Original Article

Orthodontic Bracket Shear Bond Strengths Produced by Two High-power Light-emitting Diode Modes and Halogen Light

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Abstract: The aim of this in vitro study was to compare the shear bond strength of orthodontic brackets cured with two different high-power light-emitting diode (LED) polymerization modes with traditional halogen polymerization. A total of forty-five extracted human premolar teeth were randomly divided into three groups. Each group consisted of 15 teeth mounted in an acrylic block. Following a standard enamel etching protocol, orthodontic brackets were cured on the first group of teeth with fast-mode LED, the second group with soft-start mode LED, and on the last group with a halogen light. After bonding, the shear bond strengths of the brackets were tested with a universal testing machine. The results showed that brackets cured with soft-start mode LED produced the highest shear bond strengths (23.86 ± 6.20 MPa). No significant difference was found between fast-mode LED (17.14 ± 5.75 MPa) and the halogen group (17.38 ± 5.41 MPa) ($P >$ .05). The LED is effective for bonding metal brackets to teeth, and the soft-start mode gives higher bond strengths than the fast mode. (*Angle Orthod* 2005;75:854–857.)

Key Words: Bond strength; Fast-mode polymerization; LED; Soft-start polymerization

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 light. However, halogen technology has several shortcomings.[1] Only 1% of the total energy input is converted into light, with the remaining energy generated as heat. The short life of halogen bulbs and the noisy cooling fan are other disadvantages.

To overcome these problems, solid-state light-emitting diode (LED) technology has been proposed for curing resin-based dental adhesives.[1–5] A main advantage of the LED units is their minimal generation of heat. Reduced temperatures associated with LEDs have a lifetime over 10,000 hours, without a significant degradation in light output.[6] Furthermore, the LED lights are resistant to shock and vibration.[2] There are also cordless LEDs, which are reliable in their power and spectral output, do not need a cooling fan, and operate silently.

Recently, manufacturers have turned their attention to the high-power LED light source ($\geq$1000 mW/cm^2). With a high-power light source, more photons are available for absorption by the photosensitizers.[4] With more photons, more camphoroquinone molecules are raised to the excited state, react with the amine, and form free radicals for polymerization.[7] However, this higher light intensity produces higher contraction strains during resin polymerization, and contraction stresses may contribute to insufficient clinical shear bond strength.[8–11] To overcome this problem, the use of low-intensity lights followed by a final exposure with high-intensity light was introduced and termed soft-start polymerization (Figure 1). Studies have demonstrated that soft-start polymerization techniques significantly reduce polymerization strains and improve material properties.[8,9,12]

In recent literature, many studies have evaluated the clinical efficiency of LED as a curing unit for orthodontic bracket bonding,[13–16] but none of them compared

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Accepted: December 2004. Submitted: October 2004.

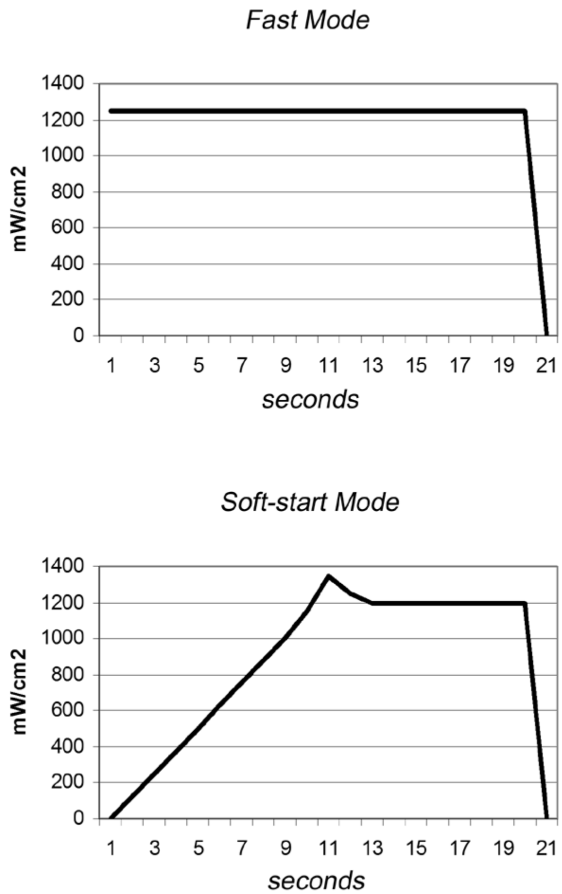

FIGURE 1. Graphical presentation of the two modes of polymerization.

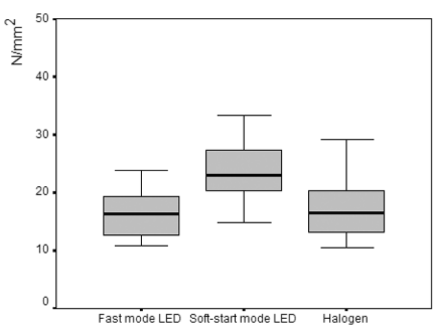

FIGURE 2. Shear bond strengths (MPa) of brackets. Results presented as boxplots. Horizontal line in middle of each boxplot shows median value; horizontal lines in box indicate 25% and 75% quartiles; lines outside box indicate 5% and 95% quartiles.

the results of the two different polymerization modes of LED. Previous studies[8,9,12] suggest that soft-start LED polymerization mode should produce higher orthodontic bracket shear bond strengths than the fast-mode LED or halogen-light polymerizations. Therefore, the aim of this in vitro study was to compare the shear bond strengths of orthodontic brackets cured with the two modes of LED light (fast and soft-start modes) and to compare these results with the shear bond strengths of brackets bonded with a halogen light.

MATERIALS AND METHODS

A total of forty-five noncarious, freshly extracted human permanent premolar teeth without any visible defects were stored in 0.1% thymol solution at room temperature. Each tooth was individually embedded in autopolymerizing acrylic resin (Meliodent, Herause Kulzer, Hanau, Germany). The mounted specimens were randomly divided into three groups of 15 and were kept in distilled water except during the bonding and testing procedures. Before bonding, the facial surfaces of the teeth were cleaned with a mixture of water and pumice. The teeth were rinsed thoroughly with water and dried with oil and moisture-free compressed air. Each tooth was etched with 37% phosphoric acid gel for 30 seconds, rinsed with a water/spray combination for 30 seconds, and dried until a characteristic frosty white etched area was observed.

A total of forty-five stainless steel orthodontic bicuspid brackets (Ormco Corp, Glendora, Calif) with a 9.63 mm^2 surface area base were directly bonded with an LC composite resin Light Bond (Reliance Orthodontic Products, Inc, Itasca, Ill). A thin, uniform layer of sealant was applied on the etched enamel with a microbrush and cured for 20 seconds. A thin coat of sealant was also painted on the metal bracket base and cured for 10 seconds before applying the paste. Using a syringe tip, the paste was applied to the bracket base. Then the bracket was positioned on the tooth and pressed lightly in the desired position. Excess adhesive was removed with a sharp scaler.

MiniLED™ (Satelec, Merignac, France) and Heliolux DLX (Vivadent ETS, Schaan, Liechtenstein) were used as curing units. MiniLED™ has one of the most powerful lamps in the market. It generates light intensity of 1,250 mW/cm^2 and produces a narrow spectrum of light spanning 410 to 490 nm.

Group I was cured with fast-mode LED for 20 seconds (10 seconds on the mesial and 10 seconds on the distal surfaces of the brackets), Group II with soft-start mode LED for 40 seconds (20 seconds on the mesial and 20 seconds on the distal surfaces of the brackets), and Group III with halogen light for 40 seconds (20 seconds on the mesial and 20 seconds on the distal surfaces of the brackets).

The cordless LED light-curing unit was returned to the battery charger after each specimen was polymerized. After bonding, the teeth were stored in distilled water for 24 hours.

Each specimen was loaded into universal testing machine (Lloyd; Fareham, Hants, England) using Nex-

TABLE 1. The Results of ANOVA Comparing the Shear Bond Strengths of the Groups[a]

Group I (Fast-mode LED)		Group II (Soft-start Mode LED)		Group III (Halogen)			Post Hoc Tests		
Mean	SD	Mean	SD	Mean	SD	Significance	I-II	I-III	II-III
17.14	5.75	23.86	6.20	17.38	5.41	0.012*	*	NS	*

[a] LED indicates light emitting diode; NS, not significant; ANOVA, analysis of variance. $P < .05$.

ijen software for testing, with the long axis of the specimen perpendicular to the direction of the applied force. The standard knife edge was positioned to make contact with the bonded specimen. Bond strength was determined in the shear mode at a crosshead speed of 0.5 mm/min until fracture occurred. Values of failure loads (N) were recorded and converted into megapascals by dividing the failure load (N) by the surface area of the bracket base (9.63 mm^2).

Statistical analysis

Descriptive statistics, including the mean, median, standard deviation, and quartiles, were calculated for each of the groups tested. One-way analysis of variance (ANOVA) and Tukey multiple comparison tests were used to compare shear bond strengths of the groups. Significance for all statistical tests was predetermined at $P < .05$. All statistics were performed with SPSS version 11.0.0 (SPSS Inc, Chicago, Ill).

RESULTS

The descriptive statistics on the shear bond strength (MPa) for the three groups are presented as boxplots in Figure 2. All groups displayed clinically acceptable mean bond strengths (over eight MPa). ANOVA indicated a significant difference between groups ($P < .05$) (Table 1). The highest shear bond strengths were measured in Group II (soft-start mode LED). No significant difference was found between Group I (fast-mode LED) and Group III (halogen) ($P > .05$).

DISCUSSION

Previous research has shown that LED-curing units are as effective as halogen-based curing units.[13–16] Dunn and Taloumis[13] reported no significant difference in bond strength of metal orthodontic brackets bonded to tooth enamel with LED or halogen-based light-curing units. Bishara et al[14] reported that LED light-curing devices offered clinicians an advantage of light-curing two orthodontic brackets with the same light exposure, without significantly influencing the shear bond strength.

Recently, high-power LEDs with light source of more than 1000 mW/cm^2 are being marketed. This higher light intensity produces higher contraction strains during resin polymerization, and clinically, contraction stresses may contribute to insufficient shear bond strength.[8,9] In orthodontics, inadequate polymerization of adhesive composites and resultant unpolymerized monomers may cause bracket failure. The use of low-intensity lights followed by a final exposure with high-intensity light, termed soft-start polymerization, has been suggested to overcome this problem.

Several studies have demonstrated that soft-start polymerization techniques significantly reduce polymerization strains and improve material properties.[8,9,12] Our results also support this suggestion because the shear bond strengths of brackets in Group II (soft-start mode LED) exhibit greater values than the others. Although the mean values of shear bond strengths of Group I (fast-mode LED) and Group II (halogen) are also sufficient to withstand orthodontic forces, it seems reasonable to use soft-start mode in high-intensity LED-curing units.

Shear bond strengths of orthodontic brackets bonded with LED-curing units at various polymerization times have been evaluated in several studies.[15,16] Researchers have tried to find the shortest polymerization time possible that still allows sufficient polymerization. Swanson et al[15] 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 cure but recommended longer periods of curing as in the manufacturer's instructions. Usumez et al[16] 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 significantly decreased values with 10-second LED curing.

In our study, we used Mini LED device in which 10 seconds of polymerization for fast-mode and 20 seconds for soft-start mode is recommended by the manufacturer. On the basis of previous data, we doubled the polymerization times and cured the brackets from the mesial and distal surfaces. Therefore, the total polymerization time for fast mode was equal to 20 seconds (10 seconds each for mesial and distal) and 40 seconds (20 seconds each for mesial and distal) for the soft-start mode.

It can be argued that higher values of shear bond strengths in Group II may be because of longer period of polymerization. But, as presented in Figure 1, the light characteristics of two modes are totally different. In the soft-start mode, the curing unit uses half of the exposure time to reach slowly to the highest level of light. Consequently, it is feasible to use longer polymerization times with the soft-start mode. In accordance with previous research,[15,16] we also suggest that 20 seconds of LED exposure in the fast mode may yield shear bond strength values comparable with those obtained by halogen-based units in 40 seconds. However, 40 seconds of exposure with the soft-start mode LED yields higher values of shear bond strengths.

CONCLUSIONS

- LED-curing units are as effective as halogen-based curing units.
- Twenty seconds of LED exposure in the fast mode gave shear bond strength values comparable with those obtained with 40 seconds of halogen-based illumination.
- Polymerization with soft-start mode LED yields highest values of shear bond strengths when compared with fast-mode LED and halogen-curing units.

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