

Original Article

Vickers Hardness of Composite Resins Cured with LED and QTH Units

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Abstract

Statement of Problem: One of the factors affecting the degree of polymerization of light-cured composites is the type of light-curing unit used. In addition, physicomechanical properties of the composite resins depend on the degree of conversion and polymerization.

Objectives: Since the type of initiator in new composite resins is not explained by manufacturers, this study is an attempt to compare the depth of hardening, with two LED and QTH light-curing units.

Materials and Methods: Fifteen samples prepared from Gradia Direct and Filtek Z250, both of which being universal, were cured with QTH (Astralis 7) and LED (Bluephase C8) light-curing units. All the samples were molded in polyester resin and cut from the middle by a disk. The hardness of the cut area was evaluated at 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5 and 4-mm depth intervals and also at the same interval as the width of the sample, with Vickers hardness machine, while the samples were placed in a darkroom. Data were statistically analyzed using one-way ANOVA, two-way ANOVA, t-test and post Hoc Tukey's tests in SPSS, version 16.

Results: Filtek Z250 was harder than Gradia Direct at all the depth with both light-curing units. The hardness of Filtek Z250 sample cured with Astralis 7 was higher than that cured with LED, but with Gradia Direct the LED unit resulted in higher hardness. Curing depth was not significantly different between the groups ($p = 0.109$).

Conclusions: Vickers hardness number for both composites used in this study is in an acceptable range for clinical implications. The composites' composition is important to be considered for selection of light unit. Based on the findings of the present study, LED did not present more curing depth compared with QTH.

Introduction

Light-cured composite resins are widely used [1-5] and have advantages over self-cured composite resins [2,3]. Today, there are basically four main sources for polymerization of light-cured composite resins [2,6,7]: Quartz-tungsten-halogen (QTH), Plasma Arc (PAC), Light-emitting diode (LED), and Laser.

For years, QTH unit, the output light intensity of which is 400–800 mW/cm², was the gold standard for composite resin polymerization [2,4,6,8-11]. The majority of QTH units used in dental offices have output light intensities lower than the least recommended values. Furthermore, slow curing and limited depth of curing are some other disadvantages [2,4,8-13].

The technique used to produce light in LED units is different from that in QTH units. Hot filaments are used for heat production in halogen lamps, but in gallium nitride LEDs, electron moving in a direction between positive and negative areas under an adequate voltage leads to the production of blue light. Hence the emitting spectrum of LED covers the absorbed spectrum by camphorquinone without filtering. The latest documents released indicate that LED lamps result in the highest polymerization and have lower energy consumption in comparison to QTH units. Previous LED units had output light intensities around 300 mW/cm², but the new models of LED units with high light intensity are claimed to have shorter exposure time and deeper curing. Based on the advantages mentioned, today LED units are widely accepted [1,2, 14,15].

The following are some of the important factors affecting the adequate polymerization of a composite resin and consequently favorable depth of curing:

a. The specification of light source, including wavelength of the output light and its intensity, the duration of light exposure and distance from the light source. b. Composition of composite resin and type of the initiator. c. The volume of the cured composite resin.

The depth of cure is the depth at which composite resin preserves 80% of its surface hardness and after that the composite resin has no sufficient polymerization [11].

The most common light initiator used in the composite resin materials is camphorquinone, the absorption spectrum of which is around 468 nm

[1,2,15,16]. However, it is possible to use the other light initiators such as phenyl propanedione (PPD) with an absorption spectrum of 410 nm or bisacyl phosphine oxide and triacyl phosphine oxide with an absorption spectrum of 320–390 nm [1,8,10,15].

Because the output spectrum of LED units is limited and it is closer to the absorption spectrum of camphorquinone, it is unlikely to have a sufficient depth of cure when other initiators are used. Manufacturers claim that the acceptable curing depth in dark-shade composite resins is achieved in shorter times with LED than QTH. There are still some questions about the depth of cure regarding the LED [16,17,18-22]. Evaluation of curing depth and also the degree of monomer conversion and composite resin polymerization is carried out using two direct methods with Fourier Transform Infrared Spectroscopy (FTIR) or Raman Spectroscopy, assessing the carbonic double bonds and an indirect method assessing composite resin hardness in different depths with Vickers device [2,7,17].

As the physical and mechanical properties of the composite resins are directly related to the degree of monomer conversion and the extent of polymerization, and that ever-increasing numbers of new composite resins are marketed with different light initiators, this study was designed to identify and compare the depth hardness of two composite resins cured with LED and QTH units. The null hypothesis stated that there would be no difference in curing depth and hardness between the two composite resins cured with two different units.

Materials and Methods

Two types of composite resin (Table 1), Filtek Z250 and Gradia Direct, both in A2 shade and universal, were light-cured with two different light-curing units, i.e. Bluphase C8 Light-emitting diode-LED (Ivoclar Vivadent, Austria) and Astralis 7 Quartz-tungsten-halogen-QTH (Ivoclar Vivadent, Austria) (Table 2).

Filtek Z250 has been used in most of previous researches as an acceptable composite in case hardness assessment of newly-introduced composites with. On the other hand, Gradia Direct as a microfil composite is now widely used in esthetic restoration, either anterior or posterior zone.

A total of 60 samples were prepared for four 15-sample groups. Composite resin samples were

Table 1: Specifications of composite resins used

Resin Composite	Manufacturer	Organic ingredient	Filler	Particle size
Filtek Z250	3M ESPE, USA	BisGMA, UDMA, BisEMA	68 vol%: Zr/Si	0.01-3.5
Gradia	GC dental Corp. Japan	UDMA	Trimodal filler system (60 vol %): PPF-Pre polymerized filler FP-Aluminoborosilicate glass NP- Silica	0.005-0.01

prepared in rubber moulds, measuring 6 mm in internal diameter and 5 mm in depth; then two groups were cured with LED Bluphase C8 and two others with QTH Astralis 7. To avoid sample porosity and air bubble entrapment, on 2.5 mm sample were put in the mould. The samples were protected from the preventing effect of the air at both sides of the mould

with a thin glass and then they were stored for 24 hours in darkness, water and room temperature for completion of polymerization. All the samples were wrapped in an epoxy resin and cut in the middle and polished using 400-, 800-, 1000-, 1500-, 2000- and 2500-grit abrasive paper. The hardness of the sectioned areas was assessed at 0, 0.5, 1, 1.5, 2, 2.5,

Table 2 : Specifications of light curing units used in the study

Light Unit	Intensity (cm/mw ²)	Radiation Time	Wavelength (nm)
LED Bluphase C8	800	20 s	360-540
QTH Astralis 7	400	40 s	400-500

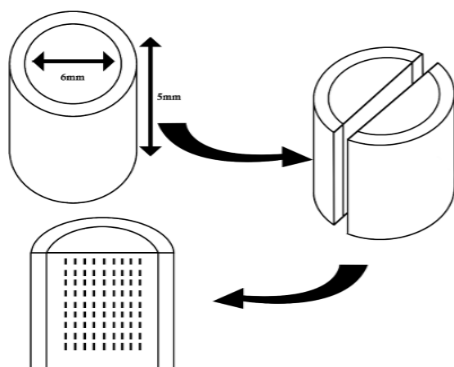


Figure 1: Schematic representation of sample fabricated (81 VHNs obtained by multiplying) points in horizon (each 0/5 mm away from the next one) into 9 points in depth (each 0/5 mm away from the next one)

3, 3.5, and 4-mm distances from the surface using Vickers device (MH2 Model, Coopa Corp., Iran) while the samples had been kept in darkness (Figure 1). The load used with the device was 500 gr for 10 seconds. Data were analyzed statistically using one-way ANOVA, two-way ANOVA and Tukey HSD tests (Table 3).

Results

Filtek Z250 was harder than Gradia Direct in all the depths with both light-curing units. The hardness of Filtek Z250 cured with Astralis 7 QTH unit was higher than that cured with Bluephase C8 LED, but

Table 3: Statistical difference of VHNs Hardness between the two composites (according to the distance from the surface)

Distance from the surface (mm)	0	0.5	1	1.5	2	2.5	3	3.5	4
Sig.	0.000	0.000	0.000	0.000	0.000	552.	0.418	0.043	0.021

for Gradia Direct the Bluephase C8 LED unit resulted in higher hardness than Astralis 7 QTH. In all the groups, 80% of the surface hardness was obtained at 2-mm depth. Curing depth was not significantly different between all the groups ($p = 0.109$). Filtek Z250 cured with each unit preserved its hardness at 3-mm depth to a level which could be identified with Vickers microhardness Device. After 3 mm, the composite could be easily removed with a scalpel blade. Gradia Direct with Bluephase C8 up to 3.5 mm and with Astralis 7 QTH had measurable hardness up to 2.5 mm, beyond which it could easily be removed with a scalpel blade. To compare the hardness of all the samples cured with the two units in all the groups, from the surface up to 2-mm depth, the hardness of the four groups was significantly different but from 2-mm up to 4-mm depth, there was no significant difference as shown in Table 3.

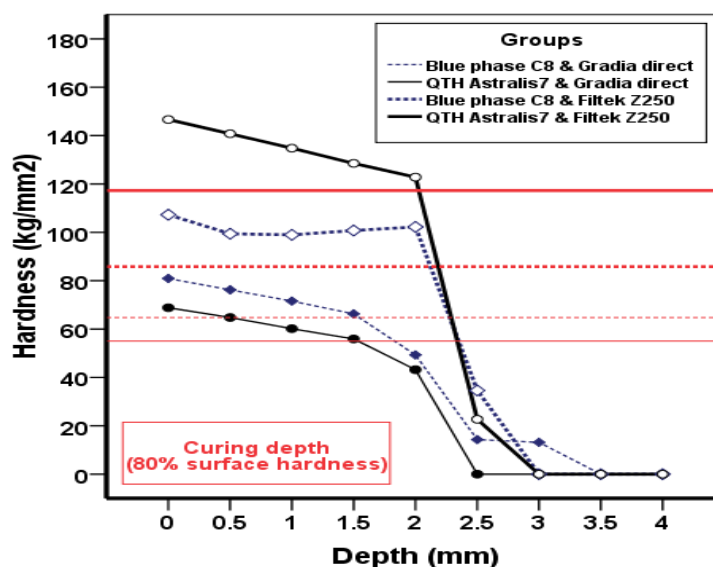
Figure 2 shows that surface hardness of the two composites is significantly different. Surface hardness

of Filtek Z250 is two times more than that of Gradia direct, whereas at 2.5 mm depth hardness drop of Filtek Z 250 is more obvious than that of Gradia direct.

Discussion

The null hypothesis was rejected. The light-curing units are of paramount importance since sufficient polymerization is necessary to achieve acceptable physical properties. There is controversy over defining the depth of cure for QTH units in comparison to LED units. Based on previous studies, the LED is superior to QTH due to its higher curing depth; hence more polymerization occurs on the composite resin. A possible explanation for this quality might be the proximity of emitted wave spectrum of LED to the absorption spectrum of camphorquinone.

Clinically speaking, the composite is added incrementally, because the maximum depth of cure is 2

**Figure 2:** Comparison of four groups based on 80% of surface VHNs hardness

millimeter, but in this experimental study the samples were used in one 5-mm diameter, since it was to check the ability of LED units to provide curing depth more than 2 mm and in clinic the distance from light cure tip is more than 2mm (5mm or more). Previous studies implemented the proportion of superficial hardness to underlying hardness and accepted that the polymerization is good if the mentioned proportion is at least 80%. According to 80% limit of hardness, two QTH Astralis 7 and LED Bluephase C8 light-curing units were used to cure two composite resin types; Filtek Z250 and Gradia Direct had almost similar curing depths. The superficial hardness of Filtek Z250 was higher than that of Gradia Direct, which is not in line with the results of Torno *et al.* because they concluded that the composite resins which were closer to the surface were cured more efficiently with all the light sources used [17].

Differences between light-curing units and exposure times can be considered as reasons for such discrepancy. In the present study, the hardness of Filtek Z250 was higher when it was cured with QTH unit compared to when it was cured with LED unit; this is consistent with the results of Sadeghiyani *et al.* and Polydorou *et al.*, who used two translucent composite resins exposed to QTH and LED units [1,18]. Sadeghiyani used Astralis 7 as QTH. In both studies, the results mentioned for better results of QTH was noticeable heat produced with light unit. Composite resin hardness after polymerization is affected by some factors, including composition of composite resin, type of light initiator, light unit, and the amount of light energy with a suitable wavelength [3].

Energy density of QTH is higher than that of LED because power density of QTH, as one factor affecting the energy density is higher than that of LED. Moreover, Filtek Z250 has a higher percentage of filler than Gradia Direct, which itself is effective in higher hardness. Based on the results reported by Price *et al.*, hardness obtained with Ultralum 2 LED was higher in all the sections compared to QTH, which is different from the results of the present study [20]. They attributed their findings to the LED light source, as QTH delivers a wide spectrum whereas the Ultralum 2 with 440-480 nm wavelength focuses on the most appropriate spectrum for polymerization that is 440-490 nm [23-26]. The reasons which can be mentioned for low hardness of Gradia Direct

are the composition of composite resin itself which is microhybrid and the lower content of fillers compared to Filtek Z250; that is why it needs longer exposure time which has been recommended by the manufacture as well, although both composite resins were A2 shade. Interestingly, although the exposure time was longer for Gradia Direct, its hardness was much lower than that of Filtek Z250.

On the other hand, Gradia Direct composite resin is a microhybrid with higher percentage of microfil fillers. Phenyl propane accompanying dimetacrylate in the composition of Gradia Direct can be considered for its different behavior from Filtek Z250. Some manufacturers use lower amounts of camphorquinone in combination with other initiators like phenyl propanedione (PPD) with an absorption spectrum of 410 nm. Gomes *et al.* reported in 2006 that these two initiators have synergistic interactions [19]. Probably absorption wavelength of PPD is closer to the output light of LED Bluephase C8, resulting in higher curing depth of Gradia Direct with this light-curing unit.

Light intensity decreases while passing through the composite resin, especially with microfil composite resins like Gradia Direct. Totally, light intensity decreases when it passes through composite resins due to absorption, refraction and reflection. That is why composite hardness decreases from surface to deep layers, and that according to manufacturers the majority of composite resins have curing depths of 2 mm. This claim was verified in this study as well. According to Figure 2, the lower hardness of Gradia direct rather than Filtek Z 250 at the surface can be the result of having microfil texture.

As shown in Figure 2, the Gradia Direct has more VHNs with Bluphase C8 LED rather than Astralis 7 QTH. It might be due to consistency of light emitted from Bluphase C8 LED with the composition of Gradia Direct, a fact that must be considered clinically.

On the contrary, Filtek Z 250 is more consistent with Astralis 7 QTH. In fact with increasing depth, both light-curing units exhibited rather similar functions, which might be attributed to a decrease in light intensity due to refraction and absorption. Another explanation for this phenomenon is the fact that a high percentage of short waves is absorbed close to the composite resin surface, so they cannot activate the co-initiator [4]. Refraction of these wavelengths occurs more than the longer wavelengths. Therefore,

when facing the new brands of composite resins on the market, their different properties must be addressed carefully.

Suggestion

It is suggested that the mentioned composite should be cured with the other kinds of LED units to see if there are findings different from those obtained from the present study.

Limitation

It was difficult and time consuming to evaluate such high number of points. .

Conclusions

VHNs hardness for both composites used in this study is in an acceptable range for clinical implications. The composite composition is important to be considered for selection of light unit. Based on the findings of the present study, LED did not present more curing depth compared with QTH.

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