

The relationship between light curing time, shear bond strength (SBS) and remanence index of adhesive (ARI)

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ABSTRACT

The objective of this study is to investigate the effect of different light curing times on the shear strength and remanence index of the adhesive. The light curing intensity was presented by Woodpecker LED light curing unit (2500 mw/cm²). The study was performed on groups of extracted premolars: The first and second groups had a light-curing time of 3 seconds, and the third and fourth groups had a light-curing time of 6 seconds. However, the first and third groups were tested after 24 hours, and the second and fourth groups after 14 days. The study showed that increasing the light curing intensity, exposure time and the time after the brackets bonding will increase SBS and will decrease ARI on the other hand, using light curing unit (2500 mw/cm²) with 6 seconds light exposer will produce sufficient SBS, and 3 seconds light cure exposer (2500 mw/cm²) will produce insufficient SBS.

Keywords: SBS, ARI, bracket, bonding, light curing, enamel, adhesive

INTRODUCTION

More than 40 years ago, orthodontic brackets were initially attached directly to teeth. The tooth surface and its preparation, the design of the attachment base, and the bonding substance itself must all be carefully taken into account for a good bonding in orthodontics.

The type of enamel conditioner used, the acid concentration utilized, the length of the etching process, the adhesive composition used, the shape of the bracket base, and the material used for the brackets are all factors that affect bond strength [1].

In orthodontics, light-activated bonding agents have become the preferred polymerization method.

Numerous factors can influence the light intensity during exposure and thus change the properties of the cured composite.

Maintaining strong light intensities both on the resin surface and throughout the substance helps polymerize the resin. The exact distance between the tip of the activating light source and the surface of the resin being exposed is one of the elements that affect light intensity, and that the practitioner can control. To avoid in-tensity loss, this distance should be kept as small as possible. In addition, the in-tensity of the light emitted from the light tip decreases in inverse proportion to the square of the distance between the tooth and the tip. However,

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there are several clear clinical scenarios in which it is difficult to position the laser spot close to the acrylic surface as required.

The following study was carried out under the null hypothesis that a slight change in the distance between the light tip and the bonding surface has no significant effect on the shear bond strength (SBS) of composites material and glass ionomer resin-modified cement (RMGIC) used for bracket bonding, taking into account the necessity and restriction of the proximity of the light tip to the acrylic skin.

Light-cure systems are commonly used in orthodontic treatments with fixed appliances [1,2].

However, light-curing has disadvantages in orthodontic treatment because each bracket is exposed to a light source [4,5].

In addition, with light curing, the metal brackets are displaced by the anchoring of the light source [6].

During treatment, the most important aspect is to achieve true bond strength to prevent further debonding. If this goal is not achieved, the cost may increase and the treatment will take more time [7,8]. Some factors may play a role in proper bond strength [9,10].

Nevertheless, the degree of light-activated curing is responsible for the physical and mechanical properties of the composites. Moreover, they are of great interest because they are also directly related to light intensity and irradiation time [11,12].

For efficient polymerization, the specific amount of energy required for exposure to the photoinitiator is crucial.

The photoinitiator is responsible for effective activation of polymerization and therefore must be brought to a certain level. The product of exposure time and irradiance is the total amount of energy supplied to the polymer cement, also called radiation exposure [11,13].

The photoinitiator is responsible for effective activation of polymerization and must therefore be excited to a certain level. The product of exposure time and irradiance is the total amount of energy delivered to the resin cement, also called radiation exposure [11,13]. Considering exposure time and irradiance, it can be theoretically assumed that the reduction of one can be compensated by the increase of the other [14,15]. The significant disadvantage of long chair time and exposure time can be reduced by newly developed powerful LED curing units with higher light intensities [11,14]. Recommendations from manufacturers of light-curing orthodontic cement blocks were that a single tooth should be exposed to approximately 400 YmW/cm² for 20-40 seconds using conventional halogen curing units, and that the total exposure time for each bracket should be divided equally between the me-

sial and distal surfaces. 21 LED -Curing devices are available for purchase-in the first phase, the luting devices emit light at an intensity of approximately 800-1000 YmW/cm² with a reduced exposure time of 10 seconds [22-24]. Newer high-power curing devices LED can produce light at 1600-2000 YmW/cm² for as little as 6 seconds for metal brackets [6].

The objective of this study is to investigate the effect of different light curing times on the shear strength and remanence index of the adhesive.

MATERIALS AND METHODS

This study was conducted on 80 individuals who had permanent premolars extracted without restoration, caries, fracture, or wear and were selected for this study. All extracted premolars were stored in normal saline to protect the enamel surface from desiccation. The regular saline was replaced every week in order to prevent bacterial growth. The enamel surface was etched using phosphoric acid with a 36% phosphoric acid concentration (Blue Etch).

The water spray was used to wash all teeth for 15 seconds, and an oil-free air compress was used to dry the enamel surface of the teeth for 5 seconds.

The brackets (Unitek TM miniature metal double brackets) were held in place with forceps, and a small amount of 3M's adhesive material (Transbond XT and Transbond adhesive paste material) was placed on the brackets base, which were firmly placed in the correct position (4 mm from the occlusal surface of the teeth) with light pressure.

The excess adhesive material was removed before light curing, respecting the position of the brackets when removing the excess adhesive material.

Prior to light curing, any excess adhesive material was removed while respecting the brackets position

After ensuring that the enamel and brackets were in good condition, a thin layer of adhesive primer (Transbond XT Primer) was applied to the teeth's enamel surface.

The adhesive material was then light-cured (Woodpecker LED Curing Light 2500 mw/cm²) for 3 seconds (1 second on the mesial side, one second on the distal side and one second on the occlusal side) or 6 seconds (3 seconds on the mesial side and 3 seconds on the distal side), depending on the experimental group.

The 80 teeth were randomly divided into 4 experimental groups.

In the first group, the light curing was applied occlusally as close as possible to the brackets; in the second group, the light curing was applied mesially and distally to the brackets as close as possible.

Light curing was performed at an angle of 45° to the adhesive surface.

The light-curing time was 3 seconds (in occlusal direction) and 6 seconds (in mesial and distal direction).

The top surface of the resin was at least 2 mm from the labial surface of the teeth.

All selected teeth were divided into four groups:

Group one: 3 seconds of light curing and testing after 24 hours. Group two: 6 seconds of light curing and testing after 24 hours. Group three: 3 seconds of light curing and testing after 14 days - Group four: 6 seconds light cured and tested after 14 days

The premolars with brackets were stored at 370°C before testing the SBS. The adhesion of the brackets to the enamel surface was determined using the shear bond strength (SBS) test. A universal testing machine (Ltd. Lloyd Instruments) was used to perform the SBS.

Occluso-cervical loads were applied with a sharp-bladed chisel to test the SBS of the ligature.

At a rate of 1 mm per minute, the occluso-cervical force was applied to the adhesive substance and bracket interface. The observed forces at the bracket's surface were recorded in Newtons (N) and then translated to Megapascals (MPa) using the formula: $SBS = F/A$ (MPa or N/mm^2), where F mean the detachment force in newtons and A mean the bracket base surface area.

After debonding, the brackets, the number of adhesive residues (ARI) 40x magnification of stereo microscope were used to calculate ARI.

Artun and Bergland scores were used to classify the adhesive residue index (ARI),

This classification was done on a scale of 0 to 3 score.

0 = no adhesive material remains on the surface of the premolars.

1 = fewer than 50% of the material adhesive remains on the premolars surface;

2 = more than 50% adhesive material remains on the surface of the premolars; and less than 100%.

3 = 100% of the material adhesive remains on the surface of the premolars

Premolars as well as bracket net impression.

One-way analysis was used for statistical analysis; however, the Kruskal-Wallis test was used to compare the groups of ARI values.

RESULTS

Comparison SBS. Figure 1 shows the mean SBS values for the four groups, considering Tukey's test, as shown in Table 1.

This study showed that the mean of SBS of group 4 (6 seconds light cured and tested after 14 days) was (8.59 MPa), which was the highest among all groups. This result is consistent with other studies stating that increasing the light curing intensity, exposure time and the time after the brackets bonding

will increase SBS, group three (3 seconds of light cure and tested after 14 days) was in the second place (7.34) because increasing the time after bracket bonding increases SBS, group two (6 seconds light curing and tested after 24 hours) had acceptable SBS (7.16) because they had adequate exposure time. Group one (3 seconds light cure and tested after 24 hours) had (5.1194 MPa), the lowest SBS of all groups and insufficient SBS.

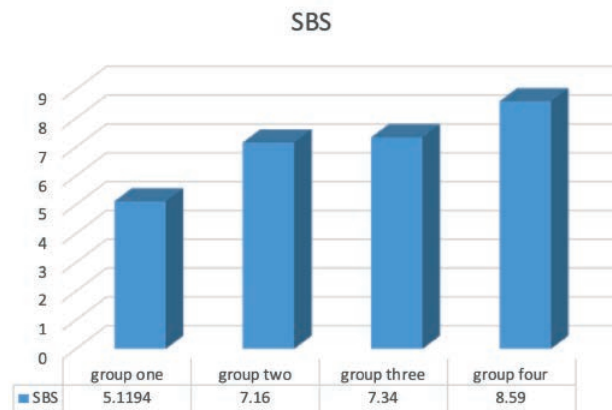


FIGURE 1. Obtained mean shear bond strength values

In this study, the statistical analysis of shear bond strength showed that there was a statistical difference between group one (3 seconds light cure and tested after 24 hours) and all groups, as well as a statistical difference between group two (6 seconds light cure and tested after 24 hours) and group four (6 seconds light cure and tested after 14 days). On the other hand, there was no statistical difference between group two (6 seconds light curing and testing after 24 hours) and group three, and no statistical difference between group three and four (6 seconds light curing and testing after 14 days).

TABLE 1. P values of Tukey test for SBS in groups Adhesive remnant index (ARI)

Treatments Pair	Tukey HSD Q Statistic	Tukey HSD P-value	Tukey HSD Inference
Group 1 vs Group 2	5.6159	0.0010053	**p <0.01
Group 1 vs Group 3	6.0994	0.0010053	**p <0.01
Group 1 vs Group 4	9.5478	0.0010053	**p <0.01
Group 2 vs Group 3	0.4835	0.8999947	insignificant
Group 2 vs Group 4	3.9319	0.0338815	*p<0.05
Group 3 vs Group 4	3.4484	0.0786190	insignificant

Descriptive statistics for ARI values between all four groups showed that significant difference was applied in all groups (p=0.001).

Table 2 shows that the mean ranking of ARI values in group one (59.35), group two (41.40), group three (36.15) and group four (25.10), mean ARI scores.

The residual adhesion index analysis reveals that there were differences between all groups that

were statistically significant (value = 0.001). Group one had the highest amount of ARI and group four had the lowest amount of ARI. This study showed that the amount of ARI on the tooth decreased when the SBS increased.

TABLE 2. Scores of adhesive remnant index (ARI) and mean post of ARI Kruskal Wallis Test, P value=0.001 Chi-Square was 24.489

	Score 0	Score 1	Score 2	Score 3	Number of teeth	Mean rank/ mean post
Group 1	0	3	10	7	20	59.35
Group 2	4	8	4	4	20	41.40
Group 3	5	9	4	2	20	36.15
Group 4	10	7	3	0	20	25.10

DISCUSSION

During orthodontic treatment with fixed appliances, orthodontic brackets are exposed to clinical loads from orthodontic arches, masticatory forces, or even iatrogenic loads. Obtaining adequate bracket adhesion of bond strength is an issue of relevant clinical importance to prevent accidental debonding.

Increasing bracket bond strength leads to a decrease in the ratio of bracket debonding, which in turn has the advantage of maintaining a healthy enamel surface and saving time [18,19].

In the present study, SBS and failure mode were statistically affected by exposure time and time duration after bracket bonding.

A factor that also contributes to the degree of polymerization is light output. There must be a minimum light power at a certain wavelength to initiate the polymerization reaction, as well as a time interval for the reaction to propagate to the deeper layers of the material and reach its maximum properties [20].

Studies [21,22,23] have reported that there is a direct correlation between the increase in shear bond strength and curing time. This was recognized to the fact that a higher monomer/polymer conversion rate occurs with increasing cure time.

The effectiveness of the light cure is the second factor. It has an impact on the adhesive's level of polymerization. When the light power is strong, more photons enter the composite and more free radicals are created, which causes the monomer to transform into a polymer [23].

Different variables could influence the SBS values, thus, one should not compare the SBS values between studies [6,9,10]. However, a minimum SBS value has been identified in different studies and articles, ranging on average from 5.88 MPa to 7.84 MPa [27,28,29].

According to some writers, the radiation exposure needed for a resin composite material to prop-

erly cure under light is constant and may be determined by dividing the light intensity by the exposure period [30,31]. When curing units with a power of 1600 YmW/cm² are employed, this notion states that an exposure time of 1 second should be adequate to produce the necessary radiation exposure [32]. However, in this study, an exposure time of 3s and 2500 YmW/cm² were found to be insufficient to achieve proper bond strength, which is also in agreement with other studies. Despite the high light intensity, the applied energy seems to be insufficient if too short exposure times are used, the energy supplied seems to be insufficient.

Such unsatisfactory polymerization appears to be associated with a high free radical break-off rate [31]. In addition, metal brackets block light, need a transmission mechanism provided thru reflection in the tooth structure. Therefore, the tip of the curing device is placed at the edges of the brackets, where the light falls right on the tooth surface, which returns it onto the adhesive component under the bracket. This process results in light absorption and scattering, which reduces the intensity light and the quantity of energy applied to the resin cement. A high rate of free radical break-off appears to be connected to such unsatisfactory polymerization [31]. Additionally, because metal brackets restrict light, a transmission mechanism is needed, which is given through reflection in the tooth structure.

In this study, it was found that increasing the exposure time to 6 seconds with LED 2500 YmW/cm² resulted in acceptable SBS. On the other hand, there was a direct correlation relationship between increasing the time duration after bracket bonding and increasing the SBS. Therefore, it is recommended to use 6 seconds LED of light curing at 2500 YmW/cm² to achieve acceptable SBS during the bracket bonding process.

Higher ARI values suggest that the majority of adhesion loss following debonding happens at the bracket-adhesive contact, with the material that is still on the surface shielding the enamel from potential harm [33].

Another consideration regarding shear bond strength is what happens if the bond strength is too strong, as more force is required to break the bond, which could lead to tooth fracture. The enamel will fracture if a force greater than 25 to 30 MPa is applied to the enamel prism's long axis. Enamel fracture can happen even with a force of less than 13 MPa if the force is applied to the curved portion of the enamel prism [34].

In this study, a shorter light-curing exposure time was associated with a decrease in the mean values of the adhesive and a failure mode in which a greater amount of resin remains on the tooth.

CONCLUSIONS

1. Increasing the light curing intensity, exposure time and the time after the brackets bonding will increase SBS and will decrease ARI on the other hand.

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