Original Article

Shear Bond Strength of Orthodontic Brackets Bonded With Different Curing Methods

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3) Running Title:

SBS of brackets bonded with different curing methods

4) Abbreviations: Adhesive remnant index (ARI)

Shear Bond Strength (SBS), Light Emitting Diodes (LED)

Abstract

Objectives: To evaluate the effect of light-cure devices and curing times on the shear bond strength (SBS) of orthodontic brackets. **Material and Methods:** 60-extracted human premolars were divided into 6-groups of 10-teeth each and bonded with stainless-steel brackets by using 3M Unitek Transbond XT composite. Specimens were cured with halogen, LED and plasma arc lights with two different times for each. The specimens were subjected to shear force till debond with a crosshead speed of 1mm/min and tested after 5min. The stress was calculated and data were subjected to statistical analysis.

Results: one-way ANOVA and Dunnett T3 post hoc comparison test were used. There were no significant differences between the 6 groups ($p < 0.05$). **Conclusions:** all curing light methods with loading force after 5 min achieved SBS more than the normal range; therefore, arch wire can be inserted at the same visit using any of tested curing light device or curing time.

Key words: Shear bond strength (SBS); Halogen light cure; LED; Plasma arc light cure.

Introduction

Advances in adhesive materials have facilitated the use of bonded attachments in fixed appliances. The use of bonded brackets had become a routine part of fixed appliance therapy. Different bonding systems have been developed, mainly are chemical or light activated. From a clinical point of view, the success of bonding is important in orthodontic therapy (1). There should be a good bond between orthodontic bracket and tooth to withstand orthodontic forces and masticatory loads. Manufacturers have introduced various light cured adhesive systems to bond orthodontic brackets. Composite resin is widely used orthodontic adhesive because of its bond strength (2). Owens and Miller (3) had recommended it because of its bond strength. In clinical use, it is important that materials used to bond attachments to etched enamel surfaces can change quickly from a fluid to a solid state. Setting polymerization may be achieved either by chemical interaction between components of

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a resin system or by photo-initiation using light curing lamps (4). Light curing method is more popular now than chemical cure (5). The main reason of its popularity is working time, which provides more time to the clinician to place the bracket accurately on the tooth surface before using light to polymerize the adhesive(6). This technique allows clean up and residue removal before polymerization (5, 7). However the disadvantage of light-cure method is the time taken to cure each bracket (7). Recent advances in light curing technology have led to the development of new high intensity light curing units, which have shorter curing times compared to conventional devices(8).

Orthodontists are in dilemma about the appropriate light-curing device to use in their practices. The ideal device for the clinician during orthodontic treatment should have a short curing time and at the same time achieve good bond strength between brackets and teeth surfaces to avoid bond failure. Therefore light-cure device providing optimal bond strength with minimal curing and setting time before arch wire placement will be more convenient. The curing light market is developing rapidly, and there are different types of devices available such as: halogen curing lights, light emitting diode (LED) and plasma arc.

Halogen curing lights:

Halogen lamps have been widely used as the main curing units for composite resins. Light is emitted from a white halogen bulb, which is filled with iodine or bromide gas and contains a tungsten filament. When connected to an electric current, the tungsten filament glows (9). This produce**s** a very powerful constant light but also a considerable amount of heat despite the placement of appropriate filters between the light source and the light guide of the halogen units (10). Numbers of light curing systems have recently been introduced in an effort to reduce curing time without compromising bonding efficiency. Conventional curing lights are being replaced by much faster curing systems such as: LED or plasma arc.

Light emitting diodes (LED) lights:

Mills et al (11) introduced light emitting diode technology for the polymerization of light activated dental materials. This technology had been introduced as an alternative curing method for curing dental materials. This was an attempt to overcome the limitations inherent to the conventional halogen-based curing units, such as the degradation of the bulb, filter, and photoconductive fibers over time; and the limited effective life time (7). LED generates light with narrow wave length and no light in the ultraviolet or infrared range is generated.

Therefore, no need for filters nor cooling fans due to no heat being produced, allowing the unit to be cordless.

Plasma arc lights:

In the late 1990s, plasma arc bulb was introduced with very short exposure time equivalent to those of the Argon laser but at lower cost. The main advantage of this device is reduced curing time per tooth from 20-40 seconds to as low as 2 seconds (4). When electricity is passed through Xenon gas, ionization starts which produces plasma of charged particles that emit blue-white light at low pressure and wavelength similar to daylight at high pressure.

Bond Strength

In the assessment of bonding potential of new adhesive materials, it is important to measure the debonding force or bond strength. Bond testing process usually involves measuring the force of debonding relative to a bonded area and observes the location of the bond failure. Reynolds (12) stated that bonded brackets required 5.9 to 7.8 MPa of SBS to withstand intraoral and orthodontic forces.

Adhesive Remnant Index (ARI)

ARI is a scale that specifies the amount of restorative material remaining on the tooth after debonding. ARI developed by Artun and Berglund (13) and had been used by investigators to help standardize the bond failure analysis (13). The criteria of ARI recording are in (Table 1). The ARI index provides information that has considerable clinical implications for clean-up following debonding of brackets. Minimizing the amount of residual resin left adhering to the enamel surface minimizes iatrogenic damage to the enamel during clean-up procedures (14). According to Hobson et al (15) and O'Brien et al (16), there are number of factors that influence the ARI score, including bonding procedure, debonding technique, the design of bracket base and the adhesive used. In orthodontic treatment, it is desirable that bond failure occurs in the enamel-adhesive interface so that the subsequent replacement of adhesive is simpler and quicker (17). Moreover, the cleaning procedures to remove adhesive remnant are always accompanied by a degree of enamel loss (18). In this current study we tested the effect of three light cure sources with different curing times on shear bond strength of bonded orthodontic brackets.

Materials and Methods

60 extracted human premolars were collected; carious, defective or restored teeth were excluded. Distilled water was used as storage medium for the teeth and was replaced every week to minimize deterioration (ISO 3696, 2003). We embedded the teeth horizontally in plastic rings using die stone. The total samples were divided into 6 groups of 10 teeth each (Table 2). Non-fluoridated prophylaxis paste was used to clean the buccal surface of the teeth with a rubber cup at low speed for 15 second, this was followed by water rinse for 10 seconds and dryness with air spray. Then we etched the teeth using 37% phosphoric acid gel for 30 seconds (3M ESPE AG, Seefeld, USA), followed by water rinse for 10 seconds and surface drying with air spray. Adhesive Primer (3M Unitek Transbond™ XT) was applied to the buccal surface of each tooth, thinned with gentle stream of air and cured for 10 seconds according to the manufacturer's recommendations. 60 Upper premolar orthodontic anatomical brackets (Mini Master) were used. Composite resin capsule (3M Unitek Transbond™ XT, Monorovia, Ca, USA) was applied to all bracket bases. The brackets were then firmly pressed onto the flattest area on the middle of the buccal surface with a plastic instrument, an explorer was used to remove excess adhesive before curing. Brackets were placed so that the bond interface is parallel to the direction of the force delivered by the testing machine and the slot were parallel to the shearing rod during the shear strength test. Polymerization was carried out by holding the light guide at 45º to the tooth surface, 1 - 2 mm to the bracket, curing both mesial and distal sides. The exposure time for each device was equally divided between the mesial and distal part of the bracket. Two different times were being done for each curing device (Table 2).

Using dose meter device (SDI radiometer) before every curing, we calibrated the power of each device. The halogen light was 470 Mw/cm², LED was 1800 Mw/cm² and plasma arc was 2050 Mw/cm². After photo polymerization, the groups of the specimens were subjected to a shear force after 5 minutes of bonding time with a universal testing machine (Shimadzu Precision Universal Tester) until the bond failure.

The block with the tooth was aligned vertically and the slot of the bracket was parallel to the jig blade (Figure 1). The shear bond force was applied by the rod. The sample was loaded till debond occurred with a crosshead speed of 1mm/min. The force in Newton (N) was recorded, and stress was calculated. The brackets were examined using scanning electron microscope (SEM) (Carl Zeiss SUPRA™ 40 VP) at magnification 300X. Remaining adhesive was assessed and ARI score was recorded. The collected data were analysed statistically using SPSS version 16 (SPSS, Chicago, Illinois, USA) to identify differences in mean SBS with respect to curing light method and force loading. ANOVA and Dunnett T3 post hoc multiple comparison test were used. The level of significance was established at $p < 0.05$.

Results and Statistical Analyses

The mean SBS of all 6 groups is presented in Figure 2. One way ANOVA comparing the SBS of all groups showed no significant difference. SBS of the 6 groups was above the range recommended by Reynolds in 1975(12). The ARI score was 2 for all groups except group 2 (Table 2) which had a score of 1, which may be due to longer curing time and more polymerization.

Discussion

There were no significant differences between the 6 groups with debonding force after 5 min (*P > 0.05*). Therefore halogen (20 & 40 seconds), LED (10 &20 seconds) and plasma arc (6 & 10 seconds) may all be used, and force loading can be done after 5 min. Manzo et al (19) found that there was no significant difference in SBS immediately after bonding between plasma arc curing light for 6 seconds and halogen light for 20 seconds, which was in agreement with this study. Koupis et al (20) and Mirabella et al (21) also found no significant differences in SBS after bonding between LED 20 seconds and halogen 20 seconds. There was an agreement with Ip and Rock (4) finding, that there are no significant differences between halogen light for 20 and 40 seconds. In the present study higher score of ARI indicated that the weak link was between the bracket base and the adhesive, this could be due to short curing interval or incomplete polymerization near the bracket base, leading to inadequate mechanical retention of the adhesive to the bracket (14). In the current study the weakest link in the bonding process was at the bracket/adhesive interface which was in agreement with other studies (22-24).

Conclusions

Within the limitations of this study it would appear that all curing light devices achieved ad equate SBS (Figure 2), more than that recommended by Reynolds (12). Therefore halogen light with curing time (20, 40 seconds), LED with curing time (10, 20 seconds) and plasma arc with curing time (6, 10 seconds) can all be used for curing methods.

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Figure Legends :

Figure 1: Shimadzu Precision Universal Tester with the Specimen and the Jig
Figure 2: Mean Shear Bond Strength for all Groups

Tables:

Point	Criteria
0	No adhesive left on the tooth
1	less than half of the adhesive left on the tooth
2	more than half of the adhesive left on the tooth
3	All adhesive left on the tooth with distinct impression of the bracket mesh

Table 1: ARI Point Scale Criteria

Halogen light cure		Light emitting diode(LED)		Plasma arc	
G1 (20s)	G2 (40s)	G3 (10s)	G4 (20s)	G5 (6s)	G6 (10s)

Table 2: Light cure devices, curing times and Groups of the study

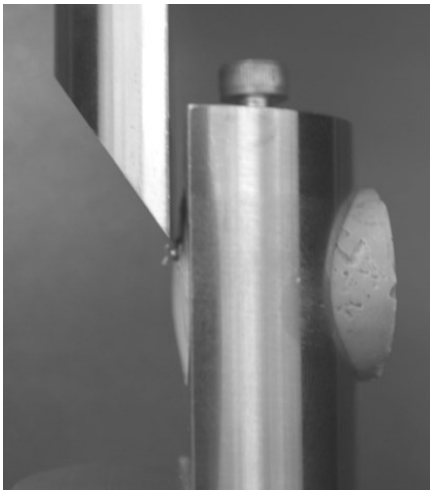

Figure 1: Shimadzu Precision Universal Testing Machine. The block with the tooth was placed vertically and the slot of the bracket was parallel to the jig blade

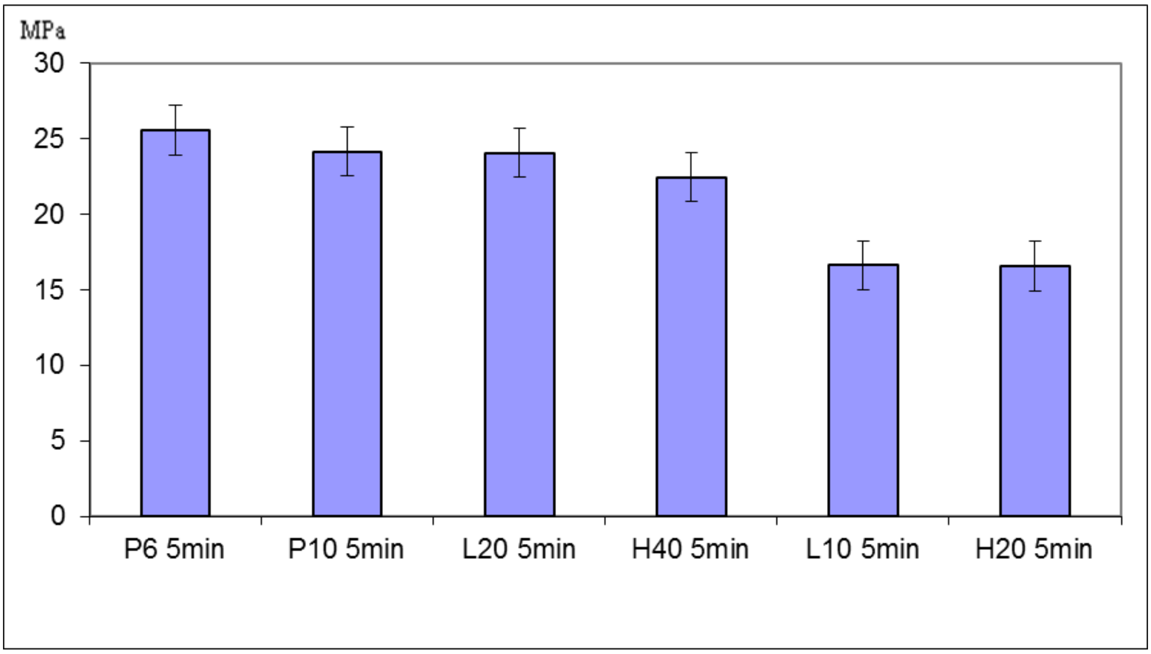

Figure 2: Mean Shear Bond Strength (MPa) for Groups 1-6 with debonding force after 5 Minutes