Influence of Light Curing Method and Curing Time on the Surface Hardness and Degree of Cure in Composite Resins

Sa'di Shirshab Thiab
University of Babylon

Abstract

The aim of study was to determine the surface hardness (SH) and the degree of cure (DgOC) of light-activated composite polymerized with a halogen (HLCU) and LED (LED LCU) light cure units with different curing intervals. 100 samples were prepared that divided into 10 groups of 10 samples for each group using a tube-like stainless steel mold utilizing two composite materials (SwissTEC and Tetric®Ceram), shade A I cured for 20, 40 and 60 seconds with HLCU, 5,10 seconds with LED LCU type. The cured samples with 2 mm thickness removed from the mold and the hardness were measured with Vickers test for the exposure (top) and the inner (bottom) sides. 2-way ANOVA (at p ≥ 0.05) followed by Duncan multiple range test. The results showed that DgOC with LED was high significantly more than that for halogen. The conclusions of this study, that all materials, and curing times passed the ISO 2000/4049 requirements, the hardness of the exposure (top) and the inner (bottom) sides was higher for the samples cured with halogen than that cured with LED and also was more with SwissTec than the samples of Tetric®Ceram.

Key words: Degree of Cure, DgOC surface hardness, SH, light cure, composite, curing time.

Introduction

The visible light curing units (LCUs), now are an integral part of modern adhesive dentistry (Dunn & Bush, 2002). Quartz-tungsten-halogen bulbs (HLCUs) for many years have been used as the lighting source to light cured composite resins (Arrais et al., 2007). HLCUs generate light when electrical energy heats a small tungsten filament to extremely high temperatures. Most of the energy put into the halogen system is changed into heat, but a small portion is given off as light. Selective filters screen the other wavelengths so that only blue light is emitted (Dunn & Bush, 2002). Although the usefulness of halogen units with appropriate wavelengths is well known in clinical practice, there is still a need for using a more efficient light source because of inherent drawbacks such as a limited effective life time and reduced output (Tanoue et al., 2007). HLCUs present other shortcomings, such as the restricted depth of cure, heat generation and relatively long irradiation time (Bona et al., 2007). High heat generation, degrades the bulb's components over time, therefore, halogen bulbs have a limited effective lifetime (Rueggeberg et al., 1994; Bhamra et al., 2010; Martinelli et al., 2006) of approximately 100 hours (Rueggeberg et al., 1994; Bhamra et al., 2010). Blue light emitting diode (LED) technology has been indicated as an alternative to conventional halogen lights (Arrais et al., 2007), to overcome the shortcomings of HLCUs, LED technology, or proposed light-emitting diode (LEDLCUs), introduced in 1995 to polymerize light-activated dental materials, where instead of the hot filaments used in halogen bulbs, LEDLCUs use junctions of adopted semiconductors for generating light, they have life times of more than 10,000 hours and undergo little degradation of output over this time, do not require filters to produce blue light, resistant to shock and vibration and consume little power in operating (Dunn & Bush, 2002). Moreover, the
semiconductors used for light emission instead of hot metal filaments found in halogen bulbs generate less heat and

In addition to the materials (composite) composition, other factors may affect light curing of a resin-based composite, including the peak wavelengths and bandwidth of the curing light, the intensity of the light and the irradiation time (Dunn & Bush, 2002; Fan et al., Dunne et al., 2008).

When the light passes through the bulk of the composite resin, it is absorbed, dispersed and attenuated, decreasing the irradiance and curing effectiveness (Ruyter et al., 1982). This may cause deeper layers of an increment not to polymerize sufficiently, resulting in an inferior physical and mechanical properties of the restoration (Ruyter & Oysaed, 2005).

So light from the curing source must be able to adequately polymerize deeper composite regions than just the top irradiated surface (Cefaly et al., 2005), also the light may adequately reach the deepest composite layers and lead to greater polymerization, thus reducing possible marginal degradation that might occur if polymerization was incomplete (Poskus et al., 2004) and because the insufficiently polymerized composite resin may present quite a lot of problems such as; poor color stability, greater stain uptake, risk of pulp aggression by non-polymerized monomers (Rueggeberg et al., 1994; Shortall et al., 1995). Low hardness values are usually linked to poor wear resistance and susceptibility to scratching, which can compromise fatigue strength and lead to restoration failures (de Moraes et al., 2008), while the higher degrees of cure will improve the final properties of the material (Hegde et al., 2008). Since, a reduction in hardness was also obtained with increased depth of the composite (Sobrinho et al., 2000), it is suggested that, if necessary, visible light-activated composites should be placed and polymerized in about 2-mm increments(Kurachi et al., 2001). Because the physical properties of resin-based materials increase proportionally with the extent of cure or degree of conversion of monomer to polymer, one can estimate the extent of cure by measuring hardness(Yue et al., 2009).

Micro hardness testing has been widely used as a viable method to assess the relative degree of cure of resins and therefore the efficiency of the light source (Kurachi et al., 2001), as hardness of a material is a relative measure of its resistance to indentation when a specific, constant load is applied. By definition, hardness is a measure of the ability of a material to resist indentation or scratching. Hardness values have been used to indicate the relative ability of a material to resist scratching, these values have also been considered to provide an indication of their wear resistance properties (Mandikos et al., 2001).

The ratio of bottom-surface hardness to the top-surface hardness of a polymerized resin-based composite often is used to evaluate degree of cure, according to ISO 4049/2000 a ratio of 80 percent or higher usually is considered an adequate cure (Dunn & Bush, 2002; Aravamudhan et al., 2006; Price et al., 2005; Yazici et al., 2007).

As a result, the factors that affect light curing and how these factors influence the cure of resin-based composites are in need for a better evaluation. This study was performed to determine the curing ability of two commercially available light curing technologies by the evaluation of SH and DgOC on two direct composite materials cured by means of these polymerization systems with different curing intervals.
Materials & Methods

A stainless steel model with 6 mm diameter and 10 mm height was fabricated by using a stainless steel cylinder which has a highly polished tube like hollow gap inside, and it has a corresponding shaft (rod) that can be perfectly fitted within the gap. The body of the cylinder is cut by turning machine at length of 10 mm, thereby a solid tube mold with highly smooth inner surface have been obtained. The corresponding shaft is cut at length of 8 mm so when it is inserted into the mold from one side there will be a gap of 2 mm on the other mold's side (the difference between the lengths of mold and shaft). By this design a push-out model have been obtained, which is used to fabricate the samples of composite.

The composite materials used:

The information about each material is listed in Table (1) according to the leaflet.

Table (1): The composite materials used.

<table>
<thead>
<tr>
<th>Material</th>
<th>Type</th>
<th>Fillers% by volume</th>
<th>Fillers% by wt</th>
<th>Particles size range</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>SwissTec</td>
<td>Hybrid</td>
<td>59</td>
<td>78</td>
<td>0.04-2.8 µm</td>
<td>Coltene®/Whaledent AG (Manufacturer) Feldwiesenstrasse 209450 Altstatten/Switzerland</td>
</tr>
<tr>
<td>Tetric®Ceram</td>
<td>Hybrid</td>
<td>60</td>
<td>79</td>
<td>0.04-3 µm</td>
<td>Ivoclair Vivadent AG,FL-9494 Schaan/ Liechtenstein</td>
</tr>
</tbody>
</table>

The light cure systems used:
1. Coltolux®50.
2. FlashSoft.

The information about each system is listed in Table (2) according to the users manual. A new device for first time is used.
Table (2): The light cure units

<table>
<thead>
<tr>
<th>Light cure System</th>
<th>Type</th>
<th>Wave length</th>
<th>Intensity</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coltolux®50 Fig(1)</td>
<td>halogen with preset times of curing 20, 40, 60 seconds</td>
<td>505 nm</td>
<td>495 mw/cm²</td>
<td>Coltene® / Whaledent GmbH Fischenzstrasse 39 D-78462 Konstanz Germany</td>
</tr>
<tr>
<td>FlashSoft Fig(2)</td>
<td>LED with preset times of curing 5, 10 seconds</td>
<td>480 nm</td>
<td>950 mw/cm²</td>
<td>CMS Dental . Njalsgade 21 G, Copenhagen 2300 S Denmark</td>
</tr>
</tbody>
</table>

Light wave length and intensity was evaluated by radiometer (CROMATEST 7041, Germany).

Samples fabrication:

One hundred samples were prepared, fifty specimens per restorative material as each material samples divided into 5 groups each group of ten samples were cured by each curing run for each material with each LCUS at each time interval. The samples polymerized in about 2 mm increments(Council on Dental Materials, Instruments, and Equipment. Visible light-cured composites and activating units, 1985).

Ten samples (6 mm diameter and 2 mm depth)( Leforestier et al., 2005) were cured by each curing run .To prepare each specimen, after insertion of the cut rod in side
the mold, the mold-rod assembly placed on a flat glass slab to confirm that the lower side of the mold and the lower margin of the rod will be with the same level to initiate a constant distance of 2 mm gap at the upper side of the mold to receive the composite at each turn. The mold filled with the resin-based composite incrementally then the top of material was covered with clear polyester strip (transparent strips), (Hawe neo Dental CH-6925 Gentilino Switzerland), supported by another flat glass slab, hand pressure was applied to press a glass slide against the top layer of polyester film to extrude excess resin-based composite to flow prior to curing of the increment to ensure that the sample was flat (Pires-de-Souza et al., 2002).

After removing the top glass plate, the sample polymerized from the top surface for 20, 40, 60 seconds with HLCU type and for 5, 10 seconds with LED type. In order to standardize the light activation distance, the curing tip distance was 0 mm and the tip of LCUs was placed on the top layer of polyester film and each sample irradiated for a specific time as mentioned (Yue Ch, et al., 2009; Sobrinho et al., 2000; Aravamudhan et al., 2006; Dalli’magro et al., 2008). For the LED system, to minimize the effect of a battery's running low from continuous use, we alternated the method of light-curing for each specimen (Dunn & Bush, 2002), while for the halogen type no need for alteration as it act on direct power not chargeable battery as in LED system.

After matrix removal, the rod pushed from the bottom side, as it slip inside the mold pushing the sample to the out side of the mold. The specimens were stored at room temperature in a light-proof (dark) plastic container, twenty-four hours later hardness indentations have been done (Dunn & Bush, 2002; Cefaly et al., 2005; de Moraes et al., 2008; Yazici et al., 2007; Pires-de-Souza et al., 2007), with a Vickers' micro hardness test (Bhamra et al., 2010; Possus et al., 2004; Kurachi et al., 2001; Mandikos et al., 2001; Souza et al., 2010; Okic et al., 2006), which is carried out by Brooks Hardness Tester MAT24/CRBV (Brooks Inspection Equipment Ltd, 6 Grange Way Business Park, Whitehall road, Colchester, Essex CO2 8HF, England) the samples were positioned beneath the indenter of a microhardness tester to determine the Vickers' Hardness number (VHN) of the top and of the bottom surfaces, we measured the top surface (U) and the bottom surface (L) of each specimen.

Each sample is measured three times per face and the mean value of these three readings was recorded (Cefaly et al., 2005; Yazici et al., 2007; Leforestier et al., 2005; Faria et al., 2007). The mean VHN of U is regarded as the value of the surface hardness of the material. The DgOC of the specimens were then calculated using the formula:

\[
\text{(Hardness Ratio\%} = \left(\frac{\text{VHN of bottom surface}}{\text{VHN of top surface}}\right) \times 100\%
\]

(Yazici et al., 2007).

If that mean value exceeded 80%, the specimen was considered to be adequately polymerized (Dunn & Bush, 2002; Aravamudhan et al., 2006; Price et al., 2005; Yazici et al., 2007). We conducted our experiments using the methods and instrumentation described in ISO standard 4049,
Results
1. Surface Hardness:
Mean and standard deviation of the surface hardness (SH) for each tested group were calculated and listed in Table (3) and represented by a histogram in Figure (1). Data were analyzed using 2 factor analysis of variance (2-way ANOVA) to indicate if there are any statistical differences among groups (p ≤ 0.05), as shown in Table (4).

Table (3)
Mean and Standard Deviation of Surface Hardness for All Tested Groups.

<table>
<thead>
<tr>
<th>Groups (Composite – Curing Methods)</th>
<th>N</th>
<th>Mean VHN</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>SwissTEC - H 20s</td>
<td>10</td>
<td>156.40</td>
<td>1.23</td>
</tr>
<tr>
<td>SwissTEC – H 40s</td>
<td>10</td>
<td>162.53</td>
<td>0.803</td>
</tr>
<tr>
<td>SwissTEC – H 60s</td>
<td>10</td>
<td>167.80</td>
<td>0.767</td>
</tr>
<tr>
<td>SwissTEC – L 5s</td>
<td>10</td>
<td>131.13</td>
<td>0.380</td>
</tr>
<tr>
<td>SwissTEC – L 10s</td>
<td>10</td>
<td>144.40</td>
<td>0.796</td>
</tr>
<tr>
<td>Tetric – H 20s</td>
<td>10</td>
<td>146.27</td>
<td>0.925</td>
</tr>
<tr>
<td>Tetric – H 40s</td>
<td>10</td>
<td>160.60</td>
<td>1.19</td>
</tr>
<tr>
<td>Tetric – H 60s</td>
<td>10</td>
<td>163.33</td>
<td>0.913</td>
</tr>
<tr>
<td>Tetric – L 5s</td>
<td>10</td>
<td>128.27</td>
<td>0.435</td>
</tr>
<tr>
<td>Tetric - L 10s</td>
<td>10</td>
<td>135.13</td>
<td>0.730</td>
</tr>
</tbody>
</table>

N = number of samples  s = seconds  H = Halogen  L = LED  Std = Standard Deviation

Table (4)
Analysis of Variance (2-way ANOVA) for Surface Hardness.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>MS</th>
<th>F-value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curing Method</td>
<td>4</td>
<td>2234.59</td>
<td>3038.13</td>
<td>** 0.0001</td>
</tr>
<tr>
<td>Composite</td>
<td>1</td>
<td>410.86</td>
<td>558.60</td>
<td>** 0.0001</td>
</tr>
<tr>
<td>Curing Method × Composite</td>
<td>4</td>
<td>35.07</td>
<td>47.68</td>
<td>** 0.0001</td>
</tr>
<tr>
<td>Error</td>
<td>90</td>
<td>0.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>99</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DF = degree of freedom  ** = highly significant (p<0.001)  F=F calculated,
Effect of Light Curing Methods:

Analysis of variance Table (4) shows that there is a highly significant difference in SH among the all different light curing sources and methods used in this study. Duncan multiple range test for the five methods that is represented in Table (5) and Figure (4) indicates that SH of Halogen 60s (165.57) is significantly more than that of all other methods, followed by Halogen 40s (161.57), then Halogen 20s (151.33), then LED 10s (139.77), while the least SH value was for LED 5s (129.70).

Table (5)
Duncan Multiple Range Test for Surface Hardness of Light Curing Methods

<table>
<thead>
<tr>
<th>Light Curing Methods</th>
<th>N</th>
<th>Mean VHN</th>
<th>Std</th>
<th>Duncan grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>H 20s</td>
<td>20</td>
<td>151.33</td>
<td>5.44</td>
<td>C</td>
</tr>
<tr>
<td>H 40s</td>
<td>20</td>
<td>161.57</td>
<td>1.40</td>
<td>B</td>
</tr>
<tr>
<td>H 60s</td>
<td>20</td>
<td>165.57</td>
<td>2.48</td>
<td>A</td>
</tr>
<tr>
<td>L 5s</td>
<td>20</td>
<td>129.70</td>
<td>1.56</td>
<td>E</td>
</tr>
<tr>
<td>L 10s</td>
<td>20</td>
<td>139.77</td>
<td>4.94</td>
<td>D</td>
</tr>
</tbody>
</table>

N = number of samples  
$s =$ seconds  
H = Halogen  
L = LED  
Std = Standard Deviation  
Groups with same Duncan grouping letters are not significantly different.
Figure (4)
Duncan Multiple Range Test for Surface Hardness of the Five Light Curing Methods

Composite Material Type:

Analysis of variance Table (4) reveals that SwissTEC gave significantly higher SH values compared with Tetric Ceram composite material. The SH for SwissTEC was (152.45) while for Tetric Ceram was (146.72) as in Table (6) and Figure (5)

Table (6)
Duncan Multiple Range Test for Surface Hardness of the Two Composite Materials.

<table>
<thead>
<tr>
<th>Composite Type</th>
<th>N</th>
<th>Mean VHN</th>
<th>Std</th>
<th>Duncan grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>SwissTEC</td>
<td>50</td>
<td>152.45</td>
<td>13.50</td>
<td>A</td>
</tr>
<tr>
<td>Tetric Ceram</td>
<td>50</td>
<td>146.72</td>
<td>14.04</td>
<td>B</td>
</tr>
</tbody>
</table>

N = number of samples , Std = Standard Deviation ,
Groups with same Duncan grouping letters are not significantly different
Effect of Composite Type and Curing Method Interaction:
ANOVA indicates that there are high significant differences at the level of composite type and curing method interaction as shown in Table (4). Duncan multiple range test revealed that all groups are significantly different as in Table (7).

Table (7):
Duncan Multiple Range Test for Surface Hardness of Light Curing Methods – Composite interactions.

<table>
<thead>
<tr>
<th>Groups (Composite–Curing Methods)</th>
<th>N</th>
<th>Mean VHN</th>
<th>Std</th>
<th>Duncan grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>SwissTEC – H 20s</td>
<td>10</td>
<td>156.40</td>
<td>1.23</td>
<td>E</td>
</tr>
<tr>
<td>SwissTEC – H 40s</td>
<td>10</td>
<td>162.53</td>
<td>0.803</td>
<td>C</td>
</tr>
<tr>
<td>SwissTEC – H 60s</td>
<td>10</td>
<td>167.80</td>
<td>0.767</td>
<td>A</td>
</tr>
<tr>
<td>SwissTEC – L 5s</td>
<td>10</td>
<td>131.13</td>
<td>0.380</td>
<td>I</td>
</tr>
<tr>
<td>SwissTEC – L 10s</td>
<td>10</td>
<td>144.40</td>
<td>0.796</td>
<td>G</td>
</tr>
<tr>
<td>Tetric – H 20s</td>
<td>10</td>
<td>146.27</td>
<td>0.925</td>
<td>F</td>
</tr>
<tr>
<td>Tetric – H 40s</td>
<td>10</td>
<td>160.60</td>
<td>1.19</td>
<td>D</td>
</tr>
<tr>
<td>Tetric – H 60s</td>
<td>10</td>
<td>163.33</td>
<td>0.913</td>
<td>B</td>
</tr>
<tr>
<td>Tetric – L 5s</td>
<td>10</td>
<td>128.27</td>
<td>0.435</td>
<td>J</td>
</tr>
<tr>
<td>Tetric - L 10s</td>
<td>10</td>
<td>135.13</td>
<td>0.730</td>
<td>H</td>
</tr>
</tbody>
</table>

N = number of samples    s = seconds    H = Halogen    L = LED
Std = Standard Deviation
Groups with same Duncan grouping letters are not significantly different
2- Degree of Cure:
Mean and standard deviation of the DgOC percentage for each tested group were calculated and listed in Table (8) and represented by a histogram in Figure (6). Data were analyzed using -factor analysis of variance (2-way ANOVA) to indicate if there are any statistical differences among groups (p ≤ 0.05), as shown in Table (9).

Table (8): Mean and Standard Deviation of DgOC for All Tested Groups.

<table>
<thead>
<tr>
<th>Groups (Composite – Curing Methods)</th>
<th>N</th>
<th>Mean %</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>SwissTEC - H 20s</td>
<td>10</td>
<td>90.415</td>
<td>1.049</td>
</tr>
<tr>
<td>SwissTEC – H 40s</td>
<td>10</td>
<td>92.865</td>
<td>0.729</td>
</tr>
<tr>
<td>SwissTEC – H 60s</td>
<td>10</td>
<td>94.320</td>
<td>0.604</td>
</tr>
<tr>
<td>SwissTEC – L 5s</td>
<td>10</td>
<td>93.950</td>
<td>0.441</td>
</tr>
<tr>
<td>SwissTEC – L 10s</td>
<td>10</td>
<td>96.495</td>
<td>1.157</td>
</tr>
<tr>
<td>Tetric – H 20s</td>
<td>10</td>
<td>91.251</td>
<td>0.772</td>
</tr>
<tr>
<td>Tetric – H 40s</td>
<td>10</td>
<td>92.238</td>
<td>0.932</td>
</tr>
<tr>
<td>Tetric – H 60s</td>
<td>10</td>
<td>93.388</td>
<td>0.418</td>
</tr>
<tr>
<td>Tetric – L 5s</td>
<td>10</td>
<td>93.764</td>
<td>0.533</td>
</tr>
<tr>
<td>Tetric - L 10s</td>
<td>10</td>
<td>96.797</td>
<td>1.072</td>
</tr>
</tbody>
</table>

N = number of samples          s = seconds            H = Halogen       L = LED
Std = Standard Deviation

Table (9)
Analysis of Variance (2-way ANOVA) for DgOC.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>MS</th>
<th>F-value</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curing Method</td>
<td>4</td>
<td>45.3815</td>
<td>68.71</td>
<td>** 0.0001</td>
</tr>
<tr>
<td>Composite</td>
<td>1</td>
<td>0.1837</td>
<td>0.28</td>
<td>0.601</td>
</tr>
<tr>
<td>Curing Method × Composite</td>
<td>4</td>
<td>1.2581</td>
<td>1.90</td>
<td>0.128</td>
</tr>
<tr>
<td>Error</td>
<td>90</td>
<td>0.6605</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>99</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DF = degree of freedom , ** = highly significant (p<0.001) , F=F calculated ,
P = probability value, MS = mean square
Column with same color are not significantly different

Figure (6)
Mean and Standard Deviation of DgOC for All Tested Groups

Effect of Light Curing Methods:
Analysis of variance Table (9) shows that there is a highly significant difference in DgOC between the different light curing sources and methods used in this study. Duncan multiple range test for the five methods that is represented in Table (10) and Figure (7) indicates that DgOC of LED 10s (96.646) is significantly more than that of all other methods. While there was no significant difference between LED 5s (93.857) and Halogen 60s (93.854) and both were significantly higher than Halogen 40s (92.552). Halogen 20s showed significantly lower DgOC values compared with all other light curing methods.

Table (10)
Duncan Multiple Range Test for DgOC of Light Curing Methods.

<table>
<thead>
<tr>
<th>Light Methods</th>
<th>Curing</th>
<th>N</th>
<th>Mean (%)</th>
<th>Std</th>
<th>Duncan grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>H 20s</td>
<td></td>
<td>20</td>
<td>90.833</td>
<td>0.974</td>
<td>D</td>
</tr>
<tr>
<td>H 40s</td>
<td></td>
<td>20</td>
<td>92.552</td>
<td>0.855</td>
<td>C</td>
</tr>
<tr>
<td>H 60s</td>
<td></td>
<td>20</td>
<td>93.854</td>
<td>0.694</td>
<td>B</td>
</tr>
<tr>
<td>L 5s</td>
<td></td>
<td>20</td>
<td>93.857</td>
<td>0.472</td>
<td>B</td>
</tr>
<tr>
<td>L 10s</td>
<td></td>
<td>20</td>
<td>96.646</td>
<td>1.064</td>
<td>A</td>
</tr>
</tbody>
</table>

N = number of samples     s = seconds     H = Halogen     L = LED
Std = Standard Deviation
Groups with same Duncan grouping letters are not significantly different

Columns with same color are not significantly different Composite Figure (7)
Duncan Multiple Range Test for DgOC for the Five Light Curing Methods.

Material Type:
Analysis of variance Table (9) reveals that there is no significant difference in DgOC percentage between the two composite materials; SwissTEC (93.609) and Tetric Ceram (93.488) that used in this study, as in Table (11).

Table (11)
Duncan Multiple Range Test for DgOC of the two Composite Materials.

<table>
<thead>
<tr>
<th>Composite Type</th>
<th>N</th>
<th>Mean (%)</th>
<th>Std</th>
<th>Duncan grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>SwissTEC</td>
<td>50</td>
<td>93.609</td>
<td>2.16</td>
<td>A</td>
</tr>
<tr>
<td>Tetric Ceram</td>
<td>50</td>
<td>93.488</td>
<td>2.044</td>
<td>A</td>
</tr>
</tbody>
</table>

N = number of samples , Std = Standard Deviation ,
Groups with same Duncan grouping letters are not significantly different

Effect of Composite Type and Curing Method Interaction:
ANOVA indicates that there are no significant differences at the level of composite type and curing method interaction as shown in Table (9).

Discussion
In this study, LEDLCU and HLCU were employed to cure composite resins. Their performances were compared to each other in order to evaluate the curing efficacy of each light source. According to the results of the present study, all samples with DgOC for each material cured with each LCU at each curing time were passing the requirements
of ISO 2000/4049, as all the records of DgOC are more than 80% requested. The ISO test method a bottom(L) : top (U) hardness ratio of 0.8:1.0 is considered as adequate cure by most researchers(Fan, 2009).

Both devices studied produced satisfactory levels of DgOC (Table:8) at each curing interval, which is an important grant of curing system. This suggests that any of these measures would provide a reliable assessment of curing efficiency for a particular light/resin-based composite combination(Aravamudhan et al., 2006).

Although the DgOC with LEDLCU in SwissTEC groups was more than that cured with HLCU (except for SwissTec 60s) and the differences were more prominent among the Tetric®Ceram groups , the VHN of the U and L with HLCU were larger than that with LEDLCU Table:(3,5,6) , these findings are consistence with study by Dunn&Bush 2002. The mean of DgOC for both materials (Table:11) showed that it is slightly more for SwissTEC groups than in Tetric®Ceram groups, this is related to the slight differences in the filler content by weight, volume, according to (Table:1) we see the filler content in Tetric® Ceram is slightly more by weight and volume than that related to SwissTec and these factors which can increase light scattering and absorption(El-mowafy et al., 2005; Cefaly et al., 2005; Chung et al., 1990).

Surface hardness measurement is a simple technique that facilitates the evaluation of a large number of specimens, their simplicity makes them suitable for comparison between different polymerization techniques(Souza et al., 2010). Both devices studied produced satisfactory levels of surface hardness all records were above 100 VHN , this is in agreement with Kuracchi et al (2001). The surface hardness of (U) appeared to be more with HLCU among the two materials than the hardness gained with curing by LEDLCU, Although the hardness of composites is directly related to volume fraction of the hard, inorganic filler component. Fillers and their properties is not regarded in this study since the present study concentrate on the curing devices and their out put so the selected materials are with one shade which was (A 1) and both of them are hybrid type with approximately similar properties as we mentioned that the fillers of the two materials is in a proximity to each other and the increased hardness is related to the energy density obtained with halogen method which is more than that with LED method . Energy density is an important parameter which is; the amount of light energy of appropriate wavelength emitted during irradiation, this energy is calculated as the product of the output of the curing light unit and the time of irradiation [power density(intensity) X exposure duration(curing time)]( Council on Dental Materials, Instruments, and Equipment. 1985; Peutzfeldt et al., 2005). The higher the energy density, the higher will be the mechanical properties. According to (Table:2) for each device and curing time, the LED with curing interval for 5 seconds is 950 X 5 = 4750 which is the least and the highest was for HLCU with 60 seconds curing interval which is 495 X 60 =29700.

The L (bottom surface) with HLCU showed higher VHN than that for LEDLCU . This is in addition to the effect of energy density, it is due to the fact that longer wavelengths of the curing unit penetrated deep into the composite, as compared to the shorter wavelengths of the LED curing unit(Hegde et al., 2008). (Table:2) we can see the difference in wave length for both systems ; the table show that the wave length of HLCU (505 nm) is more than that for LEDLCU( 480 nm)
The hardness of (L) less than the hardness of (U) this is explained as that, during polymerization, light passes through an increment of the material in which it is absorbed and scattered: consequently its intensity decreases, this may cause deeper layers of an increment not to polymerize sufficiently, resulting in an inferior physical and mechanical properties of the restoration (El-mowafy et al., 2005; Cefaly et al., 2005; Chunget al., 1990), and the failure of a LCU to effectively promote full mass curing will probably result in the formation of an apparently solid restoration body but with physical and mechanical properties that diverge from those of a high-quality material (Martinelli et al., 2006; Sobrinho et al., 2000).

Hardness is used as an indicator of degree of conversion (DC) and hardness evaluation is an indirect method to verify the DC of resin composites (Correr et al., 2005). The increase in energy density produced higher DC and, consequently, higher hardness means and DC is a critical element in the physical properties of the resultant polymers. The halogen light produces greater curing energy and higher degree of composite monomer conversion than that of LED lights, and the polymerization process seems more dependent on the total energy available for photo activation than the light intensity property (Obici et al., 2004), although manufacturers determine the composition of the materials and establish recommended irradiation times, they rarely offer any suggestions in regard to the wavelength or intensity of the curing light to be used.

Hardness is related to the degree of polymerization and a desirable property for a restorative material is the high resistance to wear. The results of this study, (Table:5) indicates that SH of Halogen 60 s (165.57) is significantly more than that of all other methods, followed by Halogen 40s (161.57), then Halogen 20 s (151.33), then LED 10 s (139.77), while the least SH value was for LED 5 s (129.70), so the samples cured with LEDLCU will be less resistant to wear than the samples cured with HLCU and in the same group of LED, LED 10 s will be more resistant to wear than the LED 5 s and for HLCU the samples cured with 40 s will be less resistant than samples cured with 60 s and more than those with 20 s.

Although both materials that used in this study are hybrid type, but however SwissTEC showed a significantly higher SH values compared with Tetric Ceram. This may be due to that SwissTEC made by the same of the used halogen LCU manufacturer (Coltene Co.). So that photoinitiator present within SwissTEC may respond more conveniently than Tetric Ceram to the light irradiated from this curing device.

The color stability of composites can be influenced by several extrinsic factors, such as intensity and duration of the polymerization (Janda et al., 2005). DC plays an essential role in the color stability of these materials (Eldiawy et al., 1995), and affected by both the types of polymerization system and the polymerization condition and Insufficient monomer conversion induces absorption of staining substances, research in the esthetic dentistry seeks to meet to the demands of the clinicians, who desire restorative materials with easier handling characteristics and superior physical, mechanical and esthetical properties. However, it is known that achieving all these characteristics in one material constitutes a difficult task (Nakazawa, 2009). Esthetic failure is one of the most common reasons for the replacement of restorations. A good combination of the tooth color and the initial color of the material before curing is an important clinical factor for a clinically successful outcome. Nonetheless, this combination must remain after the material is completely cured and throughout the
restoration life-time. If the color of the composite changes with time, its main advantage, esthetics, is lost.

The LED obtained a significantly lower temperature increase when it is compared with a conventional curing lamp. The excessive exposure times with conventional lamps may result in dangerous pulp chamber increase in temperature. The LED-based device is devoid of all these problems. There is basically no infrared light transmitted to the sample and to the tooth; therefore, no excessive heat is produced, this is in fact a significant result, which gives good future perspective to the clinical use of LED-based devices for composite curing.

Characteristics of the light source considerably affect the depth of cure, hardness, wear resistance, water sorption, and solubility of indirect composites (Nakazawa, 2009).

The oral environment plays an important role in the properties of the dental restorative materials. Water sorption may affect dental restorative materials such as composites, by compromising their physical and mechanical properties. The water absorbed by the polymer matrix could cause filler-matrix debonding or even hydrolytic degradation of the filler (El-Hejazi, 2001).

Water sorption has been identified as the principal factor in the physical and chemical degradation of resin composite materials. The uptake of water has been directly related to the degradation of the filler-matrix interface, plasticizing of the matrix, and reduction of the tensile strength and wear resistance of the material (Diaz-Arnold et al., 1992). Furthermore, resin surface degradation and inorganic filler leaching may cause microscopic changes that could alter material smoothness over the course of time, and hence interfere with both esthetics and health. Rougher surfaces are a predisposing factor for bacteria adhesion, plaque maturation, periodontal disease, and extrinsic staining.

Hardness is an important parameter that has a bearing on the behavior of composite resin restorations in the oral environment. Adequate polymerization is required for clinically successful restorations. Therefore, the influence of two kinds of light curing units with varying intensities on the surface hardness of a composite resin was evaluated in the present study. The new curing light units must help to reduce the curing time while improving the composite resin curing rate, to obtain that the polymerization with a high-intensity unit is both useful and convenient for improving properties of composite material, since it reduces handling time.

References


Fan, P L. "Personal Communication" By E-mail received on 11/8/2009.

793


