Original Research

A comparative evaluation of the polymerization of orthodontic resins cured with a second generation light emitting diode curing unit and a conventional halogen based light curing unit– An invitro study

Mudasir Khan, Department of Orthodontics, Naazia Lone, Department of Pedodontics, Aamir Rashid Purra, Department of Conservative Dentistry and endodontics, Shafak Hameedi, Ex-Resident, Govt. Dental College and Hospital, Srinagar, India. E-mail: suhaillatoo@yahoo.com


Key Words: light emitting diode (LED), conventional halogen based light curing unit, curing efficiency

Abstract
Visible light curing units are an important part of modern adhesive dentistry. They are used to cure resin based composite restorative materials. To the orthodontist, they are mainly used to bond orthodontic brackets to the teeth. The technique of bonding brackets with resin was introduced in 1964. Bonding with light activated systems is popular as the extended working time allows for precise bracket placement. LED sources with a lower irradiance than the halogen light have also achieved a greater depth of cure and can achieve a similar compressive strength. In this study, we have evaluated and compared the curing efficiency and Adhesive Remnant Index (ARI) after debonding of a light emitting diode (LED) curing unit with a conventional halogen based light curing unit by testing the shear bond strength of orthodontic brackets bonded to teeth

Introduction

Visible light curing units are an important part of modern adhesive dentistry. They are used to cure resin based composite restorative materials. To the orthodontist, they are mainly used to bond orthodontic brackets to the teeth. The technique of bonding brackets with resin was introduced in 1964. Bonding with light activated systems is popular as the extended working time allows for precise bracket placement.
Currently, most sources of visible blue light applied in dentistry use tungsten filament halogen lamps that incorporate a blue filter to produce light in the 400-500 nm regions. The basic principle of light conversion by the halogen technique is inherently inefficient. The main problems encountered with conventional halogen units are the degradation of the lamp, the filter and the reflector, leading to reduced curing effectiveness. They have a limited lifetime of 50 to 100 hours. Filters can undergo blistering and reflectors discolor. This leads to a decrease in blue light intensity and reduction in curing effectiveness. The light power output is less than 1% of the consumed electrical power and the remainder is generated as heat. The great deal of heat produced by halogen curing lamps requires intensive fan cooling, which in turn may disperse any bacterial aerosol present in the patient’s mouth. The prolonged curing time with halogen bulbs is uncomfortable to the patient, impractical with children, and inconvenient for the clinician. Various attempts have been made to enhance the speed of the light-curing process by using a larger light guide or laser devices.

LED sources have been reported to produce a depth of cure significantly greater than that achieved with conventional halogen light when assessed by Knoop hardness and Fourier Transform Infra Red (FTIR) spectroscopy degree of conversion analysis. LED sources with a lower irradiance than the halogen light have also achieved a greater depth of cure and can achieve a similar compressive strength. Degree of conversion using FTIR revealed a greater conversion of monomer to polymer in specimens cured with the LED source than in those cured with the halogen light source.

**Aims and Objectives**

The present invitro study was conducted with the following aims and objectives:

1. To evaluate and compare the curing efficiency of a light emitting diode (LED) curing unit with a conventional halogen based light curing unit by testing the shear bond strength of orthodontic brackets bonded to teeth.
2. To evaluate and compare the Adhesive Remnant Index (ARI) after debonding for the adhesive cured with light emitting diode (LED) curing unit and those cured with conventional halogen based light curing unit.

**Materials and Methods**

The present in-vitro study was carried out gar in association with the Materials Testing Laboratory, Department of Manufacturing Engineering, Annamalai University using the following materials and methods.

**Materials**

- Fifty sound premolar teeth extracted for orthodontic purpose
- Fifty P.E.A stainless steel premolar brackets with average base surface area 13.96 mm² (Roth Gemini series, 3 M Unitek, Monrovia, USA.)
- Halogen based visible light curing unit (Blue Luxer, TM)
- LED visible light curing unit (Mini L.E.D S.P, Satelec, France)
- Etchant (37% phosphoric acid)
- Transbond XT light cured adhesive (3 M Unitek, U.S.A.)
UNITEK Universal Testing Machine (Model No.94100).
Distilled water.

Methodology

Fifty sound premolar teeth extracted for orthodontic purpose were collected with the following selection criteria: 28
- Intact buccal surface.
- Free of caries.
- No pretreatment with chemicals such as hydrogen peroxide etc.
- Absence of cracks as a result of extraction pressure.
- No developmental defects of enamel.

The teeth were thoroughly washed in running water. All blood and adherent tissues were removed from the teeth and were immediately stored in the distilled water to prevent dehydration. The teeth were randomly divided into two groups.

**Group A:** 25 teeth to be cured with Halogen curing light with light activated composite as adhesive.

**Group B:** 25 teeth to be cured with Light emitting diode curing light with light activated composite as adhesive.

Teeth in each group were mounted vertically on acrylic blocks. The acrylic bases were covered up to the usual level of alveolar bone around each premolar tooth. The teeth were kept outside the distilled water only for a very short time to prevent any dehydration. 28

The teeth were then polished by means of rubber cup with non-fluoridated pumice paste for 15 seconds and were then rinsed thoroughly with distilled water, dried with oil free air stream. The buccal surfaces of the teeth were conditioned by 37% phosphoric acid for 30 seconds and were then rinsed with distilled water. 28 After rinsing the buccal surfaces, the etched surfaces were dried with oil and moisture free air stream. This was followed by application of primer, using a primer applicator brush. The primer was polymerized for 10 seconds and then the adhesive paste was applied onto the bracket base. The brackets were then placed parallel to the long axis of the tooth. Each bracket in Group A was cured using the Halogen based L.C.U. (Blue LuxerTM) for 40 seconds (20 seconds on the mesial and 20 seconds on the distal) and in Group B was cured using an L.E.D. curing unit (Mini L.E.D S.P) for 10 seconds (5 seconds on the mesial and 5 seconds on the distal). With each source, care was taken to place the light tip as close to the bracket base as possible during curing.

Fifteen minutes after bonding, the samples were stored in distilled water bath at 37°C until ready for testing. The shear bond strengths of both the groups were tested 24 hours after bonding. 28
**Determination of Shear Bond Strength**

Brackets were debonded with an Universal testing machine that was fitted with a custom jig. The custom jig allowed the brackets to be debonded with a true shear force (parallel to the buccal surface of the tooth).  

The Universal testing machine was used to apply an occlusogingival load via a shear blade\(^8,29\) which produced a shear force at a crosshead speed of 1.0mm/min. The force required for each bond failure was recorded in kilograms (kgs). The shear bond strength (SBS) in mega pascals was then calculated.

**Adhesive Remnant Index (ARI) Determination**

After bond failure, all the teeth and the bracket bases were examined under 10 X magnification to determine the bracket failure interface. The adhesive remnant index (ARI) score was determined according to the criteria given by Artun and Bergland\(^3\).

The ARI score scale ranges from 0 to 3, where
- **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.

**Statistical Analysis**

The Descriptive statistics, including the mean, standard deviation, minimum shear bond strength, maximum shear bond strength and Adhesive Remnant index (ARI) scores were calculated for each group tested. The statistical interactions of shear bond strength between the groups were analyzed with students ‘t’ test. The chi square test was used to evaluate the differences in the ARI scores between the groups. 
P value of ≤ 0.05 was considered for statistical significance.

**Results**

The obtained results were then subjected to statistical analysis with student’s t-test and Pearson’s chi square test using an SPSS package for Windows. P value of ≤ 0.05 was considered for statistical significance.
The obtained results were tabulated and graphically represented as follows:

### Table 1
**Comparison of shear bond strength (MPa) between Group A and Group B**

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>25</td>
<td>10.0408</td>
<td>1.7903</td>
<td>0.411</td>
<td>0.685</td>
</tr>
<tr>
<td>Group B</td>
<td>25</td>
<td>10.2700</td>
<td>1.5050</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The table shows the mean shear bond strength, standard deviation for Group A and Group B and comparison of the mean shear bond strengths between them. The mean shear bond strength and standard deviation for Group A was 10.04 MPa and 1.79 respectively. The mean shear bond strength and standard deviation for Group B was 10.27 MPa and 1.50 respectively. Student’s ‘t’ – test did not show any statistically significant difference (p=0.685) between both the groups for the mean shear bond strengths.

### Table 2
**Adhesive Remnant Index Scores**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Number of Specimens (N)</th>
<th>ARI Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Group A</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Group B</td>
<td>25</td>
<td>0</td>
</tr>
</tbody>
</table>

### Chi-square test for Adhesive Remnant Index Scores

<table>
<thead>
<tr>
<th>Calculated Chi-square Value (X2)</th>
<th>Degrees of freedom (DF)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0857</td>
<td>2</td>
<td>0.6514</td>
</tr>
</tbody>
</table>

The table shows the ARI scores for Group A and Group B and the comparison between them. The ARI scores of 2 had the maximum frequency among both the groups. The ARI score of 0 was the least occurring frequency. The results of Pearson’s chi-square test indicated that there were no significant differences between both the groups (p=0.6514) for the ARI scores.

**Discussion**

The curing technologies have expanded a great deal in the past few years. The selection of an effective light source is of paramount importance in order to attain adequate level of polymerization of the light cure adhesives and to minimize any risk of bond failure when orthodontic forces are applied. Bonded brackets that become
loose during treatment consume much chair time, are poor publicity for the office and are a nuisance to the orthodontist. 13

The most popular medium for delivering blue light have been halogen based light curing units (L.C.U.). 19 Although, these light cure units have established their effectiveness over the years, the technology has several drawbacks, which have led researchers to search for newer and better light sources.

The light from halogen based LCU’s is produced from a bulb. The principle of operation of these halogen based light curing units (L.C.U.) lies in electrical energy heating a small tungsten filament in the bulb to extremely high temperatures. 2 These high temperatures cause a gradual degradation of the halogen bulb, reflector and filter thereby reducing the effectiveness in curing composite resins. 4,16,19 Moreover, the halogen bulbs have a limited effective lifetime of approximately 50-100 hrs 6,26 and their effective wavelength of light drops below an effective range during this period and so need to be replaced every 6 months10

Mills et al (1995) 31 proposed solid-state light emitting diode (LED) technology for the polymerization of light activated dental materials to overcome the shortcomings of halogen visible light-curing units. LED technology is not new and different versions of it have been used in many common applications such as indicators to common electronic devices.

In LED’s, a voltage is applied across the junctions of two doped semi-conductors resulting in the generation and emission of light in a specific wavelength range. 22 By controlling the chemical composition of the semiconductor combination, one can control the wavelength range. LED’s have a lifetime of more than 10,000 hours and undergo little degradation of output over this time. 15 Because there is no infrared emission, the curing lights have low amounts of wasted energy, leading to minimum heat generation, which eliminates the need for cooling fans. 14,16 This coupled by low power consumption enables them to be battery powered, making them lightweight and suitable for portable use in cordless devices. 33

Although L.E.D.’s are being aggressively marketed, research has not determined whether this technology has been fine-tuned enough to replace halogen visible light-curing units for orthodontic bonding. So the present study was aimed at evaluating the efficacy of L.E.D. and Halogen light curing units on the basis of shear bond strength achieved with light activated adhesives as a standard.

Research on dental application of LED’s compared with halogen based light curing units has demonstrated that at the same irradiance, LED’s perform as well as or better than halogen lights. 12,19 In a clinical setup the LED-curing unit produces bonds as strong as those produced by a conventional halogen unit. In the present study the mean shear bond strength values of LED-cured specimens were found to be 10.27 ± 1.50 MPa and the mean shear bond strength values of halogen-based light-cured specimens were found to be 10.04 MPa ± 1.79 MPa. Statistically no significant differences( p>0.05) for the mean shear bond strengths were found between the two groups when light cured composite was used as adhesive. These
results corroborate the comparable efficiency of halogen and LED-curing units as attained with light cured composite as adhesive. The results obtained were found to be in agreement with previous studies conducted by Mavropoulos A et al, Krishnaswamy NR et al, Cacciafesta V et al, Dunn WJ et al and Usumez S et al, which reported no statistically significant difference in the bond strength achieved, when these two light sources were evaluated.

Light-emitting diodes (LEDs) are reported to produce light of greater intensity, which could mean reduced curing time and greater bond strength. Bishara et al, in a laboratory study, recommended a minimum exposure of 20 seconds per bracket with an LED. However, Layman and Koyama using a newer generation LED device, reported that the bond strength obtained with 10 seconds of light exposure compared well with 20 seconds of exposure with a conventional halogen light. In the present study it was found that 10 seconds of exposure with LED light curing unit for each bracket produced a mean shear bond strength comparable to the mean shear bond strength produced by halogen light curing unit for a minimum of 40 seconds of exposure for each bracket. This shows that the LED light curing unit has a distinct advantage over the conventional halogen light-curing unit in that the curing time is markedly reduced. The prolonged curing time with the halogen curing units is uncomfortable to the patient, impractical in children and inconvenient for the clinician. A shorter curing time may also reduce the risk of saliva contamination and further reduce the incidence of bond failure.

A critical factor in the production of optimal cohesive composite resin strength is the amount of polymerization. The degree of polymerization is directly related to the amount of total energy that the resin absorbs. It has also been demonstrated that the quality of light polymerization is not exclusively due to the light intensity. 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 camphoroquinone 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 lies 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 camphoroquinone. In contrast, 95% of the emission spectrum of blue LED’s is situated between 440 and 500 nm. Furthermore, the emission maximum of the blue LED’s used in this study is approximately 465 nm, which is almost identical to the absorption peak of camphoroquinone. These factors may explain the similar SBS values obtained by LED with shorter exposure.

In the present study it was found that 76% of the specimens in group B (L.E.D light curing unit) displayed an ARI score of 2 whereas 64% of the specimens in group A (halogen light curing unit) displayed an ARI score of 2. An evaluation of the adhesive remnant index with chi square test revealed no significant differences ($p>0.05$) in failure sites between the groups. This was consistent with study done by Dunn et al. Thind et al in their study also did not find any significant differences for the ARI values between L.E.D light curing unit and halogen light curing unit. In the present study, greatest frequency of ARI score 2 was observed in both the groups, indicating
a cohesive bond failure within the light cured adhesive. It has been suggested that adherence of the adhesive to the bracket, shows surface enamel removal during the debonding procedure resulting in the loss of a fluoride rich enamel surface, whereas adherence to the tooth assures an intact enamel surface. According to these observations the bond failure at bracket-adhesive interface is desirable.

Conclusion
Considering the above findings, this study gives a very encouraging picture in the use of LED curing unit as a better alternative to the conventional halogen light curing units. The LED's offer a number of advantages over the halogen light curing units. They have an effective lifetime of more than 10,000 hours and undergo little degradation of output over this time. As there is no infrared emission, the LED curing lights have low amounts of wasted energy, leading to minimum heat generation, which eliminates the need for cooling fans. This coupled by low power consumption enables them to be battery powered, making them lightweight and suitable for portable use in cordless devices. Moreover, due to their narrow emission spectra they do not require filters to produce blue light. The results show promise for the orthodontic application of the LED curing units, but more clinical studies are necessary for validation.

References


**GRAPH - 1**

**GRAPH – 2**