Amit Bhardwaj et al

Comparative Evaluation of Shear Bond Strength and Debonding Characteristics using Conventional Halogen Light Curing Unit and LED Light Curing Unit: An in vitro Study

ABSTRACT

Aim: The purpose of this study was to compare the shear bond strength of orthodontic brackets bonded to teeth with conventional halogen-based light curing units and commercially available LED curing units. LED light curing unit (Apoza) and halogen-based light curing unit (Q-Lux) were tested.

Materials and methods: Specimens consisted of one hundred twenty human maxillary premolar on which stainless steel brackets were bonded with a light-cured adhesive system (Transbond XT; 3M Unitek). The specimens were divided into 6 groups of 20 teeth each. Three groups were exposed to halogen light for 10, 20, 40 seconds and the other three groups were cured with the LED light for 10, 20, 40 seconds respectively. The specimens were stored in water at 37°C for 24 hours and then tested for shear bond strength with an Instron universal testing machine at a cross head speed of 1 mm/min until the bracket debonded. The results were subjected to Kaplan meier survival analysis (p = 0.0001 sig).

Results: The findings indicated no significant differences in the shear bond strength between the conventional halogen light and the commercially available LED-curing unit when the exposure time was 20 and 40 seconds. However, both halogen and LED lights displayed inadequate bond strength when the curing time was 10 seconds. Chi-square analysis detected no difference in the adhesive remnant index scores of the 6 groups (p = 0.0996).

Conclusion: The result of this study showed promise for the orthodontic application of LED as light curing units and 20 seconds of exposure time is adequate for both LED and Halogen light, since increasing the curing time to 40 seconds showed no significant difference.

Keywords: Shear bond strength, Transbond XT, Curing light unit.

INTRODUCTION

History reveals that one of the prominent milestones in the orthodontic field is the development of efficient attachment to the teeth.

Since, the introduction of the acid-etch technique by Buonocore in 1955 and its subsequent adaptation to orthodontics by Newman, a rapid stride in the phenomenon of bonding has made use of bands on anterior teeth nearly obsolete. Constant advances in material science have tried to improve the quality of bonding in order to improve bonding materials composition, dispensing system and mode of cure.

Thus, two-paste systems have given way to single paste system and recent self-etching primers are yet another step in simplifying the bonding procedure. The use of light cure systems in preference to chemical cure system gives the advantage of ‘command set’ allowing more precise bracket positioning and adequate curing time.

The bonded orthodontic brackets are more advantageous than bands in that they have no interproximal contact, easier to place and remove, separation of teeth not required, more esthetic, hygienic and less irritating to the gingiva. However, the frequency of bond failure during treatment has prompted the manufacturers to improve on bonding material and curing techniques.

Requirement of an efficient light cure system would be adequate depth of polymerization producing adequate bond strength. Another consideration would be that curing time required for achieving polymerization, as this would effect the chair side time and the operator.

Visible light curing units have become an important part of modern adhesive dentistry. They are used to cure resin based composite restorative materials, resin modified GIC,
preventive pit and fissure sealants, certain bases and liners, core build up materials and provisional restorative materials and most important to orthodontist to bond orthodontic bracket to teeth with resin.

Bonding with light activated system is popular because the extended working time allows for precise bracket placement and ease of manipulation. Once bracket is situated at desired location rapid command-set is accomplished through photactivation.

The four different technologies available for curing of dental composite by light are:
1. Halogen lamps
2. Plasma arc lamps
3. Lasers
4. LED lamps.

Of all the techniques mentioned above halogen lamps are most commonly used, but it has certain drawbacks:
1. Short service life (40-100 hrs)
2. High temperature
3. Continuous spectrum must be narrowed by filter system.

In 1995 Mills et al. proposed solid-state light emitting diode for the polymerization of light activated dental materials. Research has shown that LED’s have an increased lifetime and under go little degradation of output over time. Several studies have demonstrated the potential of LED technique for the light activation dental materials.

Fujibayashi et al. compared the depth of cure and the Knoop hardness produced when they used 61 LED’s to create a light with typical wave length of 450 nm and an irradiance of 100 mW/cm². And that produce by halogen unit adjusted to give an irradiance of 100 mW/cm². No difference in composite hardness and depth of cure were detected between LED and halogen light source.

Later Fujibayashi et al. constructed a LED with the typical wavelength of 470 nm and obtained a deeper cure with LED than with halogen light at 10, 20, 40 and 60 seconds.

The purpose of this study was to investigate the efficiency of commercially available LED unit as compare to the conventional halogen light curing unit and to determine the curing time required for adequate bond strength and study of debonding characteristics.

AIMS AND OBJECTIVES
1. To evaluate shear bond strength of stainless steel bracket cured with two different lights, halogen and commercially available LED curing units.
2. To establish the optimum curing time while using LED light.
3. To assess the debonding characteristics of each group by using modified adhesive remnant index (ARI) and also through scanning electron microscopy (SEM).

MATERIALS AND METHODS
One hundred and twenty freshly extracted human permanent maxillary premolar were randomly assigned to one of the six groups and stored in distilled water (Fig. 1).

The criteria for tooth selection induced intact buccal and lingual enamel with no cracks by the pressure of the extraction forceps and no caries.

Each group consisting of 20 specimens. The teeth were cleansed of soft tissue and then embedded in cold curing fast setting acrylic, with each tooth oriented so that its labial surface would be parallel to the during shear bond test.

3M Unitek Gemini series, maxillary premolar brackets were made of pH 17-4 type stainless steel with 0.22 slot Roth prescription and had a 80 gauge braze welded foil mesh base. A bracket base surface is of 10.61 mm² as described by the manufacturer (Fig. 2).

All the teeth were cleaned with rubber cup and pumice, etched using 37% phosphoric acid gel for 30 seconds, followed by thorough rinsing and drying, after application of the primer on the tooth the brackets were bonded near the center of the facial surface of the tooth with sufficient pressure to express excess adhesive, which was removed from the bracket’s base with a scaler before polymerization. The adhesive used for bonding was Transbond XT (3M/Unitek, Monrovia, La). Three groups were exposed to a conventional halogen light curing unit (light-intensity 300 mW/cm²). The remaining three groups were cured with LED (light intensity 130 mW/cm²) (Table 1) (Figs 3 and 4).

Group I: Stainless steel brackets cured for 10 seconds with halogen light curing units for 5 seconds each from the occlusal and gingival side.

Group II: Stainless steel brackets cured for 10 seconds with light emitting diode unit for 5 seconds each from the occlusal and gingival side.

Group III: Stainless steel bracket cured for 20 seconds with halogen light curing unit for 10 seconds each from the occlusal and gingival side.

Group IV: Stainless steel bracket cured for 20 seconds with light emitting diode units for 10 seconds each from the occlusal and gingival side.

Group V: Stainless steel bracket cured for 40 seconds with halogen light curing units for 20 seconds each from the occlusal and gingival side.

Group VI: Stainless steel bracket cured for 40 seconds with light emitting diode units for 20 seconds each from the occlusal and gingival side.

TESTING PROCEDURE

Shear Bond Strength Testing

All the bonded test samples were stored in distilled water at room temperature for 24 hours before testing.

Shear bond strength testing was done using a universal-testing machine, which was connected to a digital meter, and the debonding force was recorded automatically (Fig. 5).

The acrylic block was clamped in the lower vice and a chisel shaped rod was placed parallel to the bracket in the upper vice (Fig. 6).
The test samples were stressed for debonding at a crosshead speed of 1 mm/min until the bracket debonded. The force required for debonding was recorded in Newtons and converted into MPa.

\[
\text{MPa} = \frac{\text{Force in Newtons}}{\text{Surface area of bracket base}}
\]
Modified ARI Index

To assess the debonding characters, modified ARI scoring was done using steriomicroscope ‘MC 80-Zessis, Germany’ at 20x and 40x magnification (Fig. 7).

Adhesive remaining on the tooth surface was assessed and scored from 1 to 5:

Score I: All composite remained on the tooth surface along with distinct impression of bracket base.

Score II: More than 90% of composite remained on the tooth surface.

Score III: More than 10% but less than 90% of composite remained on the tooth surface.

Score IV: Less than 10% of composite remained on the tooth surface.

Score V: Indicating that no composite remained on the tooth surface.

SEM Study of Bracket Bases

All tooth surfaces were studied using a ‘Joel’ scanning electronic microscopy machine and then observed in a JSM-840. A scanning microscope (Joel-Japan) at an operative voltage of 15 to 20 kV, scanning electron micrographs were taken at 25x and 50x magnification (Figs 8 and 9).

RESULTS

The following analysis was employed to statistically evaluate the result:

- Kaplan Meier survival analysis
- Chi-square test.

Modified ARI Index

Scoring is illustrated in Table 2 and Graph 1, and photograph of each scoring is illustrated in Figure 10.

- Score I
- Score II

SEM Observation

SEM observation (Fig. 11) for debonding characteristics shows that there were no enamel cracks and loss of enamel surface from the samples.

- Score III
- Score IV
- Score V

Under the condition of this study the results of the Kaplan Meier survival analysis comparing the shear bond strength of orthodontic brackets bonded to teeth with two different light sources. Median survival time in Group I is significantly lower than the median survival time in Groups II, III, IV, V and VI (p < 0.05). Also the median survival time in Group II was significantly lower than the median survival time in Groups III, IV, V and VI (p < 0.05). However, there is no significant difference between any other groups. Result of the Chi-square analysis of ARI showed there was no significant difference between different study Groups (p = 0.996) (Table 3 and Graph 2).
Fig. 10: Stereomicroscopic photographs
Fig. 11: SEM photographs for SEM score
### Table 1: Color coding of test group 5

<table>
<thead>
<tr>
<th>Groups</th>
<th>Light curing unit</th>
<th>Time</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Halogen</td>
<td>10 sec, 5 sec each from occlusal and gingival side</td>
<td>White</td>
</tr>
<tr>
<td>II</td>
<td>LED</td>
<td>10 sec, 5 sec each from occlusal and gingival side</td>
<td>Yellow</td>
</tr>
<tr>
<td>III</td>
<td>Halogen</td>
<td>20 sec, 10 sec each from occlusal and gingival side</td>
<td>Green</td>
</tr>
<tr>
<td>IV</td>
<td>LED</td>
<td>20 sec, 10 sec each from occlusal and gingival side</td>
<td>Red</td>
</tr>
<tr>
<td>V</td>
<td>Halogen</td>
<td>40 sec, 20 sec each from occlusal and gingival side</td>
<td>Blue</td>
</tr>
<tr>
<td>VI</td>
<td>LED</td>
<td>40 sec, 20 sec each from occlusal and gingival side</td>
<td>Black</td>
</tr>
</tbody>
</table>

### Table 2: Cross tabulation of ARI score by groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>Score I</th>
<th>Score II</th>
<th>Score III</th>
<th>Score IV</th>
<th>Score V</th>
<th>Chi-square value</th>
<th>p-value*</th>
<th>Significant # groups at 5% level</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>12 (60%)</td>
<td>3 (15%)</td>
<td>3 (15%)</td>
<td>2 (10%)</td>
<td>0 (0%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>11 (55%)</td>
<td>4 (20%)</td>
<td>3 (15%)</td>
<td>2 (10%)</td>
<td>0 (0%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>11 (55%)</td>
<td>3 (15%)</td>
<td>3 (15%)</td>
<td>2 (15%)</td>
<td>1 (5%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>10 (50%)</td>
<td>4 (20%)</td>
<td>3 (15%)</td>
<td>3 (15%)</td>
<td>0 (0%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>11 (55%)</td>
<td>5 (25%)</td>
<td>3 (15%)</td>
<td>1 (5%)</td>
<td>0 (0%)</td>
<td>df = 20,</td>
<td>0.996 (NS)</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>12 (60%)</td>
<td>3 (15%)</td>
<td>3 (15%)</td>
<td>2 (10%)</td>
<td>0 (0%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NS: Not significant; df: degree of freedom; Chi-square test

### Table 3: Kaplan Meier survival analysis

<table>
<thead>
<tr>
<th>Groups</th>
<th>Median survival</th>
<th>SE</th>
<th>95% CI</th>
<th>Light curing unit</th>
<th>p-value*</th>
<th>Significant # groups at 5% level</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1.538</td>
<td>0.195</td>
<td>1.157-1.919</td>
<td>Halogen (10 sec)</td>
<td></td>
<td>I vs II, III, IV, V, VI</td>
</tr>
<tr>
<td>II</td>
<td>4.363</td>
<td>0.632</td>
<td>3.125-5.601</td>
<td>LED (10 sec)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>7.351</td>
<td>0.498</td>
<td>6.376-8.326</td>
<td>Halogen (20 sec)</td>
<td></td>
<td>II vs III, IV, V VI</td>
</tr>
<tr>
<td>IV</td>
<td>7.297</td>
<td>0.419</td>
<td>6.475-8.119</td>
<td>LED (20 sec)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>7.595</td>
<td>0.951</td>
<td>5.730-9.460</td>
<td>Halogen (40 sec)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>8.104</td>
<td>0.171</td>
<td>7.769-8.439</td>
<td>LED (40 sec)</td>
<td>&lt;0.0001 (S)</td>
<td></td>
</tr>
</tbody>
</table>

S: Significant

### DISCUSSION

Reynolds\(^4\) reported 6 to 8 MPa is the minimal shear bond strength that is required to withstand normal orthodontic forces. While numerous factors affect bond strength, the degree of polymerization is one such critical factor.

Fujibayashi et al\(^3\) also found an LED source producing the same irradiance as a halogen source and produced a significantly greater depth of cure than the halogen source. William J Dunn\(^5\) and Vittorio Cacciafesta\(^6\) found that there is no significant difference between the two. In our study both LED and halogen light did not show clinically adequate bond strength with 10 sec exposure. However, both LED and halogen light showed adequate bond strength when the exposure time was increased to 20 seconds and there was no significant difference in bond strength when the exposure time was increased to 40 seconds.
The LED showed comparable performance with halogen light even though the irradiance of LED was 130 mW/cm² as compared to halogen light, which was 300 mW/cm².

This is similar to the result found out by Mills et al⁷ who compared LED light having irradiance of 290 mW/cm² with Halogen light having irradiance of 455 mW/cm² and found out that they displayed comparable result. They attributed this to the spectrum flux of LED being concentrated over a much narrower wavelength band than for halogen light and that has a higher irradiance in the peak absorption for camphoroquinone (i.e. 468 nm).

It has been shown that blue light in different parts of absorption spectrum of camphoroquinone has different effectiveness and that light near to the absorption peak is more effective at curing.

CONCLUSION

- Ten seconds of curing time is not adequate for both halogen and LED light.
- Twenty seconds of curing time is adequate for both LED and halogen light, since increasing the curing time to 40 seconds it showed no significant difference.
- The result of this study showed promise for the orthodontic application of LED as light curing units. Therefore, LEDs can be recommended as a viable alternative to halogen light for orthodontic bonding.
- There was no significant difference in the debonding characteristics with most of the debonding taking place at the bracket-adhesive interface.

REFERENCES