant variance in the μSBS between self-cure and light cure universal adhesive systems.

MATERIALS AND METHODS

Materials

Two types of universal adhesives and one nanofilled composite were utilized in the current research as listed in **(Table 1)**.

TABLE (1) Materials used in this research:

Brand name and material specification	Composition	Manufacturer
Single bond universal adhesive (Light cure universal adhesive)	10-MDP, Bis-GMA, phosphate monomer, dimethacrylate resins, HEMA, methacrylatemodified polyalkenoic acid copolymer, filler, ethanol, water, initiators, silane-treated silica, silane.	3M ESPE, USA.
Palfique universal bond (Self-cure universal adhesive)	Bond A: Phosphoric acid monomer (New 3D.SR monomer), MTU-6, HEMA, Bis-GMA, TEGDMA, and acetone. Bond B: γ-MPTES, borate, peroxide, acetone, isopropyl alcohol, and water.	Tokuyama Dental Corporation Inc, Japan.
Palfique lx5 composite (Nanofilled composite)	Monomer matrix composition: Bis-GMA and TEG-DMA. Filler content: 82% wt, 71% vol. silica-zirconia filler and composite filler. Particle size range: 0.1 to 0.3 micron.	Tokuyama Dental Corporation Inc, Japan.

MDP: methacryloyloxy-decyl-dihydrogen-phosphate. Bis-GMA: bisphenol-A-glycidyl methacrylate. HEMA: 2-hydroxyethyl methacrylate. MTU-6: 6-methacryloyloxyhexyl-2-thiouraci 5-carboxylate. TEG-DMA: triethyleneglycol dimethacrylate. γ-MPTES: γmethacryloyloxypropyltriethoxysilane.

Methods

Sample size calculation:

According to Bagiz et al (2008) [13] the sample size estimation used in the G power test analysis program (version 3.1.9.4) recorded a total of 24 specimens. The total sample size was assigned to two main groups (n=12) based on the application mode (manual or sonic), then further subdivided according to the curing mode (Chemical & Light) into two subgroups, (n=6) will be adequate to identify a significant effect size (f) = 0.8 in each, using a two-sided hypothesis test significance threshold (α error) of 0.05 (5%) and real power (1-β error) of 0.8 (80%). As our study had 2 observations times (T1 and T2), the number of samples will be doubled to a total sample size=48 specimens (6 in each of the 8 subgroups).

Grouping of specimens:

A total of 16 molars were used to obtain 48 specimens (three specimens from each tooth) which were categorized into 2 main groups (n=24) based on the application mode: group (A) sonic application and group (B) manual application. Every main group was then divided into 2 subgroups based on the type of universal adhesive system; (n=12); subgroup 1 (S1) self-cure and subgroup 2 (S2) light cure. Every subgroup was finally subdivided into 2 divisions based on the storage time (n=6); (T1) three months and (T2) six months.

Preparation of the occlusal dentin surface:

A custom-made cylindrical plastic mold (15×20 mm) was fabricated and packed with self-curing acrylic resin. Every tooth was placed vertically in the mold with the occlusal surface protruding over the mold's surface, at the height of the cemento-enamel junction. Furthermore, the teeth were removed from the mold after acrylic curing. Employing a grit carborundum disc, a grinding device was utilized to wet reduction the occlusal surface 2 mm and the dentin was exposed. To establish a uniform smear layer, the dentin surface was subsequently eroded for 60 seconds beneath tap water using wet silicon carbide abrasive paper of #600 grit [1].

Construction of custom-made sheet for adhesives and composite application:

A custom-made mold was constructed from aluminum material. The mold consists of; A) frame, B) cover, C) condenser **(Figure 1)**. The frame, with a thickness of 3mm, features four horizontal projections (1mm in height) in the half, allowing for complete seating over the tooth's occlusal surface. The cover features five 1mm height and 1.2mm diameter projections, separated by 2.5mm. Five specimens from each tooth were obtained compensate for the specimen's distortion during storage and/or testing. The special constructed condenser (1.2mm in diameter) was used in the packing of composite resin in the holes created in the silicon mold.

The frame was placed on the tooth surface with four projections, then transparent silicon was poured, and a cover was placed with pressure to allow the excess to escape. After the material was set the cover and frame were removed to obtain a custom-made sheet with 1mm thickness and 1.2mm diameter holes.

Application of adhesive systems and composite:

a) Manual application:

The custom-made sheet which was constructed for adhesives and composite application was seated over the tooth. The application of the two adhesive systems followed the manufacturer's recommendations. For the self-cure adhesive; the product was supplied in two bottles, bottle A and bottle B, one drop from each bottle was added in the rubber mixing well, and mixed with each other using the micro brush provided by the manufacturer. Then applied to the dentin surface and left for 10s, gentle air dried until movement of the bond disappeared, no curing required.

For the light cure adhesive; the bottle was shacked thoroughly, using the micro brush the bond was applied to dentin surface and rubbed for 20s, gentle air dryness for 5s, then curing for 10s with a LED light curing unit (Premium plus, UK ltd, Co2 curing light, China, wavelength 390~430nm/440~480nm, light intensity 1200 mW/cm^2) [3].

Afterward, the custom-made sheet was removed and completely dried then reapply it. The nanofilled composite resin (PALFIQUE LX5) was added and packed into the holes using the custom-made condenser and light cured for 40s, then the silicon sheet was removed easily to obtain five composite projections 1mm height and 1.2 mm diameter at dentin surface.

b) Sonic application:

After application of the self-cure and light cure adhesive systems on the dentin surface, the micro brush of adhesives was cut and attached to a sonic application device with a frequency of 170 Hz (Spark Innovators Corp. New York) and applied to the dispersed adhesives on the dentin surface to produce sonic vibration to the adhesive for 20s [11].

The specimens were maintained at 37°C in an incubator with 100% humidity in water at different storage periods (3 and 6-months) up till the μSBS evaluation was performed [13].

Microshear Bond Strength Testing

Following each storage time, the specimen-filled acrylic block was secured to the universal testing device's lower fixed head. Each tube was tested for μSBS employing a 0.14-inch-diameter stainless steel wire that was secured to the testing device's upper moving head. It was positioned in closest proximity to the interface between the dentin and composite, then 1.0 mm/min crosshead speed was used to apply shear force until the specimen broke [1]. The device's program (BlueHill 3 Instron England) calculated the μSBS in MPa by dividing the force needed for failure (Newton) by the surface area (mm2).

Statistical analysis

The Shapiro-Wilk test was used to determine the normality of the data. Statistical analysis was performed using IBM SPSS Statistics software, version 25. Statistical analysis was conducted to compare the data using one-way ANOVA, followed by the Tukey post hoc test for multiple comparisons of μSBS mean values. The statistical significance was preset at $P \leq 0.05$.

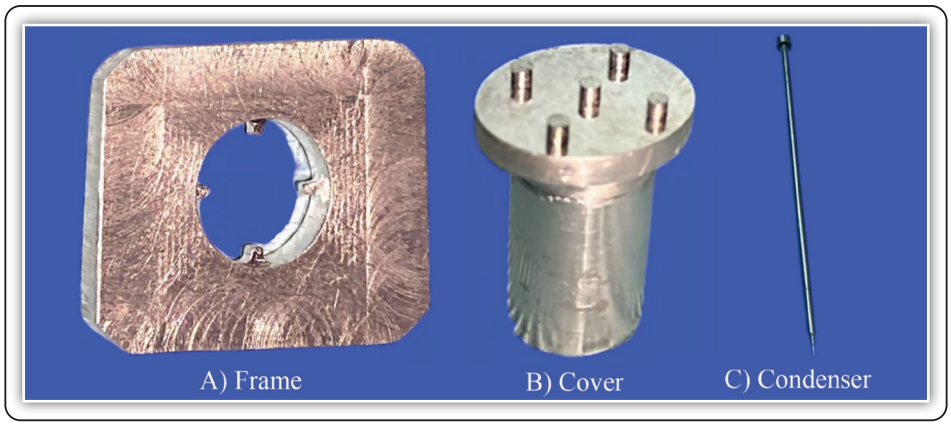

FIG (1) A custom-made mold.

RESULTS

Effect of different application modes on the microshear bond strength:

The results displayed that the comparison between the two application modes under the same time interval and the same adhesive system was statistically significant (P-value ≤ 0.001) according to the Tukey post hoc test. In comparison to manual application, the sonic application mode produced a statistically significant greater μSBS for both evaluated adhesive systems (p =0.000*). **(Table 2).**

Effect of curing type on the microshear bond strength

The results showed that the comparison between the two types of adhesive systems under the same time interval and the same application mode was not statistically significant (P-value > 0.05) according to the Tukey post hoc. However, the light-cure adhesive displayed a non-significant higher μSBS than the self-cure adhesive. **(Table 3).**

Effect of storage time on the microshear bond strength:

According to the Tukey post hoc, the results showed that the comparison between the two time intervals under the same types of adhesive systems and the same application mode was not statistically significant (P-value > 0.05). However, there was a non-significant decrease in the value of μSBS with time in both adhesives and the higher mean of μSBS was achieved at 3 months, while the lower value was achieved after 6 months. **(Table 4).**

TABLE (2) Comparison of microshear bond strength between the different application modes (sonic and manual) in the two types of adhesive systems at the two time intervals:

Storage periods	Light-cure adhesive		P-value	Self-cure adhesive		P-value
	Sonic application	Manual application		Sonic application	Manual application	
3 months	20.79±0.51	18.18±0.36	0.000*	20.47±0.36	17.86±0.12	0.000*
6 months	20.46±0.55	18.1±0.13	0.000*	20.11±0.46	17.62±0.41	0.000*

**: Significant at P ≤ 0.05.*

TABLE (3) Comparison of microshear bond strength between the two types of adhesive systems for the different application modes (sonic and manual) at the two time intervals:

Application modes	3 Months			6 Months		
	Light-cure adhesive	Self-cure adhesive	P-value	Light-cure adhesive	Self-cure adhesive	P-value
Sonic	20.79±0.51	20.47±0.36	0.992^{NS}	20.46±0.55	20.11±0.46	0.661^{NS}
Manual	18.18±0.36	17.86±0.12	0.958^{NS}	18.1±0.13	17.62±0.41	0.199^{NS}

NS= Non-significance (P < 0.05).

TABLE (4) Comparison of microshear bond strength between the two time intervals for the different application modes (sonic and manual) in the two types of adhesive systems:

Application modes	Light-cure adhesive		P-value	Self-cure adhesive		P-value
	3-months	6-months		3-months	6-months	
Sonic application	20.79±0.51	20.46±0.55	0.530^{NS}	20.47±0.36	20.11±0.46	0.345^{NS}
Manual application	18.18±0.36	18.1±0.13	0.989^{NS}	17.86±0.12	17.62±0.41	0.668^{NS}

NS= Non-significance (P < 0.05).

DISCUSSION

Since the development of resin-based restorations, their lifetime has been dependent on the adhesive joint's bond strength and stability. As a result, producers continued creating new adhesive agents with the goal of enhancing the bond strength with the enamel and dentin while also lowering method sensitivity and clinical steps [14].

Our results revealed that the sonic application of both adhesives led to a significant increase in the μSBS. This may be attributed to the rapid vibration of the micro-brush generates pressure waves and shear pressures inside the adhesive, potentially resulting in increased resins infiltration into the porosities resulting from demineralization [11]. These results agreed with those found by Awad et al [15] who found that the sonic application of one step universal adhesive system significantly enhanced the resin–dentin bond strength.

In particular, sonic vibration on a micro-brush applies sonic vibration to the adhesive solution which enhances the adhesion of adhesive solutions, allowing fresh monomers to penetrate deeper into the tooth substrate, resulting in deeper demineralization. This furthermore produces microscopic bubbles, which are pushed back toward the applied solution with force. It has been suggested that ultrasonic devices might improve accommodation and dispersion of the adhesive material [16].

Moreover, sonic vibration can enhance the chemical bonding of functional monomers with tooth substrate minerals by stimulating solution molecules with high-speed vibration applied to a micro-brush, leading to approximation and increased chemical interactions among monomers [3]. However, in contrast to our findings, Serin-Kalay et al [17] found that the active application of self-cure universal adhesive lowered its dentin bond strength. They explained that the rubbing action harms the chemical polymerization process, and it probably results from the degradation of the interface bonding layer.

Regarding to the type of adhesive system, our results displayed that the μSBS of the light cure adhesive was higher than the self-cure one, but not significantly. This may be due to the different chemical composition of each adhesive system in which the light cure adhesive contains (HEMA, 10 MDP) while the self-cure one contains (HEMA) only. The 10-MDP enhances bond strength, while HEMA decreases it to dentin [18]. Moreover, the combination of 10-MDP as the acidic monomer with HEMA claims to enhance dentin's calcium ion chelation and tooth surface wetness [19]. The outcomes aligned with the findings of Çeşme et al [20] who stated that the light-cure universal adhesive system demonstrated a non-significantly stronger dentin bond strength than the self-cure.

Additionally, 10-MDP is a hydrophobic monomer with mild-etching properties, making it suitable for universal adhesives. It is chemically

bonded to dentin hydroxyapatite crystals through ionic bonds with calcium ions, resulting in an insoluble MDP-Ca salt. Additionally, its phosphate groups create covalent bonds with hydroxyapatite crystals, forming insoluble salts [21].

Our results showed that the μSBS of the self-curing adhesive was comparable to the light cure one. This may be due to the self-curing adhesive, containing a Borate catalyst initiator, promoting polymerization and generating free radicals when interacting with acidic phosphoric monomer, increasing the conversion degree of the adhesive layer [17]. In addition, self-curing adhesive based on 3D self-reinforcing (SR) technology can chemically bond to the hard teeth structure by generating many calcium-dependent ionic bonding sites. The "gel effect" of borate-based SR adhesive content aids in penetrating dentin tubules [22].

On the other hand, our findings were in contrast with Katsumata et al [23] who found that the self-curing adhesive had higher dentin bond strength than the light cure one. They stated that the self-curing adhesive's improved bond performance may have been influenced by the potent borate catalyst.

Concerning the time, our findings displayed that there wasn't significant variation among the storage periods. This can be attributed to that the self-etch adhesive systems utilize micro-mechanical bonding which provides mechanical strength and chemical bonding which reduces hydrolytic, ensuring long-lasting marginal sealing for restorations [24]. These results agreed with Çeşme et al [20] who evaluated the dentin bond strength of both universal adhesives after 5,000 cycles of thermocycling which is comparable to 6-months of water storage. They found that there were no significant changes in dentin bond strength between them after thermal ageing.

The presence of 10-MDP (in light-cure adhesive) resulted in strong and long-lasting adhesion to calcium ions in hydroxyapatite which contributes to bond durability. As it forms insoluble nanolayers and keeps the hybrid layer from being hydrolyzed [25]. Furthermore, 3D-SR's solubility stability in self-cure adhesive was most likely comparable to that of 10-MDP. Because the phosphate monomer in 3D-SR has the ability to partially self-organize inside an adhesive and form multifunctional monomer constructions with various phosphate groups. Those several phosphate groups are capable of interacting with calcium at multiple sites and forming ionic bonds [26].

However, we found that there was a little non-significant decrease in the μSBS with the time of both adhesives. This may be because of the water absorption capabilities of simplified resin bonding systems. This leads to gradual hydrolytic degradation within the hybrid layer, which is further exacerbated by water penetration through nanoleakage channels. As a result, the bonding strength decreased with time [27].

Unlike our result, Jowkar et al [28] found that the dentin μSBS of light cure universal adhesive significantly reduced after 6-months of water storage. Also, in contrast to our results, Gutiérrez et al [29] found that the self-cure universal adhesive had a significant reduction in μSBS after 6 months of water storage. They explained that the hydrophilic monomers promote water uptake and hydrolysis at the adhesive interface, affecting the durability of the bond.

According to our results, the null hypothesis was accepted as the sonic application significantly increased the μSBS and there was no significant variation in the μSBS among self-cure and light cure universal adhesive systems.

CONCLUSIONS

Under the constraints of this research, we may conclude that:

1. Sonic application may be considered an effective technique that can be used to improve the dentin bonding strength of self-cure and light-cure universal adhesive systems.

2. The self-cure universal adhesive provided a comparable dentin bond strength to the light cure one.
3. Both universal adhesive systems provided relatively stable dentin bond strength over the storage time.

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