IJMAHS

RESEARCH ARTICLE

Depth of cure of Microfilled composite resin (A2 shade) at different depths using two different light curing units - an in vitro study.

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ABSTRACT:

Aim: Light-emitting diode light curing units (LED LCUs) have become more popular than halogen LCUs in routine dental restorative treatment. The aim of the study is to compare the effects of conventional halogen (Hilux 200) and LED light Blue phase (ivoclar vivadent) light curing units on the depth of cure and the microhardness of micro filled composite resin, Swiss TEC – A2 shade esthetic restorative materials.

Materials and Methods: One micro filled resin composite, Swiss TEC – A2 shade is used for this study. Two light curing units are the QTH lamp Hilux 200 (Benlioglu Dental, Ankara, Turkey) and the LED light Blue phase (ivoclar vivadent). A white transparent hollow tube will be taken (6 mm in diameter), cut by Bard-Parker blade at length of 2 mm, 4 mm, 6 mm & 8 mm. The composite resin will be placed in the cylindrical moulds. The composite resin will be cured by QTH lamp and LED light. The resin composite specimens so prepared will be subjected to be micro hardness tester (Vickers Hardness Tester LV700) applying a 100g load through a Vickers indenter on the top surface of each composite samples. The results are statistically analyzed.

Results: According to our results, microfilled composite cured by LED (for all the depth and diameter) exhibit higher depth of cure and microhardness than microfilled composite cured by QTH (for all the depth and diameter).

Conclusion: 1. Microhardness of the composite resins are influenced by the depth of the composite resin increments. **2.** Microhardness or depth of cure of composite resins gradually decreased, when depth of the composite resin increments are increased. **3.** Microfilled composite cured by LED (for all the depth and diameter) exhibit higher depth of cure and microhardness than microfilled composite cured by QTH (for all the depth and diameter).

INTRODUCTION :

The evolutionary development of filling materials leads to an increasing need for better tooth colored restorative materials to replace missing tooth structure and to modify tooth color and contour, thus enhance facial esthetics. Polymeric restoratives have continued to evolve into the direct restorative materials of choice mainly because of their superior aesthetic characteristics. Currently, composites are the most widely used material in restorative dentistry (2).

The development of dental resin based composite restorative materials, started in the late 1950s and early 1960s by Bowen. Basically, Dental composite is a highly cross linked polymeric material reinforced by a dispersion of amorphous silica, glass, crystalline or organic resin filler particles and short fibers bonded to the matrix by a coupling agent (3).

These materials are indicated for use as follows:

i) Class I, II, III, IV, V and VI restorations. ii) Foundations or core buildups. iii) Sealants and prevented resin restorations. iv) Esthetic enhancement procedures- partial veneers, full veneers, tooth contour modifications & diastema closures. v) Temporary restorations. vi) Periodontal splinting (4).

The depth of polymerization is of vital importance not only in order to achieve optimum mechanical properties including hardness but also to ensure that the clinical problems like microleakage and gap formation do not arise due to partially polymerized material in the base of the cavity (5).

Along with many advantages, there are few disadvantages of composite restorations. They are - i) polymerization shrinkage. ii) time consuming, costly and insertion is more difficult and iii) more technique sensitive.

Dental composite restorations have a major drawback: the degree to which they cure which is proportional to the amount of light to which they are exposed. So, they polymerize to a certain depth which varies with the penetration of a light beam in the bulk material. This extent of cure has been termed (depth of cure) and has significant influence on both physical and biological properties of restorations (6)

Energy of the light emitted from a light curing unit decreases drastically when transmitted through resin composite (7), leading to a gradual decrease in degree of conversion of the resin composite material at increasing distance from the irradiated surface. Decrease in degree of conversion compromise physical properties and increase residual monomer concentration (8) and thus may lead to premature failure of a restoration or may negatively affect the pulp tissue. When restoring cavities with light cure resin composites, it has therefore been regarded as the gold standard to apply and cure the resin composite in increments of limited thickness. The maximal increment thickness has been generally defined as 2 mm (9).

Nowadays, light curing dental materials are extensively used in dentistry. Four types of light cure polymerization sources have been developed and applied: Quartz tungsten halogen (QTH) lamps, Light emitting diodes (LED) units, Plasma arc lamps and Argon lasers curing system (10).

Halogen lights and LED units are overwhelmingly applied in daily clinical practice (10). Halogen lamps, a low cost technology, have been the most frequent source employed for polymerization of resin composite materials (11), QTH lamps have a quartz bulb with a tungsten filament that irradiates both UV and white light that must be filtered to remove heat and all wavelengths except those in the violet-blue range 400 to 500 nm. LED lamps, using a solid-state, emit radiation only in the blue part of the visible spectrum between 440 and 480 nm and they do not require filters as their broad emission spectrum allows the polymerization of all known resin composite materials available (12).

However, LED lamps 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 (13). 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 (12). Moreover, light filters degrade with time due to the high operating temperatures and proximity to the halogen bulb (14).

Several studies have pointed out that many halogen units used by clinicians do not reach the minimum power output specified by the manufactures (15). 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 (14). The lifespan of a conventional quartz tungsten halogen lamp ranges between 30-50 hours (16). These shortcomings could result in inadequate curing which could negatively affect restoration long time success (17).

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 (18). LEDs use a combination of two different doped semiconductors instead of a hot filament (12). The spectral output of gallium nitride blue LED conveniently falls within the absorption spectrum of camphoroquinone (10, 14, and 19). Therefore, they do not require filters to produce blue light and they convert electricity into light more efficiently (11). The amount of heat produced by LED lamp is $11.8\pm1.3^{\circ}C$ (29). So, no cooling fan is required and they can be smaller and cordless. Moreover, LEDs can operate for thousands of hours with a constant light output in power and spectra (19).

Contrary to first generation LED curing lights, newer units deliver with a density power higher than $400 mW/cm^2$, allowing a reduction of the exposure time recommended by composite manufactures (20).

An adequate polymerization of resin composites is essential for the ultimate success of the restorations (21). The degree of cure of resin composite materials influences their mechanical properties, solubility, dimensional stability, color change and biocompatibility (22). The effectiveness of the composite cure can be assessed directly or indirectly. Direct methods that assess the degree of conversion, such as infrared spectroscopy and laser Raman spectroscopy, have not been accepted for routine use as they are complex, expensive and time consuming. Indirect methods have included visual, scraping and hardness testing. Depths of cure and microhardness testing have been widely used to assess the relative degree of cure of resins and thus, the efficiency of light sources (23).

Physical properties of composite resin are also dependent on the Depth of cure of the resin matrix. A positive correlation has been demonstrated between increasing hardness and increasing Depth of cure, however, it was concluded that an absolute hardness number could not be used to predict Depth of cure, when different resin composites are compared. A previously published study showed a significant correlation between the degree of conversion and hardness, modulus of elasticity and flexural strength of dental restorative resins. However incremental surface hardness has been shown to be an indicator of the degree of conversion and a good correlation between Knoops hardness and infrared spectroscopy has also been reported.

Therefore the aim of this study is to evaluate the Depth of cure of microfilled composite resin cured with a quartz tungsten halogen (QTH) and a light emitting diodes (LED) curing light unit.

MATERIALS AND METHODS:

One micro filled resin composite, Swiss TEC – A2 shade is used for this study (Figure 1).

Two light curing units are the QTH lamp Hilux 200 (Benlioglu Dental, Ankara, Turkey) and the LED light Blue phase (ivoclar vivadent) (Figure 2).

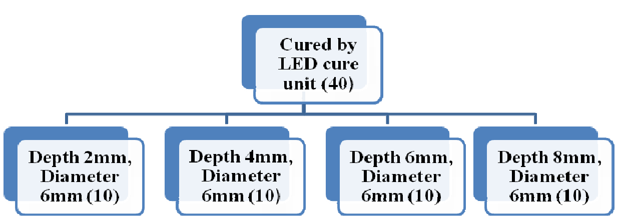
Depth of cure by Vickers hardness profiles

A white transparent hollow tube will be taken (6 mm in diameter), cut by Bard-Parker blade at length of 2 mm, 4 mm, 6 mm & 8 mm. The composite resin will be placed in the cylindrical moulds. The composite resin will be cured by QTH lamp and LED light. The resin composite specimens so prepared will be subjected to be micro hardness test.

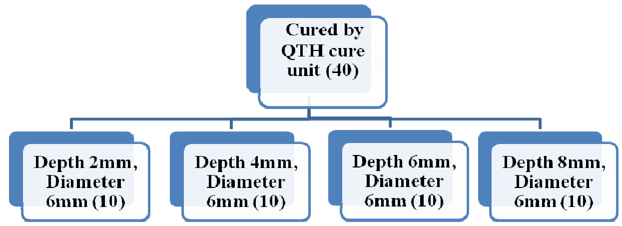
Figure 1: Micro filled resin composite, Figure 2: LED light Blue phase and QTH Swiss TEC – A2 lamp Hilux 200

Study Design:
The 80 samples (solid composite cylinders) so prepared will be divided into groups as follows and subjected to experimentation. (Figure 3)

Group I.



GroupII.



Method:
Microhardness (Vickers Hardness Number, VHN) is determined using a digital microhardness tester (Vickers Hardness Tester LV700) applying a 100g load through a Vickers indenter on the top surface of each composite samples. (Figure 4)

Figure 3: Samples (solid composite cylinders)
Figure 4: Vickers Hardness Tester

RESULTS:

Table 1 shows the values of microhardness (VHN) of Microfilled composite resin cured by LED curing light unit for 20 seconds

Sample	Load	Mean Hv	Mean GPa
Depth 2mm Diameter 6mm	100g	68.6	0.6727602
Depth 4mm Diameter 6mm	100g	58.1	0.5697867
Depth 6mm Diameter 6mm	100g	56.6	0.5550762
Depth 8mm Diameter 6mm	100g	49.8	0.4883886

Table 2 shows the values of mean microhardness (VHN) of Microfilled composite resin cured by QTH curing light unit for 20 seconds

Sample	Load	Mean Hv	Mean GPa
Depth 2mm Diameter 6mm	100g	59.8	0.5864586
Depth 4mm Diameter 6mm	100g	48.7	0.4776009
Depth 6mm Diameter 6mm	100g	38.5	0.3775695
Depth 8mm Diameter 6mm	100g	34.9	0.3422643

Table-1: Comparison of mean Hv values

Depth and Diameter	**LED (n=10)**	**QTH (n=10)**	**t_8-value**	**p-value**
Depth 2mm Diameter 6mm	68.6 ±2.55		5.79	<0.01
Depth 4mm Diameter 6mm	58.1 ±3.02	48.7 ±3.71	11.09	<0.01
Depth 6mm Diameter 6mm	56.6 ±1.83	38.5 ±1.92	15.25	<0.01
Depth 8mm Diameter 6mm	49.8 ±1.56	34.9 ±1.24	16.71	<0.01

<0.01 – Statistically Significant at 1% level of significance

NS- Statistically not significant

For all the depth and diameter the mean Hv values of LED was significantly higher than that of QTH (p<0.01).

Table-2: Comparison of mean GPa values

Depth and Diameter	**LED (n=10)**	**QTH (n=10)**	**t_8-value**	**p-value**
Depth 2mm Diameter 6mm	0.6727602 ±0.007	0.5864586 ±0.004	23.93	<0.01
Depth 4mm Diameter 6mm	0.5697867 ±0.005	0.4776009 ±0.002	11.40	<0.01
Depth 6mm Diameter 6mm	0.5550762 ±0.004	0.3775695 ±0.003	79.38	<0.01
Depth 8mm Diameter 6mm	0.4883886 ±0.003	0.3422643 ±0.001	103.32	<0.01

<0.01 – Statistically Significant at 1% level of significance

For all the depth and diameter the mean GPa values of LED was significantly higher than that of QTH (p<0.01).

DISCUSSION:

Composite resins are used worldwide in dentistry, mainly because of their aesthetic quality and good physical properties. One of the most important parameters deciding the composites resins' resistance to stress is the depth of cure. Several studies have demonstrated that the degree of polymerization of light cured composite resin depends on many parameters, such as type and relative amount of monomer, filler and initiator, the wavelength distribution, the intensity of the incident light and the irradiation time.

The polymerization reaction is accompanied by a dimensional change that resulted in shrinkage. Shrinkage is caused by the monomers becoming covalently bonded by the polymerization reaction, thus exchanging Vander Waals distance for covalent bond distances.

The variabilities that influence polymerization shrinkage of composite resin are i) Size of the monomer molecules, ii) the volume fraction of filler, iii) the degree of polymerization which is directly proportional to increased shrinkage, iv) the nature of resin and consequently the mechanism of polymerization. The shrinkage of composite is about 1-5 volume% and can be divided into two phases, the Pre gel and Post gel phase. During the pre gel phase, the composite flows and stresses within the structure are relieved. After gelation, flow ceases and cannot compensate for shrinkage stresses. Thus the post gel polymerization results in significant stresses in the tooth structure and composite tooth bonding.

Relief from polymerization shrinkage stresses can be eliminated in the following ways-

The first method is incremental placement of composite resin.

The second approach to stress reduction is the application of liner.

The effectiveness of cured composite can be assessed by direct and indirect methods.

Direct methods that assess the degree of conversion are:

Fourier transformation infrared spectroscope

Laser Raman spectroscope

Differential thermal analysis

Magnetic resonance microimaging

Indirect methods to find the degree of conversion are:

- Calorimetric investigation
- Scraping method
- Dye method
- Surface microhardness

In the present work curing effectiveness is measured using indirect method that is hardness testing. Another indirect method is present that is scraping method. Direct methods that assess the degree of conversion, like infrared spectroscopy and laser Raman spectroscopy are complex, expensive and time consuming (24). These techniques are also more qualitative than quantitative in nature (13). ISO standard scrape test has some drawbacks like overestimation of the depth of cure and low sensitivity (25). This is the reason why hardness is also assessed by a digital microhardness tester as it exhibits a good correlation with degree of conversion (25).

Among the indirect methods to determine the degree of cure, microhardness method appeared to be the most popular. In composite resin, the physical properties are closely related to the degree of conversion and the hardness measurement is an effective method to evaluate the degree of cure. Hence for study Vicker Hardness Test is followed to determine the degree of cure. Surface hardness measurement at top and bottom surface of cured composite resin samples has been used as a means of measuring the degree of conversion after polymerization.

Hardness of a composite resin is influenced by the type and composition of the resin matrix, filler type and filler load (26). It has been reported that LED technology polymerizes resin composites as well or better than some QTH lights. However, interactions between light curing source and exposure time and between light curing unit and depth significantly influenced microhardness results. In terms of shade, LED lights gave greater curing depths with A3 shade, while QTH and HQTH lights gave greater curing depths with C4 shade (31).

Specimens irradiated for 20 seconds with the LED light Blue phase (ivoclar vivadent) exhibited statistically higher hardness value than when photopolymerized under the halogen lamp Hilux 200.

Light emitted by LED lamps allows a reduction of the exposure time from that recommended by composite manufactures for

QTH curing lights, in accordance to previous authors. Regarding the effect of light curing source and depth, both lamps achieved similar microhardness values at 0.5, 1.5 and 2.5 mm depths, as previously stated by other authors (27). As light passes through the mass of the resin composite its intensity is greatly decreased due to light absorption and scattering by restorative material attenuating its potential to cure (28). This is in consistency with the significant and gradual reduction in hardness observed for depths higher than3.5 mm irrespectively of the curing light evaluated. Thus, the resin composites evaluated should not be cured in 3.5 mm or higher increments using LED lamp or QTH curing light. Both light curing units sufficiently polymerized composite to a depth of 2 mm which is the value acceptable for clinical application (20).

In the present study, microhardness values were significantly influenced by the depth of the composite resin. For all the depth and diameter the mean GPa values of LED was significantly higher than that of QTH. Denehy et al. found that the top surface hardness of composites is less dependent on light intensity than the bottom surface. The top surface is actually receiving the maximum energy from curing light.

In 2002, WILLIAM J. DUNN, D.D.S et al used two halogen-based light- curing units (Optilux 400 and 501, Demetron Research Corp., Danbury, Conn.) and two commercially available LED LCUs (LumaCure, LumaLite, Spring Valley, Calif., and VersaLux, Centrix, Shelton, Conn.) to polymerize top surfaces of hybrid (Filtek Z- 250, 3M, St. Paul, Minn.) and microfilled (Renamel, Cosmedent, Chicago) resin-based composite specimens. Specimens were indented on their top and bottom surfaces with a Knoop hardness tester and measured for hardness. According to the authors regardless of composite type, the two halogen-based lights produced harder top and bottom composite surfaces than the two LED LCUs (29).

In 2007 DANIEL L et al used composite type (Silux Plus [microfill], Z-100 [hybrid]), and curing light (ZAP Dual Curing™ Light, LumaCure™, VersaLux™, Optilux 401™) for Knoop hardness measurements. They found that the power density between 450 and 500 nm was at least four times greater for the halogen lamp than for the purely LED lights. As a result, the LED-based curing lights required from 39 to 61 seconds to cure a 2-mm thick hybrid I resin composite and between 83 and 131 seconds to adequately cure a microfill resin composite. By I comparison, the QTH light required only 21 and 42 seconds to cure the hybrid and microfill resin composites, respectively (30).

In 2000 K.D Jandt et al used Dental composite (Spectrum TPH, shades A2 and A4) and cured for 40 s with a commercial halogen LCU and LED LCU, respectively. The composites' depth of cure was measured with a penetrometer. The results were compared using a Student's *t*-test. The conventional halogen LCU cured composites significantly deeper than did the LED LCU (28).

Therefore, the previously mentioned studies are colclusive to the fact that the QTH light is more fovourable than LED curing light for depth of cure of microfilled composite resin.

But, following studies have been made to show the efficacy of LED curing light is more pronounced than QTH curing light for depth of cure of composite resin.

In 2004 Tsai PC et al examined the depth of cure and surface microhardness of Filtek Z250 composite resin (3M-Espe) (shades B1, A3, and C4) when cured with three commercially available light emitting diode (LED) curing lights [E-light (GC), Elipar Freelight (3M-ESPE), 475H (RF Lab Systems)], compared with a high intensity quartz tungsten halogen (HQTH) light (Kerr Demetron Optilux 501) and a conventional quartz tungsten halogen (QTH) lamp (Sirona S1 dental unit). . Depth of cure after 40 s of exposure was determined using the ISO 4049:2000 method, and Vickers hardness determined at 1.0 mm intervals. HQTH and QTH lamps gave the greatest depth of cure. In terms of shade, LED lights gave greater curing depths with A3 shade, while QTH and HQTH lights gave greater curing depths with C4 shade (31).

In 2011 Batu Can Yaman et al compare the effects of two conventional halogen (Hilux Plus and VIP) and two LED (Elipar FreeLight 2 and Smart Lite) light curing units on the depth of cure and the microhardness of a compomer (Dyract Extra), a resin-modified glass ionomer (Vitremer), a packable composite (Sculpt It), an ormocer (Admira), a hybrid composite (Tetric Ceram), two microhybrid composites (Miris and Clearfil Photo Posterior) and, a nanofil composite (Filtek Supreme), using a scraping method based on ISO 4049 and a Vicker's microhardness hardness tester. The LEDs were found to be more successful than the halogen units with respect to both curing depth and microhardness properties (34).

In 2013 Dr.Nishad.N.T1 et al evaluated the curing depth and surface microhardness of nanocomposite resin cured with LED and QTH Light curing units. Depth of cure of composite measured using ISO:4049 scraping test5 and surface microhardness measured using universal testing machine. LED light curing units offers better performance for curing nanocomposite resins as compared to QTH light curing units (32).

In 2012 M Bhalla et al evaluate and compare the micro-hardness of microhybrid composite resin (Filtek Z-250) cured with light-emitting diode (LED) and halogen curing unit, using Vickers micro-hardness test by using micro-hardness tester machine at a load of 100 g for 10 sec. It was concluded that the LED lamp has the highest hardness values (33).

According to our results, microfilled composite cured by LED (for all the depth and diameter) exhibit higher depth of cure and microhardness than microfilled composite cured by QTH (for all the depth and diameter).

Conclusion: - within the limitations of this in-vitro study it can be concluded that:-

Microhardness of the composite resins are influenced by the depth of the composite resin increments.

Microhardness or depth of cure of composite resins gradually decreased, when depth of the composite resin increments are increased.

Microfilled composite cured by LED (for all the depth and diameter) exhibit higher depth of cure and microhardness than microfilled composite cured by QTH (for all the depth and diameter).

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Cite this article as: Paromita Mazumdar, Utpal Kumar Das, Neelanjana Majumdar, *Depth of cure of Microfilled composite resin (A2 shade) at different depths using two different light curing units - an in vitro study*, Int J Medicine and Allied Health Sciences, 2015; 4: 428-433