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Surface microhardness and depth of cure of composite resin cured with LED and Halogen units

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Abstract

The aim of this study was to evaluate the surface hardness and depth of cure of resin composites cured with a quartz tungsten halogen (QTH) lamp or a light emitting diodes (LED) unit.

Swiss Tec (colten/whaledent AG, Switzerland) resin composite was placed in1, 2, 3, and 4 mm depth and 8 mm width metallic molds and cured using the QTH light or the LED unit for 40s.

A total of 40 samples were made that divided into two groups according to the type of curing light with 20 samples each. Each group was subdivided into 4 groups according to the height of the mold with 5 samples each. Microhardness measurements were performed using a calibrated Vickers indenter (100 g load and 30s dwell time). Measurement of depth of cure was carried out by means of hardness ratio (bottom/top × 100).

Results were analyzed by paired student's t-tests ($P < 0.05$). Results showed that LED exhibited higher microhardness values than QTH unit and the difference was statistically significant ($P = 0.03$) at the top surface and highly significant ($P = 0.001$) at the bottom surface.

Further more the results revealed that LED produced samples with hardness ratio (depth of cure) higher than QTH unit and the difference was highly significant ($P = 0.004$) at 3 mm depth. Both curing lights inadequately cure samples at 4 mm depth.

Conclusions: Curing effectiveness of resin composite is better with LED than QTH unit especially when the composite thickness exceed 2 mm.

Keywords: Curing effectiveness, Surface hardness, Depth of cure.

Introduction

Nowadays, light-curing dental materials are extensively used in dentistry. Four types of polymerization sources have been developed and applied: quartz tungsten halogen (QTH) lamps, light emitting diodes (LED) units, plasma-arc lamps and argon-ion lasers [(1)]. Halogen lights and LED units are overwhelmingly applied in daily clinical practice [(2)]. Halogen lamps, a low cost technology, have been the most frequent source employed for polymerization of resin composite materials [(3)] as their broad emission spectrum allows the polymerization of all known resin composite materials available [(2)]. However, they have several drawbacks. Their efficiency in converting electronic energy into light is estimated to be low. Up to 70% is transformed to heat and only 10% is visible light, including the blue range desired for polymerization [(4)].

Therefore, filters are required to reduce heat energy transferred to the oral structures and provide further restriction of visible light into the narrower spectrum of photoinitiators [2]. Of the visible light, due to the use of cut-off filters, a further 90% is wasted. Therefore, the final blue light output is less than 1% of the total energy input [2]. Moreover, light filters degrade with time due to the high operating temperatures and proximity to the halogen bulb [5]. Several studies have pointed out that many halogen units used by clinicians do not reach the minimum power output specified by the manufacturers [6]. A lack of maintenance, such as omitting to check the light curing units´ irradiance or to replace the halogen bulb from time to time, is the reason for this [5].

The lifespan of a conventional quartz-tungsten-halogen lamp ranges between 30-50 hours [7]. These shortcomings could result in inadequate curing which could negatively affect restoration long-time success [8].With the objective of overcoming these limitations inherent to halogen lamps, in 2001, the first light emitting diode (LED) curing units were introduced into the dental market [9]. LEDs use a combination of two different doped semiconductors instead of a hot filament [2, 5]. The spectral output of gallium nitride blue LED conveniently falls within the absorption spectrum of camphoroquinone [10]. Therefore, they do not require filters to produce blue light and they convert electricity into light more efficiently [3]. They produce less heat so no cooling fan is required and they can be smaller and cordless (9). Moreover, LEDs can operate for thousands of hours with a constant light output in power and spectra [10]. Contrary to first generation LED curing lights, newer units deliver with a density power higher than 400 mW/cm2, allowing a reduction of the exposure time recommended by composite manufacturers [11]. An adequate polymerization of resin composites is essential for the ultimate success of the restorations [12]. The degree of cure of resin composite materials influences their mechanical properties, solubility, dimensional stability, color change and biocompatibility [13, 14]. Depth of cure and microhardness testing has been widely used to assess the relative degree of cure of resins and, thus, the efficiency of light sources [15, 16]. The aim of this study was to evaluate the surface hardness and depth of cure of resin composites cured with a quartz tungsten halogen (QTH) lamp or a light emitting diodes (LED) unit.

Materials and method

Sample preparation:

According to the manufacturer instruction, small amount of composite resin (Swiss Tec composite, Colten / Whaledent AG, Switzerland) shade A3 was dispensed on a paper pad then packed by a plastic spatula in to the cylindrical metallic mold with dimensions of 8 mm in diameter and 1, 2, 3, or 4 mm height. The metallic mold was placed over a glass slide and a thin polyester strip (0.05 mm thick) (Prodvits Dentaires S.A. C4-1800 Vevey / swiss) was placed between the mold and the glass slide. The resin composite was slightly overfilling the mold. Another polyester strip was placed on the top of the mold and overlaid with a glass slide with finger pressure to extrude the excess material and forming a flat surface. At that time the glass slide on the top surface was removed and each sample was immediately irradiated through the polyester strip with either QTH unit (Hangzhov Yinya, new materials, China) or LED unit (Changsha Deyve,

High-Tech., China) depending on samples grouping. The time used for irradiation of each sample was 40 seconds for both light curing units.

Sample grouping:

Figure (1) shows grouping of samples according to the type of curing light and thickness of resin composite.

Hardness testing:

Prior to the hardness measurement, the top and bottom surfaces of the previous samples were polished using HA264031 finishing bur (Toboom Shanghai precise abrasive tool Co. Ltd. China). Microhardness test was performed 24 hours after specimen preparation and during this time they were kept in darkness at room temperature (31-33ºC).Microhardness (Vickers Hardness Number, VHN) was determined using a digital microhardness tester (Buelher 2101, Lake Bluff, Illinois, USA) applying a 100 g load through a Vickers indenter with a dwell time of 30s.Two indentations were made on each surface and the mean of them was taken. The depth of cure was measured by mean of hardness ratio (bottom / top × 100).

Statistical analysis:

Mean values and standard deviations of microhardness and depth of cure were calculated for each group of specimens. Paired student t-test was performed to determine the significant differences between the groups ($P < 0.05$).

Results

Surface hardness:

Tables1 and 2 show the means and standard deviations of the microhardness values (VHNs) for the top and bottom surfaces for all groups. It is clear that VHNs were higher in samples that cured with LED than samples cured with QTH. Analysis of samples with 1 mm thickness by Student t-test revealed that the differences in microhardness values were statistically significant ($P = 0.03$) at the top surface and highly significant ($P = 0.001$) at the bottom surface (table 3).

Depth of cure:

Means and standard deviations of the hardness ratio (depth of cure) for all groups are presented in tables 1 and 2. It is obvious from those tables that LED produced samples with hardness ratios higher than QTH curing unit. Also it can be seen that the adequate polymerization (when hardness ratio more than 80%) can be achieved with both light curing units at 1 and 2 mm thickness of composite, while the adequate polymerization for samples with 3 mm thickness can be seen only with LED unit. Also the results showing that both light curing units produced inadequate polymerization for samples with 4 mm thickness, so that these samples (4 mm thickness) were excluded from comparison with paired t-test.

Statistical analysis of the results with paired t-test (table 4) revealed that the differences were highly significant ($P = 0.004$) when comparing samples with 3 mm thickness (G3 vs. GC). While the differences were non significant between the other groups.

Discussion

In the present work, curing effectiveness was measured using indirect methods such as depth of cure and hardness testing. Direct methods that assess the degree of conversion, like infrared spectroscopy and laser Raman spectroscopy are complex, expensive and time-consuming [17]. Depth of cure and microhardness are considered essential physical properties of composite resin materials,

relevant to the clinical technique of incremental packing and curing [18]. However the surface hardness was assessed by a digital microhardness tester as it exhibits a good correlation with degree of conversion of composite [19].

According to the results, the LED produce hardness values significantly higher than values produced by QTH in both top and bottom surfaces. This could be related to the fact that the spectral output of gallium nitride blue LED falls conveniently within the absorption spectrum of the camphoroquinone photo-initiator (400-500 nm) presented in most light activated resin composite. The polymerization starts with the excitation of the camphoroquinone molecules by the blue light. The absorption peak of camphoroquinone is around 470 nm. Thus, the narrower the light spectrum around this peak, the more effective the polymerization will be. Also the results of the present study showed that the increase of depth reduced the composite hardness for all groups. However, with the increase of composite depth part of the light is spread, absorbed, or its passage become more difficult because of the increase of density of the polymer formed which reduce the activation of the deeper camphoroquinone molecules [20]. To ascertain depth of cure, the bottom hardness values was divided by the top hardness values and multiply the results by 100 [21]. In the present study, at 1 and 2 mm depth, both light curing units produced adequate polymerization (more than 80%). In spite of the LED produced hardness values higher than QTH but these differences was significant only between samples with 3 mm thickness and this could be related to the excessive attenuation of light energy as it passed in the deeper layers. And this energy will reach to a level that become unable to adequately polymerize the composite materials especially when sample thickness reach 4 mm in case of LED or 3 mm and 4 mm in case of QTH.

Within the limitation of the present study we can conclude that:

1- Regarding the surface hardness, the LED can cure the composite resin more efficiently than QTH unit.
2- LED can adequately cure composite even when composite thickness reach 3 mm. while in case of curing with QTH the composite thickness should not exceed 2 mm.
3- Both light curing units tested were unable to adequately cure the composite material at 4 mm depth.

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Table (1): Means ± Standard deviations of surface hardness and Hardness Ratio after curing with LED.

	1 mm	2 mm	3 mm	4 mm
Top	31.17 ± 4.83	26.4 ± 1.34	22.44 ± 1.6	27.11 ± 1.43
Bottom	28.88 ± 3.28	24.42 ± 3.22	19.4 ± 0.82	9.17 ± 1.6
Hrd. Ratio (%)	93.93 ± 13.43	91.47 ± 8.69	86.61 ± 3.38	34.05 ± 7.07

Table (2): Means ± Standard deviations of surface hardness and Hardness Ratio after curing with QTH.

	1 mm	2 mm	3 mm	4 mm
Top	23.09 ± 1.68	24.09 ± 0.78	22.25 ± 3.39	22.49 ± 0.61
Bottom	18.63 ± 0.92	19.37 ± 1.52	12.58 ± 1.37	7.83 ± 0.99
Har. Ratio (%)	81.13 ± 8.27	80.55 ± 8.01	57.62 ± 10.01	34.8 ± 5.1

Table (3): T-test comparing the microhardness values between QTH and LED units regarding the top and bottom surfaces.

QTH vs. LED	T-value	P-value	Level of significance
Top surface	3.02	0.39	significant
Bottom surface	8.41	0.001	Highly significant

Table (4): T-test comparing the Hardness Ratios between different groups.

Groups	T- value	P- value	Level of significance
G.1 vs. G.A	1.74	0.157	Non significant
G.2 vs. G.B	1.57	0.191	Non significant
G.3 vs. G.C	5.97	0.004	Highly significant

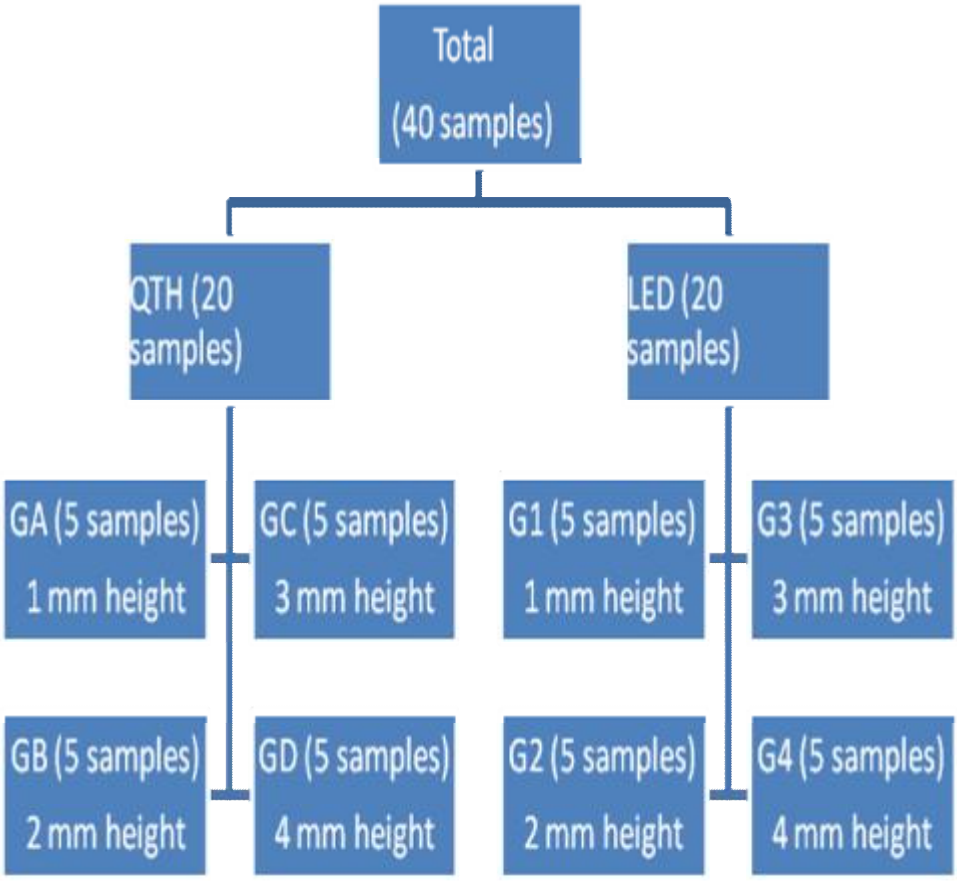

Figure (1): Grouping of samples.