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# Evaluation of bond strength of orthodontic brackets using light- and chemical-cure adhesive systems over time: An *in-vitro* study

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## Abstract

**AIMS:** This study aimed to evaluate the bond strength of light- and chemical-cure adhesive systems over six months.

**MATERIALS AND METHODS:** A total of 144 sound human maxillary first and second premolars were randomly divided into six groups according to the adhesive type (i.e., Transbond XT and Unite) and evaluation time. The groups were T0 (24-h group without thermocycling), T1 (24-h group with thermocycling), T2 (1-month group), T3 (2-month group), T4 (4-month group), and T5 (6-month group). The bond strength was then measured and the data were analyzed by SPSS software (version 23) through the independent t-test and one-way ANOVA. A $P$ value less than 0.05 was considered statistically significant.

**RESULTS:** The results of this study showed that shear bond strength of chemical-cure orthodontic adhesive (Unite, 15.37 MPa) at all-time points was significantly 1.37 times higher than that of the Transbond XT light-cure adhesive (11.15 MPa). Moreover, shear bond strength of self-cure adhesive (Unite) 1 month after debonding showed a significant difference with the 24-h group without thermocycling ($P = 0.002$), 24-h group with thermocycling ($P = 0.008$), and 6-month group ($P = 0.016$). The highest shear bond strength in both adhesives was observed at one month. Furthermore, the shear bond strength of Transbond XT light-cure adhesive one month after debonding showed a significant difference with the 24-h group without thermocycling ($P = 0.000$) and 24-h group with thermocycling ($P = 0.000$), as well as with the 2-month ($P = 0.008$), 4-month ($P = 0.000$), and 6-month groups ($P = 0.016$).

**CONCLUSION:** Unite self-cure adhesive compared to Transbond XT light-cure adhesive has higher bond strength and is recommended for rebonding brackets in patients with multiple rebonds.

**Keywords:**
Adhesive resins, orthodontic brackets, shear bond strength

## Introduction

Brackets as an important part of fixed orthodontics, are bonded to tooth surfaces using various adhesives. Since tooth movement during treatment depends on the wires and springs attached to the brackets, the procedures for their bonding are critical in obtaining optimal results in orthodontic therapy.[1] Bracket debonding during the treatment process increases treatment duration, enamel damage, and chair-side time because rebonding evidently requires more time. Hence, not only will the patient experience an increase in treatment time but also the patient's attitude to proper dental hygiene will negatively change. Moreover, the risk of irreversible enamel decalcification could increase followed by the total cost of the treatment.[2,3]



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Regarding more efficient direct bonding, adhesive and attachment strength of the bond should be adequate to endure mastication pressures and arch-wire stress, and facilitate tooth movement control in all three dimensions.[4] Many factors affect the bond strength of the brackets, such as those related to materials, enamel surface preparation type, etching technique and material, type of bracket, size and shape of brackets, as well as adhesives and tooth-related factors.[2] Many studies have compared the shear bond strength (SBS) of the brackets in terms of the type of acid, concentration of acid, etching time, and different etching patterns.[5,6]

A variety of bonding agents were produced after the introduction of the acid-etch technique, and chemical-curing bonding systems were presented as the most popular bonding resins. The major disadvantage of these systems is the inability to control the setting time of the composite resins.[7,8] Light-curing resin composites were introduced with the advantage of extended working time, which allows practitioners to choose the time for the initiation of the adhesive curing cycle. As a consequence, the placement of the brackets can be performed more accurately.[7] This study aimed to evaluate the SBS of the brackets bonded to enamel with two different chemical and light-cured composite resins.

## Materials and Method

The study utilized a total of 144 sound permanent maxillary premolar teeth free of caries, fillings, hypoplasia, or other visible defects that were extracted for orthodontic reasons. The teeth were stored in thymol 0.1% solution to prevent dehydration and bacterial growth. Initially, the teeth were cleaned using fluoride-free pumice powder for 10 sec, and subsequently, they were thoroughly rinsed with water and dried with compressed air. Next, each tooth was etched by 37% phosphoric acid for 30 sec, rinsed by water spray for 30 sec, and air-dried until the frosty white etched area was visible.

After the cleansing process was completed, the teeth were divided into two chemical-cured and light-cured composite groups. In the chemical-cured composite group, a layer of composite primer (Unite, 3M, Unitek, USA) was applied on the tooth and bracket base. Subsequently, an adequate amount of composite adhesive was applied on the base of the brackets. The brackets were attached to the center of the buccal surface and compressed with an 11-12 explorer to obtain maximum contact with the tooth buccal surface. The excess composite surrounding the brackets was removed gently by an explorer. MBT 0.22 bicuspid metal brackets (Dentaurum, Discovery Smart Brackets, Germany) were utilized in this study.

In the light-cured composite group, a layer of resin was applied over the tooth, and then composite was applied to the base of the bracket and compressed on the center of the tooth crown. The excessive composite was removed and cured for 20 sec in each mesial, distal, occlusal, and gingival direction.

After 60 sec passed from the initial setting, all teeth were stored in distilled water and incubated for 24 hours. Each composite group was divided into six subgroups of 12 teeth. In order to simulate the thermal stress conditions of the oral temperature changes, the specimens were thermocycled for 30 cycles a day between 5°C (cold bath) and 55°C (warm bath) (30 sec in each temperature and 15 sec for transportation time). After thermocycling, the specimens were incubated in artificial saliva until the testing time.

The subgroups included:

T0: 24-h group without thermocycling

T1: 24-h group with 30 thermocycling cycles

T2: 1-month group with 900 thermocycling cycles (incubated for one month in artificial saliva after thermocycling)

T3: 2-month group with 1800 thermocycling cycles

T4: 4-month group with 3600 thermocycling cycles

T5: 6-month group with 5400 thermocycling cycles

Each tooth was mounted in acrylic resin in such a way that the vertical groove of the bracket was perpendicular to the surveyor bars. The setting molds remained in the water during the setting time to prevent an increase in temperature. Afterward, the SBS test was performed using the Universal Testing Machine (Sintam, Iran) in the shear mode with a crosshead speed of 0.5 mm/min. The machine reported the values of failure load (N), and they were then converted into megapascals (MPa) dividing N by the surface area of the bracket base (12.96 $mm^2$). Due to the continuity of the main variable, the mean ± SD was employed to describe the data, and the Kolmogorov-Smirnov test was used to evaluate normal distribution. Moreover, to compare the groups, the t-test and one-way ANOVA were performed. The data were analyzed by SPSS software (version 23). A $P$ value less than 0.05 was considered statistically significant.

## Results

According to the Kolmogorov-Smirnov test, the SBS values of the light-cure ($P$ = 0.200) and chemical-cure adhesives ($P$ = 0.200) demonstrated normal distribution.

Table 1 tabulates the mean ± SD of SBS for the different times and two types of adhesive bonding (Transbond-XT and Unite).

After comparing all specimens, the results showed that the chemical-cured adhesive (Unite) obtained a significantly higher mean SBS (15.37 MPa), which was 1.37 times higher, compared to the light-cured adhesive (Transbond-XT) (11.15 MPa). The adhesive bonding systems were evaluated separately to analyze the SBS difference regarding different times after the bonding procedure. The one-way ANOVA was performed for each adhesive, and the results showed a significant difference between the Unite group ($P = 0.002$) and the Transbond-XT group ($P = 0.000$) in this regard. Moreover, the post-hoc Tukey test was performed, and different times were compared in a group. Table 2 summarizes the comparison of different times for Unite chemical-cure adhesive. The 1-month group reveals a significant difference with the 24-h group without ($P = 0.002$) and with thermocycling ($P = 0.008$) and the 6-month group ($P = 0.016$). Moreover, the 1-month group obtained the maximum SBS value (18.89 ± 2.68 MPa).

The comparison of different times for the Transbond-XT light-cure adhesive is listed in Table 3. The 1-month group showed a significant difference with the 24-h group without ($P = 0.000$) and with thermocycling ($P = 0.000$), as well as the 2-month ($P = 0.008$), 4-month ($P = 0.000$), and 6-month groups ($P = 0.000$). It should be noted that the 1-month group obtained the maximum SBS value.

The mean values and comparison of two adhesive bonding techniques at different times are illustrated in Figure 1, indicating the highest increase in SBS values 1 month after the bonding procedure, which gradually decreased in 6 months.

## Discussion

SBS depends on various parameters, such as adhesive material features, adhesion of different interphases, and composite bonding material polymerization. This study aimed to compare the SBS of two light-cure and chemical-cure adhesive systems.[9] Since the use of Transbond-XT light-cure adhesive is most common in orthodontics, it was compared with the Unite chemical-cured adhesive from the same company.[10]

Reynolds[11] suggested the minimum SBS values for clinical orthodontic use should be at 5.9-7.8 MPa. In this study, all mean amounts of SBS were higher, making them acceptable for clinical use. However, there was a difference between the clinical and *in vitro* situation in this regard. Since the current study was done *in vitro*, the differences among temperature, humidity, and forces in the oral cavity, should be mentioned.

The results of this study showed that SBS of chemical-cure orthodontic adhesive (no mix Unite, 15.37 MPa) at all times (24 h, as well as 1, 2, 4, and 6 months) was significantly higher than that of Transbond XT light-cure adhesive (11.15 MPa). Since it was about 1.37 times higher, the null hypothesis was rejected. Higher filler content in the Unite can be the reason for its higher SBS values, compared to Transbond-XT. On the other hand, the fact of being a dual-cure and the gradual curing of Transbond-XT can be the reason for its lower SBS.[12]

There are a limited number of studies comparing the SBS of light-cure and chemical-cure adhesive systems. Bulut *et al*.[13] evaluated the SBS of three adhesive systems in combination with the antibacterial adhesive component although different times were not evaluated. No-mix Unite, Concise, and Transbond-XT were used in the aforementioned study, wherein the control and

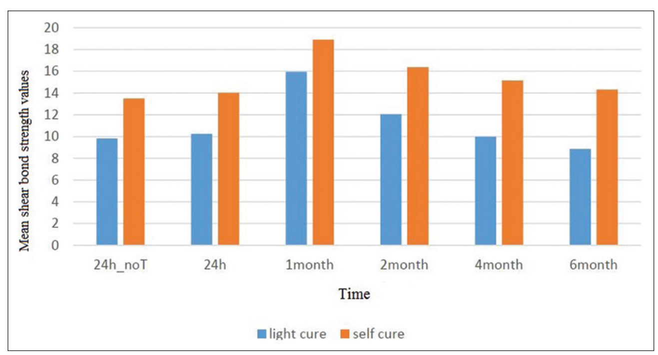


**Figure 1:** The mean values and comparison of two adhesive bonding techniques at different times

**Table 1: Mean and standard deviation of shear bond strength due to type of adhesive bonding material and duration after bonding procedure and T-test result**

| Time duration after bonding | Number | Unite (MPa) | Number | Transbond XT (MPa) | Test result |
|---|---|---|---|---|---|
| 24 hours | 12 | 13.49±3.56 | 12 | 9.82±2.1 | $P$=0.006 |
| 24 hours (Thermocycle) | 12 | 14.02±3.78 | 12 | 10.24±2.08 | $P$=0.006 |
| 1 month | 12 | 18.89±2.68 | 12 | 15.94±3.81 | $P$=0.039 |
| 2 months | 12 | 16.37±2.9 | 12 | 12.06±2.88 | $P$=0.001 |
| 4 months | 12 | 15.15±4.06 | 12 | 9.98±2.75 | $P$=0.001 |
| 6 months | 12 | 14.32±2.73 | 12 | 8.85±1.76 | $P$<0.000 |
| Total | 72 | 15.37±3.7 | 72 | 11.15±3.48 | |

**Table 2: A comparison of shear bond strength in different time groups of this study for Unite adhesive bonding**

| Time duration after bonding | 24 hours (Thermocycle) | 1 month | 2 months | 4 months | 6 months |
|---|---|---|---|---|---|
| 24 hours | 0.999 | 0.002* | 0.291 | 0.825 | 0.990 |
| 24 hours (Thermocycle) | | 0.008* | 0.519 | 0.961 | 1.000 |
| 1 month | 0.008 | | 0.441 | 0.079 | 0.016* |
| 2 months | 0.519 | 0.441 | | 0.946 | 0.661 |
| 4 months | 0.961 | 0.079 | 0.946 | | 0.990 |

**Table 3: A comparison of shear bond strength in different time groups of this study for Transbond-XT adhesive bonding**

| Time duration after bonding | 24 Hhours (Thermocycle) | 1 month | 2 months | 4 months | 6 months |
|---|---|---|---|---|---|
| 24 hours | 0.999 | 0.000* | 0.321 | 1.000 | 0.947 |
| 24 hours (Thermocycle) | | 0.000* | 0.554 | 1.000 | 0.794 |
| 1 month | 0.000* | | 0.008* | 0.000* | 0.000* |
| 2 months | 0.554 | 0.008* | | 0.406 | 0.048 |
| 4 months | 1.000 | 0.000* | 0.406 | | 0.901 |

experimental groups used each adhesive. All specimens were stored in water for 24 h and then thermocycled for 500 cycles. The results showed that the SBS values of Unite were higher than those of the Transbond-XT in the control group although it was not statically significant.

Similarly, Omidkhoda *et al*.[14] compared the *in vivo* SBS values of no mix Unite and Transbond-XT and reported significantly higher SBS in the Unite group, which was consistent with the result of this study. Likewise, Ravadgar *et al*.[15] evaluated the bond strength of Transbond-XT (with and without self-etch primer) and Unite TM. According to the results, the bond strength of Unite TM was higher than that of the Transbond-XT (with self-etch primer) and lower than that of the Transbond-XT (without self-etch primer); however, the difference was not significant in this regard. In the study, acid phosphoric 37% was utilized before adhesive application; therefore, the results were not comparable. Nonetheless, it was shown that the bond strength of chemical-cure adhesive was higher than that of the light-cure when using etching application. During thermocycling, the specimens are exposed to thermal changes, and the difference among metal brackets, adhesive, and teeth regarding thermal expansion coefficient can cause repetitive contraction and expansion stress, so the influence of thermal stresses on bonding strength can be evaluated by this artificial aging test.[16] In addition, bond strength evaluation in the study had significant alteration over time, and the highest SBS for both adhesives were observed one month after bonding the specimens. Over time, a gradual increase was observed in the SBS amount in the first month followed by a decrease in the 2-month (1800 cycle), 4-month (3600 cycles), and 6-month (5400 cycles) groups. It seems that 30 and 900 cycles cannot simulate the aging process of the orthodontic treatments. It is possible that some of the adhesive systems gradually change some parts of adhesive-enamel adhesion surfaces; accordingly, many studies showed significant differences only in the case of long thermocycling periods.[12]

Hajrassie *et al*.[17] evaluated *in vitro* and *in vivo* SBS for Transbond-XT at different times (10 min, 24 h, 1 week, and 4 weeks after bonding). The results showed that mean debonding forces were significantly lower in the in vivo, compared to the *in vitro*. Furthermore, there was no significant difference among the different periods in the study. Since Hajrassie *et al*. did not employ thermocycling, the differences in the results may be attributed to the effect of thermal changes and shocks in the current study.

In 2014, Vinagre *et al*.[12] analyzed the SBS amounts of Transbond-XT at different times (15 min, 24 h without thermocycling, and 24 h with 500 cycles of thermocycling). The results revealed an increase in the values of SBS from 15 min to 24 h, which was in line with the results of this study. It was also reported that thermocycling had no negative effect on bond strength, which was also consistent with the findings of the current study in the 24-h group.

Furthermore, Elekdag-Turk *et al*.[16] assessed the SBS of light-cured Transbond-XT (with and without self-etch primer) using different times of thermocycling (0, 2000, and 5000 cycles). The results reported a decrease in the SBS values after 2000 and 5000 cycles of thermocycling; however, it was only significant in the self-etch primer group. In the current study, the bond strength was decreased after 1800 (2 months), 3600 (4 months), and 5400 cycles (6 months) in descending order.

Finally, the differences between the results of this study and those of other studies can be attributed to specimen storage condition, method of specimen disinfecting, type of bracket used, type of thermocycling, type of light-cure device, and force used for bracket adhesion.

For clinical situations, the utilization of Unite self-cure adhesive may result in a lower debonding rate and a decrease in the time-consuming and costly process of replacing the brackets, especially for non-cooperative patients with a history of debonded brackets many times. Also, it will reduce damage to the enamel caused by repeated etching, and will increase the patient's satisfaction.

## Conclusion

SBS of chemical-cure orthodontic adhesive (Unite, 15.37 MPa) was significantly 1.37 times higher than that of the Transbond XT light-cure adhesive (11.15 MPa) at all timed (24 h, and 1, 2, 4, and 6 months). Moreover, the SBS of Unite chemical-cure adhesive one month after debonding showed a significant difference with the 24-h group without thermocycling ($P = 0.002$), 24-h group with thermocycling ($P = 0.008$), and 6-month group ($P = 0.016$).

It is worth mentioning that the highest SBS in both adhesive techniques was observed at one month.

All SBS values in this study were higher than the minimum required for orthodontic bracket bonding in fixed appliances. Furthermore, Unite chemical-cure adhesive has higher bond strength, compared to Transbond XT light-cure adhesive, and is recommended for rebonding brackets in patients with multiple rebonds.

### Author contribution's

Dr. Omidkhoda: conception, design, Supervision and critical review

Dr. Eslami: conception, Design and critical review.

Dr. Mazloum: Data collection and Processing, Analysis and literature review.

Dr. Entezari: Data collection and analysis, literature review, and Writing.

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### Ethical consideration

This study was registered (ethic code: IR.MUMS.DENTISTRY.REC.1397.113) in the Mashhad University of Medical Sciences. Informed consent was not taken due to the study being *in vitro*, which only used extracted teeth.

### Main Points:

- Orthodontic bracket debonding during the treatment process increases the treatment duration and chair side time.
- Shear bond strength was compared after using light and chemical cured adhesive.
- Unite no-mix adhesive compared to Transbond XT adhesive has higher bond strength.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

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