Light-curing time reduction with a new high-power halogen lamp

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Abstract
Orthodontic brackets are routinely bonded with light-cured adhesives. Conventional halogen lights used in bonding have the disadvantage of a long curing time, and the available alternatives (laser and plasma lights) are expensive. Our aim was to investigate the minimum time necessary to bond brackets with a new, relatively low-priced, high-power halogen light.

Reference

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Light-curing time reduction with a new high-power halogen lamp

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Introduction: Orthodontic brackets are routinely bonded with light-cured adhesives. Conventional halogen lights used in bonding have the disadvantage of a long curing time, and the available alternatives (laser and plasma lights) are expensive. Our aim was to investigate the minimum time necessary to bond brackets with a new, relatively low-priced, high-power halogen light. Methods: Five groups of 15 deciduous bovine incisors were bonded with stainless steel brackets (Mini Diamond Twin, Ormco, Orange, Calif) by using different lamps and curing times. Three of the groups were bonded by using a high-power halogen light (Swiss Master Light, Electro Medical Systems, Nyon, Switzerland) for 2, 3, and 6 seconds, respectively. The fourth group, bonded with a fast halogen light (Optilux 501, Sybron Dental Specialties, Danbury, Conn) for 40 seconds, served as the positive control group. The fifth group, the comparison group, was bonded with a plasma light (Remecure, Remedent, Deurle, Belgium) for 4 seconds. After storage for 24 hours in the dark at 37°C in water, shear bond strength was measured with a universal testing machine. Results: A curing time of 2 seconds with the high-power halogen light negatively affected the bond strength and the probability of bond survival. The adhesive remnant index scores were not significantly different among the groups. Most failures occurred at the bracket base/adhesive interface. Conclusions: The high-power halogen light seems to be a cost-effective solution to reducing curing time. The recommended curing times to bond stainless steel brackets are 6 seconds and, with caution, even 3 seconds. (Am J Orthod Dentofacial Orthop 2005;128:749-54)
The aim of this study was to evaluate a relatively low-cost, high-power halogen light (Swiss Master Light, no. M 00042, Electro Medical Systems SA, Nyon, Switzerland) to estimate the minimum exposure time necessary to achieve bond strength equivalent to the bond strength obtained with a fast halogen light. These results were also compared with a plasma light, which until now has been the most advanced device available for curing time and price. Our null hypothesis was that the shear bond strength obtained with the new high-power halogen light for short irradiation periods would be equivalent to a fast halogen light with a relatively long curing time.

**MATERIAL AND METHODS**

Seventy-five deciduous bovine incisors (extracted about age 18 months) were divided into 5 groups of 15 teeth. They were stored in 0.2% thymol for 2 to 3 months. The root of each tooth was cut off, and the crown was polished for 15 seconds with a handpiece-brush by using water and a fluoride-free pumice (Bimsstein Pulver, Prochimie, Avenches, Switzerland). Each tooth was then rinsed thoroughly under tap water for 20 seconds.

The teeth were dried with oil-free air for 5 seconds and etched on the buccal side for 30 seconds with 35% phosphoric acid gel (Transbond XT etching gel, no. 712-039, 3M Unitek, Monrovia, Calif). Each tooth was then rinsed under tap water for 30 seconds and dried again with oil-free air for 5 seconds, followed by application of the primer (Transbond XT Light Cure Adhesive Primer, no. 712-034, 3M Unitek). Composite (Transbond XT Light Cure Paste, no. 712-036, 3M Unitek) was applied to the bracket-base (stainless steel brackets: Mini Diamond Twin, for the maxillary right central incisor, no. 351-0130, Ormco, Orange Calif). The bracket was then firmly placed onto the flattest area of the crown with respect to the occlusal/gingival side. Excess composite was carefully removed. Light-curing was performed with the following devices and curing times:

Three groups were bonded with a high-power halogen light (Swiss Master Light) in the fast-cure mode. In the first 2 groups, curing times of 2 and 3 seconds were used. The light tip was positioned on the middle of the bracket during each exposure. For the third group, the total curing time was 6 seconds. Because the manufacturer suggested not more than 4 seconds of curing time at once, the time of 6 seconds was divided into 3 seconds on the mesial side and 3 seconds on the distal side of the bracket.

The fourth group was bonded with a fast halogen light (Optilux 501 with turbo light guide, serial no. 53109080, Sybron Dental Specialities, Danbury, Conn) for 20 seconds on the mesial side and 20 seconds on the distal side of the bracket. The total curing time of 40 seconds was according to the light’s operation instructions. The technical characteristics of these curing lights are described in Table I.

The fifth group, the comparison group, was bonded with a xenon plasma arc curing light (Remecure, model CL-15E, serial no. CL15E-A0100, Remedent, Deurle, Belgium) for 2 seconds on the mesial side and 2 seconds on the distal side of the bracket. The total curing time of 4 seconds was according to the light’s operation instructions. The technical characteristics of these curing lights are described in Table I.

We made sure that the polymerization of the composite was not affected by the position of the light-guiding tip with respect to the bracket. The large tip of the high-power halogen lamp during the 1-shot light exposure covered the bracket completely. Throughout the mesial and distal light exposures, the tip overlapped the middle of the bracket (about 1 mm) to resemble the coverage of the high-power halogen lamp. Therefore, even with the smallest light-guiding tip diameter, the 2 radii of light it produced covered all areas around the bracket. Furthermore, the tip was held at an angle of 90° to the bracket to direct the light at the same angle on each occasion.

The shear bond strength was measured with a universal testing machine (Model 1114, serial no. H-1377, Instron Corp, Canton, Mass) (Fig 1). A rectangular rod transmitted the shear force on the occlusal edge of the bracket base until the bracket failed. The following procedure of standardization was developed to ensure that the bracket base would be parallel to the force-exerting rod during bond strength testing.9,19

Each bonded specimen was embedded in a rectangular acrylic block (Technovit 4071, Lot 021584, Ch.-B. 011102, Heraeus Kulzer, Wehrheim/Taunus, Germany). For this purpose, a metallic cubic blade (2 ×
2 mm) was fixed into the vertical slot of the bracket to ensure that the tooth-bracket interface was parallel to and projecting slightly above the acrylic surface.10 When this blade was laid over the mold, the bracket was situated in the middle of the acrylic block, and the edges of the bracket base were parallel to the edges of the block. After storage for 24 hours in the dark at 37°C2,12,20 in water,21 the acrylic block with the bonded tooth was secured onto the lower jaw of the testing machine. The shear bond force was applied by the rod. The samples were stressed in an occlusogingival direction with a crosshead speed of 0.5 mm/minute.22 Due to our special embedding procedure, the direction of the shear force exerted by the rod was parallel to the tooth-bracket interface, and the edge of the rod was parallel to the occlusal edge of the bracket base (Fig 1). The force necessary to debond the brackets was recorded in Newtons and then converted into megapascals (MPa) by dividing the Newtons by the surface area 12.41 mm² of the bracket base.9,19

The adhesive remnant index (ARI) was used to measure according to the following 4-point scale introduced by Årtun and Bergland23: 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 a distinct impression of the bracket mesh.

Statistical analyses

For the statistical evaluation, SPSS software (version 11.5, SPSS, Chicago, Ill) was used. The level of significance was set at $P < .05$.

Because the distribution of the shear bond strength values was normal, parametric tests were applied. The mean, standard deviation, and 95% confidence interval of the mean were estimated for each group.

Comparisons of shear bond strength between lights and curing times were performed by analysis of variance (ANOVA). If a statistically significant difference was found, the post-hoc Tukey test was used to identify which groups were different. Additionally, the groups were classified into Tukey homogeneous subsets. The Weibull survival analysis was also applied to compare the performance of each sample by calculating survival probability at given values of shear stress.10,13

The nonparametric Kruskal-Wallis test was used to test for significant differences between groups regarding the ARI.

RESULTS

Descriptive statistics for shear bond strength of the different groups are shown in Table II. ANOVA indicated statistically significant differences between groups ($P < .001$). Shear bond strength was significantly lower for the 2-second high-power halogen light than the 6-second high-power halogen light ($P = .001$), the fast halogen ($P = .002$), and the xenon plasma arc light ($P = .007$) (Table II).

The Tukey homogeneous subsets test showed a weaker subset, which included the 2- and 3-second high-power halogen groups ($P = .06$). The stronger subset included the 3- and 6-second high-power halogen light, the fast halogen, and the plasma light ($P = .565$).

The bracket survival probability at given levels of shear stress, estimated with the Weibull survival distribution, is shown in Figure 2. The curve of the 2-second high-power halogen lamp differs significantly: the survival probability declines more rapidly at a lower stress level; eg, the vertical dotted lines in Figure 2 correspond to 6-8 MPa that is suggested as the minimum acceptable bracket bond strength for clinical use.24 In the range of 6-8 MPa, the probability of survival would be approximately 80% for the 2-second high-power halogen light, whereas it would be above 90% for the other groups. A shear stress of approximately 10 MPa would cause 50% bond failures in the case of the 2-second high-power halogen light.
halogen lamp, whereas, to reach the same bond failure rate, a stress of over 15 MPa would be required for the other groups. No statistically significant differences were found between the groups regarding the ARI (P = .72) (Table III). More than half of the adhesive was left on the tooth in most cases (>60%) in every group after debonding.

DISCUSSION

These results support our hypothesis that the high-power halogen light minimizes curing time dramatically without compromising the bond strength of orthodontic brackets. Exposure to the high-power halogen light for 6 seconds and even for 3 seconds led to shear bond strengths equivalent to those achieved after 40 seconds of exposure to the fast halogen light. An exposure time of only 2 seconds is, however, not recommended because it led to significantly inferior shear bond strength values. An exposure time of 3 seconds should be used with caution, because the 3-second group was not significantly different from the 2-second group. We, therefore, recommend a curing time of 6 seconds for bonding stainless steel brackets. For ceramic brackets, the curing time might be less because the light polymerizes the composite through transillumination of the bracket as well.

Curing time is reportedly not influenced by the bandwidth of the emission spectrum of different lights as long as it corresponds approximately to the absorption spectrum of camphorquinone. It is shown that the double bond conversion rate of resin composites is not influenced by the emission spectrum, if the irradiated light energy is the same.25 Therefore, the parameter that allowed relevant reduction in curing time in our study seems to be the increase in power density (3000 mW/cm² for the high-power halogen light compared with 1000 mW/cm² for the fast halogen light). However, such a high power density might not be necessary to reduce curing time in the order of magnitude we

<table>
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<th>Curing device*</th>
<th>Time (seconds)</th>
<th>N</th>
<th>Mean †</th>
<th>SD</th>
<th>95%</th>
<th>Minimum</th>
<th>Maximum</th>
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<td>4.1</td>
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<td>12.6</td>
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<tr>
<td></td>
<td>6</td>
<td>15</td>
<td>20.1†</td>
<td>6.6</td>
<td>16.4</td>
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<td>40</td>
<td>15</td>
<td>19.2‡</td>
<td>6.9</td>
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<tr>
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<td>7.0</td>
<td>15.3</td>
<td>18.6</td>
<td>4.8</td>
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</table>

*Swiss Master Light, high-power halogen light; Optilux 501, fast halogen light; Remecure, xenon plasma arc light.
†‡ significant difference (P < .05) between groups with different symbols.

Fig 2. Bracket survival probability plotted against shear stress [MPa] (Weibull survival analysis) for high-power halogen (Swiss Master Light, SML), fast halogen (Optilux 501), and xenon plasma arc light (Remecure) with different curing times (seconds). Vertical dotted lines represent stress range of 6-8 MPa. Horizontal dotted line corresponds to failure probability of 50%.
demonstrated. The xenon plasma arc light had a power density of only 1600 mW/cm². Exposure to the xenon plasma arc light for 4 seconds was sufficient to obtain bond strength equivalent to that achieved after 3 or 6 seconds of exposure to the high-power halogen light and after 40 seconds to the fast halogen light. This observation leads to the assumption that, from a certain power density on, further increase in power density ceases to reduce curing time considerably. Such a threshold was previously detected, suggesting that there might be no benefit to polymerization of resin composite when power density is increased above approximately 1000 mW/cm².²⁶

The innovations of the high-power halogen light are its high power density and the unique size of its light-guiding tip (diameter, 11 mm). The light-guiding tip covers the entire bracket, and, in our study, a 1-shot application of 3 seconds was shown to be acceptable. However, the power increase of the high-power halogen light, made possible by an innovative water-cooling system, is accompanied by a bulky (270 × 256 mm) and heavy (7 kg) device. Nevertheless, the high-power halogen lamp is considerably less expensive than the laser or the plasma lamp. Only the LED lamps are less expensive, but no information is available on the new generation of high-intensity LEDs.

The bond strength to bovine enamel is weaker than to human enamel.²⁷ Nevertheless, the use of bovine enamel from deciduous teeth (as in this study) instead of permanent bovine enamel resembles more closely the bond strength values of human enamel.²⁷ Even when human enamel is used in vitro and in vivo, there is a difference in bond strength: in-vivo values are significantly lower.²⁸ Thus, a direct extrapolation of in-vitro observations to the clinical situation is difficult, and clinical studies are necessary. Furthermore, clinical studies could determine the minimum bracket bond strength necessary to withstand the forces due to occlusal loading. Recent information on such a threshold is lacking in the literature, and the only indication for the minimum necessary bond strength is given by Reynolds,²⁴ who suggested 6-8 MPa. If we rely on this finding, the mean shear bond strength of every group in our study would be sufficient (Table II, Fig 2). Even the minimum in every group would be within Reynolds’ suggested limits, with the exception of the 2-second light-curing with the high-power halogen light. However, the bond strength values measured in this study are common in analogous studies.²,⁹,¹²,²⁰ One must also consider that in-vivo bond strength values are lower.²⁸

The site of bond failure was unaffected by light source and curing time. Most failures at debonding were located at the bracket-adhesive interface; this agrees with other shear-bond testing studies.⁶,⁸,¹¹,¹³,¹⁹ The relatively weak mechanical retention between the composite and the bracket base reduces the risk of enamel fractures.

**CONCLUSIONS**

The results of this study support the use of the high-power halogen light. It is a cost-effective solution to reduce light-curing time. The recommended curing time for bonding stainless steel brackets is 6 seconds or, with caution, even 3 seconds. Our results are based on in-vitro laboratory conditions, and the clinical relevance of our findings should be confirmed in vivo.

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**REFERENCES**


