Effect of light curing units on physical properties of composites

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Summary

Objective. **The objective of this study is to determine the polymerization efficiency of three light curing units on two different thicknesses of different composites.**
Material and method. **Three commercial composite resins were used to prepare disk shaped specimens (10 mm x 2 mm and 10 mm x 3 mm). All the specimens were light-polymerized for 40 seconds with three different light curing units at zero distance. 18 groups and 8 specimens for 1 group of light-cure composite at A1 shade were used in this study. Surface hardness was determined in top and bottom surfaces of each sample with Vickers hardness tester (Zwick).**
Results. **Statistical analyses of the study were made by Kruskal Wallis test and Mann Whitney U test. The light curing units did not demonstrate any significant difference in top surfaces for all groups except for the samples cured with Halogen light. The best results were obtained for bottom surfaces when 2 mm samples of Supreme were exposed by Led 2 (Mean = 64.40 ± 12.27). The significantly high number of samples exposed with Led 2 shows the percentage ratio for bottom/top hardness values exceeded 80% ($p<0.01$). Also samples cured with halogen light showed significantly better bottom/top hardness ratio than the samples cured with Led 1 ($p<0.05$)**
Conclusion. **The second generation Led technology shows a significantly better depth of cure from QTH (quartz tungsten halogen) lights without some drawbacks like heat transmission and limited effective lifetime. The maximum thickness for composite resins must be 2 mm, even curing with high intensity light sources. Also it should be taken into account that the composite resin filler type and composition may cause low polymerization efficiency due to limited light passing through the bottom surface.**

Key words: **Light Curing, QTH, light intensity, microhardness, composite.**

Introduction

Since 1970, light activated resin composite restoratives have been widely used in clinical dentistry. There has been a rapid increase in demand for esthetic restorative materials as well as light curing units since the introduction of single-paste light cured composites [1]. As the polymerization of light cured resins depends mainly on the characteristics and type of the radiation source used, a way to achieve better properties of the final restoration cured is the improvement of the curing unit. Visible light-curing units are an important part of modern adhesive dentistry. They are used to cure resin based composite restorative materials, resin modified glass ionomers, preventive pit and fissure sealants, certain bases and liners, core build-up materials and provisional restorative materials [2,3].

Visible light activated resin systems use a diketone absorber to create free radicals that initiate the polymerization process

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[4,5]. Most dental photoinitiator systems use camphoroquinone as the diketone absorber, with the absorption maximum in the blue region of the visible light spectrum at a wavelength of 470 nanometers (nm) [6,7]. The most popular method of delivering blue light has been with halogen-based light curing units [8]. Despite their popularity, halogen technology light curing units used to polymerize dental materials have several drawbacks [9]. For example, halogen bulbs have a limited effective lifetime of approximately 40-100 h [10]. In addition, the LCU's bulb, reflector and filter degrade over time due to the high operating temperatures and the large quantity of heat, which is produced during the duty cycles. This results in a reduction of the LCU's curing effectiveness over time [11]. To overcome the problems inherent to halogen LCUs, solid-state light emitting diode (LED) technology has been proposed for curing light activated dental materials [12].

LCUs that use blue LEDs produce a narrow band of wavelengths, specifically chosen to excite the photoinitiators commonly used in dental resins [6,13]. LEDs last for thousands of hours, convert electricity into light more efficiently, and they produce less heat [6,14,15]. The first generation of LED curing lights, which often contained multiple LEDs, had a relatively low power output, and they did not perform as well as conventional QTH lights [13,16,17]. The second generation of LED curing lights delivers a different spectral distribution with a greater power output than the first generation lights and may therefore offer better performance and shorter curing times [18]. For the light cured materials it is obvious that the degree of polymerization is affected by the irradiation time and light intensity. The filler type size and translucency of the material can also affect the depth of cure [19]. As light passes through composite it is absorbed and scattered, attenuating the intensity and reducing the effectiveness of the light for resin polymerization.

The objective of this study is to determine the polymerization efficiency of three light curing units on two different thicknesses of different composites.

Material and method

Three commercial composite resins (Admira, Voco; Supreme, 3M-ESPE; Carisma, Heraeus Kulzer) were used to prepare disk shaped specimens (10 mm x 2 mm and 10 mm x 3 mm). All the specimens were light polymerized for 40 seconds with three different light curing units (Led 1: Hilux, Ledmax 1; Led 2: Freelight 2, 3M-ESPE; QTH: Coltolux 75, Coltone) at zero distance. 18 groups and 8 specimens for 1 group of light-cure composite at A1 shade were used in this study. After the curing process the samples are stored in 100% humidity at 37°C degrees for 24 hours. Surface hardness was determined from top and bottom surfaces of each sample with Vickers hardness tester (Zwick). Before examination, a 250-gram load was applied to four different places for both surfaces.

Results

Statistical analyses of the study were made by Kruskal Wallis test and Mann Whitney U test. The light curing units did not show any significant difference in top surfaces for all groups except for the samples cured with Halogen light. Best results were gained from the samples of Supreme in 2 mm ($p<0.01$). Also samples cured with Led 2 in 3 mm Supreme show significantly better results than other composites ($p<0.05$). Led 1 shows significantly lower hardness values than Led 2 and QTH except for 3 mm samples of Carisma at bottom surfaces. There is no significant difference for all light curing units at 3 mm samples of

Table 1. Vickers Hardness Values

Light Source	Thickness (mm)		*Composite*						*p*
			Carisma		*Supreme*		*Ormoser*		
			Ort.	**S.D.**	**Ort.**	**S.D.**	**Ort.**	**S.D.**	
LED 1	**2**	**Top**	51.25	1.52	73.82	2.99	60.67	8.09	***0.012****
		Bottom	30.67	5.10	35.15	10.93	26.30	2.32	***0.537***
	3	**Top**	46.17	14.90	73.20	1.23	46.70	4.78	***0.020****
		Bottom	35.87	9.73	21.30	0.94	19.17	1.62	***0.010****
LED 2	**2**	**Top**	56.30	4.46	77.52	4.48	53.48	3.11	***0.019****
		Bottom	47.87	4.03	64.40	12.27	47.87	1.88	***0.038****
	3	**Top**	54.97	1.23	73.25	6.32	52.30	3.63	***0.017****
		Bottom	45.22	2.21	52.75	13.87	39.15	3.72	***0.174***
HALOGEN	**2**	**Top**	68.87	1.94	88.52	11.79	57.90	3.79	***0.007*****
		Bottom	44.07	0.91	56.97	15.74	48.72	0.55	***0.190***
	3	**Top**	60.32	17.04	66.35	4.82	53.35	5.94	***0.292***
		Bottom	36.45	6.88	42.20	11.27	38.07	3.10	***0.841***

Carisma. Led 2 shows significantly better hardness values than QTH for all 2 mm samples except Ormocer. The best results were obtained for bottom surfaces when 2 mm samples of Supreme were exposed with Led 2 (Mean = 64.40 ± 12.27), *(Table 1).* Significantly high number of samples exposed with Led 2 shows the percentage ratio for bottom/top hardness values exceeded 80% ($p<0.01$). Also samples cured with halogen light are significantly better than the samples cured with Led 1 ($p<0.05$) *(Table 2).*

Discussion

Studies have demonstrated that light-curing units can cause a temperature increase that could damage pulp [20]. Thermal transfer to pulp varies with the type of unit used during curing [21]. The depth of cure and surface microhardness has been related to the energy output of the light-curing unit [22].

Newer light-curing units have been designed to increase the light energy output, but increasing the light intensity could increase thermal transfer to pulp [23]. In addition, curing units that have lower polymerization efficiency can cause residual monomers; these monomers can pass through dentin tubules and result in irreversible pulpitis. For all these reasons we can say that the biological properties of dental materials may be affected by the curing unit used [24]. Due to the need for high output and less temperature rise, LED technology is the best alternative to conventional halogen bulb curing devices. The temperature rise during polymerization and heating

Table 2. Top/Bottom Hardness Ratios

Top/Bottom Percentages	Led1		Led2		Halogen	
	n	%	n	%	n	%
< %79 and lower	44	91.7	18	37.5	40	83.3
> %80 and higher	4	8.3	30	62.5	8	16.7
Total	48	100	48	100	48	100

from radiation was lower with LED compared to QTH curing [25].

The first generation LED curing devices has advantages such as low heat transmission and better wavelengths produced for composite polymerization but the results of our study showed that the Led 1 polymerization device has lower intensity than QTH units that overcome a lower polymerization efficiency. Our data supports the study of Kurachi et al. [26]. Also Dunn et al. [16] mentioned that the light output of commercially available diodes for resin-based composite polymerization still requires improvement to rival the adequacy of cure of halogen-based LCUs.

Soh et al. [17] showed that the efficiency of Led 2 curing units is comparable to QTH devices at different type and thickness of composites. Also Yoon et al. [27] mentioned that the degree of conversion is influenced by three variables of material: depth from surface, light source and energy level. For each light curing unit and material, there was a linear relationship between the depth of cure and the logarithm of the amount of exposure, which is defined as the product of the irradiation and irradiation time [28]. They showed that Led 2 curing units exhibit better polymerization efficiency than others.

Uhl et al [29] showed that the spectral output of the second-generation light emitting diodes fits better than the other light sources for polymerization of composite resins. They found out that at the thickness of 2 mm, second generation LED polymerization devices have better polymerization depth than other conventional polymerization devices.

Fujibayashi et al. showed that at the same irradiance, LEDs perform as well as or better values than do halogen-based units [30,31].

In this study the hardness ratios showed that Led 2 curing units have equal or better performance than QTH devices up to the composite resin used.

The polymerization of composites is affected by the wavelength of light, and the transmittance and absorbency of composites also depend on the wavelength of light [28]. Nomoto figured out that the depth of cure is dependent upon the light permeability of the filler, as well as the monomer composition and type and concentration of initiator, inhibitor and accelerator in the resin materials. Also Yoon et al. [27] mentioned that the degree to which materials cure is proportional to the amount of light to which they are exposed. At the upper surface of a restoration, where no overlaying composite interfaces with light transmission, it has been found that even a curing source with relatively low intensity can cure the resin matrix to an extent almost equal to that when high intensity light was used. For the Supreme composite resin we found out that the top surface values show better Vickers hardness values than the other composites used in this study. These data proved that not only the light source used but also the particular size and composition of the material affects the polymerization of the composite resin even at the nearest parts to the light source tip.

Conclusion

The second generation Led technology shows significantly better depth of cure from QTH lights without some drawbacks like heat transmission and limited effective lifetime. The maximum thickness for composite resins must be 2 mm even when curing with high intensity light sources. The composite resin filler type and composition may cause low polymerization efficiency due to limited light passing through the bottom surface.

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