Original Article

A Comparison of the Shear Bond Strength of Orthodontic Brackets Bonded With Light-Emitting Diode and Halogen Light-Curing Units

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Abstract:

Statement of the problem: Various methods such as light emitting diode (LED) have been used to enhance the polymerization of resin-based orthodontic adhesives. There is a lack of information on the advantages and disadvantages of different light curing systems.

Purpose: The aim of this study was to compare the effect of LED and halogen light curing systems on the shear bond strength of orthodontic brackets.

Materials and Methods: Forty extracted human premolars were etched with 37% phosphoric acid and cleansed with water spray and air dried. The sealant was applied on the tooth surface and the brackets were bonded using Transbond adhesive (3M Unitek, Monrovia, Calif). Adhesives were cured for 40 and 20 seconds with halogen (Blue Light, APOZA, Taiwan) and LED (Blue dent, Smart, Yugoslavia) light-curing systems, respectively. Specimens were thermocycled 2500 times (from 5 to 55 °C) and the shear bond strength of the adhesive system was evaluated with an Universal testing machine (Zwick GmbH, Ulm, Germany) at a crosshead speed of 1 mm/min until the brackets were detached from the tooth. Adhesive remnant index (ARI) scores were determined after bracket failure. The data were submitted to statistical analysis, using Mann-Whitney analysis and t-test.

Results: No significant difference was found in bond strength between the LED and halogen groups (P=0.12). A significant difference was not observed in the adhesive remnant index scores between the two groups (P=0.97).

Conclusion: Within the limitations of this in vitro study, the shear bond strength of resin-based orthodontic adhesives cured with a LED was statistically equivalent to those cured with a conventional halogen-based unit. LED light-curing units can be suggested for the polymerization of orthodontic bonding adhesives.

Key Words: Light emitting diode; Shear bond strength, Orthodontic bracket

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INTRODUCTION

Visible light–cured adhesives have several advantages over two-paste or one-paste self-cured resin systems, because they offer adequate time for precise bracket positioning and immediate curing. Light-cured orthodontic adhesives have been cured almost exclusively with light emitted from a halogen source. However, Tungsten-quartz halogen curing units have several shortcomings. Only 1% of the total energy input is converted into light and the remaining is generated as heat. The short life of halogen bulbs and the noisy cooling fan are other disadvantages. To

overcome these problems, light curing units with gallium nitride blue light–emitting diodes (LEDs) have been proposed for curing resin-based dental adhesives [1]. The spectral output of LEDs falls within the absorption spectrum of camphorquinone, so the LEDs require no filters to produce blue light.
Mills et al [1] were among the first to suggest the use of solid-state LEDs for the polymerization of light-sensitive dental materials. The use of LED technology has two major advantages, namely, avoiding the use of the heat-generating halogen bulbs and the fact that they have 10,000 hours lifetime with little degradation of output [2].
With photoactivated orthodontic adhesives, clinicians have difficulty in determining the depth of cure and the time it takes for complete polymerization. Ruyter and Gyorosi [3] using infrared spectroscopy, demonstrated that commercially available sealants exhibited different degrees of conversion 24 hours after the start of polymerization. They found that under conditions comparable with an optimal clinical situation, the quantities of the remaining unpolymerized methacrylate ranged between 15% and 35%. Fan et al [4], Ruggeberger et al [5], and Johnston et al [6] described a number of factors that affect the depth of photoactivated cures including duration and intensity of irradiation, filler type and shade, the reflective characteristics of the backing, the mold size, and the optical configuration of the experimental setup.
LEDs showed about 83% of the irradiance produced by the halogen curing units and the depth of cure produced by the halogen curing unit sources was larger than that obtained with the LEDs [7]. Furthermore, advances in the power output of LEDs have allowed them to achieve a higher irradiance than halogen curing units. These high-intensity LEDs may decrease total light-curing time [8]. Several studies compared the shear bond strengths (SBSs) of orthodontic brackets bonded to teeth with LED and other curing units [9,10].
The aim of this study was to compare the shear bond strength of orthodontic brackets bonded to teeth with conventional halogen light sources and commercial LED curing units.

MATERIALS AND METHODS

The test sample consisted of forty noncarious human premolars extracted for orthodontic purposes. Teeth with hypoplastic areas, cracks, or gross irregularities of the enamel structure were excluded from the study. The samples were stored in 0.1% thymol solution at room temperature after extraction for maximum 3 months and were randomly divided into two groups of 20 teeth each. Each tooth was mounted vertically in autopolymerizing acrylic resin (Meliodent, Herause Kulzer, Hanau, Germany) with the crown remaining exposed. The buccal enamel surfaces of the teeth were polished with nonfluoridated pumice using rubber prophylactic cups and were washed and dried before the bonding procedure. A 37% phosphoric acid gel (Email Preparator, Vivadent, Liechtenstein) was used to etch the premolars for 30 seconds. The teeth were then rinsed with water for 30 seconds and dried with an oil-free air source for 20 seconds. In all treated cases the frosty white appearance of the enamel was considered as complete enamel etches.
Forty stainless steel premolar brackets (3M Unitek, Monrovia, Calif) with a mesh base surface area of 11.8 mm^2 were used for this study. After surface preparation, the brackets were bonded on the teeth with Transbond XT (3M Unitek, Monrovia, Calif), and all excess resin was removed with an explorer before polymerization.
In the first group a conventional halogen light source (Blue Light, APOZA, Taiwan) was used for curing. The bracket-adhesive interface was cured for a total of 40 seconds, 20 seconds from the mesial and 20 seconds from the distal sides. In the second group a commercial LED

curing unit (Blue dent, Smart, Yugoslavia) was employed for 20 seconds, 10 seconds from the mesial and 10 seconds from the distal sides , followed by thermocycling for 2500 times, between 5 and 55° C [8].

Before starting the procedure, both light sources were tested using a Curing Radiometer Model 100 (Demetron Research Corp, Danbury, Conn). Both light units registered values of 450 mW/cm^2.

Before debonding, the embedded specimens were secured in a jig attached to the base plate of a universal testing machine (Zwick GmbH, Ulm, Germany). A chisel-edge plunger was mounted in the movable crosshead of the testing machine and positioned such that the leading edge aimed the enamel-adhesive interface before being brought into contact at a crosshead speed of 1 mm/min. An occluso-gingival load was applied to the bracket producing a shear force at the bracket-tooth interface. A computer electronically connected with the Zwick testing machine recorded the results of each test. The force required to dislodge the brackets was measured in Newton, and the shear bond strength (SBS) was calculated by dividing the force values by the bracket base areas (11.8 mm^2).

After debonding, the teeth and brackets were examined under ×10 magnification. Any adhesive remaining after bracket removal was assessed and scored according to the modified adhesive remnant index (ARI) as follows: 0 = no adhesive left on tooth, 1=less than half the adhesive left on tooth, 2 = more than half the adhesive left on tooth, and 3 =enamel bonding site covered entirely with adhesive [11].

Statistical analysis was performed with SPSS 13 software (SPSS Inc, Chicago). The two sample homoscedastic *t*-test was used to compare the shear bond strengths of the study groups. The Mann-Whitney U test was applied to determine differences in the ARI scores among the test groups. Significance for all statistical tests was predetermined at a probability value of 0.05 or less.

RESULTS

The effects of LED and halogen based light curing units on the shear bond strength of orthodontic brackets were compared. The mean values of shear bond strength were 16.6 (5.8) and 19.74 (6.8) for halogen curing unit and LED respectively. According to the applied *t*-test, no significant difference (P=0.12) in bond strength values was observed between two groups. The results of the Mann-Whitney U test indicated that there were no significant differences between the two groups (P=0.97). There was a greater frequency of ARI scores of 1 (all adhesive remained on the tooth) in all groups, which indicated that failures were mainly in the adhesive-bracket interface (Table I).

DISCUSSION

The in vitro use of light-cured materials for orthodontic bonding was first described in 1979. Considering that tooth structure transmits visible light, the material is cured under metal-based brackets by direct illumination from different sides and by trans-illumination when using the direct bonding technique. Under visible light, a rapid polymerization occurs producing a “command set” that is of great advantage. Such setting “on demand”, results in a nearly unlimited working time, allowing more accurate bracket placement [١2].

In orthodontics, inadequate polymerization of adhesive composites and resultant unpolymerized monomers may cause bracket failure.

Table I: Frequency Distributions of ARI score for the experimental groups.

Group	ARI Scores			
	0	1	2	3
Halogen	5(22%)	12 (54.5%)	3 (13.6%)	2 (9.1%)
LED	4 (18.2%)	14 (86.3%)	2 (9.1%)	2 (9.1%)

The aim of the present study was to compare the effect of LED and halogen light curing systems on the shear bond strength (SBS) of orthodontic brackets. The results of *t*-test comparing the two groups indicated no significant difference in bond strength between the LED and halogen groups (P=0.12). However, the mean shear bond strength of the LED group (19.74 MPa) was higher than the halogen group (16.6 MPa).

Previous studies have shown that LED-curing units are as effective as halogen-based sources. Dunn and Taloumis [8] found no significant difference in bond strength of metal orthodontic brackets bonded to tooth enamel with LED or halogen-based light-curing units. They also reported that the size of the tip of the LED unit tested in their investigation was able to cure one bracket at a time. According to Bishara et al [9] LED light-curing devices offer clinicians an advantage of light-curing two orthodontic brackets with the same light exposure, without significant influence on the shear bond strength. In the present study, exposure time was 20 seconds in the LED group and 40 seconds when using the halogen curing unit. Swanson et al [12] compared shear bond strengths of orthodontic brackets bonded with LED-curing units for 40, 20, and 10 seconds. They found clinically satisfactory shear bond strengths, even with a 10-second curing time but recommended longer periods of curing as suggested by the manufacturer(s). Usumez et al [8] suggested that 20 seconds of LED exposure might yield shear bond strengths comparable with those obtained with halogen-based units in 40 seconds. However, they also reported significant decreased values with 10-second LED curing.

The narrow absorption peak of the initiator system must also be taken into account. This makes the emitted spectrum an important determinant of a curing light's performance. The absorption curve of camphoroquinine extends between 360 and 520 nm, with its maximum at 465 nm. It has been shown that within this range, the optimal emission bandwidth of the light source stands between 450 and 490 nm. With conventional curing devices, a major portion of the photons is emitted outside the optimal spectrum range for light curing. These photons cannot, or can only with reduced probability, be absorbed by camphoroquinine. In contrast, 95% of the emission spectrum of blue LEDs is situated between 440 and 500 nm [8] Furthermore, the maximum emission of the blue LEDs used in this study is approximately 465 nm, which is almost identical to the absorption peak of camphoroquinie. These factors may explain the similar SBS values obtained by LED with shorter exposure time.

The ARI scores in the present study indicate that, regardless of the type of light-curing, most of the composite resin remained on the tooth after bracket debonding. This type of failure suggests that the weak link in the adhesive chain occurred between the bracket base and the composite. This implies that resin penetrated into the undercuts of the bracket base and was unable to resist the shear stresses when not fully cured. The results obtained in the current investigation are in agreement with previous studies [2,13].

The LED light units are cordless, smaller, and lighter with estimated lifetimes of over 10 000 hours, and they do not require a noisy cooling fan [2]. Therefore, it seems that they are a better choice as compared to halogen sources. Further investigation under clinical conditions is suggested to compare the results to previous in vitro studies.

CONCLUSIONS

Within the limitations of this investigation, the results suggest that the shear bond strength of LED light-curing systems was similar to conventional halogen-based sources. There were no significant differences in the ARI scores of the light-curing units tested.

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