Effectiveness of Four Different Light-activated Composites Cure with Different Light Energy Densities

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Abstract

Background: This study investigated the influence of light energy density (intensity x time) on the effectiveness of composite cure in view of the curing profiles of light-polymerization units with different light- activated composites to determine the energy density that satisfies adequate polymerization of all light-activated composites types used in this study.

Materials and methods: This study investigated the hardness of the top/bottom surfaces and hardness ratio of 2-mm thick composite specimens after exposure to different light energy densities. Parameters included five light intensities (200, 300, 400, 500 and 600 mW/cm^2) and seven curing times (20, 40, 60, 90, 120, 150 and 180 seconds) for each of the four different light-activated composite materials (Tetric Ceram, Heliomolar, Herculite XRV and Degufill Mineral).

Results: Statistical analysis of the data by using the one-way analysis of variance revealed that, most of the hardness ratios exhibited a very highly significant difference according to intensity, composite type and curing time. The results indicated that, Heliomolar and Degufill Mineral light-activated composites required approximately (36 J/cm²) energy density for adequate polymerization for a 2-mm thick specimen while, Herculite XRV and Tertric Ceram light-activated composites required approximately (12 J/cm²) energy density for adequate polymerization for a 2-mm thick specimen.

Conclusion: This study indicated that, final curing should not be done with energy density less than (300 mW/cm^2 for 120 seconds, 400 mW/cm^2 for 90 seconds and 600 mW/cm^2 for 60 seconds) for Heliomolar and Degufill Mineral light-activated composites.

Key words: Resin composite, light curing, microhardness, photo-activation and composite cure.

Introduction

Light-activated resin composites, introduced in the 1970s, revolutionized clinical dentistry by maximizing working time and minimizing setting time. Over the last few years, composite restoratives and adhesive techniques have become the foundation of modern dentistry. The hardening of a dental composite results from a chemical reaction between dimethacrylate resin monomers that produces a rigid and heavily cross-linked polymer network surrounding the inert filler particles [(1)].

The extent of this reaction often is referred to as the degree or

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effectiveness of cure, is very important in that it dictates many physical and mechanical properties of the composite restoration [2]. Inadequate polymerization has been associated with inferior physical properties, higher solubility, retention failures and adverse pulpal responses due to unpolymerized monomers [3].

The effectiveness of composite cure may be assessed directly or indirectly.

Direct methods that assess degree of conversion, such as infrared spectroscopy and laser Raman spectroscopy, have not been accepted for routine use because these methods are complex, expensive, and time - consuming [4].

Indirect methods have included visual, scrapping and hardness testing. Surface-hardness

has been shown to be an indicator of the degree of conversion [5]. High intensity lights may provide higher values for degree of conversion, but they also produce higher contraction strains during composite polymerization [6]. A slower curing process that permits composite flow may allow for stress relaxation to take place during photo-polymerization [7], as the polymerization process is dependent on total light energy rather than light intensity alone [8].

A slower curing process with an equivalent degree of conversion can be obtained by applying a lower intensity light for a longer time or using variable intensities over a given time period. The objective of this research was to investigate the influence of different light energy densities on the effectiveness of cure of four different light-activated composites and to determine the minimum energy density required by each type of composite used to be adequately polymerized.

Materials and methods

A conventional Quartz tungsten halogen light-curing unit (Quayle Dental, Worthing England) with an 8-mm diameter curing-tip was used and modified into a variable intensity polymerizer (VIP) to be used as the light source for all curing procedures later on. A digital light meter (Coltolux) (Coltène/Whaledent.com, France) was used to measure the light intensity delivered from the curing tip. Four different light-activated resin composites of A2 shade were selected: Tetric Ceram (Ivoclar, Vivadent AG FL-9494 Schaan/Liechtenstein.Lot: E58102), Heliomolar (Ivoclar, Vivadent AG FL-9494 Schaan/Liechtenstein.Lot: C37535), Herculite XRV (sds Kerr, 1717 West Collins Orange, CA 92867, U.S.A.Lot: 205466.Item No.: 22860) and Degufill Mineral (Degussa-Hüls AG, Degussa Dental GmbH & Co. KG, Postfach 1364. D-63403 Hanau, Germany.Lot: 0885).

A stainless steel cylindrical mold of 2-mm high and 4-mm in diameter (Iraqi construction) was used as a mold for the composite material. To prepare each specimen, the mold was placed on a clear glass slide (Blue star glass industries, Delhi, India) with a transparent celluloid strip (Hawe-Neos Dental, CH-6925 Gentilino, Switzerland) in between, and the resin composite material was carried and placed in the mold. Then, another transparent celluloid strip was placed on the top surface of the mold over which, a cover slide (0.3 mm in thickness) was then placed and excess material was extruded by finger pressure application. The composite was then cured from the top through the cover slide and the celluloid strip using different light energy densities. Parameters investigated included five light intensities (200, 300, 400, 500

and 600 mW/cm^2) and seven curing times (20, 40, 60, 90, 120, 150 and 180 seconds) for each type of the four different light-activated composite materials. One hour after light polymerization the specimens in their molds, were positioned centrally beneath the Micromet Vickers micro-hardness tester (Adolph I. Buehler Inc. Optical and Metallurgical instruments 2120 Greenwood st /Evanston ILL USA 60204) (Figure 1) to calculate Vickers hardness number (VHN) of the top and bottom surfaces.

Ten specimens were assigned for each of the different light intensities and each type of composite materials. Hardness ratio was calculated using the following formula:

Hardness ratio=VHN of bottom surface/VHN of top surface

That means if the value exceeded 0.8, the specimen was considered adequately polymerized [(9)].

Mean and standard deviation were calculated for each specific hardness ratio. The results were analyzed with one-way ANOVA at significance level 0.05.

Results

Mean hardness ratios of the four light-activated composites at different light intensities and different time intervals are listed in Table 1.

1. The effect of intensity on the hardness ratio:

Statistical analysis of the data by using the one-way analysis of variance revealed that, there was statistically very highly significant difference (***)($p<0.001$) for all the hardness ratios with the light intensity except the hardness ratio of Tetric Ceram composite cured for 90 seconds where, there was non significant difference (NS) ($p>0.05$) and the hardness ratios of Tetric Ceram composite cured for 60 seconds, Tetric Ceram composite cured for 120 seconds, Herculite XRV composite cured for 120 seconds where, there was a highly significant difference (**)($p<0.01$) and the hardness ratio of Heliomolar composite cured for 150 seconds where there was only a significant difference (*)($p<0.05$).

2. The effect of composite type on the hardness ratio:

Statistical analysis of the data by using the one-way analysis of variance revealed that, there was statistically very highly significant difference (***)($p<0.001$) for all the hardness ratios with the composite type except the hardness ratio of 200mW/cm² light intensity and curing time for 20 seconds where, there was non significant difference (NS) ($p>0.05$) because, the comparison occurs between only two types of composites (Tetric Ceram and Herculite XRV) and their mean hardness ratios were (0.58,0.57 respectively).

The mean hardness ratios of Heliomolar and Degufill composites were not calculated because their bottom surfaces were poorly polymerized. Also, there was non significant difference (NS) ($p>0.05$) carried out in the hardness ratio of 500 mW/cm² light intensity and curing time for 150 seconds. There was a highly significant difference (**)($p<0.01$) in the hardness ratios of 300 mW/cm² light intensity and curing time for 120 seconds, 400 mW/cm² light intensity and curing time for 90 seconds, 500 mW/cm² light intensity and curing time for 180 seconds and 600 mW/cm² light intensity and curing time for 60 seconds. There was only a significant difference (*)($p<0.05$) in the hardness ratios of 600 mW/cm² light intensity and curing time for 120 seconds, 600 mW/cm² light intensity and curing time for 150 seconds and 600 mW/cm² light

intensity and curing time for 180 seconds.

3.The effect of curing time on the hardness ratio:

Statistical analysis of the data by using the one-way analysis of variance revealed that, there was statistically very highly significant difference (***) ($p<0.001$) for all the hardness ratios with the curing time except the hardness ratio of Heliomolar composite cured at 300 mW/cm² light intensity, Heliomolar composite cured at 400 mW/cm² light intensity and Herculite composite cured at 600 mW/cm² light intensity where, there was non significant difference (NS) ($p>0.05$).

Discussion

The relative importance of microhardness test lies in the fact that it sheds a light on the mechanical properties of a material [10]. The higher the degree of conversion, the better the mechanical properties, hardness, biocompatibility, water sorption, color stability and wear resistance of the resin composites [11].

In this study, the top surface was not as susceptible to the effects of light intensities as the bottom surface. This finding agrees with Soh *et al.* [12], who stated that, duration of exposure (curing time) is the most important factor in polymerization of surface resin composites. In this study, all the specimens of the four different light-activated composites in microhardness tests, exhibited high VHN of the top surfaces in relation to that of the bottom surfaces for all the energy densities being tested and this finding is in an agreement with the findings of Tate et al. [13] who found that, the polymerization of resin composites generally decreases from the surface of the restoration inwardly.

The composite type, light intensity and curing time significantly affected the effectiveness of composite cure (hardness ratio). It is believed that microfills exhibit this reduced depth of cure because their small filler particles cause light scattering, which decreases the effectiveness of the curing light [14]. Composites that contained prepolymerized filler particles (Heliomolar) exhibited significantly lower physical properties than composites that contained round, irregular-shaped filler particles (Herculite XRV), or a mixture of prepolymerized and irregular-shaped particles. The results of this study were, in agreement with the findings of Kim et al. [15], who found that the filler loading also affected the physical properties including microhardness of the composites evaluated.

The results of this study showed a direct relationship with the filler load level (weight percent). This is due to the fact that, Herculite XRV composite contains 79% by weight filler loading and in other reference [16] 87.1% by weight filler loading and this increased filler loading or the type of its filler loading could be the main cause for its highest VHN followed by Degufill Mineral (80% filler loading by weight), Tetric Ceram (79% filler loading by weight) and finally Heliomolar (66.7% filler loading by weight). The bottom surfaces of Herculite XRV light-activated composite exhibited the highest VHN for all the energy densities followed by Degufill Mineral, Tetric Ceram and Heliomolar, which exhibited the lowest VHN and this is true for the high energy densities.

The bottom surfaces of Herculite XRV light-activated composite exhibited the highest VHN for all the energy densities followed by Tetric Ceram, Degufill Mineral and Heliomolar, which exhibited the lowest VHN and this is true for the low energy densities. This means that, in spite of its high filler loading by

weight, Degufill Mineral required high energy density for adequate polymerization and this could be due to the fact that, Degufill Mineral is one of the fluoride releasing composites and the incorporation of borosilicate and calcium phosphate-fluoride-apatite filler particles might interfere with light transmission through the composite material.

In this study, whatever the light energy density was, Heliomolar light-activated composite (microfill) exhibited the lowest hardness ratio than all the composites being tested followed by Degufill Mineral, Tetric Ceram and Herculite XRV, which exhibited the highest hardness ratio (starting from the lowest to the highest values). The hardness ratio of Heliomolar was not calculated for 20, 40 seconds at 200, 300, 400 mW/cm² light intensities and 20 seconds at 500 mW/cm² light intensity, because its bottom surfaces were poorly polymerized in spite of the manufacturer recommendation of 40 seconds curing time for each 2-mm thickness increment (manufacturers' data) without prescribing the energy density or at least the light intensity that should accompanied this curing time.

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Figure 1: Micromet Vickers micro-hardness tester.

Table 1: Mean hardness ratio of the four different light-activated composites at different time intervals at light intensity of 200-600 mW/cm² respectively.

Energy density		*Tetric Ceram*	*Helio molar*	*Herculite XRV*	*Degufill Mineral*
Intensity (mW/cm²)	*Curing time (seconds)*	*HR*	*HR*	*HR*	*HR*
200	20	0.58(0.06)	?	0.57 (0.05)	?
	40	0.75 (0.06)	?	0.77 (0.08)	0.4 (0.03)
	60	0.79 (0.10)	0.57 (0.04)	0.88 (0.05)	0.63 (0.06)
	90	0.93 (0.07)	0.58 (0.02)	0.85 (0.05)	0.69 (0.05)
	120	0.93 (0.05)	0.71 (0.07)	0.86 (0.04)	0.71 (0.05)
	150	0.94 (0.05)	0.75 (0.06)	0.84 (0.04)	0.73 (0.05)
	180	0.93 (0.05)	0.75 (0.08)	0.85 (0.04)	0.75 (0.05)
300	20	0.67 (0.06)	?	0.78 (0.04)	0.41 (0.06)
	40	0.68 (0.06)	?	0.75 (0.03)	0.43 (0.06)
	60	0.79 (0.07)	0.76 (0.09)	0.88 (0.06)	0.65 (0.05)
	90	0.89 (0.05)	0.77 (0.10)	0.88 (0.06)	0.65 (0.05)
	120	0.86 (0.03)	0.78 (0.09)	0.88 (0.06)	0.8 (0.06)
	150	0.87 (0.11)	0.80 (0.09)	0.9 (0.04)	0.75 (0.05)
	180	0.87 (0.02)	0.80 (0.07)	0.9 (0.05)	0.76 (0.03)
400	20	0.62 (0.03)	?	0.82 (0.08)	0.59 (0.04)
	40	0.7 (0.05)	?	0.8 (0.09)	0.63 (0.04)
	60	0.83 (0.07)	0.73 (0.07)	0.88 (0.05)	0.68 (0.04)
	90	0.88 (0.06)	0.8 (0.05)	0.87 (0.05)	0.81 (0.04)
	120	0.88 (0.04)	0.8 (0.06)	0.89 (0.03)	0.76 (0.04)
	150	0.89 (0.04)	0.81 (0.09)	0.9 (0.03)	0.76 (0.03)
	180	0.89 (0.06)	0.81 (0.08)	0.91 (0.03)	0.76 (0.03)
500	20	0.7 (0.09)	?	0.82 (0.03)	0.69 (0.07)
	40	0.76 (0.06)	0.64 (0.05)	0.89 (0.04)	0.68 (0.04)
	60	0.85 (0.04)	0.74 (0.05)	0.88 (0.05)	0.68 (0.03)
	90	0.87 (0.06)	0.8 (0.04)	0.88 (0.04)	0.80 (0.03)
	120	0.85 (0.04)	0.81 (0.07)	0.9 (0.05)	0.79 (0.03)
	150	0.85 (0.06)	0.86 (0.14)	0.9 (0.04)	0.8 (0.03)
	180	0.87 (0.03)	0.86 (0.10)	0.91 (0.04)	0.8 (0.01)
600	20	0.83 (0.08)	0.73 (0.05)	0.97 (0.04)	0.75 (0.06)
	40	0.84 (0.09)	0.77 (0.07)	0.98 (0.06)	0.74 (0.06)
	60	0.93 (0.08)	0.84 (0.15)	0.99 (0.03)	0.83 (0.07)
	90	0.92 (0.04)	0.86 (0.04)	0.96 (0.03)	0.89 (0.06)
	120	0.92 (0.04)	0.9 (0.06)	0.95 (0.03)	0.88 (0.06)
	150	0.97 (0.05)	0.92 (0.12)	0.96 (0.04)	0.88 (0.06)
	180	0.97 (0.07)	0.93 (0.10)	0.97 (0.04)	0.88 (0.05)
Standard deviation in parentheses. ? : The hardness ratio is not calculated, because of the poor polymerization of the bottom surface.					